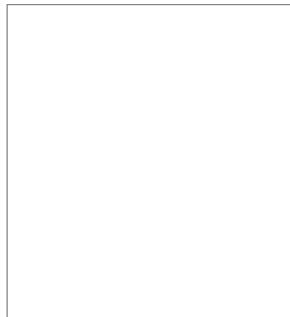


ELEMENTS
THE
PSYCHOPHYSICS
FROM
GUSTAV THEODOR FEEDER.
SECOND UNCHANGED EDITION.
WITH ADDITIONS TO THE AUTHOR LATER WORK AND ONE
CHRONO LOGICLY LOCATED DIRECTORY OF HIS ALL-SCRIPTURE.

SECOND PART.



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Foreword to the second part.

I think it useful to add to the general introductory remarks in the preface to the first part, and to add a few introductory remarks on the content of this second part in particular.

It contains, with the exception of a historical chapter, in which I have recorded the precedents, the origin and course of these investigations, some additions and a register of new or specially defined expressions used in this document, - three main sections:

- 1) formulas and polings of the psychic measure;
- 2) special investigations on some sensory areas;
- 3) internal psychophysics.

The first of these sections essentially contains only the mathematical presentation and linking of what is present in the first part of laws and facts, and will therefore offer no new factual content to physiologists and psychologists. Also, after looking at the mass formulas contained in this section, you will probably wonder what's actually gained by that. I have set this out in relation to one of the main formulas, the measure formula, briefly stated in Chap. 16, and in the other formulas I do not fail to point out the applications which they promise or grant. Thus, the distributional formulas of sensation in Chapter 21 give rise to many interesting implications the application of the difference measure formula to the estimation of the star magnitudes and the position formulas on the assessment of the ratios of constant errors are discussed in special chapters (25th and 27th), and the resolution described in Chap. 30th of the riddle of the octave has been given in the tone theory, may perhaps take a special interest.

The main interest, however, as to these formulas for now, is always the theoretical, previously missing measure not only for simple sensations, but also for the representation of their functional relations, and the principles of the treatment of this subject much more important than the formulas, which are only special cases of applying the principles. The principles, as described in chap. 6, 7, 18, 22, 30, 31 and 32 are, according to their essentials, also understandable to those less knowledgeable in mathematics, and their durability is based on the durability of the doctrine presented in this work. As for the formulas, they may be subject to many modifications. That they, as they are placed here, are only an approximation everywhere, As long as one wishes to make use of it in the field of external psychophysics, I have already explained it earlier, as I have just stated in the beginning of this part, and emphasize it here again with special emphasis. These formulas will require different senses, and indeed different modes of application of the senses of various modifications or corrections, but which, even if they were

already established with greater certainty than at the time of the case, could not fit into the general treatment of the subject here, not only because they have to be different for different areas¹⁾, but also because they would indisputably have to be eliminated altogether for internal psychophysics. But also for the external and hereby experimental psychophysics the formulas given here will remain, to which the further development and more precise determination of the mathematical part of the theory of sensation has to tie up, as well as a recent progress made with regard to the sensation of light, of which I am in to remember the additions and really did.

¹⁾ Thus, Weber's law, in its application to the sensitivity to differences in weight according to Th. I, p. 197. 200, shows a deviation at the lower limit, which is not the same as that at light differences according to Th. I, p Nature is, and would require a different consideration in the formulas of external psychophysics in order to be covered by it.

That I have given special names to the most important formulas can perhaps be reproached as a sophisticated gimmick; and, indeed, if a special name were to be given in all mathematical investigations of any formula, mathematics would soon compete with botany and zoology for the wealth of names; but in view of the manifold back reference which I had to make to the main formulas, and which will be elsewhere in the future, if the doctrine put forward here takes place, the advantage of brevity and saving of references thereby obtained will not be insignificant.

The second section may well give rise to the question of why some objects are so extensively dealt with in it, and so much of the same claim to have been dealt with in psychophysics has been completely ignored. My answer is simple. I have sought as thoroughly as possible to treat the objects to which a new light has been thrown from the doctrine presented here, or whose treatment has effectively intervened in the general of this doctrine, as thoroughly as this Scripture as a whole more carries the character of the investigation than the textbook; Incidentally, it was believed that I would not be grateful to find again elsewhere in the Physiology and Physics of elsewhere. It is indisputable that from a certain point of view the whole theory of nerves and theories of the senses can be drawn into psychophysics, and physiology and physics, in their ever-increasing extent, will in the future gladly leave to some self-constituted psychophysics some border areas which they now draw into their domain; but it will always be better for this doctrine to rely on and supplement it than repeating it.

In connection with the presentation of a series of tactile experiments in the second section, I have made a tentative completion of what has been said in the first volume on the method of mean error, as to a few points; since I will probably only have to wait and see whether the public will even take sufficient interest in the whole circle of these investigations, the "measurement methods" to which I have referred in the past to the detail of the methods and still have to refer in many respects to be able to appear.

In the third section one would search in vain for a complete and well-rounded system of internal psychophysics; entire main areas that once belonged to are missing. Mainly it was only for the time being to obtain general points of view for the same and first entry points into which the same research is possible with increasing certainty of results. If I am not mistaken, those who are at the forefront of internal psychophysics (chapters 36, 37, 38, 39) carry this character, and again I place the emphasis on the principles. From the words I've tried, I've gradually left more and more, and even now, I'm worried I've given too much rather than too little. But the matter had to be attacked to show that she was capable of attack, Also, some attack points should be replaced by more appropriate and some attacks by more skillful or more valid in the future. From this point of view, I would like to consider the few versions of internal psychophysics. Thus, the schematic representation of some of the most general and important psychophysical relationships, of which I have made particular use in the 42nd and 45th chapters, is from one side only a framework, from another a surrogate. I find this presentation useful, indeed very useful, in contrast to an otherwise empty void; but this framework must once be filled with certainty, the surrogate replaced by more direct representations that it has yet to represent.

For those whose interest is primarily empirical, this volume offers some new material of experience only in the 34th, 35th, and 44th chapters. The Observations on Contrast Conditions, to which Th. II, Chap. 24, partly because they have not yet been fully edited, partly have gained a little to a large extent, have not been able to find room here, but are quite at the same time with this gang in the reports of the Saxon Soc. Published in 1860 under the heading "About the Contrast Sensation". I report in the additions on the, unfortunately unsuccessful, subsequent employment of an important acoustic experiment in Th. II, p. 174, which also contains the reference to some recent important investigations by Helmholtz.

If one wishes, one can consider as a supplement to this work a soon-to-be-published, partly expanding, slightly expanding, little popular essay "On the Soul Question," which concludes by briefly mentioning the text in the 45th chapter Prospects opening up from a more general version of psychophysics into the field of religion and natural philosophy are treated. The points of view from which it occurs, without claiming an exactness in form and matter that is not yet sufficient here, are likely to be as close to the exact ones as the nature of the tasks and our means of knowledge permit since then, and I have them under that Sought to formulate names of principles of faith more precisely. If the views summarized in this case in their contradiction to the now prevailing mean, both as a theological and philosophical view of the world, have not since enjoyed any particular resonance, and just as little hope of finding one soon, can be deduced from the discussions of the 45th and 46th chapters of the present specification are easily overlooked as being merely the anticipation of the onetime goal of psychophysics evolving on the basis of the principles of this work. It will not become universal without broadening, deepening and increasing the mental scale of the world beyond the limits now assumed. I say this with the conviction

Leipzig, 18 August 1860.

Continuation of external psychophysics.

Formulas and Consequences of Psychic Measure.

XIV. General reminder. The most important properties of the logarithms .

In general, as I proceed to develop the formulas by means of which the psychic measure is achievable, I have to note that here (apart from a chapter in which, for example, another assumption is made) the validity of Weber's Law and the fact is everywhere the threshold is assumed. Insofar as the former presupposition does not apply everywhere, or only within certain limits, or only with a certain approximation in the areas of the senses of mind, this will of course also apply to the formulas based thereon; meanwhile, with regard to the limited applicability which can only be attributed to these formulas, the following is to be remembered and remembered.

- 1) The chief relations which it is to be regarded in the realm of sensation in the ordinary use of the senses, will always be under the control of the exact or approximate validity of Weber's law, and of deviations of small order or under exceptional cases of the use of the senses In the beginning, when it is only necessary to overlook the main conditions, they can be abstracted, as Th. IS 66 f. was asserted.
- 2) The deviations from Weber's law at its lower limit, which depend on the existence of internal causes of sensation, and many other deviations, do not invalidate the formulas based on the law, but can be introduced into them in such a way that they even their effects on sensation can be represented by these formulas; what will be further discussed in the sequel opportunity.
- 3) Where the formulas based on Weber's law cease to be valid for external psychophysics, they do not lose their significance for the inner, insofar as the validity of Weber's law for psychophysical activities goes beyond indisputable Stimuli from which they are triggered, like Th. L. P. 67 f. and will be the subject of further discussion in the future.
- 4) Even where Weber's law is not sufficient, and there is another relationship between constant increases in sensation and variable stimuli in the rise of sensation and stimulus, which is expressed by Weber's law, this is sufficient in the seventh chapter of the The first part discussed the principle according to which just as well any other relation between those additional formulas of measure would be grounded; but the following formulas can be considered, at any rate, as the most

important example of the application of this general principle; as already discussed in Th. IS 65.

In the following, since we are constantly dealing with logarithms, and many circumstances will come into consideration and application which do not occur in the ordinary use of the logarithms, many who are no longer familiar with these conditions may welcome a brief recapitulation of them.

If one successively raises a number fixed once and for all, which is called the fundamental number of the logarithmic system, to different powers, then different numbers result from it. The power to which the basic number must be raised in order to obtain a given number is called the logarithm of that number.

In the system of the common or so-called Briggian logarithms, for which the ordinary tablets are arranged, 10 is the basic number and hereafter z . For example, 1 is the logarithm of 10; 2 the logarithm of 100; 3 the logarithm of 1000 usf

Depending on the choice of other basic numbers one obtains other logarithmic systems; and while one stands still for practical use in the system of common logarithms, mathematical analysis is often necessary, and in the following it will often be necessary to refer to a different one, the so-called natural, logarithmic system, the basic number of which , following always with e to be designated Irrazionalzahl

$$e = 2.7182818284 \dots$$

is. In this system, not 2, but 4,605170 is the logarithm of 100, in which e , raised to this power, gives 100.

Notwithstanding that the logarithms in the ordinary and natural systems are very different for the same number, the relation of them remains always the same, for whatever number one may consider it. This constant ratio between the common and

natural logarithms agrees with the common logarithm of the fundamental number of the natural logarithm e ; it is called the modulus of the common logarithmic system and will always be denoted by M in the future. Its value is 0.434294481 So it has

$$M = \boxed{} = \log \text{comm. } e = 0.434294481$$

and hereafter:

$$\log \text{comm.} = M \log \text{nat.}; \text{ and } \log$$

$$\text{nat.} = \boxed{}$$

Accordingly, one can obtain the common logarithm of any number from the natural one by multiplying it by M , and the natural logarithm of that number by dividing it

by M or \square multiplying it by M . Since in such a transformation the common logarithms of M and may be \square of use, we establish them:

$$\log \text{comm. } M = 0.6377843 - 1.$$

$$\log \text{comm. } \square = 0.3622156.$$

A table of natural logarithms, which saves the translation from the common logarithms by division with M , can be found in Hüsse's collection of mathematical tables. Plate VI. p. 456th

From the general definition of the logarithm it follows that in order to find the number from the logarithm of a number, one has to raise the basic number to the power indicated by the logarithm of the number. In general, let β be the number, γ its logarithm

$$\gamma = \log \beta$$

so , if a is the basic number,

$$\beta = a^\gamma.$$

The equations $\gamma = \log \beta$ and $\beta = a^\gamma$ thus require each other mutually; and differ only in that in the first γ is εξπρεσσεδ as a function of β , in the second β as a function of γ ; a relationship that needs to be taken into account, as it will decrease in the future.

In every logarithmic system the logarithm of 1 is equal to zero, the logarithm of the fundamental number is equal to 1, and if the logarithm of 0 has a negatively infinite value , the logarithm of $+\infty$ has a positive infinite value.

In every logarithmic system, the logarithms of numbers exceeding 1 have positive values, the logarithm of fractions smaller than 1; negative values.

The logarithm of a number and the logarithm of the reciprocal of the number, ie

z. B. $\log 4$ and $\log \frac{1}{4}$, $\log 3$ and $\log \frac{1}{3}$, a general $\log \beta$ and $\log \square$ are the absolute values according to the same size everywhere and only of opposite sign. Therefore,

you can also log instead of $\log \square - \log \beta$ and instead of $\log \beta - \log \square$.

Similarly, the logarithm of a fraction \square and the logarithm of the reciprocal value of that fraction \square , which are also the numbers β, b , are equal in absolute value

and of opposite sign, so that one can also substitute $\log \boxed{} - \log \boxed{}$ and $\log \boxed{}$ instead $\boxed{}$ can set $-\log \boxed{}$.

It is also known that, instead of the sum of the logarithms of two numbers, one can set the logarithm of their product and vice versa; instead of the difference of the logarithms of two numbers, the logarithm of their quotient, and vice versa; instead of n times the logarithm of a number, the logarithm of the n th power of the number and vice versa; instead of the logarithm of the n th root of a number, the n th part of the logarithm of the number $\boxed{} \log \beta$ and vice versa.

Transformations of this kind will ceaselessly recur in the following, and it is therefore necessary to familiarize them with them. Here is the compilation of the formulas which contain their expression:

$$\boxed{}$$

(1)

$$\boxed{}$$

(2)

$$\boxed{}$$

(3)

$$\log \beta + \log b = \log \beta b \quad (4)$$

$$\log \beta - \log b = \log \boxed{}$$

(5)

$$\boxed{}$$

(6)

$$\boxed{}$$

(7)

It is important to have an expression, such as

$$\boxed{}$$

not with the printouts

$$\boxed{}$$

to be confused. The former can be transformed according to previous sentences into $\log \beta - \log b$, the latter does not permit such a transformation. Similarly, $\log \beta \beta'$ should not be confused with $\log \beta \log \beta'$. The first expression can be transformed into $\log \beta + \log \beta'$, the latter not.

If a number differs only a little from 1, and α is the small positive or negative difference between them of 1, then, inasmuch as the higher powers of α can be neglected over the first, one can assume in the case of ordinary logarithms

$$\log(1 + \alpha) = M\alpha,$$

where M is the modulus, or simply in the case of natural logarithms

$$\log(1 + \alpha) = \alpha.$$

The resulting substitution of $M\alpha$ or α for $\log(1 + \alpha)$ is often of useful application. Generally one has, even with not very small values of α , in the case of usual logarithms



which formula passes from α to the above by neglecting the higher powers, and by substituting 1 for M also applies to natural logarithms.

XV. A mathematical auxiliary principle.

In our derivation of psychological measurement function from the Weber's law, a mathematical auxiliary principle will be useful to us, what I want to first explain a few examples before his general dictum¹⁾.

Logarithms and associated numbers do not progress proportionally. But if one takes the difference of two numbers close to each other and the difference of the associated logarithms, there is marked proportionality between the parts of the difference belonging to each other or small increments of the one number and the associated logarithm, whereupon the interpolation method by means of the in the logarithmic tables underlying differences.

A curve generally does not progress in proportion to the length of the abscissa. But if one takes such a small part of the curve that it agrees markedly with a straight line, there is noticeable proportionality between the mutually belonging increases in the abscissa and the length of the curve for this small part.

The movement of the earth around the sun is not uniform, but in the vicinity of the sun larger spaces are covered in the same time as in the distance from the sun; In short, the progress of time and the associated progress of the earth in space do not go in proportion to each other as a whole. But in a third and a half days, the third and half of the space that is covered in a whole day is noticeably covered. It is only this third, this half as well as the whole in a day passed space in the sun nearer than in the Sonnenferne.

¹⁾ It is found, inter alia, in Cournot's *Traité des fonctions* (Ie 19) and emphasized with special emphasis.

The light illuminates an area at twice the distance with only $\frac{1}{4}$ of the intensity, as at a simple distance. So the strength of the lighting as a whole does not decrease in the simple, but in the quadratic ratio of the distance of the light from the illuminated surface. If, however, only a slight displacement of the light is envisaged, the change in the illumination to change the distance will not be quadratic, but simple, but the quadratic relationship will again assert itself as the change in illumination for a given distance at twice the distance of light small displacement of light is less than at simple light intervals.

In general, the relative changes, increases of two interdependent continuous magnitudes, pursued by a constant initial value on or within any part of the magnitudes, are perceptibly proportional to each other as long as they remain very small, as well as the dependence relationship between magnitudes and how much the course of the great and the whole may deviate from the law of proportionality.

It is not to be overlooked that, while the mutually related changes of two magnitudes, following from a given initial value, are proportional to each other, so long as they remain very small, the magnitude of these relative changes may be very different after being pursued by this or that initial value, or within this or that related parts of both quantities, as has already been asserted in the last explanatory examples.

If one asks, what does it mean to say very small in the expression of the principle? - very small is quite relative - so the remaining uncertainty in the expression of the principle is to be raised by the following explanation: In any case, the parts belonging to each other can be so small that the law of proportionality between the smaller ones Sharing the same noticeable; or, in so far as the expression also noticeably includes an indeterminacy, that it exists so far that the deviation falls below an arbitrary limit. However, how small they are to be taken depends, on the one hand, on the functional relation of the quantities and, on the other hand, on the approximation required, and both admit no general rule. Absolutely exactly, of course, proportionality, apart from special cases,

Pay attention that the pronounced principle is bound not only to no definite relationship of dependence between the given quantities but also to any specific nature of these quantities, ie of the objects to which the concept of size applies, but is bound only to the general concept of continuous size-dependence. So where there is a constant size dependence, it applies. Now, however, there is one between stimulus size and sensation size. To be sure, we are not yet able to give a definite relation according to which the sensation changes with the action of the stimulus, as long as we have no measure of sensation; but we know that the sensation changes in constant dependence on the stimulus effect, that the sensation of light,

We can therefore safely pronounce the sentence: the changes in sensation are noticeably proportional to the changes in stimulus size as long as the changes remain very small on both sides.

Set z. For example, two weights have a certain small difference, and this is perceived with a certain strength, intensity, and distinctness, so we can say, in our principle, that a difference twice as large, from the same starting point, is perceptibly twice as large. a threefold is perceived as noticeably three times as large; but this remains valid only as long as the difference of the weights remains small, and that does not exclude that an equal weight difference between weights of different size is felt with quite different values, about which the mathematical principle gives no information, but here the weaver The law comes in addition to the experience side.

One can not demand a direct experimental proof that this is so; rather, the task of determining the size-dependence between stimulus and sensation in the sense of mathematical principles, the application of the mathematical principles of size-dependence, valid without regard to all experiment just mentioned belongs, presupposes of itself. An indirect proof of the applicability of this principle to psychic quantities, however, can be found in the fact that the dependence between psychic and physical quantities determined by the same, to the exposition of which we now turn, leads to empirically proven results, as will be shown in the sequel ,

XVI. The Fandamental formula and measurement formula.¹⁾

still have a measure of sensation without, you can but the pronounced by the Weber's law case the sensation difference remains the same as the relative stimulus difference remains the same, and justified by the auxiliary mathematical principle proposition that small Empfindungszuwächse the Pursuit proportions, in conjunction with a sharp mathematical expression.

Suppose, as in the experiments for the proof of Weber's law in general, that the difference between two stimuli, or, what is the same thing, the growth of stimuli, is very small in proportion to this. The attraction takes place at which the increment hot, β , the small increment hot $d\beta$, where the letter d is not to be regarded as a special size, but merely as a sign that $d\beta$ a small increment to β is; Already now one

can think of the differential sign. Such is the relative stimulus growth \square . The sensation on the other hand, which depends on the stimulus β , is called γ , The small increment of sensation, which in terms of growth of the stimulus to $d\beta$ arises hot $d\gamma$, where d again to be understood only as a sign of small Zuwuchses. $d\beta$ and $d\gamma$ are each a unit of their kind that is arbitrary to think related.

¹⁾ In terms of p. 7-14. Revision p. 182 ff. Psych. Maßprinzipien, p. 199 f. For divergent interpretations and formulations of Weber's law cf. P. 14 ff. Revision



According to Weber's law, $d\gamma$ remains constant when \square constant. which absolute values also assume $d\beta$ and β ; and after the *a priori* valid auxiliary mathematical principle the changes remain $d\gamma$, and $d\beta$ proportional to each other as long as they remain very small. Both ratios can be expressed in the context of the following equation

$$\square \quad (1)$$

where K is a constant (dependent on γ and β units). In fact, multiply $d\beta$ and β both by arbitrary, but always both by the same numbers, so the ratio remains unchanged, hence the difference in sensation $d\gamma$ constant. This is Weber's Law. It will double, verdreifache the amount of change $d\beta$ alone, without the output value β to change, so does the change $d\gamma$ twice, three times the value. This is the mathematical



principle. the equation \square . Thus, at the same time, it completely satisfies that law and principle; and indeed no other equation satisfies both together. It shall be called the fundamental formula, by the derivation of all further formulas based on it.

The fundamental formula does not presuppose any measure of sensation, but it does not provide any such, but merely expresses the legal relation which takes place between small relative stimulus growths and sensory growths. In a word, it is nothing else than the one-word expression of Weber's law and the mathematical auxiliary principle through mathematical signs.

But with this formula, by infinitesimal summation, there is connected another, which establishes a general relation of magnitudes between the quantity of stimulus summed up from stimulus gains and the sensation summed up from sensation gains, in such a way that with the correctness of the first formula, the fact is co-prerequisite the threshold is shown in solidarity at the same time the correctness of the last.

Subject to the later more precise derivation, I first of all seek to make the connection between the two formulas generally comprehensible as follows.

It is easy to note that the relation between the increments $d\gamma$ and $d\beta$ in the fundamental formula corresponds to the relationship between the increments of a logarithm and the increments of the corresponding number. For, as one can easily convince, be it from theory or from the plates, the logarithms grow by the same amount, not when the corresponding numbers grow by the same amount, but when they grow by the same proportion; in other words, the increments of the logarithms remain the same if the relative number increases remain the same. So z. For example, combine the following numbers and logarithms:

Number. Logarithm.

| | |
|------|-----------|
| 10 | 1.000000 |
| 11 | 1.0413927 |
| 100 | 2.000000 |
| 110 | 2.0413927 |
| 1000 | 3.000000 |
| 1100 | 3.0413927 |

according to which the increase of the number 10 by 1 carries with it an increase of the corresponding logarithm just as great as the number 100 by 10 and the number 1000 by 100. Everywhere the logarithmic increase is 0.0413927. Besides, as was stated earlier for the explanation of the mathematical auxiliary principle, increases in logarithms are proportional to increases of numbers as long as they remain very small. It can therefore be said that Weber's law and the mathematical auxiliary principle apply equally to the growth of logarithm and number relative to one another, rather than to the growth of sensation and stimulus.

The fact of the threshold is just as valid in the relation between logarithm and number as in the relation between sensation and stimulus. The sensation begins with values that exceed the zero value, not at the zero value, but at a finite value of the stimulus, the thresholds, and thus a logarithm begins with values that exceed the null value, not at the zero value of the numbers, but at one finite values of the numbers, the value 1, if the logarithm of 1 is equal to zero.

If, after all, the growth of sensation and stimulus stand in a corresponding relation, as that of logarithm and number, the point from which sensible values begin to assume stands in a corresponding relation to the stimulus, as the point from which If one obtains positive values for the logarithms, as numbers, then one may expect that sensation and stimulus itself are in a corresponding relation, as logarithm and number, which, like these, can be regarded as summed up from successive increases.

After that, the simplest relationship between the two we can set up would be

$$\gamma = \log \beta .$$

In fact, it will soon be shown that by choosing appropriate units of stimulus and sensation, the functional relationship between the two returns to this simplest form. In the meantime it is not the most general which can be established, but only under the presupposition of certain units of sensation and charm, of which later, valid, and to require a direct and strict for the preceding indirect and non-strict derivation.

The expert immediately overlooks how this can be achieved by treating and integrating the fundamental formula as a differential formula. In the following chapter one finds this carried out; here it is presupposed to have happened, and to the one who is unable to follow a simple infinitesimal derivation, he claims to accept the result as a mathematical fact. This result is the following function formula between stimulus and sensation, which leads to the name Maßformel and is now to be discussed further:

$$\gamma = k (\log \beta - \log b) (2).$$

In this formula, k , in turn, a, and, dependent on the chosen units and at the same time from the logarithmic systems constant, b is a second constant which the threshold value of the stimulus β denotes where the sensation γ begins and shrinks.

According to the derivation of the formula given in the following chapter, the constant k coincides with the constant K of the fundamental formula when using

natural logarithms; while using ordinary logarithms and $K = kM$, where M is the modulus of the common logarithmic system in the meaning already given.

According to the proposition that the logarithm of its quotient is substitutable for the difference of the logarithms of two numbers (see Chapter 14), one can substitute for the above form of the dimensional formula also the following more convenient, usually for the derivation of conclusions

$$\gamma = k \log \frac{\beta}{\beta_0} \quad (3).$$

Flows from this form that sensation size γ not as a simple function of the stimulus value β , but its relationship to the threshold values b , is to look at where the

sensation begins and shrinks. In the future, this relative stimulus value should be called the fundamental stimulus value or fundamental value of the stimulus.

Translated into words, the measure formula is:

The size of the sensation (γ) is in proportion not to the absolute size of the stimulus (β), but to the logarithm of the size of the stimulus when it is related to its threshold value (b), that is to say the unit size at which Sensation arises and disappears, or in short, it is proportional to the logarithm of the fundamental stimulus value.

Let us hurry, before proceeding further, to show that the dimensional formula correctly expresses as inference the relations between stimulus and sensation from which it is derived, and thus finds its probation backward in so far as they are confirmed in experience. At the same time we receive the simplest examples of the application of the dimensional formula.

The measure formula is based on Weber's law and the fact of the stimulus threshold; and both must therefore flow out of it again.

As far as Weber's law is concerned, it can be obtained by the differentiation of the measure-formula under the form that equal increases of sensation belong to the same relative stimulus increases, provided that this returns to the fundamental formula which contains the expression of the law in this form.

In the other form, that the same differences in sensation belong to the same stimulus-relations, it can be deduced quite fundamentally as follows.

Let be two sensations whose difference we have to consider, γ and γ' , and the stimuli β and β' which belong to them. Then we have the measurement formula

$$\gamma = k (\log \beta - \log b)$$

$$\gamma' = k (\log \beta' - \log b')$$

and therefore for the sensation difference

$$\gamma - \gamma' =$$

$$k (\log \beta - \log \beta')$$

or, since $\log \beta - \log \beta' = \log \frac{\beta}{\beta'}$,

$$\gamma - \gamma' = k \log \frac{\beta}{\beta'}.$$

It follows from this formula that the sensation difference $\gamma - \gamma'$ is a function of the

stimulus ratio $\frac{\beta}{\beta'}$, and it remains the same, whatever values β, β' may assume, if only their ratio remains unchanged, which is the statement of Weber's law.

In a later chapter, we will come back to the above formula, as one of the simplest implications of the measure formula, under the name of the difference formula.

As for the fact of the threshold, which rests in the fact that the sensation has its zero value not at a zero value, but at finite values of the stimulus, from where it first begins to assume appreciable values as the stimulus value increases, it is contained in the measure formula insofar as as γ does not assume the value zero according to the measure formula, if $\beta = 0$, but if β is equal to the finite value b , as is evident from the form (2) and (3) of the measure formula, from (2) directly, from (3) in

consideration that when β is equal to b is, $\log \frac{\beta}{b} = \log 1$ is, and $\log 1 = 0$.

Of course, all the implications of Weber's law and the fact of the threshold will also be the consequences of our measure formula.

It flows from the former law that every given increase in a stimulus gives rise to less increase in sensation than the stimulus to which it grows, is greater, and at high degrees of stimulation is no longer felt considerably, while in the lower it may seem exceptionally considerable.

In fact, the increase of a large number β by a given quantity only implies a smaller increase in the associated logarithm γ without comparison, than the increase of a small number β by the same increase. If the number 10 increases by 10, ie increases to 20, then the logarithm 1 belonging to 10 increases to 1.3010. But if the number 1000 increases by 10, then the logarithm 3 belonging to 1000 grows to only 3.0043. First case has the logarithm by about $1 / 3$, in the latter case by only about $1 / 700$ increases its size.

The consequence of the fact of the threshold is the fact that the more the stimulus sinks below its threshold, the farther the sensibility is removed. This distance of the sensibility from the distinctiveness, or depth, of it below the threshold, is, according

to our measure-formula, represented just as well by negative values of γ , as the elevation over the same by positive values.

In fact is overlooked from the mold (2) immediately that, if β is less than b and thus $\log \beta$ as a small $\log b$ is the sensation γ assumes negative values; and the same flows

from the form (3) after considering that \square becomes a true break if $\beta < b$; the logarithm of a true fraction, however, is negative.

Insofar as we call sensations which are stimulated by a stimulus but are not sufficiently conscious to affect consciousness, in short unconscious, those which affect it, the unconscious sensations become negative, the conscious ones positive values in our formula represents. We will return to this representation in a special chapter (chapter 18) because of its special importance, and perhaps not every immediately obvious meaningfulness. For now I do not want to stop it.

Our measurement formula corresponds to the above experience:

1) In the **equals cases**, where a sensation difference remains constant when the absolute strength of the stimuli changes (Weber's Law).

2) In the **borderline cases**, where the sensation itself, and where its change ceases to be noticeable or significant, the former, when it comes to the threshold, the latter, when it has risen so high that a given stimulus increase is no longer felt significantly.

3) In the **contrasting** cases between sensations, which exceed the finesse and which do not reach the notability, briefly conscious and unconscious sensations.

Hereafter, she should be regarded as well-founded.

For the first sight one might be inclined to believe, not only the fact of the stimulus threshold, but also the threshold of difference must be deduced from the measure-formula, because this was based on it. In fact, Weber's law, and herewith the main document of the measure-formula, is largely inferred from the method of just noticeable differences from experiments on the constancy of a just noticeable difference in sensation, which is related to the threshold of difference and closely approximates. But, let us see more closely, it is only the same magnitude of this difference with the same relative differences of stimulus, not that the notability occurs only in the case of a finite value of this difference in stimulus, which is used for the foundation of the fundamental formula and hence measure-formula; Therefore, the difference of this justification, which is just noticeable, can be represented just as well by an average, rather than just noticeable, as by the method of right and wrong cases, or by an average smaller, as in the case of the mean error. insofar as it allows an assessment of equality. On the other hand, the fact that the threshold of difference does not contradict the measure-formula, but necessarily takes account of it and takes it into a mathematical expression, enters into a more general formula (difference-measure-formula), the reasoning and discussion of which is reserved for a later chapter, a formula which accomplishes the same thing for specially understood (so-called perceived) differences between sensations,

The parallel law, according to which a difference in sensation remains the same, if the irritability and herewith the threshold b for the different stimuli change in the same ratio, is an inference of our formula, if k remains constant, only that after a proper course the constancy of k itself can only be inferred from the parallel law, as shown below.

With the measure-formula, we have now obtained a general dependence relationship between the magnitude of the fundamental stimulus value and the size of the corresponding sensation, which is no longer valid only for equality cases of sensation, and which allows one to calculate from the proportions of the first the how-many-times of the last the sensation is given.

A n times stronger sensation γ will henceforth not be the one which belongs to n times as large values of the external or equivalent internal stimulus β , but which belongs to such a value of β , which according to the measure formula is n times as large Value of γ gives.

If the sensation γ is given for a certain fundamental value of the stimulus, then γ will increase to n times the value of the fundamental stimulus, increasing to n times the power, and decreasing to $\frac{1}{n}$ its value, if from the fundamental stimulus the n -th root is pulled.

For what the first is concerned, we shall have, by acting on both sides of the measurement formula with n multiplied

$$n \gamma = nk \log \quad (4).$$

Since, however, the n - fold logarithm of a number can be substituted for the logarithm of the n - th power of the number, one can also substitute $\log n$ for $\log n$ and thus obtains:

$$n \gamma = k \log \quad (5).$$

No less, one has to divide by n on both sides of the measure formula , or, what comes to the same thing, to multiply by $1/n$:

$$\boxed{} \\ \boxed{} \quad (6)$$

if known generally



In general, however, the relation of two sensations γ , γ' belongs to the stimuli β , β' :



(7)

that is, equal to the ratio of the logarithms of the fundamental stimuli.

In the measure-formula and its derivations, both the magnitude of the stimulus and the sensation are each related to a unity of their kind. For since stimulus and sensation are of a very heterogeneous nature, they can only be specially measured by units of their kind, but they can not be given a common unity. In fact, in our measure of the sensation, we do not explain it as a multiple of the stimulus, but as a multiple of a sentient quantity of the same kind, and only the relation of the sensation to its unity is determined by the relation of the stimulus to its unity. in that both relations are a function of each other, which is such that if one relationship is given, the other is to be inferred from it. This function is what is represented by our measurement formula.

In the arbitrary choice of the units of stimulus and sensation, various considerations can be determined. One can let the units of stimulus and sensation coincide, ie, assume the unity of sensation in the stimulus value, which is assumed to be the unity of the stimulus, but it can just as well fall apart, ie, the unity of the sensation in a stimulus other than the stimulus Take the stimulus unit, since there is no need to bring both together. Only with every other choice of units do the constants of the formula change, and herewith the absolute size of the number, by which a sentiment is expressed, but without the proportions of sensation, which alone matter in the measure, others thereby become.

If you ask for the simplest possible form of the measurement formula

$$\gamma = \log \beta \quad (8)$$

in which $b = 1$, $k = 1$, one can not shift the units of stimulus and sensation to the same point. Because, to set $b = 1$, one is bound to the threshold value of the stimulus as a unit; on which one can not at the same time drop the unity of the sensation, since the null-sensation falls upon it, which grants no unity. But the simplest form is obtained by taking the unit of stimulus at thresholds, whereby all stimuli become fundamental, but the unit of sensation in a fundamental stimulus whose logarithm is 1, which is equal to the fundamental number of logarithms applied, that is, using common logarithms at 10 times, using natural at the etimes (2,718 .. .fold) the threshold.

That $k = 1$, if you set the sensation unit at a fundamental stimulus values equal to the base number of the logarithm applied, is easily found as: Be generally, in some

systems taken, basic number a , then one has by at the sensation unit $\boxed{}$ sets, ie $\gamma = 1$, after substitution of these values into the formula

$$1 = k \log a$$

therefore



Since in every system the logarithm of the basic number is $\log a = 1$, this gives k the value 1.

These units of stimulus and sensation, which make $b = 1$ and $k = 1$, and thus reduce the simplest possible form of the measure formula $\gamma = \log \beta$, will in future be called the fundamental units, ordinary or natural, depending on whether they are ordinary or natural logarithms presupposes. The stimulus unit remains the same in both cases; but the unit of sensation changes according to the logarithmic system in the ratio of 10 : 2,718

On the premise of the fundamental units, one can simply say that **the strength of the sensation is the logarithm of the strength of the stimulus**, and the number expression for the size of the sensation varies, depending on the logarithmic system used, but the absolute magnitude is different in view of the different ones To find the unit of equal size, as one can set the length 12 for the length 1, and with the latter number will denote no greater length than with the former, if one understands by twelve twelve inches and under one foot.

After that z. For example, using ordinary fundamental units, a doubling of sensation 1 will take place if the stimulus increases tenfold, since $\log 10 = 1$, $\log 100 = 2$. But one would be wrong to say that any sensation ever doubles when the stimulus but only that sensation 1, which belongs to the value $\beta = 10$, ie a stimulus that is 10 times greater than its threshold value. Should the sensation 2, which belongs to the stimulus 100, be doubled, this would take place with a stimulus whose logarithm is 4, ie, at 10,000, that is, the stimulus need not increase tenfold, but must multiply an hundredfold, and so on

Also, when sensation 1 using ordinary fundamental units doubles when the stimulus is increased tenfold, it does not take place when using natural fundamental units, because sensation 1 here amounts to a lower stimulus, not 10 times, but 2,718 ... -fold the threshold value, and thus corresponds to a lower absolute magnitude of the sensation. This will double when the stimulus rises to 2.718 times.

If one wishes to combine the unit of sensation and the unit of stimulus in the same point, one will obtain the next simple form of the measure-formula, if the stimulus unit and the unit of sensation are taken together at a fundamental stimulus value equal

to the fundamental number of the applied logarithms. This form of measurement formula is

$$\gamma = \log \beta + 1 \quad (9).$$

In fact, the condition that $\gamma = 1$, if $\square = a$, gives by substituting these values into the measure formula

$$1 = k \log a$$

di $k = 1$, because $\log a = 1$.

Further, the condition that γ and β are 1 at the same time by substituting 1 for both γ and β in the form of the measure formula (2) and setting $k = 1$

$$1 = \log 1 - \log b.$$

But since $\log 1 = 0$, we get $-\log b = +1$.

If one finally substitutes these values $k = 1$ and $-\log b = +1$ into the general form of the dimensional formula $\gamma = k (\log \beta - \log b)$, we obtain the above form.

The simplest form of the measure formula $\gamma = \log \beta$ can serve everywhere and will permit everywhere the simplest derivation of the results, where the threshold value of the stimulus remains constant, then always having it in its power to apply the fundamental units, thus the unity of the stimulus constant at b , and that of sensation at the fundamental stimulus value equal to the basic number of logarithms used. But where changes in irritability occur, or the possibility of them being considered, b can not be set generally = 1; and we will therefore frequently, but not always, use the simplest form of the dimensional formula.

How easy it is to consider that the dependence of sensation on the stimulus automatically implies the reverse dependence of the stimulus on sensation, not insofar as the stimulus in its existence is dependent on the sensation, but insofar the size of the stimulus which is necessary given sensation depends on the size of the sensation. This dependency ratio is expressed by reversing the dimensional formula

$$\square \quad (10)$$

where a is the basic number of applied logarithms, which formula simplifies using the fundamental units to the following:

$$\beta = a \gamma \quad (11)$$

For the formula $\gamma = k \log \square$ leads first to $\log \square$, this according to Chap. 14 too $\square = \square$ and this too \square .

With regard to the meaning and use of the dimensional formula, the following remarks are important.

It is a formula which, according to its founding principle, can directly be regarded as authoritative only for the dependence of the intensity or strength of the sensation on the intensity or strength of the stimulus, if a stimulus at a point or in the same ratio exists at all points where it exists. decreases or increases. Therefore, when we speak of the measurement of sensation by the stimulus by means of the measure-formula, the measurement of the intensity of sensation by intensity, not by the quantity of stimulus extending over a given temporal or spatial extension, is always meant by it.

If the sensation is to be measured simply as a function of the stimulus by means of the measure formula, then the threshold value of the stimulus b must be known and, like k , constant at the various degrees of stimulus. Now, k remains unchanged by the action of stimuli, as I show especially below, but not b , in that irritability changes by stimulus. But the more it dulls, the greater the value of the stimulus is to raise the sensation to the threshold, the more b . In the meantime, this circumstance does not upset the applicability of the dimensional formula, but rather expands it. For it shows that it is not merely decisive for the dependence of sensation on stimuli, but also for the degree of sensitivity with which it is conceived. Just as we can introduce a variable β into the formula and track the change of γ that depends on it, we can introduce a variable b and then follow the changes of γ .

This, of course, calls for a more precise study of the law of changes in b by stimuli, and then introduces b into the formula as a function of the strength and duration of the stimulus. But to this study of a relation which is important in itself, the measure-formula itself offers the most suitable support. It seems that b in the case of any stimulus not too violent, with a prolonged duration of the same, to a limit, or, in the case of rapid periodic recurrence, to an intermediate value, which is related to the magnitude of the stimulus and the duration of the period in a, but not yet ascertained, legal relation; and by substitution of some of the initial value, otherwise of that limit or mean value, will be covered in the measure-formula principal cases of their application.

Where the threshold value b is not known, and therefore an absolute measure of the sensation can not take place through the measure formula, it can nevertheless be used to measure sensation differences, by taking the same for two different sensations and taking the difference of the expressions. the threshold b disappears from this difference, as we have already noticed, and will be discussed further in a later chapter.

If one sets the constant b as a function of the other variables in the dimension formula, one obtains from formula 11 the following



(12)

when a basic number of logarithms is applied, after which b the stimuli β is proportional to a given sensation γ carries. Thereafter, the reciprocal value of

can b , di virtually regarded as scale of the absolute sensitivity or in terms of Th. 51

IS understood irritability, if these is the reciprocal of the stimuli according to previous definition, which triggers a given sensation.

This is assuming what is proved in the following intervention that k does not change with b .

If one builds k in the measure formula as a function of the other values, one obtains

$$\boxed{\text{Equation 13}}$$

according to which k is proportional to the sensation γ , which results from a given

fundamental stimulus relation $\boxed{\text{Equation 13}}$. Now, generally speaking, it would be possible to think that if the threshold value of the stimulus b changes by changing the irritability,

the fundamental stimulus ratio $\boxed{\text{Equation 13}}$ at which a given sensation quantity γ arises also changes. In this case, according to the previous formula, the value k would change with the value b , depend on it, and thus one must only apply a constant value of k in the measure formula as long as the absolute sensitivity or irritability, of which b depends, the same remains. From the other side, however, it is generally conceivable that, just as the threshold value b changes, the sensation remains the

same if only the fundamental stimulus ratio $\boxed{\text{Equation 13}}$ remains the same. In this case, k is independent of the irritability and can be applied to the most different values of b the same k in the Maßformel.

Only experience can decide this important question, and it decides for the last assumption. In the chapter on the parallel law it has been shown that a difference between two stimuli appears equally clear, be it with fatigued organs, whereby the threshold b changes, or be interpreted as fatigued. If, at first, the corresponding values of the constants b and k , and finally b and k , and both the stimuli whose difference is to be understood, be β and β_1 , then the sensation difference is at first

$$\boxed{\text{Equation 14}}$$

from which the second form results, by converting the difference of the logarithms into the logarithm of the quotient. Second, the sensation difference

$$\boxed{\text{Equation 15}},$$

Now if both differences are to be the same, as experience shows, then $k' = k$, d. i. the value of k independently of the values b be ²⁾

2) A difference to be made later between sensory differences and perceived differences will not change much in this deduction.

It will be seen hereinafter that the parallel law is an essential complement to Weber's law in the establishment of the measure formula.

Hereinafter, the following noteworthy sentence can be derived from the dimension formula:

If the stimulus value b , at which a sensation comes to the threshold, increases or decreases in a given ratio, then every stimulus value by which a sensation of given strength is to be produced increases or decreases in the same ratio. So if z. B. Somebody who approaches deafness needs a sound that is n times as strong as to listen to it at all, than someone else with sound ears, and he will need a sound that is n times as strong to equal him to hear this no matter what strength one may base on

this. Because we have the measure formula $\gamma = k \log \frac{b}{b_0}$. Should now be at n -fold values of b , the value of γ still be the same size as in the case of simple ones, then the n -times β must also be used.

We have no direct means of comparing the strength of sensations in different individuals. But it is not without interest that by determining the threshold value b in different individuals we obtain an indirect means which is sufficient for the whole scale of sensation strengths at once.

By the way, shows the shape of the measurement formula that it comes out for the size of sensation to the same whether one β reduced in a given situation or b in the same ratio increased thinks. This results in a double representation of altered irritability, and it may be more appropriate to use one or the other. A reduced irritability can be represented by a reduced stimulus β at the same threshold value b as by an increased threshold b at the same stimulus effect β . The former can be described as a blunting of the stimulus or stimulus, the latter as a blunting of irritability. In the translation of the stimulus into its dependent psychophysical movement, which, however, has space in internal psychophysics, only the first representation is applicable, provided that diminished irritability presupposes only that there is a diminished psychophysical effect of the stimulus which we then have to express by a diminished β . But in external psychophysics, on whose ground we now stand, we have, in order to represent without preconditions only the factual relations through the formula, the stimulus β in its real size, to introduce it into the formula, and to represent the variability of its effect by altering the irritability by varying the constant b , whereby we remain at first in the following.

If we call B the value of β , at which the unity of the sensation γ is assumed, then in the general expressions which have hitherto been given for b and k , we shall have to set the value of $\gamma = 1$, if we also have $\beta = B$ put. Thus we obtain these constants as a function of the empirical value B , namely

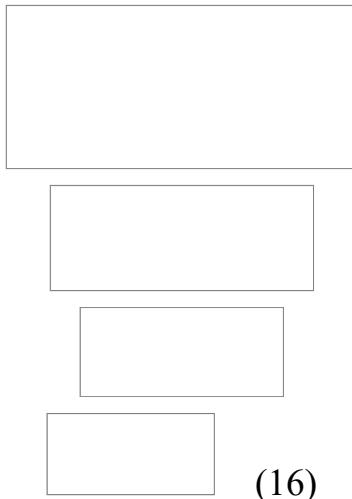


(14)



(15)

These values for b and k can then be arbitrarily substituted in the dimension formula. Substitution of the value of b has one



The substitution of $\boxed{\quad}$ for $\log \boxed{\quad}$ in this derivation, which leads back to the already found result, is due to the fact that $\log \boxed{\quad} = \boxed{\quad} \log a$, and that $\log a = 1$, because a is the basic number.

Substitution of the value of k is easy



(17)

Meanwhile, the simple application of the letters b and k in the measure formula will generally be more convenient for deriving conclusions.

Among the circumstances to be considered when applying the measure formula is the presence of internal sensory stimuli. If present, their size should be added to the size of the external stimuli to obtain the value of β to be introduced into the formula. But their existence and their greatness can only be inferred from the existence and strength of sensations in the absence of external stimuli, and taken into account in an equivalent after comparison with their effect. So we have to add to each external light stimuli a small size and the so increased appeal in the formula as β to obtain the result of the sensation of light completely, if, after several previous discussions, even without external stimulus, a faint light sensation in the existence of the eye-black asserts itself, which presupposes the existence of an internal cause of

the sensation of light, which we briefly call the inner stimulus. If this additional quantity can not be determined precisely for the external stimulus, then its existence must be taken into account, since it acquires the most important influence in weak external light stimuli, and relatively strong external light stimuli must be applied relatively where its influence is to be neglected.

On the other hand, it must be taken into account that, apart from the numbing of the irritability they carry, some stimuli produce a mechanism limiting their action, the effect of which grows with the strength of the stimuli. At least this is true of the light stimuli, as long as the pupil narrows due to the intensified light stimulus, and it would be very possible that something similar would happen in the hearing and perhaps also in other senses. Of course, the stimulus can be introduced only with regard to this restriction in the Maßformel, which one can satisfy arbitrarily by a corresponding reduction of β or increase of b .

Each stimulus radiates in a certain circle and each sounds for a certain time; once his impression has been made. From this too, there may be increases to be taken into account for the direct and instantaneous stimuli.

In other ways, according to the laws of contrast, previous and accompanying stimuli alter the size of sensation produced by a given stimulus. If, with reference to this, the measure-formula should find simple application, then either all the stimuli must change in the same ratio, or all the stimuli except the changing one must be kept constant; at least it is probable that under these two conditions the simple application of the dimensional formula can take place. The Weber law is confirmed under the first condition when trying with the cloud nuances (Th. IS 140), under the second condition when estimating the star sizes.

Finally, one thing to remember is the point of attention to be considered in the applications of the measurement formula. For the time being, we require a comparable state of attention for a comparable application of the measurement formula. It will become clear later that the different degrees of attention, within certain limits and in a sense, are not considered in the applications of the measure-formula to sensations. Secondly, that the measure-formula can apply to the measure of attention itself. However, many discussions of internal psychophysics must first precede this.

It may well be seen from the foregoing that, as simple as the measure-formula is, its application is not too simple a matter. And with these difficulties of its application, it is easy to ask whether something and what has ever been won with it.

In this respect, it should be noted that the principal interest of the measure-formula is not that it permits the comparison of sensations in numbers, which should not easily be a scientific or practical occasion, except that:

- 1) with the fundamental possibility of measure, which can be realized under favorable circumstances, the concept of which is built on a firm, clear, exact foundation, and hereby psychophysics is at all assured of the mathematical basis; that
- 2) in the functional combination of the values γ , β , b the relation of stimulus,

sensation, and sensibility finds an expression which justifies a clear and sharp conception of this relation according to factual relation, and gives the investigation of it clear and sure points of attack; (3) According to this functional relation, it can generally be foreseen, even without special measure, how, with the alteration of these and those relations, the course and state of sensation phenomena must change, as is the case with the borderline cases and turning points of the latter; So there too, where no special measure is possible, but general conclusions are possible.

These advantages are already present in the field of external psychophysics, and in such cases, rather than in the possibility of execution of measure, which is so seldom to be realized as it is to be realized, the importance of the dimensional formula in this field must be sought.

However, in my opinion, the main interest of the measure formula does not lie in the external, but in the inner psychophysics, provided that in the dimensional relation between stimulus and sensation expressed by them, not the entrance into internal psychophysics, but, as it were, the key to its door is.

In fact, even if the measure-formula can do much to orient us in the field of relations of stimulus and sensation, yet, according to all the above, a pure and strict application of them will never take place here. Only in certain, more or less wide, never quite definite boundaries, with more or less approximation, can we expect proportionality between stimulus and psychophysical activity, and where this proportionality is disturbed or ceased, the applicability of the measure formula is disturbed or canceled. The main achievement of external psychophysics in establishing the measure formula, therefore, is that, in my opinion, it is based on having established it so far in its field, despite all the disturbances.

In the meantime, with the measure formula, we are still in the very outset of outward psychophysics, and must first consider their achievements and limitations on this ground. The more complete, more faithful, more presuppositionless, but this happens, the better we will work out the transition into internal psychophysics.

The strength of the stimuli in the realm of light and sound is directly representable by their living force, and to be assumed by them as by other stimuli, that they only act as stimuli, insofar as their living force triggers and thus represents a living force of psychophysical movement in the body. Accordingly, it has an interest in establishing our formulas as a function of the living force of the stimulus or the movement that is triggered thereby. At first, this appears only from the point of view of a mathematical speculation; nor is it to be decided from the outset whether formulas which, according to experience, could at first be set up only for the living force of whole vibrations, are also transferable to the living force of the individual moments of vibrations, and whether the power of a whole vibration and of other forms of motion for sensation can be correctly rediscovered by summing up what their individual moments contribute according to these formulas, whereby only the transmission to moments might be justified and useful. Since in the meantime such a justification seems to arise through a later chapter, we presuppose the elementary formulas relating to it.

Let us imagine a particle of mass m , which moves in a given moment of time at velocity v , and thus has the living force mv^2 , by virtue of which it acts as a stimulus to a sentient organ, or even as a psychophysically active element and thus makes a contribution to the total sensation which, by summation of the elementary effects, is to be regarded as resulting, as will be explained in more detail in the following.

Let b be the velocity of the particle at which its contribution to the total sensation is extinguished; then we obtain by substitution of mv^2 for β and of mb^2 for b in the measure formula

$$\boxed{\text{[Redacted]}}$$

and in the fundamental formula

$$\boxed{\text{[Redacted]}}$$



The equality of $\boxed{\text{[Redacted]}}$ with $\boxed{\text{[Redacted]}}$ in the last formula is proved by the differential calculus, if $d \cdot v^2$ taken as a differential = $2 v dv$. So we have a short one

$$\boxed{\text{[Redacted]}} ; \boxed{\text{[Redacted]}}$$

which values will still have to be multiplied by the time element dt in order, on the one hand, to obtain the contribution γdt , which a stimulus, which has the magnitude mv^2 at time t , gives to the sensation in the time element dt , and, on the other hand, the sensation gain $d \gamma dt$, which experiences the sensation occurring at time t when the stimulus mv^2 in the time element dt grows by $d \cdot mv^2$.

The following noteworthy conclusions flow from previous formulas:

- 1) The dimensions of the particles are not included in the elementary formulas.
- 2) It does not matter whether one introduces the living force or the simple velocity into the formulas, by doubling only the constants k and K at the end .
- 3) The sign of v , and hence the direction of velocity, has no influence on the value of sensation and sensation difference , since the same sign always appears in the numerator and denominator of the expressions, for even b we shall have to assume homologous to the v , to which it belongs ,

On the first point, it is undeniably not without interest, and, if one wishes, appropriate to the character of a mental measure, that the physical mass disappears completely from these formulas. The elemental mental intensity then depends only on movement, not on mass. However, what applies to elements should not be transferred to systems. Applying the formulas to the total stimulus, the impulses expressed by different particles may in part sum up for the same point of the sensible organ, as two bells together more than one sound, and partly distribute them to different ones, as two stars two In each case, the total size of the sensation will have to increase with

the number of irritating particles, and hence the total mass of the stimulus. If we apply the formulas to the psychophysically excited organ itself, the same will apply to the number of irritated particles. It is also undisputed that a particle of double mass with equal velocity equal to a sum of two particles of simple mass must be considered at that velocity.

The formulas hitherto have been set forth in the simplest and nearest condition, that the dependence which exists after experience between the magnitude of the sensation and the living force of a whole vibration, is translatable into a dependence between the contribution, a single moment of a vibration in a temporal element to the whole sensation, and the living force existing in this element of time, having shown that it essentially comes down to it, whether we find the square of velocity or the simple velocity for β into the formulas. It may be remarked, however, that in the case of light and sound, on the conditions of which we alone could base ourselves, the changes in velocity which occur in the course of each oscillation grow in proportion to the speed of the oscillating particles; If the amplitude doubles, the speed doubles and the speed change doubles in each moment at the same time. And it is just as much reason to think that β to substitute the change of velocity as the velocity itself into the elementary formulas. Between them the decision can only be made as to which of the two conditions of the task is better suited to produce the experiential dependence of the whole sensation on the whole movement by summation of elementary contributions; and there is a relatively simple case which is well suited to the study of this question, but which I will deal with only in the future.

If, after such an investigation, the assumption seems to be really preferable-and indeed it will be-that in the fundamental formula and measure formula for β , instead of the simple velocity, the change in velocity, or what we shall call second-order velocity in the future, too By the way, in the form of the above formulas, this would not change anything by understanding such a second order or a change of velocity just under v instead of a first-order velocity and the above three points would retain their validity:

- 1) that the mass disappears from the elementary formulas;
- 2) that, apart from the value of the constant k , K , *it is* immaterial whether one uses the second-order velocities simply or in squares;
- 3) that their positive or negative value, that is, whether they act as acceleration or deceleration, has no influence on the sensation result.

The closer examination of the question itself, however, is in fact only later appropriate, because up to now neither a special need nor a reason has offered to decide it.

In the foregoing, I have only discussed the fundamental formula and the measure formula according to the main points which come into consideration, in so far as the most general and the general connection of these points comes to light; yet to the individual of them in the following chapters will come back with more specific discussions, just as the applications of the formulas must be pursued. Furthermore, I

come to a generalization of the Maßformel and the whole Maßprinzip, which I briefly indicate here in advance.

The measure formula gives the dependence of the sensation on the stimulus. As the more general of them, a formula which I call the difference formula may hold, whereby the dependence of a difference in sensation on the stimulus is given, by considering the measure-formula as the particular case of the difference-formula, where the one sensation, the difference between them, becomes zero. The formulas for sensory differences can be further generalized to those for differences between sensory differences or differences of higher order. There can be a distinction between differences of sensibility, which may later be explained by facts, according as they appear in the sensation or are to be specially understood. and for the latter, the introduction of the ratio threshold into the difference formula, thereby creating the difference measure formula. Finally, the whole measure principle can be represented independently of Weber's law.

XVII. Mathematical derivation of the dimension formula.

The fundamental formula developed in the beginning of the previous chapter



relies on experiments on differences that are at the limit of the peculiarity. *Thereafter*, dy and $d\beta$ can be considered and treated as differentials in it. By integrating them, one then first finds, assuming natural logarithms

$$\gamma = K \log \beta + C,$$

where C is the integration constant. If one determines it by the condition that the sensation γ disappears at the threshold of the stimulus $\beta = b$, one has

$$0 = K \log b + C,$$

therefore

$$C = -K \log b$$

and

$$\gamma = K (\log \beta - \log b).$$

Since an ordinary logarithm is equal to the natural logarithm multiplied by the

modulus $M = 0.4342945$, then, using ordinary logarithms and theorem of $\boxed{\quad}$, the previous formula goes over into

$$\gamma = k (\log \beta - \log b) = k \log \boxed{\quad}.$$

This derivation would become illusory if the fact of the threshold did not exist, which, together with Weber's law, together forms the permissible basis of the measure-formula and thus of the absolute measure of sensation. In fact, rather than a finite value, sensation should be extinguished at a zero value of the stimulus, we would obtain a negatively infinite value for the constant C , and there would be no finite expression for an absolute sensation value; but nothing would prevent the measuring of sensation differences in which expression C disappears. Euler's formula for pitches, and Steinheil's formula for star sizes, as not based on the fact of the threshold, therefore also refer only to sensory differences.

Even without infinitesimal calculus one can derive the measure formula from Weber's law by reference to the fact of the threshold; if one expresses Weber's law in such a way that the sensation difference remains the same, if the stimulus-relation remains the same. And it merits this derivation by name, insofar as it enables it to reverse the previous course, ie, instead of arriving at the fundamental data from the empirical data, in order to derive the measure formula from integration in the manner just described, but rather to the measure formula to derive the fundamental formula by differentiation.

In fact, if γ and γ' are two sensations which belong, respectively, to the stimuli β and β' , Weber's law in the last-mentioned form says that $\gamma - \gamma'$ remains

constant as long as $\boxed{\quad}$ it remains constant, or that

$$\gamma - \gamma' = \boxed{\quad}$$

if f is the general function character.

Without reference to the fact of the threshold, the function f could now be arbitrarily taken, the condition of Weber's law would always be fulfilled. In fact, the following formulas would

$$\begin{aligned} \gamma - \gamma' &= \boxed{\quad} \\ &= \boxed{\quad} \\ &= \boxed{\quad} \text{ etc.} \end{aligned}$$



Equally well satisfy the condition that $\gamma - \gamma'$ remains constant, as long as it remains constant, as the formula

$$\gamma - \gamma' = k \log \boxed{\quad}.$$

But if we add the condition that the sensation disappears at a finite value b of the stimulus, then only the latter form is possible.

In fact, we put in the equation

$$\gamma - \gamma' = \boxed{}$$

the sensation $\gamma' = 0$ and the corresponding stimulus $\beta' = b$, so goes. she over in

$$\gamma = \boxed{}.$$

Accordingly, we get out of the equation

$$\gamma' - \gamma = \boxed{}$$

by putting $\gamma = 0$ at the value $\beta = b$,

$$\gamma' = \boxed{}.$$

This gives the difference

$$\gamma - \gamma' = \boxed{} - \boxed{},$$

which difference was found initially

$$\gamma - \gamma' = \boxed{}$$

must be the same. Ie. you have to have

$$\boxed{} = \boxed{} - \boxed{}$$

or

$$\boxed{} = \boxed{} + \boxed{}$$

Now, according to evidence that *algébr* in Cauchy's *Cours d'analysis*. p. 109 suiv., In Schlomilch's Handb. D. algebr. Analysis p. 86 and elsewhere, the equation

$$f(xy) = f(x) + f(y)$$

not be satisfied otherwise than to set

$$f(x) = k \log x$$

$$f(y) = k \log y$$

$$f(xy) = k \log xy$$

where k is a constant.



Substituting in previous equations \square for x , \square for y , hence the product of both for xy , it becomes identical with the above, and it follows that one has to set



However, if β, β' with γ, γ' approach zero at the same time, ie $b = 0$, then this



derivative would not take place because of the infinite values which assume $\log \square$,

$\log \square$, and the function f could be taken arbitrarily.

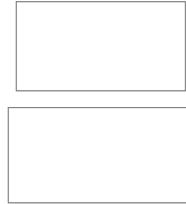
The logarithmic function of the stimulus-relation, to which we find ourselves so necessary, is also distinguished from all other functions of the stimulus-relation which one might try to substitute for it, by a quality which, insofar as it can be established by experience no less than the condition of the threshold can serve, by gaining access to Weber's law, to establish the logarithmic function with certainty; and without which no account could be taken with sentimental values on the basis of Weber's law, as without the previous one; in that the mathematical axiom that by summing two differences one obtains something the same as the total difference, can exist only by means of the logarithmic function of the stimulus-ratio for sensory differences,

Be z. B, given three stimuli in descending order of quantities β, β', β'' with the corresponding sensations $\gamma, \gamma', \gamma''$, then, by no means, as our logarithmic function of the stimulus relation, would the difference between the extreme sensations γ and γ'' are equal to the sum of the differences we find between γ and γ' , γ' and γ'' .

Let's explain it to star sizes. The three stimuli β, β', β'' are supposed to be represented by three star sizes, 1, 2, 3. Class If the difference in sensation is some other function of the stimulus ratio than our logarithmic one, then the difference of the brightness one finds if one passes directly with the eye from the 1st to the 3rd magnitude, appear larger or smaller, than the difference of the brightness, which one finds, if one of the 1 . goes to the second, plus the difference that one finds when one passes from the 2nd to the 3rd, and it can be inserted between the sizes no fractional sizes whose differences of the whole neighboring sizes the total difference of the same reproduced. But since astronomers really insert fractional quantities according to this principle upon the judgment of the eye, the axiom in question must be valid here. Likewise, the interval of the octave could not be as large as the sum of fifth and

fourth, but that is an empirical fact. And if one does not dare to pronounce this equality of the total difference of sensation with the sum of the partial sensations in the sphere of other sensations just as decidedly as the result of experience, as in the domain of pitch-pitches,

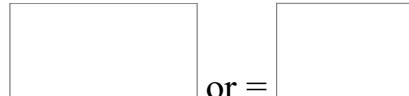
It is first of all empirically convincing that, if $\gamma, \gamma', \gamma''$ are the three sensations which belong to the three stimuli β, β', β'' , according to none of the functions set forth above, the logarithmic $\gamma - \gamma'' (\gamma - \gamma') + (\gamma' - \gamma'')$ is obtained, supposing that the first form is valid, one would have



Should now $\gamma - \gamma' = (\gamma - \gamma') + (\gamma' - \gamma'')$ be so would



be, so



which is not general, but only under the very particular assumption that [] the case might be. No less would one find inequalities for all other functions; except the logarithmic. In fact, after this one has



Equivalence between

$$\gamma - \gamma'' \text{ and } (\gamma - \gamma') + (\gamma' - \gamma'').$$

General, if

$$\gamma - \gamma' = \boxed{}; \gamma' - \gamma'' = \boxed{}$$

$$; \gamma - \gamma'' = \boxed{}$$

as is the case under Weber's Law, and when it is required that

$$(\gamma - \gamma') + (\gamma' - \gamma'') = \gamma - \gamma'',$$

so must

$$\boxed{} + \boxed{} = \boxed{}$$
$$\boxed{} = \boxed{} \cdot \boxed{}$$

which equation, considering that $\boxed{} = \boxed{} \cdot \boxed{}$, can not be satisfied otherwise than what is said (supra)

$$\boxed{} = k \log \boxed{}$$

Just as there are conditions which strongly require one to stand by the logarithmic function, so there are those by which this or that of the functions given above are decidedly excluded. Should the function have this shape

$$\gamma - \gamma' = k \boxed{}$$

Thus a difference in sensation should not only always be the same if the stimulus ratio is the same, but also grow in the same ratio as the stimulus ratio grows, irrespective of the size of the stimuli. But that contradicts the experience. For z. For example, in the case of star magnitudes, doubling the difference between two successive star sizes, or the difference of one star size from the third does not by any means duplicate the ratio of light intensities associated with successive star magnitudes. On the other hand, the shape should be this

$$\gamma - \gamma' = \kappa \sin \boxed{}$$

so the sensation difference would increase and decrease periodically with increasing intensity of one stimulus while the other remains unchanged, which is also not the case.

XVIII. The negative sensory values in particular. Representation of the contrast between the sensation of warmth and cold. ¹⁾

The totality of cases, which are understood by the measure-formula, can, according to the discussion of the sixteenth chapter, be reduced to three main cases, which are briefly indicated by saying:

In one case, the fundamental stimulus value is equal to 1, secondarily greater than 1, third less than 1.

¹⁾ In matters p. 88 ff., P. 122 ff. Revision p. 206 ff. Psych. Maßprinzipien, p. 218 ff.

The first case is that where sensation comes to the threshold, the second, where it exceeds the threshold, assumes conscious values; the third one, where it remains under the threshold and thus unconscious, the magnitude of the negative values measuring the distance of the sensation from the point where it becomes appreciable or the depth of the unconscious, as the magnitude of the positive values the elevation above this point, or the strength with which it enters consciousness. Thus, our dimensional formula in a connexion gives the measure both for the degree of consciousness and unconsciousness of a sensation.

The representation of unconscious psychic values by negative quantities is a fundamental point for psychophysics, whose validity one might be tempted to question; in that a different conception of them can be opposed, which makes it all the more necessary for me to approach something in detail, as it was formerly opposed to me by an honorable authority as the more proper one; the notion that the value of a sensation of a negative character, such as cold-sensation, discomfort-sensation of heat, and pleasure-sensation, is expressed by a negative sensation-value, but the magnitude of all unconscious sensations is simply zero denote.

The pervasive reason for not grasping the matter in such a way is that the connection of facts is mathematically unrepresentable. Our measurement formula just as well represents the course of sensations as a function of the stimulus above the threshold, as does the fact of the threshold itself. If the mathematical representation of the facts is to persist even for lower stimuli, then one must, of course, relate the corresponding negative sensations to what but these are not opposite sensations, but absent sensations, in such a way that greater negative values correspond to a growing distance from the perceptibility or reality of sensation.

Nor does the spirit of mathematics contradict this. For mathematically, the antithesis of signs can just as well be related to the opposition of reality and non-reality as to increase and decrease or directions. It all depends on the nature of what it is to designate. Thus in the system of right-angled coordinates he signifies a contrast of directions on lines, in the system of polar coordinates the contrast of reality and non-reality of a line, but so that larger negative values signify a greater distance from reality than smaller ones. It can not be the slightest obstacle to transfer what is valid for the radius vector as a function of an angle to the sensation as a function of a stimulus.

Just as in pure mathematics we now have to grasp and treat the real and the imaginary in order to present the context and the relations of the real to ourselves, and conclusions from the imaginary to the real are no less strict than those which It is also the case in the psychophysical application of mathematics to move only in the real. In order to understand the relations of the conscious, one must grasp them in connection with those of the unconscious.

The following relationship to an analogous example will also explain the validity of the previous conception.

Someone may have assets or debts that are not in money and goods in themselves, but in the positive or negative possession of the same. Now one refers to the net wealth, where there is neither positive nor negative fortune, a man has nothing, but also has no debts, with a zero value; whereas it would be quite irresponsible to designate even larger and smaller debts with zero values, regardless of which man has nothing here, since they are rather to be designated with larger and smaller negative values, which express that more or less money, goods to Acquisitions must first be added in order to bring about the zero state only.

In a quite analogous case, however, we find ourselves with unconsciousness. As in the case of debts a greater or lesser increase of money and goods is necessary to bring about the zero state of wealth, beyond which first the positive faculty begins, in the case of unconsciousness a greater or lesser increase of the stimulus, and hence the psychophysical to be elicited Movement, to bring about the zero state of sensation, from where it first gains positive consciousness values. And one can say quite in the same sense: one feels in the unconscious state less than nothing, as one can say in the case of debts: one has less than nothing; insofar as one wants to regard expressions of the kind as valid. They just become valid, by giving them the right factual relation.

Having been forced by the context to use the antithesis of the sign before the sensation γ to designate a relation which depends on its quantity, we naturally can not use it also to designate an opposite quality of sensation. Cold, unpleasure can be felt just as strongly as warmth, pleasure, are just as powerful effects in the soul as heat, pleasure; Thus, according to the spirit and the interrelation of mathematical considerations so far, the positive sign just as well comes to them as long as they are above the threshold, ie, they are really felt.

It is not the sensations of warmth, pleasure, cold, discomfort in themselves, but only their causes, consequences, and associated circumstances, that are opposed in such a way that the mathematical antithesis of the signs applies to them, as already mentioned in Th. Feeling of coldness results from a lowering of the skin temperature below a certain degree, a sensation of heat by an increase above it; in that, the skin contracts and the blood goes inwards, at this the skin swells and the blood goes out; Lust generally associates itself with a turn towards the object that awakens it, aversion with aversion to it; and perhaps that which is subject to pleasure and aversion on the physical side is in some ways as opposite as positive and negative, although we know nothing specific about this. Thus, however, one will have to apply the contrast of the signs in the representation of those sensations as a function of bodily relations, as well as the reverse representation of the corporeal in its dependence on the spiritual; but not to the sensations themselves, but to the stimuli, or movements, with which they are functionally related. Very easily, however, one confuses the antithesis of what is essentially associated with the sensation, or causally related to the sensation, with a contradiction of the sensations themselves. but not to the sensations themselves, but to the stimuli, or movements,

with which they are functionally related. Very easily, however, one confuses the antithesis of what is essentially associated with the sensation, or causally related to the sensation, with a contradiction of the sensations themselves. but not to the sensations themselves, but to the stimuli, or movements, with which they are functionally related. Very easily, however, one confuses the antithesis of what is essentially associated with the sensation, or causally related to the sensation, with a contradiction of the sensations themselves.

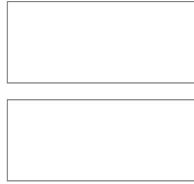
The following psychophysical representation of the sensation of heat and cold has essentially only a theoretical meaning, insofar as it is intended to show the principle by which the mathematical representation of so-called opposing sensations and the use of sign-contradiction would take place. The extent to which this representation reproduces the actual conditions depends on the question, which has not yet been sufficiently decided, of how far Weber's law, which is the basis of this representation, is really applicable to temperature sensations. The fact that it is not applicable to the experiment within too wide limits has been admitted earlier, which does not exclude the possibility that it may be more valid in the transmission of stimulus to the psychophysical movement than the experiment shows. However, this question is not so important here; since the assumption of Weber's law here serves only as an indication to explain the treatment of contradictory sensations without being limited to the presupposition of Weber's law.

As a measure of the heat stimulus β is not the absolute temperature level, but the difference of that temperature, where we feel neither cold nor heat to see or any function of this difference, since the temperature sensation increases in proportion to the distance from that mean temperature. If, on the simplest assumption, we put $\beta = t - T$, where T means the temperature at which neither heat nor cold is felt, t the temperature just existing, then the fundamental formula becomes, using Weber's law



Now it should be noted that for the middle case of both sensations, where $t = T$, the second term of this equation becomes infinite, that is, becomes discontinuous according to mathematical expressions. The two general cases, separated by this middle case, where t is smaller, and where t is greater than the mean temperature T , can therefore not be combined under the same integral, and each requires an independent determination of the integral of integration.

Let us assume at the outset that both the sensation of heat and cold has a threshold, that is, that both cease to be noticeable not only at the mean temperature T , but at some distance beyond this and the middle temperature T , and at the interval between the two temperatures neither warmth nor cold is felt, an assumption which is to be regarded as the more universal one compared to the later, that the threshold would be zero, so we shall, when we call the threshold temperature of heat c , that of cold c' , heat and cold are obtained by integration with the following two formulas, where k has the ratio (given) to K :



Since the constant $c' - T$ is negative, while $c - T$ is positive, the expressions for heat and cold differ by a sign - opposite behind the logarithm, and by the way become equal if c' is just below T as c above T , but this is not necessary for the following general conclusions.

The first of these formulas makes γ correctly equal to zero, if $c = t$, the second one can find $\gamma' = 0$ if $t = c'$. The formulas give really real values for the heat γ and imaginary ones for the cold γ' , if $t > T$; conversely, if $t < T$; as it is easily taken into account that the logarithm of a negative magnitude is imaginary. The formulas finally give properly conscious or unconscious, ie positive or negative, values for heat γ , coldness γ' , depending on whether the numerators of the fractions below the logarithm mark are larger or smaller than the denominators. Thus, they represent properly all general relationships which are to be represented.

This assuming two, by a certain distance apart, threshold temperatures c, c' for heat and cold. In the meantime it can be questioned whether this condition is valid. To be sure, experience teaches that a certain range of temperatures around the middle can sustain the absence of a particular sensation of heat or cold, and this seems to be a distance between the two thresholds beyond and T on this side to speak. But it must be taken into account that this could also be due to the accidental capacity of the stimulus sensitivity or sensitivity threshold of the skin, and which we have to recognize for any other reason. The experiments of the ninth chapter have shown that there is an average temperature of a certain width between the frost point and the heat of the blood, where such small temperature differences are still perceived with the feeling that the corresponding temperature differences at the thermometer almost correspond to the order of the observation errors. This agrees better that in the middle of this average temperature a common threshold, that is from the height zero, for heat and cold, lies, because otherwise instead of the greatest possible sensitivity, insensitivity in a certain temperature range would be expected.

EH Weber agrees with this by saying in a comparison of the sensation of light and heat (Programmata collecta p.

"Sensus caliginis est sensus deficientis lucis ad cernenduna necessariae. Quae cum nunquam plane deficiat, grad tantum differnnt sensus lucis et sensus caliginis. Hinc fit, ut crescente aut decrescente luce sensim paulatimque age sensus in alterum transeat, neque gradus medius existance, quo neque lucis neque caliginis sensu afficimur. Contra talis medius gradus temperiei corporum nos tangentium, quo nee frigore nee calore afficimur, vere existit, arctissimis vero terminis circumscriptus est. Causa in eo posita est, quod corpori nostro calor a calidioribus corporibus comnaunicatur, a frigidioribus autem detrahitur, lux autem nunquam ocalis

detrahitur, sed semper communicatur. Frigus et calor igitur se habent ut numeri positivi et negativi, inter quos medium est punetum indifferentiae,

Incidentally, if the question of whether the thresholds for heat and cold coincide absolutely in a threshold zero point is of theoretical interest, then the thresholds would always be regarded as noticeably coincidental for the experiment, and the exact determination of the constants c , c' impossible to fall. Therefore, in any case, a different choice of constants must appear to be expedient in the integration, which, if the thresholds coincide exactly, would automatically be necessary. Now that the general integral of the formula is this:

$$\gamma = k \log (t - T) + C$$

is one, the constant C by reference not to the temperature, where most conveniently $\gamma = 0$, but where (arbitrarily) $\gamma = 1$ is set, to determine what the event of heat at a temperature above, for the case of refrigeration at a temperature below T 's. If we now let c , c' denote these two temperatures, then C will be determined by the equations for the case of heat and cold:

$$1 = k \log (c - T) + C$$

$$1 = k \log (c' - T) + C.$$

The resulting values for C , substituted into the general equation, give



It is important to note that the unit for frost per se does not permit a size comparison with the unit of heat, because rather both units are independent of each other. Thus, in spite of our measure principle, even in the mathematical spirit of it, we will never be able to say whether and if we are as cold as we are warm; or freezing again as much as they are warm, while the principal possibility is to say how many times more we freeze or are warm in one case than in another; it would be necessary to discover more general mathematical relations between sensations of different kinds than are present.

But after the values of c , c' , for which we will assume the unit of temperature sensations are arbitrary, it is obvious that we can not do better than they symmetric to T , ie c' just as far below as to assume c above. On this most natural assumption, however, a comparison between heat and cold can be based, which claims to be valid for nature, even if it is not mathematically necessary. Hereby $c - T = T - c'$ and the contrast of heat and cold is reduced to that for $t - T$ in the formula for heat $T - t$ occurs in the formula for coldness, then in turn reduces itself to a contrast of the signs under the logarithmic sign.

So far the theory leads on the assumption that Weber's law holds, and *kis* common for heat and cold. I have already stated that, after the frost point, Weber's law loses its validity; however, on the other hand, it has been remarked that the deviations from

Weber's law under the influence of external stimuli do not necessarily take place in relation to the psychophysical movements induced thereby; so that the previous considerations with regard to these can at least retain their meaning. The main purpose of the previous discussion, however, was not at all to establish the measure function for the temperature sensation, which in fact requires even more experimental preliminary investigations than are present until now, when the mathematical conception of a contrast of sensations, such as heat and cold, in general.

XIX. Reference passage of stimulus and sensation.

The sensation increases with the stimulus, but by no means proportionally. Rather, we know that while the stimulus rises to the threshold, the sensation is not noticeable at all, and even higher, not growing in a simple, but logarithmic, ratio. He is interested in following the main conditions of this passage a little more closely than has hitherto been done by the mere distinction and consideration of the three main cases which are conceived under the formula. This chapter is intended for this purpose.

In order to simplify the derivation of the relative course of stimulus and sensation, let us consider the measure formula reduced to its simplest form $\gamma = \log \beta$, where the threshold b is the unit of the stimulus, and the stimulus values β the meaning of fundamental values in (so) Accept meaning. With e will, as always, the base number of natural logarithms 2.718 are called.

In general, each positive sensation value for a given stimulus β equals an equal negative for reciprocal stimulus value $\frac{1}{\beta}$; according to the general relation (chapter 14, formula 2), that $\log \frac{1}{\beta} = -\log \beta$, whereafter the two series of stimulus values

$$1; 2; 3; 4 \dots$$
$$1; \frac{1}{2}; \frac{1}{3}; \frac{1}{4} \dots$$

two series belonging to the absolute number expressions of equally sized sensation values, the first one series of positive sensory values, the second series of equally large negative sensation values which coincide at the threshold value of the stimulus 1 in zero values or thresholds of sensation. According to this, it is only necessary to follow the course of the sensation with respect to the stimulus for values of β which are greater than 1, in order to find from the previous relation the course with respect to the stimulus values which are smaller.

Both the series of positive and negative sensation values runs according to β as $\gamma = \log \beta$ or $\gamma = \log \frac{1}{\beta}$ grows to infinity, into an infinite positive or negative

size; the former denotes an infinitely strong sensation, the latter the absolute unconsciousness of a sensation. But as far as the first is concerned, one must not forget that our formula holds only so long as Weber's law holds, and that this ceases to be valid after the establishment of our organism when the stimuli are too strong; Increase of the stimulus in man does not allow to increase indefinitely, as it would be the case according to the abstract validity of the formula. On the other hand, nothing hinders presupposing that if the psychophysical movement could be increased to an indeterminate degree, the dependence of sensation on it would also lead to the indeterminacy of the formula.

The whole range of negative values of perception from a negative infinity to a threshold corresponds to rather small final intervals of stimuli from 0 to 1, however a number of positive values from threshold to infinitely strong positive feeling to infinite intervals of irritants from 1 to ∞ listened.

Let us now follow the course of positive sensory values.

Is calculated on the basis of any logarithmic system according to the formula $\gamma = \log \beta$ the values of γ , which the growing of the sleeper 1 to values β belong, it is found that γ initially at a faster relations as β increases, as can be

seen therein, that the ratio $\frac{\gamma_2 - \gamma_1}{\beta_2 - \beta_1}$ grows initially. But if you increase β more and

more, then the associated ratio $\frac{\gamma_2 - \gamma_1}{\beta_2 - \beta_1}$ decreases again. In short, if the stimulus is increased from its threshold value, the sensation initially increases more rapidly than the stimulus, but above a certain limit it rises more slowly.

Since the sensation itself is zero at the threshold value, but every finite value is infinitely so great as zero, the increase in sensation occurs when the threshold value is exceeded by an even finite quantity in infinitely strong proportions. On the other hand, if we set the ideal case of an infinite strength of the stimulus, maintaining the validity of the formula, a finite increase in the stimulus is no longer felt in any appreciable increase in the sensation. The transition from one boundary to another, where sensation grows in infinite proportions, and where it no longer appreciably grows through a given finite increase of the stimulus, is now mediated by the fact that, up to certain limits, they are faster and, beyond certain limits, slower the stimulus grows.

In between there must necessarily be a definite middle case, where the sensation grows neither faster nor slower than the stimulus, but (strictly speaking, only within an infinitely small interval) proportionally. And having up to this means the case of

the value $\frac{\gamma_2 - \gamma_1}{\beta_2 - \beta_1} = \frac{1}{\beta_2 - \beta_1}$ growth of β increases, decreases in addition, this case has the maximum of $\frac{\gamma_2 - \gamma_1}{\beta_2 - \beta_1}$ match.

At the same time, this condition provides the way to determine the stimulus value β at which this inflection point occurs. By known rules of differential calculus

(by zeroing the differential of $\boxed{\quad}$) we find that the value β , which corresponds to the maximum $\boxed{\quad}$, is equal to e , di equal to the fundamental number of the natural logarithms. Thus, if the stimulus is 2.718 times its threshold, and changes a little from there, the sensation of change in the stimulus changes in exactly the same proportion.

If the stimulus continues to rise above this value, the sensation still grows absolute, but decreases in proportion to the stimulus. If it sinks noticeably below, the sensation at the same time sinks absolutely and relative to the stimulus.

The point at which this relative maximum of sensation occurs is to be called the cardinal point, and the stimulus value at which it occurs, that is, e - times the threshold value, and the corresponding sensation the cardinal value of the stimulus and the sensation.

So when a stimulus in the e times the strength of its threshold or with its cardinal values acts, he gives the proportionate maximum of sensation power or the Cardinal sensation. And if it is therefore in his power to use a given quantity of stimulus in a more concentrated or more distributed manner, then in order to obtain the greatest possible sensation, one will have to distribute it in such a way that it coincides with the e -fold strength of the threshold or acts as a cardinal stimulus. If one concentrates it more, the sensation becomes more intense; but there will be so much lesser amount of such intense sensations that, on the whole, sensation is lost; if it is distributed more, the greater amount of sensations will not be able to compensate for the loss due to the lower intensity. Later, in the distributional formulas of sensation, we will find ourselves led to the same result in another way.

Since values change only slowly at each maximum value, $\boxed{\quad}$ their value will remain almost constant, and thus not only at the cardinal value of the stimulus, but also near it, the sensation grows noticeably proportional to the stimulus.

The functional relationship between stimulus and sensation thus includes some special cases of some preferential importance in the relative course of both, the threshold point and the cardinal point. At the threshold point the sensation is zero, at the cardinal point it has the relative maximum to the stimulus. The first signifies, for the rise of the stimulus, the point where the negative values of the sensation change into positive, the second the point where the relative increase to the stimulus passes into relative decrease. In the first, the sensation increases infinitely fast compared with the rise of the stimulus, in the second it increases in proportion as the stimulus rises.

In addition to this, there is the formally important fact that, according to the determinations (see Chapter 16), the threshold value as a unit of stimulus and the cardinal value as unit of sensation are the simplest possible form of the measure

formula ($\gamma = \log \beta$) which determines the relationship between stimulus and sensation, in the case of natural logarithms, whose system has a mathematically preferred meaning over any other system.

Here is a small table, which gives for the presupposition of the unit of stimulus at threshold values, and sensory unit at cardinal values the values of stimulus and sensation with increasing stimulus and increasing sensation, on page I, that the corresponding sensation-quantities correspond to the given stimuli-magnitudes, reversed on page II.

Page I is by natural logarithms of the formula $\gamma = \log \beta$ or, which gives equivalent values, mean by the formula



calculated; Page II according to the formula



With regard to the attached values, it \square is to be noted that their absolute magnitude has no meaning, because it depends on the arbitrary units of stimulus and sensation, but only on the independent course or relations of these values with ascent of γ and β .

I. II.

| β | Γ | \square | Γ | β | \square |
|---------|-----------|-----------|----------|---------|-----------------------|
| 0 | $-\infty$ | $-\infty$ | 0 | 1 | 0 |
| 1 | 0 | 0 | 1 | 2.7183 | 0.36788 |
| 1.5 | .4055 | 0.27031 | 1.5 | 4.4817 | 0.33469 |
| 2 | 0.6931 | 0.34657 | 2 | 7.3891 | 0.27067 |
| 2.718 | 1.0000 | 0.36788 | 2.718 | 15.154 | 0.17938 |
| 3 | 1.0986 | 0.36620 | 3 | 20.086 | 0.14936 |
| 4 | 1.3863 | 0.34657 | 4 | 54.598 | 0.07326 |
| 5 | 1.6094 | 0.32188 | 5 | 148.41 | 0.03369 |
| 6 | 1.7918 | 0.29821 | 6 | 403.43 | 0.01487 |
| 7 | 1.9459 | 0.27799 | 7 | 1,096.6 | 0.00640 |
| 8th | 2.0794 | 0.25993 | 8th | 2,981.0 | 0.00268 |
| 9 | 3.1972 | 0.24413 | 9 | 8,103.1 | 0.00088 |
| 10 | 2.3026 | 0.23026 | 10 | 22026 | 0.00005 ¹⁾ |

¹⁾ Exactly 0.0000454.

It can be seen on page I that the stimulus zero corresponds to a negatively infinite value of sensation, ie, the lowest possible degree of unconsciousness, the absolute unconsciousness. While the stimulus increases from zero to 1, where the conscious sensation begins, the sensation goes through all possible negative values, according to the formula the negative sensations for the stimulus mentioned above in the

table [redacted] and the positive for the stimulus 2, 3, 4 usf in absolute Zahlwerthe correspond. If the stimulus rises above its threshold h , then, according to what has been said, the sensation at first increases more rapidly than the stimulus; in that the

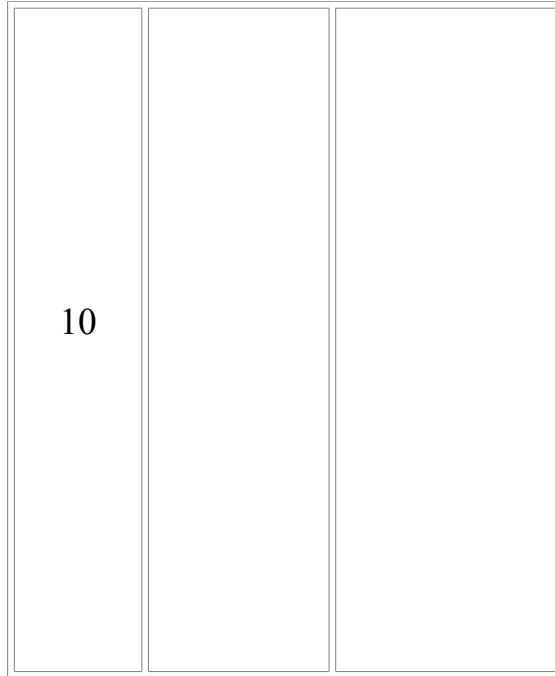
relation [redacted] with the growth of β grows at first. At $\beta = e = 2.718$, ie the cardinal value

of the stimulus, the maximum of $[redacted] = [redacted] = 0.36788$ is shown, and around this value from $\beta = 2$ to $\beta = 4$ the sensation increases appreciably in the ratio of the

stimulus, since the ratio remains nearly [redacted] constant; whereas, on further growth of the stimulus, it decreases more and more conspicuously.

Here, according to the previous table, for the successive differences of the sensation γ , if it always grows from 0 by the same magnitude 1, the corresponding differences of the stimulus β .

| Γ | Diff. Γ | Diff. β |
|----------|----------------|---------------|
| 0 | 1 | 1.7183 |
| 1 | 1 | 4.6708 |
| 2 | 1 | 12.697 |
| 3 | 1 | 34.512 |
| 4 | 1 | 93.81 |
| 5 | 1 | 255.02 |
| 6 | 1 | 693.2 |
| 7 | 1 | 1,884.4 |
| 8th | 1 | 5,122.1 |
| 9 | 1 | 13,923.0 |



Thus, while the stimulus to grow the sensation from 0 to the cardinal or the natural fundamental unit has to rise only 1.7183 above its threshold 1, it must increase by 13923 in order to grow the sensation of 9 to 10 ,

There is a very simple case to which you can actually refer to the previous course. If one successively approaches a continuous sound of constant intensity, then, if this happens from an infinite distance, all degrees of unconsciousness will pass from the negative infinity until, at some point, the distinctiveness and thus the threshold value of the sound occurs which then follows the course of sensation in a positive sense as shown in the table.

Since the strength of the sound β is in inverse proportion to the square of the distance, let it be 1 in the unit of the distance, and as this unit the distance be set where the sound just begins to become noticeable. Then the strength of the sound

is $\boxed{}$ in the distance D . Further, if the unity of the sensation is at the cardinal value, then the course of the sensation in natural logarithms is transmitted

$$\gamma = \log \boxed{} = -2 \log D$$

given. The positive values of γ here correspond to values of D which are smaller than the threshold distance, hence fraction values; what makes $\log D$ negative and $-\log D$ positive.

It may be noted in the above table, as a peculiarity, that the ratio $\boxed{}$ at $\beta = 2$ below the cardinal point coincides entirely with the ratio at 4 above that point, namely both 0.34657, and that at the same time the ratio of these stimuli is $\beta = 2$ and $\beta = 4$, coincides with the ratios of the associated sensations 0.6931 and 1.3863.

The last is a natural consequence of the first, because if



it is necessary at the same time



The first, however, is easily derived from the Maßformel.



Namely, if $\gamma = \log \beta$, then \square . If one puts $\beta = 2$ and $\beta = 4$ after each other, then one has

for $\beta = 2$

.....

for $\beta = 4$

.....



But by $\log 4 = \log 2 \cdot 2 = 2 \log 2$, both values are identical.

But it may be further remarked that by no means does the relation of sensation generally coincide with the relation of the corresponding fundamental stimuli. This would require using fundamental units that



which does not take place in general, if one sets arbitrary numbers for β, β' . However, the stated equality ratio is not limited to the single case of the fundamental stimuli 2 and 4, but this is only a special and especially excellent case among infinitely many cases.



In general, any given value above the cardinal point corresponds to an equal below the cardinal point, and vice versa, and in general the ratio of the fundamental stimuli agrees with that of the sensation values. The corresponding values should be called corresponding and the corresponding fundamental stimuli, especially with x, y be designated. There is some interest in determining their relationships as long as they denote two intensities in which a given stimulus quantum gives the same sensory power when brought to these intensities by proper distribution. The further apart they are from each other and from the cardinal values, the lower the power of the quantum at these intensities. In the cardinal values themselves, both corresponding values coincide in a same maximum.

The derivation of the circumstances in question is this:

If x and y are the corresponding stimuli and γ , γ' are the associated sensations, then we have



But $\gamma = \log x$, $\gamma' = \log y$, it follows



If we now \square substitute yn for x in the previous equation, we obtain

$$n = \square$$

$$n \log y = \log ny \square$$

$$\log y^n = \log ny$$

$$y^n = ny$$

$$y^{n-1} = n$$

$$(n-1) \log y = \log n$$



$$x = ny = \square$$

In general, following the above derivation, the following strange, equivalent, relationships take place for the corresponding stimulus values:

$$x^y = y^x$$



from which, if one \square sets, the following determination of x and y flows:



So are one to any arbitrary ratio $\frac{x}{y}$, in which the corresponding stimulus intensities should be available, one can according to the previous equations, the corresponding intensities x, y find itself, the stimulus unit of the threshold value, the feeling unit is arbitrary.

Here is a small table calculated according to these formulas, on the second page of which the power values of the first page are resolved into their numerical values.

I. II.

| n | x | y | x | y |
|-----|----------------|----------------|-------|-------|
| 1 | e | e | 2,718 | 2,718 |
| 2 | 2^2 | 2^1 | 4,000 | 2,000 |
| 3 | $3^{3/2}$ | $3\frac{1}{2}$ | 5,196 | .1732 |
| 4 | $4^{4/3}$ | $4^{1/3}$ | 6,350 | .1582 |
| 5 | $5^{5/4}$ | $5\frac{1}{4}$ | 7,477 | .1495 |
| 10 | $10^{10/9}$ | $10^{1/9}$ | 12.92 | .1291 |
| 100 | $100^{100/99}$ | $100^{1/99}$ | 104.8 | 1,048 |

It can be seen from this table that the higher the intensity of one corresponding stimulus increases, the weaker is that of the other, which holds the balance in the same relative sensation, so that z. For example, a stimulus which is 104.8 times its threshold corresponds to a stimulus which is only 1.048 times its threshold, ie $1/\sqrt[100]{104.8}$ of the previous one, and one achieves the same sensation with the same stimulus quantum, if it is expressed in this or that strength is used by the proper propagation of the stimulus replacing the loss of its intensity. Here, too, the later distributional formulas of sensation will lead us back in a different way.

It can now be noted that the corresponding fundamental stimuli 2 and 4, which

have the cardinal value e fairly in the middle, and between them $\sqrt[3]{e}$ the sensation and the stimulus grow remarkably proportionally, and at the same time the only ones which express themselves in whole numbers, that they present the simplest possible ratios in even numbers at the threshold value 1, and the upper is the double and square of the lower one. Thus they have a mathematical distinction in front of all others, which coincides with their real meaning in delimiting an interval of secondary importance, nearest to the principal interval between threshold and cardinal point, the interval of noticeably proportional progress of stimulus and sensation; which one might call the cardinal interval, while one may call that the fundamental interval.

If we look for the mean size of the sensation in these two principal intervals, then,

assuming the cardinal value of the sensation as a unit, we find the median sensation of the fundamental interval = 0.36788, and that of the cardinal interval $3 \log \text{nat. } 2 - 1 = 1.07944$. The mean sensation is obtained for the interval from threshold until the fundamental stimulus values e^2 , and the general expression for the average of a sensation in the interval from the fundamental stimulus values x to y is

$$\boxed{\text{[Equation box]}}$$

The mean value of the sensation in the interval between two stimulus values x , y can be given by assuming $k = 1, b = 1$

$$\boxed{\text{[Equation box]}}$$

being represented; which value leads to the above determinations by integration.

On the second page of the table (see above), apart from the sensational values 1.5 and 2.7183 added in by the circuit, the series of sensations is represented as an arithmetic with the difference 1. One sees that it corresponds to a geometric one of the stimulus values, in that each following stimulus value results from the former by multiplication by the exponent $e = 2.7183$.

This result of belonging together the series of arithmetic series and geometrical stimulus series is not tied to the particular units chosen here; but in general every arithmetic series of sensations, including other units and other differences, corresponds to a geometric one of stimulus values. And indeed the exponent of a series of sensations with the difference 1 is generally equal to the fundamental stimulus-value, by which we set the unity of sensation, in the case of our table e , but in any other difference equal to the power of this fundamental stimulus-value, signified by the difference becomes. Thus, according to our table for a number of feelings 1,3,5 ... where the difference is 2, there is a geometrical series of stimuli with exponent e^2 .

The measure-formula may still be put forward under a slightly different form than before, according to which the stimulus β is equal to a part b equal to the threshold, and a positive or negative increment a , as the stimulus is above or below the threshold value, that is, let $\beta = b + a$, so that the measure formula passes into

$$\boxed{\text{[Equation box]}}$$

Thus $\gamma \alpha \pi \epsilon \alpha \rho \sigma$ as a function of the relation which the increase has to the threshold against the threshold, whereas the former form $\gamma \alpha \omega \epsilon$ as a function of the relation which the given stimulus has to the threshold.

The current form is convenient to derive the following results.

As long as the stimulus exceeds the threshold very little, that is, is a very small fraction, small enough that the higher powers are neglected in comparison with the

first one, then according to Ch. 14 for \log substitute M , where M is the modulus. After which a sensation, as long as it is very weak, stands and rises in direct proportion. If, on the other hand, the stimulus is so great that 1 is

negligible, the sensation increases proportionally with $\log = \log a - \log b$, and if it is finally so great that $\log b$ also neglects $\log a$, then it increases proportionally with $\log a$, and will be independent of thresholds.

The way in which the sensation increases with the growth of the stimulus according to the measure-formula can easily be graphically represented by the logarithmic curve, by representing the size of the stimulus by abscissa, and the corresponding values of the sensation by the ordinates at right angles thereto.

XX. Summation of sensations. 1)

It is of fundamental importance, the case where there is an increase to a stimulus on a given point, so that thereby the intensity of the stimulation and sensation is increased, to distinguish from the case where the stimulus increase falls on others discreetly from that points of feeling thus increasing the number of irritated and sensory points, and herewith the extension of irritation and sensation. As in the chapter. 16, only the first case comes directly below the measure-formula, which is immediately decisive only for the dependence of the sensation on the intensity of the stimulus; but it does not hinder to sum up in sum and to compare these sums, which follows from the measure formula for the individual points according to the strength of their irritation. Nobody will be decent when the retina is uniformly lit, to say that the whole retina gives twice as much sensation as each of its halves; and if a sound is endured evenly for a certain time (and construed with constant sensitivity), that in the whole time twice as much as in half is felt. Thus, in view of the spatial or temporal extension, through which a stimulus and the sensation awakened by it suffice, to speak a sense of larger and smaller sentiment sums, and to compare them even according to their size. For the sake of brevity, we may differentiate the sums of space and time sums of the sensation, as we sum up the sensation for different points or points in time. and if a sound is endured evenly for a certain time (and construed with constant sensitivity), that in the whole time twice as much as in half is felt. Thus, in view of the spatial or temporal extension, through which a stimulus and the sensation awakened by it suffice, to speak a sense of larger and smaller sentiment sums, and to compare them even according to their size. For the sake of brevity, we

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1) Revision p. 187 ff.

In the following we mean by dots, spatial or temporal points (moments) no mathematical points everywhere, but in general (space or time elements of the same size, or calculated according to their relative size), that the sensory contribution, the one through them passage-extending stimulus can be considered to be of constant intensity for each element; however, the intensities may be different for different points.

After that, when a given area is irritated, e.g. If, for example, a given surface of the retina is illuminated, then the quantum of the sensation of what we have is to be understood as the sum of the sensations which the individual points or surface elements of the illuminated part afford, but not on the sum total of that sensation to calculate the effect of the light stimulus by means of the logarithmic measure formula as a whole, but to make the calculation for each individual point (element) according to the intensity of its irritation, and then to take the sum of what applies to the individual points or elements.

In the same way, when one wonders what sum of sensation one has had during a certain time, one will have to take the sum of the sensations which one has had during all the individual parts of this time, and this sum will not be taken as our measure For every moment or moment, so small a part of time, that the sensation therein can be regarded as constant, one becomes the strength of the sensation after the present action and to calculate the effect of the aftereffective aftereffect of the stimulus, and to take from this the sum for all the individual moments.

The difference, according to which the increase of a stimulus increases the irritation of given points (elements) or falls to new points, follows from the above that at first the increase of the stimulus is to be added to the stimulus below the logarithm,

secondly the logarithm of the increase to the logarithm of the stimulus is to have the result of the increase for the sensation.

However, the question may be raised as to whether, when many points are stimulated together, the sensation that each gives is still determined in the same way as a function of the stimulus, as if an individual is irritated by himself. But supposing that the combination of many points influences the way in which each one gives its sensation, this would not invalidate the axiom, that the sum of the sensation which all points grant increases by the addition of what the individual grants be found; The only question that might arise is whether, when many points of irritation are combined, each of them gives a lesser or greater sensation than when connected less so much more irritated. This circumstance, if it took place, would have no influence on the general rules of addition of sensation, but merely change the size of the additional elements. For, as our formulas are not based on experiences at individual points, but on combinations of such, it can not be assumed that the form of our formulas is altered by the combination of points, but only that the constants of them may possibly be altered thereby; and there remains, however, a matter for future investigation, as to what this is the case, and what influence the constants undergo. The constant that their constants may be altered thereby; and there remains, however, a matter for future investigation, as to what this is the case, and what influence the constants undergo. The constant that their constants may be altered thereby; and there remains, however, a matter for future investigation, as to what this is the case, and what influence the constants undergo. The constant b could be variable according to the size of an irritated area, then this variability would have to be considered in the summation, but otherwise the rules of summation remain the same. I'll come back to that in the future; But now abstract from this possibility.

Sentiments of sensation, which differ in the extension and intensity of the sensations contained in them, are, no matter how peculiarly different, nonetheless capable of quantitative comparison. In fact, given initially only one element of given extension with given intensity of irritation, a given total magnitude of sensation will depend on it; this, we can now precisely so extensively reproduce in given circumstances the fact that we increase the number of so irritated elements, as intense in that we increase the intensity of stimulation without increasing the number of elements, and can according to one and the other direction in given ratios originally multiplied equals quantitatively,

So we can have a cube that is on the earth, extend in horizontal sense and in vertical sense, and find size equations between the two thus formed columns, regardless they are in completely different directions, so that they do not let superimpose after these different directions ,

A very important consideration to take in summations is as follows:

As a stimulus rises above the threshold due to an increase in the stimulus, or decreases by the withdrawal of stimulus below it, the sensation becomes positive, conscious, or negative, unconscious, and we always simply have a positive or negative sensation. But if, for a majority of discretely sensed points above the

threshold, which gives a positive sum of sensation, a different majority of points below the threshold, and thus giving a negative sum of sensation, the positive sensation is not diminished by them, but persists next to the negative fort; the negative does not differ from the positive one, and is not compensated by the positive one, and we have both positive and negative feelings of being weighed up against each other and weighed against each other,

Herein lies no break in the mathematical consequence; Rather, one can explain the previous relationship quite well on the very analogous case of a curve whose mathematical representation shows the corresponding. In an ellipse, the positive ordinates built on the positive abscissa side fill a positive space according to mathematical representation, those below erect just such a negative space, or more precisely, the measures by which one measures both spaces are given a mathematically opposite sign. Adding both spaces algebraically, you get a sum equal to zero. But this algebraic addition means nothing. Rather, one must take the positive and negative space in particular because they are determined by ordinates belonging to different points. In the same way one must especially understand the positive and negative sums of feeling which derive from sensations which belong to different points. Against this it makes sense to form sums of itself out of the positive subspaces of the ellipse for itself as well as the negative subspaces. And so it makes sense to sum up the feelings for points with positive values and those with negative values.

In short, one can not regard the algebraic sum of positive and negative sensations which supply the various parts of an irritated organ, as a measure of the total sum of conscious sensation which it supplies, and the sign of this algebraic sum, as decisive for the state of consciousness this organ is produced; Instead, one must sum up the positive conscious values and negative unconscious values which belong to the individual points, as if one were thinking of the sum of the stimuli accumulated on the same point. Otherwise one would obtain the absurd result that nothing had been felt with an organ, which felt very strongly with one part, while with another part it was correspondingly deep below the threshold.

The same applies to summation of the sensations that have taken place for a certain time. The sum of conscious sensation, which has taken place during a part of the time, is to be determined for himself, and not the sum of unconscious sensation, which has taken place during another part, in subtraction of it, but only in counteraction and comparison.

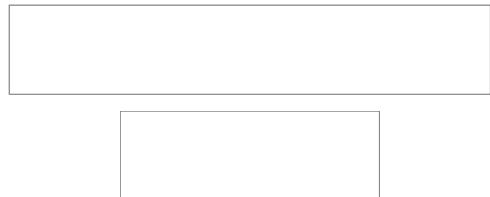
The considerations which we have made here are of general importance not only for the clarity and use of empirical formulas in external psychophysics, but will also prove to be very important as regards the correct interpretation of the conditions of internal psychophysics and their application in experimentation. Feelings to construct elementary to find. Let me remind you of the following: Sleep and waking are indisputably dependent on a greater oscillation of the living force of our psychophysical movements. We can not determine the sum of consciousness for 24 hours by deducting the negative values of consciousness during sleep from the positive ones during waking, or by taking the algebraic sum of both; but every time

that has been conscious remains conscious, and if so much unconsciousness should be counted against another time. More than likely, every sensation depends, in particular, on some very small oscillations of psychophysical activity. If the fact of the threshold reaches into the elemental, these oscillations may only be above the threshold for part of the time²⁾; because their speed comes down periodically to zero. Regardless of the above considerations, one might now think that the result of consciousness is given by the algebraic sum of the positive sensory contributions above the threshold and negative below the threshold, where it would probably be very weak or zero. But this is not permissible; but only the positive contributions come into consideration for the consciousness, and the negative ones simply fall out for the consciousness; but the conscious values, because we have no consciousness of the meantime, close to each other, in a similar way, as the blind spot in the eye does not interrupt the continuity of the spatial sensation of the face.

²⁾ This applies at least in general to rectilinear vibrations, but in general to vibrations of every kind, if they should be speeds of the second order rather than the first order.

Afterwards I give the following sum formulas of the sensation for a multiplicity of irritated points, which together apply to space sums and time sums, provided that the sensory contribution of each individual point is determined by our measure formula.

Let the summing sensations γ' , γ'' , γ''' ... which belong to the stimuli β' , β'' , β''' ... , which act on different points . Provided that the points on which these stimuli act, may have different sensitivity, we use them the threshold b' , b'' , b''' ... belong. Now let's say $\gamma' + \gamma'' + \gamma'''$... with $\sum \gamma$, so we have



According to this, the συμ oφ sensation $\sum \gamma$, which arises from the stimulation of a majority of different points, is compared with the sensation $\gamma = k \log$ [] , which arises from the stimulation of a single such point by setting

$$[] = []$$

the two are the same if the fundamental stimulus value of the one point is equal to the product of the fundamental stimuli of the different points.

A remarkable conclusion of this formula is that if different points with different sensitivities are irritated differently, the sensation sum does not change, if the stimuli

on the points with different sensitivities are arbitrarily changed, or if the sensitivity for the different stimuli is reversed.

Let be $\boxed{}$ the geometric mean of the fundamental stimuli of the different points, and their number n , is

$$\boxed{} = \boxed{}$$

and the molecular formula can also be written like this

$$\begin{aligned} \sum \gamma &= k \log \boxed{} \\ &= nk \log \boxed{}, \end{aligned}$$

according to which the sum of sensations for n arbitrarily excited and arbitrarily sensitive points is as great as if all n points were excited by the geometric mean of the fundamental stimuli of the different points.

In general, in a majority of points of different irritation, one may ask for the mean or average sensation of the same as that which, if it were to coincide with all points, would give the same sum, as obtained in the sum of the different stimulations of the same. This mean sensation is obtained at n stimulated points by dividing the above summation $\Sigma \gamma$ by n , whereby one finds

$$\boxed{},$$

According to this, the arithmetic mean of given sensation corresponds to the geometric mean of the associated fundamental stimuli in the sense of the measure formula.

So far, we have assumed a finite number of points, but it is a summation for extended periods or sentient surfaces, we are generally, if the stimulus variable intensity acts, every little time or space element with there acting strength of the stimulus β fraught have to think and have to win the sum of sensation by infinitesimal summation of partial feelings which come these partial irritant effects ³⁾; which, when we consider time and spatial extension at the same time, is expressed by the formula

$$\boxed{}$$

where dt is the time element, ds the space element expresses. β is to be represented as a function of t and s . If b is variable, the change can be transferred from b to β . The integration of this formula has to be done within the bounds for which one seeks the sum of sensation, s and t are to refer to their units, and consider as unity of the sum of sensation those which for the unity of s and t and an arbitrary unity of β applies.

³⁾ It is undeniable, however, only with a similar consideration as with which the infinitesimal summation of the attractions of the parts of a body can take place in the atomistic system.

The simplest case considered here is that where a stimulus acts uniformly, maintaining, for a given time or in a given extent, equal sensitivity. Then one simply has as sensation sum for time t or extension s

$$kt \log \boxed{} \text{ or } ks \log \boxed{}$$

and considering s and t together

$$kst \log \boxed{}$$

where t and s are calculated from zero.

The next simple case may find room here as an example of calculation, even if I could not make any special application for it now. It is that where a stimulus (the stimulus effect) grows in proportion to the time or spatial extent from a certain point on. How will the time or space sum of the sensation that he grants during a given time or space stretch behave?

The temporal or spatial extent, from the point where the stimulus is zero, is called x , and the stimulus at the distance x from the starting point is px , where p is a constant. Then we have to determine the συμ of sensations $\sum \gamma$ in the interval from $x = A$ to $x = B$, by setting $k = 1$, $b = 1$:

$$\boxed{}$$

$$= B (\log pB - 1) - A (\log pA - 1)$$

or, if we denote by a the basic number of applied logarithms, hereby the magnitude of the stimulus for which the sensation of a point is set = 1 (see Chap.

$$\boxed{}$$

If we divide this expression by $B - A$, we obtain the mean sensation in the interval $B - A$.

Now, with a uniform distribution of a stimulus of the intensity β^1 , the sum of sensations in the interval $B - A$ is

$$\sum \gamma = (B - A) \log \beta^1.$$

So to the stimulus intensity β^1 find, which provides for uniform distribution in this interval the same sensation sum than the intensity px , we both previous values $\oplus \gamma$ to equate what for the given value β^1 are



When applying these formulas, it is to be considered that if we wanted to take the sum of sensations from the point where the stimulus is zero, we wanted to set A to zero, whereas we think the value of B to which we think the stimulus to grow Above the threshold, we would assume that negative and positive, conscious and unconscious values of sensation, in sum, would be conserved, which would not give any indication of the sum of the conscious values in particular. Therefore, we have to divide the sensation sum into two parts, an unconscious from $A = 0$ to $B = 1$, if the threshold = 1 is set, and a conscious one from $A = 1$ to any value of B within which we can also pick out any intervals by setting $A > 1$.

Since the unit of expansion is arbitrary, we can set that = 1 by which the stimulus passes from zero to threshold 1, thus $p = 1$, and the values B and A at the same time the bounds of extents and the associated stimuli, between which one takes the sums, designate. Assuming the sum of sensations from the threshold 1, we have $pA = 1$. If we unite both assumptions, then $A = 1$, and we obtain the formulas

$$\sum \gamma = B (\log B - 1) + 1$$



The first, using natural fundamental υντσ , where the sensation unit is at the cardinal point, γ_1 the value $\sum \gamma = 1$ for $B = e$, ie, when the stimulus uniformly increases from the threshold to the cardinal, for which he has an *etimes* as long a time or distance as it takes to rise from zero to threshold points; thus it produces a sum of sensations equal to that which would be obtained if the sensation intensity of the cardinal point (set as 1) remained uniform during the time or distance required for the stimulus to be uniform from zero to zero to rise to the threshold. The second formula gives as stimulus, which, in the case of a uniform continuity, would do the same thing by the same time or distance, as the stimulus, uniformly increasing from the threshold to the cardinal point



Greater universality and more general applicability has the solution of the following task. The stimulus does not increase from zero, but is proportional to a certain value R on the path, so that when the starting point of the distance da where the proportional growth begins is taken, at the end of the distance x it becomes the value

$$R + px$$

Has. The sum of the sensation is then sought within this distance. Since every variable stimulus of a given starting point within a sufficiently small distance can be regarded as changing proportionally in proportion to the same (see Chapter 15), this task thus gains great generality.

The sensation sum is general in this case, taken between $x = A$ and $x = B$:

$$\boxed{\int_A^B \dots dx}$$

or, if you take them from the beginning of proportional growth, where $A = 0$, bare

$$\boxed{\int_0^x \dots dx},$$

Notwithstanding, in the formulas of this chapter, the decline to the elemental is not presupposed, which we have anticipated in chapter 16 (since it was not here to psychophysically calculate the formation of the sensation in the individual points or elements, for which those formulas may be useful), these formulas would nevertheless find application if such a decline were to be permitted at all; and then we would only need to substitute for β in previous formulas v in its meaning as velocity of first or second order. A summation of this kind will be discussed in a later chapter.

XXI. Distributional relations of sensation.

The same quantity of light may concentrate on a few points of the retina, or may spread over a larger surface, may spread uniformly or nonuniformly, and many uninteresting results can be drawn from the formulas developed so far on the circumstances prevailing here, and of a generalization as well capable of other areas; Incidentally, partly because of other forms, it can only be ascribed to results to



which the consideration of the values $\boxed{\dots}$ in Chapter 19 has already led us .

In so far as the sensation of the face is concerned, the prerequisites are made: 1) that the greater or lesser number of retinal spots hit by the light, and consequently the size of an illuminated surface, have no influence on the intensity of the sensation which each individual point gives us , outer; 2) that the retinal spots on which the spreading takes place have the same sensitivity.

Undoubtedly, these two assumptions are not strictly correct, or they can not be made in strict terms, but in many cases they can be regarded as approximatively correct, and in any case are to be treated first as the simplest assumptions.

As to the first assumption, to prove that the size of a surface has an influence on its visibility, it may be said that small areas of light disappear at a distance to the eye, where larger ones of the same photometric intensity are still seen; yet it is not yet sufficiently decided how far the scattering of light by irradiation, which is more in the interest of small areas of light which are just vanishing into the eye, is to blame for the difference, on which more detailed discussions can be found in the 11th chapter of the previous part. It may further be pointed out that, according to Weber's experience, warm water appears warmer on immersion of the whole hand than on the immersion

of a finger, which seems to indicate that the intensity of sensation grows by increasing the number of sensory points. Meanwhile, it can be observed that the temperature difference between the area immersed in warm water and the rest of the body must be reduced by the compensating blood flow, more and more quickly at a small than a large submerged area, such as a glass of warm water under the same external cooling Influences cooled more easily than a barrel; and it is the question of how much can be attached to this, at least not yet discussed and done. However, as with the heat sensation of the skin, it is certain that this experience has no effect on the face, because, on the contrary, white loses brightness rather than gains by the proximity of white (by contrast laws). In the meantime, this too is by no means noticeable in all circumstances, and in general one will not be able to detect a somehow decided difference in brightness between larger and smaller pieces of white paper, whether they are taken next to or in succession with the central part of the retina. A more definite indication of this is provided by Steinheil after measurement with his prismatic photometer, which deserves special trust, since it was for this precise observer to ascertain what circumstances are of influence on the photometric estimate¹⁾. According to this, "the size and position of the surfaces of light against each other has no decisive influence on the judgment of equal intensity"; just as little the distance in which one thinks of the surface of light and on which one accordingly accommodates the eye, just as little a wavering of the eye. This may justify the assertion that the first assumption can be considered, at least in many cases, as approximate; even if I myself do not consider them as strictly correct.

¹⁾ Elements of the brightness measurements in the dep. D. Münch. Akad. L837. P. 110.

As to the second presupposition, it can not be considered as strictly realizable in so far as the retinal points at different distances from the center have a different sensitivity. In the meantime, for not too large expansions, it will also be considered as approximate.

Incidentally, the application of the following distribution formulas to the retina is only one example of much more general applicability of the same, which I will continue with.

Now let the stimulus with the intensity β only at one point (this within the meaning of Sec. Understood 20) generally uniformly distributed in a certain set as a unit number of points or so is using the fundamental units dependent on the stimulus intensity sensation strength $\log \beta$ be and as this takes place over the whole number of points summarized as a unit, it will at the same time express with strength the sum or the quantity of the sensation before the distribution.

Now, if the stimulus is distributed from the simple number of points to the n - fold number, then every single point instead of β comes only \square , and the intensity of the

sensation will log for that point $\boxed{\beta}$. But since this intensity repeats on the n - fold number of points, we obtain the expression for the total quantum G of the sensation

$$G = n \log \boxed{\beta} = n (\log \beta - \log n)$$

and as the ratio of the distributed to the original sensation quantum

$$\boxed{\frac{G}{\beta}},$$

This ratio generally deviates from unity, which shows that by distributing one stimulus to another number of points, the quantity of sensation generally changes.

Now you ask yourself, does the sentient quantum decrease or increase through the distribution? The answer is: depending on the cases.

If we distribute a strongly concentrated stimulus to twice the number of points, the quantity of sensation doubles noticeably, and, in general, if the distribution of a strong stimulus is not too strong, it appreciably increases in proportion to the distribution; but when it is driven too far, it decreases again, and the distribution can always be driven so far that it becomes imperceptible.

In fact, if we set β very large, and n not too large, we can neglect $\log n$ significantly against $\log \beta$; then G , the n -fold of γ . But if we let n grow more and more, then $\log n = \log \beta$, with which the sensation becomes zero, and if n grows further, then G even falls into negative, that is unconscious.

We can explain the case of an enlargement of the sensation sum by the distribution of a strong stimulus on a quite bright star. If a star is quite bright photometrically, it makes little difference to the sensation whether to double or halve its light. For his

sensation $\log \beta$ passes into $\log 2 \beta$ or $\log \boxed{\beta}$; for the former one can write $\log \beta + \log 2$, for the latter $\log \beta - \log 2$; but if β is big, then $\log 2$ is against $\log \beta$ to neglect. Hence the great difficulty of comparing photometric intensities with great photometry, since the comparison can only be made by means of sensation. If we now think of such a bright star that it does not obscure the sensation in any significant proportion, halving its light, and using the light taken away to make another star, we shall now have two stars of markedly equal brightness see first, and thus see the sum perceived brightness doubled noticeably by distribution to two points.

The fact that the increasing distribution of the stimulus means that the sensation must finally become zero and beyond, follows, of course, from the fact that the stimulus of the growing distribution must finally reach the threshold and beyond. According to the distribution formula, the zero value of the distributed sensation G occurs when $\log n = \log \beta$. In fact, this corresponds to the point where the original stimulus β has fallen to the threshold value 1. In the case of sensation of light, this case can not be proved by the absolute sensation of light, because the black

of the eye always remains above the threshold, and can not be distributed, but only by the difference of the externally awakened sensation of light from the black of the eye; but, moreover, it is found everywhere that a stimulus needs only to be sufficiently distributed in order to become imperceptible to the sensation.

If, by the distribution of a strong stimulus, the quantity of sensation increases to a certain extent, and in addition decreases, there must be a distribution ratio n , which we shall call N , where it is the greatest possible. This distribution ratio is found by a known rule by differentiating the value G with respect to n and zeroing of the difference target. That's how you get



where e equals the basic number of natural logarithms.

This formula tells us first that the most favorable distribution ratio is proportional to the intensity of the stimulus β . If, therefore, a given number of points are stimulated with a given intensity, then at twice the intensity the distribution to twice the number of points will have to occur in order to produce the greatest possible quantity of sensation.

Secondly, it tells us that the number expressing the most favorable distribution ratio is found when the fundamental value which the stimulus has before the distribution has²⁾, with the basic number of natural logarithms $e = 2.71828\ldots$, divided or multiplied by $0.36788\ldots$. If the stimulus is strong or weak, it will always give you the most advantageous distribution. Third, it tells us that, as the ratio of the stimulus to its threshold value is greater or less than $2.71828\ldots$, is that the stimulus must spread to more points or concentrate on less to achieve the most advantageous distribution ratio; because at first N is larger than 1, smaller in the end.

²⁾ Since $b = 1$, β expresses fundamental values everywhere.

Between both cases is the case where $\beta \approx e$, ie, where the most favorable distribution ratio already exists.

Now, at the value $\beta = e$, the cardinal value of the stimulus and the sensation, where the relative maximum of the sensation to the stimulus takes place, lie; and so here we find the result found earlier (chapter 19) only in a somewhat different way, that the stimulus works most favorably for the generation of the greatest possible sensation, when it works with the intensity of the cardinal value. If he has just that intensity, he is neither to concentrate nor to distribute to give the greatest possible quantum of sensation.

The largest possible quantum itself, which takes place at the distribution value $N = \boxed{}$

, is obtained by substituting this value for n in the expression for $G = n \log \boxed{}$. This is the maximum of G



di

$$0.15996 \beta$$

using common logarithms, or

$$0.36788 \beta$$

using natural logarithms, which values deviate from one another because our sensation unit, which is assumed to be fundamental values, and hence also the measure of the sensation, changes according to the logarithmic system.

Also, in order to give them a certain value, the above expressions are based on the underlying unity of the quantum of sensation which takes place when, for all points combined as a unit before distribution, the fundamental unit of sensation exists.

What is the relationship β and the stimulus before distribution to its thresholds have now, so sensation is the 0.15996 to vorteilhaftester distribution, the total quantity β be fold this unit when you put the unit sensation at 10 times the threshold, however, the 0.36788 β times when placed at the 2,71828 ... times the threshold.

Before the distribution of the total quantum of sensation had the expression $\log \beta$, we have in



the expression for the relation between the quantum of the sensation of most favorable distribution and before the distribution of the stimulus, where the logarithms can be taken in any system without the value being different, since the ratio of the logarithm of given numbers in all logarithmic systems is the same is.



The formula $\boxed{}$ for the maximum of the sentient quantum, which we have come to the top, is of interest from several points of view. The stimulus β appears here out of the logarithmic relation, and the sensation becomes simply proportional to it, since $\log e$ and e are constants. According to this, it is possible, in principle, to let the total quantum of the sensation of the related stimulus increase in proportion, if only the stimulus is distributed so as to obtain the maximum of the sensation.

Applying natural logarithms, where $\log e = 1$, the maximum of sensation receives the same expression $\boxed{}$ as the distribution number N at which this maximum occurs.

Depending on β , οηιχη is larger or smaller than e , the maximum is the sensation quantum, which can be obtained with given β , larger or smaller than the unit of the sensation quantum, and for $\beta = e$ even equal to this unit.

Below and above the most advantageous distribution, there must be two degrees of distribution giving the same amount of sensation.

We go from any distribution of degree than the original, where the sensation Quantum $\log \beta$, it is according to the distribution of the n - times the number of points $n \log$, and for the case that both distributions are intended to provide a similar sensation Quantum

$$\log \beta = n \log$$

to determine from which equation n is to be determined in order to have the ratio in which the stimulus from the first distribution to the second has to be further distributed. After some analytic operations with regard to the properties of the logarithms and powers, this eventually leads to it

a formula which solves our problem insofar as it allows one to compute the corresponding stimulus value β (understood in relation to its threshold value) for each distribution ratio n , which restores the sensory quantum taking place in the original distribution 1, and with which Chapter 19). If you set z. B. $n = 2$, then $\beta = 4$; ie, if a stimulus whose intensity is four times its threshold is distributed over twice the number of points, then the same quantum of sensation takes place as without distribution, which, however, is smaller than the maximum of the sensation quantum. By now 1 at high n noticeably against n disappears, simplifies the formula for the following approximate formula for this case

$$n = \beta$$

which says that a stimulus must, in order to give, after a strong distribution, the same quantity of sensation as without distribution, be distributed in a ratio which approaches its ratio to the threshold value, ie, itself descend almost to the threshold value, the great number of irritated points weakening compensated for the intensity.

The derivation of the general formula from the equation $\log \beta = n \log$ is this:

First, the latter equation can be found in

transform, from which follows



$$n^n = \beta^n - 1$$



Although we have no means of proving the previous maximum determinations by direct experience, they are necessarily related to their presuppositions and can be considered equally valid. Now, there is a question of interest. Is the sensation of light, which normally exists in the eye, independent of the external light stimuli, the sensation of the eye-black, below or above the favorable possible. The closer meaning of the question is this:

By which also the sensation of the black is excited in us, inasmuch as, according to the earlier discussions, we may still regard it as a slight sensation of light, which may well be distinguished from nothingness, we can also see in that inner cause the equivalent of an external light-stimulus, which would have been capable of to produce the same faint sensation of light. Now, for a given magnitude, such a one would have produced the maximum of the sensation, if it had been distributed so that its intensity was equal to 2.71828 times its threshold value, and thus a certain intensity of the sensation of light would arise. The question then arises, is the black in the eye lighter or darker than this most advantageous intensity? - Or even if we reflect directly on the psychophysical activity to which the inner sensation of light depends,

Although we can not confidently decide on this, the coincidence of two points of view seems to me to establish a certain probability that the deepest black of the eye corresponds to the most advantageous intensity, so that every inner illumination of the same - and in fact the black can through loss of both inner and outer causes - a loss arises inasmuch as the psychophysical activity which produces this elucidation would have produced by greater distribution a greater sum of sensation, but every loss of the deepest black produces no less a loss by the facial sensation would then ever approach the extinction, an approach that we actually observe at the boundaries of the visual field in the closed eye.

In the first place, the question must be raised as to what would happen if the cause of the inner light were to approach the threshold even more than the deepest black of the eye, which occurs, is the case. Impossible, the black can further deepen to the thresholds, because here the facial sensation rather stops, whereas a deepened black is still a facial sensation. So there must be a turning point above the threshold from where the black begins to move indistinctly, and one would not know what to call this turning point unless it is our maximum intensity from which loss in a sense other than above suffered becomes. In a sense, we really do feel the deepest black as a maximum.

By the way, should not the pale, colorless images and patterns that accompany our ordinary performance, and of which we can not say that they appear black, belong to that interval between the threshold and the maximum point?

The previous point is the following:

Otherwise, we generally find the facilities in our organism so that as little effort as possible is made in terms of strength and resources. If, indeed, the black of the unexcited eye should correspond to that maximum value, then the case would be realized with the least possible expenditure of inner stimulus or equivalent living force of the psychophysical activity, but the greatest possible sum of sensation would be produced.

Of course, all that remains for now but only hypothesis. But should it be valid, we would-and this is a new point of interest, which may well cause us to investigate the matter further-appear in the deepest blackness that exists in our eye, at the same time finding the natural fundamental unit of light-sensation represented which we used to be guided purely from a mathematical point of view. In addition, we could pronounce the paradox that the blackest night-dark gives the greatest possible brightness, the greatest possible, which can be achieved with the same amount of light-stimulus.

It may further be remarked that under this condition the weakest sensations of light and excitations of light which exceed the black of the eye would be remarkably proportional to each other, since this cardinal value of sensation takes place after earlier.

Similar relations to those of the distribution of the stimulus through space must also take place with respect to the distribution of it through time, and according to an analogous derivation the same formula is decisive. One will obtain neither the greatest quantity of sensation, if one concentrates one stimulus at once, or if one lets it act gradually in too great a dilution. But he will do the maximum, if he acts with the 2.718 ... strength of his threshold. This does not mean that it must always be of the same intensity if the state of the stimulus-susceptibility of the organism, on which the threshold value of the stimulus itself depends, should change, and on the contrary be dulled in proportion to the sensitivity to irritation, and the b . As the measure formula increases, the stimulus will also have to increase to produce the maximum of sensation.

The same principles will apply in the following cases.

Everyone knows that a stimulant, whatever it may be, is distributed evenly according to space and time, be it between different people, be it in the same person, as a whole, but not least, that it does not serve, a stimulant to a person or a time too much to accumulate. Our formula contains the principle of the right measure, if even a real calculation afterwards would not be somehow executable, and in such a case also the faster blunting of the irritability would have to be taken into account by heaped stimulus.

If money or good, which is to be regarded as the stimulus of a sum of valuable sensations, is to be distributed, it is first and foremost established in the principle represented by our formulas that the *fortune be paid* most with this *fortune physique* for the poorest but neither too great a fragmentation nor too great a concentration will be the most advantageous. The possession of goods, where man is

just makeshift, wants to be considered as the threshold value of possession of formulas that one wanted to apply to this case.

If we let n mean a fractional value in our distribution formula, it holds for the case that a stimulus, instead of being distributed in the ratio n , is concentrated in this ratio.

From this an interesting result can be drawn. If a stimulus concentrates more and more on a space or time, then the limit is an infinite concentration ratio; then $n = \boxed{\quad}$ and the distribution formula gives $G = \boxed{\quad} \log \infty = 0$. It is well known that the mathematical analysis finds the expression $\boxed{\quad} \log \infty = 0$.

This result can not be produced purely in experience, because every stimulus, even if it seems to strike or strike only a simple point, nevertheless works around it in a certain extent, and radiates, as it does with a certain amount of after-life. so that even the dot image of the star appears radiating or as a small circle, the touch of a needle point is felt by propagation of the pressure in a certain circle, the instantaneous flash its afterimage in the eye, every bang leaves its reverberation in the ear. But one can find the only possible approach to the result in that z. For example, anyone will prefer to pull off a tooth with a jerk, as more slowly, and everyone instinctively prefers the quickest death by the most violent means to slow killing.

The previous one concerned the dependency of the sensation quantum on the distribution variable, which presupposes a uniform distribution of the stimulus; Another consequence of the measure formula concerns the dependence on the distribution of the stimulus. This conclusion is based on the fact that the total size of the sensation becomes a maximum for a uniform distribution of the stimulus.

First, I remember the following sentence:

Given a sum of n numbers $a, b, c \dots = S$, the product of the numbers is the greatest possible if all the numbers $a, b, c \dots$ are $\boxed{\quad}$ equal to each other and hence to the mean .

For example, if the sum S is 12 and the numbers are 3, then the maximum product is obtained by $4 \cdot 4 \cdot 4 = 64$. The product $6 \cdot 4 \cdot 2$ would only 48, the product $7 \cdot 4 \cdot 1$ only give 28, etc. This rule also applies to fractions. If z. For example, divide the number 1 into 3 fractions; thus giving $1/3 \cdot 1/3 \cdot 1/3$ the maximum.

Let us now add the memory that the sum of the logarithms of given numbers is equal to the logarithm of their product, and the numbers with the logarithms grow and decrease, so the following derivation will be no more difficult.

If one has n sensitive points, which are respectively irritated with the intensities $\beta, \beta', \beta'' \dots$, whose sum is S , the following will be the total sum of the sensation

$$\log \beta + \log \beta' + \log \beta'' \dots = \log \beta \beta' \beta'' \dots$$

The maximum of the product $\beta \beta' \beta'' \dots$ is obtained according to the above theorem,

if $\beta = \beta' = \beta'' \dots = \boxed{}$, and hereby also the maximum of $\log \beta \beta' \beta'' \dots$, and hereby the maximum of the total quantum of the sensation.

If all points of an irritated surface are above the threshold, the application of the previous sentence is not subject to any difficulty. But if a stimulus, which, by uniform distribution over a large area or for a long time, passes under the threshold, and thus gives no conscious sensation, passes over the threshold by concentrating on individual points of that surface or time, then, in spite of it, it gives unequal distribution a conscious sensation, which seems to contradict the previous sentence.

This difficulty is highlighted by the following consideration:

If, under previous conditions, a positive conscious quantum of sensation arises for certain points through the nonuniform distribution, the deepening of the unconscious by deprivation of the stimulus grows from the other side all the more for the other points, which depression for the totality of the latter increases its mathematical measure in a negative one. Sensation quantum finds, and the excess of this negative quantum of sensation over the positive exceeds in the uneven distribution the presupposed negative quantum of sensation in the uniform. Thus the mathematical correctness of the sentence remains in force, which is based only on this mathematical relation or the algebraic sum of conscious and unconscious sensation. Insofar as conscious and unconscious sensations are particularly important to the eye, he can not find any application to specially determine the maximum of conscious sensation. Rather, it shows that it may be advantageous to disperse a stimulus in the manner that certain points cross the threshold at the expense of others, which sink deeper into the threshold.

If one asks what is most advantageous in order to obtain the greatest possible quantity of positive conscious sensation, without regard to the quantity of negative unconscious sensation, which thus arises from the other side, then one is led back to the already given determinations and it becomes most advantageous when the distribution size and distribution over an indeterminate area or time is free to allow so much of that area or time to go below the threshold that the part above the threshold is 2,71828 ... times its threshold value and is irritated as uniformly as possible over its entire surface.

Incidentally, it must be remembered in advance what will soon be found in its further execution, that the soul, apart from sums, is also affected by differences in sensation, and that the sensation of differences is not to be regarded as something arising in the sum-effect, but as something that accompanies it. Thus, the entire sensory output of different stimuli can not be attributed to their cumulative effect. But this sum effect is a part or a side of the whole performance, and the clarity demands to consider one moment after another, in particular, insofar as it is capable of a separate consideration.

XXII. Distinction between sensory differences and contrast sensations. ¹⁾

Besides the sum of the sensations, which take place according to the sum and distribution of the stimulus over different points of time or space, it is also necessary to consider the difference of the sensations according to their dependence on the difference of the stimulation at these points. But before we make the formulas related to this, it will be necessary to make a distinction that has not been emphasized so far, and yet it is important.

¹⁾ With regard to p. 9. Revision p. 183. 330. Psych. Maßprinzipien p. 188.

One sensation may quite well differ from another, without the difference being perceived as a difference, coming into consciousness. This is immediately apparent in sensations that exist in different individuals. As great as the difference may be, it can not be sensed, but the one sensation is felt, the other is felt, but the difference is not perceived, since it implies that the one falls into the same consciousness with the other. It is no less evident that there are differences in the sensations of the same individual, which in time are so far apart that one is forgotten when the other enters. While there is a common consciousness for both, but by not passing remembrance from one to the other, apparently there is no volume in consciousness, which is essential to the perception of a difference between them. And so their difference can exist just as in two different individuals, and yet it can not be perceived as a difference.

In general, two different sensations will always be based either on the excitement of different parts of a sensory organ, such as the eye, the skin, in so far as they belong to different spaces, or will successively be excited in different times insofar as they belong to different times, or finally they will become different spaces and the times and circumstances of their excitement will everywhere have an influence on whether and how the difference is felt, while the true difference of the sensations depends only on their actual size, but not on the external conditions of their excitation. So it is generally said that the difference is less noticeable simultaneously with different organs or with different parts of an organ of perceived components,

Thus, we must concede the possibility and the existence of various sensations, the difference of which does not fall into consciousness, and must not readily identify the sensation of a difference with the difference of sensations, even if, under otherwise equal circumstances, there is a greater difference between sensations also carries a stronger sense of difference, so that under certain circumstances both may be subject to a common consideration. In general, however, the distinction is to be drawn

between differences which exist between sensations without being conceived as differences, and those which really enter into consciousness as differences. Both should, where their distinction applies, as sensory differences, strictly speaking or in the narrow sense, and as perceived differences or sensations of differences; for the latter, too, we shall need the term contrast sensations, for what is called contrast essentially coincides with a difference of impressions, stimuli, subject to sensation. But the above will not hinder, since where it depends not on a juxtaposition of sensory differences in the narrower sense and perceived differences but rather on a common consideration of them, as hitherto to use the name sensory differences in the broader sense as the commoner for both

By previous distinction, the following apparent contradiction dissolves.

If we let a tone or a light grow more and more above the threshold of strength, we feel the continuous growth through all intermediate values from the lower to the higher value, and every smallest increase of the stimulus necessarily causes an increase of the sensation, since only then the sensation of the sensation lower to higher values. So every smallest increase in stimulus or stimulus difference in a corresponding sensation gain, sensation differences is felt. On the other hand, however, the fact of the difference threshold has proved to us that not every slight increase in stimulus, difference in stimulus, is sensed above the threshold, but that it requires a certain amount of it, otherwise it is imperceptible. A too small light and weight difference is not felt.

Here two facts seem to contradict each other directly. After the first, every smallest difference in stimulus above the threshold is felt, after the second, it is not felt, but first requires a certain finite size. But facts can not contradict each other in truth, but the contradiction can rest only in our conception, by identifying what is not identical, and so this apparent contradiction simply dissolves in that we note that it is, after all, a mere one Sensation difference, secondarily a perceived difference; but the threshold of difference is merely a matter of the latter.

In fact, when the sound or the light grows continuously, the sensation grows along, and we are well aware of the growing sensation, but not of the growth as such, the difference goes, as we like to express ourselves, indistinguishable in sensation until growth reaches or exceeds a certain size; then we may also be particularly aware that the later sensation is greater than the earlier one, and, on the basis of the principle of continuity, conclude that it must have grown by all intermediate degrees without our being able to grow through the smallest differences could pursue with special sensations.

According to this, we can also distinguish differences of sensation in the narrower sense, insofar as they exist between and with sensations, without, however, being perceived as differences, and distinguish the differences which really feel themselves as differences of sensation arising in the sensation and especially apprehended.

It may be remarked that in the case where every smallest difference between two sensations is really sensed, the distinction between sensory differences and perceived differences would be idle, and that the perceived difference would coincide with the

sensory differences. Now, among all the possible ways in which a difference can be felt, one can also think of the case as a limiting case, that even the smallest difference that exists would really be felt, which would designate the greatest possible degree of difference sensitivity. In this respect, a sensory difference can always be identified with such a limit case, and laws and relationships regarding the dependence of sensation values on the ratios of the stimuli, which remain equally valid for every degree of sensitivity, even though they could only be ascertained by perceived differences, but allow a transference to differences of sensation, since we should have to consider sensitivity increased only to its limit, by the magnitude of the perceived difference to see the difference in sensation coincide. Thus Weber's law can only be proved by perceived differences; but this does not prevent it from being valid also for sensory differences in the narrower sense, and to deduce the fundamental formula for small sensory differences from it, using the mathematical auxiliary principle, which then leads further to the dimensional formula and to the difference formula to be considered in the following chapter. even if they could only be ascertained by perceived differences, but allow a transference to differences of sensation, since we would have to think of the sensitivity merely increased to its limit, in order to see the magnitude of the perceived difference coinciding with that of the difference of sensation. Thus Weber's law can only be proved by perceived differences; but this does not prevent it from being valid also for sensory differences in the narrower sense, and to deduce the fundamental formula for small sensory differences from it, using the mathematical auxiliary principle, which then leads further to the dimensional formula and to the difference formula to be considered in the following chapter. even if they could only be ascertained by perceived differences, but allow a transference to differences of sensation, since we would have to think of the sensitivity merely increased to its limit, in order to see the magnitude of the perceived difference coinciding with that of the difference of sensation. Thus Weber's law can only be proved by perceived differences; but this does not prevent it from being valid also for sensory differences in the narrower sense, and to deduce the fundamental formula for small sensory differences from it, using the mathematical auxiliary principle, which then leads further to the dimensional formula and to the difference formula to be considered in the following chapter. since we would have to think of the sensitivity only increased to its limit, in order to see the magnitude of the perceived difference coinciding with that of the sensation difference. Thus Weber's law can only be proved by perceived differences; but this does not prevent it from being valid also for sensory differences in the narrower sense, and to deduce the fundamental formula for small sensory differences from it, using the mathematical auxiliary principle, which then leads further to the dimensional formula and to the difference formula to be considered in the following chapter. since we would have to think of the sensitivity only increased to its limit, in order to see the magnitude of the perceived difference coinciding with that of the sensation difference. Thus Weber's law can only be proved by perceived differences; but this does not prevent it from being valid also for sensory differences in the narrower sense, and to deduce the fundamental formula for small sensory differences from it, using the mathematical auxiliary principle, which then leads further to the dimensional formula and to the

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The conception of a difference of sensations is a peculiar act of consciousness which, as we have seen, is not self-evident in and with the existence of sensations, but requires special conditions for coming about. We may call it a higher act of consciousness than the simple conception of a sensation, as long as it presupposes a comparison between a majority of sensations, that is, the consciousness of a relation between them.

The concept of spiritual height appears here for the first time in accordance with the course we have taken, and this first appearance, like every beginning, must be observed. From now on, we generally understand this concept such that, if *A* specifically includes the conscious relation or connection between the phenomena *a* and *b* or is abstract, *A* is higher than *a* and *b* is called. Whereupon our whole soul, which includes the conscious relation of all its phenomena, is the concrete highest, the unity of consciousness in us the abstract highest, and a simple sensation in general the lowest, which exists in us. In fact, we have to make the distinction everywhere between the abstract and concrete version of height, according as we think the relationship abstract or related. In the same way we can think of the sensation of the difference abstract or the different sensations in perceived differences.

It is not an aside for a confrontation of the whole step structure of spiritual height in man, but the first step of these leaders and the direction of the ascension has to occupy us first of all.

Insofar as the following chapters will show that a perceived difference in measure is no less capable than the sensations themselves between which he insists that both measures can be separated and connected; and that the differences between differences of sensibility can no less be sensed, and these higher sensations are in principle measurable, it is directly proved that the higher spiritual, abstract and concrete, is no less accessible to measure than the lower, and that it is also a principle here, from the lower to the higher to ascend, not lacking.

If we delve into the previous considerations, we shall find that the distinction which we found between two kinds of differences of sensibility extends also to the sensations themselves, insofar as every sensation can also be regarded as a difference of sensation from zero and vice versa. In fact, in the sensations we encounter an

apparent antinomy of the same kind, as in the sensory differences, which can be solved in the same way.

Just as a stimulus rises above the threshold, sensation sets in according to our standard formula, and even if it rises so little above the threshold. But one can only become aware of this sensation in such a way that one can compare it with others that we have at another time or that are aroused in other parts of the organism, and then distinguish them from others; this can only be achieved if they have a certain strength has reached. Until then we may call them a consciously lower-minded, for the sake of brevity semi-conscious, moreover, a more conscious, in short, fully conscious.

There is a characteristic difference between the two degrees of consciousness. One can not remember half-conscious sensations; one is able to fully conscious ones. This difference is linked to the essential difference between the two. In order to be able to distinguish one sensation from another, one must be able to superimpose or remember it in memory of it. The threshold of full consciousness, then, lies where the possibility of remembrance awakens, and thus has a definable and very important meaning. We may have innumerable sensations as half-conscious without our being able to remember them.

What applies to sensations can be transferred to the whole of consciousness. The moment when man wakes up early in the morning is not at the same time where he becomes aware of or becomes conscious of his waking, but for this the waking must first to a certain extent have developed or a means of revival to reach a certain strength. Conversely, when somebody falls asleep, the higher consciousness of what he has of his consciousness fades away from falling asleep. No one can ever remember the moment he fell asleep and where he woke up. In fact, one reaches for sleep, the means of counting. If you really fall asleep then you will never be able to remember what the last numbers were that you counted before you fell asleep.

In a longer period of time the semiconscious state seems to occur in drunkenness and chloroformation; since drunks, after past intoxication, often can not remember at all what happened to them during the drunkenness and that they themselves undertook; and because some chloroforms scream during the operation for pain, of which they know afterwards nothing more.

It is undisputed that a difference in sensation was felt; to become fully aware of a sensation, indeed, that it can become conscious at all, not only on the proportions of the stimulus, but also on the degree of attention; but here, as always, we presuppose an equal degree of tension of attention, as far as it depends on arbitrariness, only to consider that which depends on the magnitude of the stimuli; since the representation of attention can only be discussed in internal psychophysics.

You can find it striking and maybe it *a priori* It is impossible to find that feelings of contrast, sensations of difference, can arise just as well between successive and simultaneous impressions, or even more distinct between them than between the latter; for how can a past still assert its relation to a present? Now we do not need to engage in speculation for now, as our formulas are based on the fact and on the fact, and this is what it is. In the meantime, it may be pointed out that the past impression

is undoubtedly still present in after-effects, which are related to the new impressions, and it is very conceivable that impressions successively made on the same part of the organ may therefore be more easily distinguished under otherwise identical circumstances. as simultaneously made on different parts of the organs, because the temporally succiding impressions also leave spatially succiding and thus non-mixing after-effects, whereas on simultaneous impressions effects are interdependent. But this is just supposed to be an incidental hypothesis.

XXIII. The difference formula.¹⁾

When it is necessary to measure the difference between two sensations produced by two stimuli acting in different points of time or space, irrespective of whether this difference is felt or not, that is, a sensory difference in the narrower sense of the previous chapter Of course, only the difference of the absolute measures which apply to the individual sensations can serve to measure a perceived difference. These measures are given by the measure formula, and thus the measure of the sensation difference will simply be determined as the difference between two values given by the measure formula.

¹⁾ With regard to p. 9. Revision p. 184 f.

Let the two sensations, whose difference it is to be determined, be γ, γ' , the corresponding stimuli β, β' , and, to begin with the simplest assumption, assume an equal sensitivity for β, β' , hence b for both constant, we have the two equations according to the first form of the dimensional formula (chapter 16)

$$\gamma = k (\log \beta - \log b)$$

$$\gamma' = k (\log \beta' - \log b)$$

as a difference of both

$$\begin{aligned} \gamma - \gamma' &= k \\ (\log \beta - \log \beta') & \end{aligned}$$



which formula has already been derived in the same way (chapter 16). We are also led to the same formula if we take the second form of the measure

formula $\boxed{\quad}$ as the basis, and then obtain it first

$$\boxed{\quad}.$$

which formula in turn is reduced to the previous one by setting the logarithm of the quotient for the difference of the logarithms.

Let's call this formula the simple difference formula or simply difference formula par excellence.

Instead of deriving the difference formula in the manner indicated from the measurement formula, can be obtained directly by integrating the fundamental formula them as the more general of measurement formula by enough to the integration constant during derivation of the measurement formula by reduction of the sensation equal to zero at the stimuli b determined was to be determined by the fact that we generally put the sensation $= \gamma'$ at the stimulus value β' .

It can be seen that the threshold b has disappeared from the difference formula. If, therefore, out of ignorance of the threshold value no absolute measure of the sensation by the measure-formula itself is possible, yet the simple difference-formula can still serve to compare differences in sensation according to their size, as long as the stimulus-threshold can only be presupposed as constant. It is further seen that the difference in sensation is generally not a function of the stimulus difference but of the stimulus ratio, being proportional to the logarithm of it.

Here a contradiction seems to be offered. If our formula is to hold universal validity, it must apply to small as well as large differences, but according to the fundamental formula the expression is valid for small differences

$$\boxed{\quad}$$

according to which the difference in sensation is proportional to the relative difference of stimulus rather than to the logarithm of the stimulus ratio, which are generally very different ratios. In the meantime it can be shown that, in the case of very small sensory differences, both conditions agree, so that in this case the difference formula comes back to the fundamental formula.

Let there be two sensations γ and $\gamma + d\gamma$, of which the second differs from the first only by the small increment $d\gamma$, and let the corresponding stimuli β and $\beta + d\beta$, which differ only by the small magnitude $d\beta$. Thus, by taking $\gamma + d\gamma$ and γ as two distinct sensations, $\beta + d\beta$ and β as the corresponding stimuli substitute in the difference formula, first

$$\boxed{\quad},$$

But as it is $\boxed{\quad}$ very small, we can go to Chap. 14 for $\boxed{\quad}$ put $\boxed{\quad}$ where M
 $\boxed{\quad}$ is the modulus. Hereby we obtain $d\gamma = k \boxed{\quad}$ and by contraction of kM into the simple constant K

$$\boxed{\quad}.$$

which is the fundamental formula.

No less than the fundamental formula can the measure-formula be represented as a special case of the difference-formula, and, as noted above, the difference-formula itself immediately derives from the fundamental-formula as the more general of the measure-formula. The dimensional formula represents the case of the difference formula where one of the two sensations between which the difference exists becomes zero, and hence the corresponding stimulus acquires the threshold value, provided that each simple sensation can also be taken as a difference from the zero value of the sensation. If one now sets $\gamma' = 0$ and $\beta' = b$, then the agreement with the dimensional formula results directly. Set $\gamma = 0$ and $\beta = b$, we obtain first

$$\boxed{\quad},$$

$$\boxed{\quad} = \boxed{\quad}$$

But as to the properties of logarithms (Ch. 14) $\boxed{\quad} = \boxed{\quad}$, we have

$$\boxed{\quad}$$

and by shifting the values of this opposite sign equation to the other side of the equation

$$\boxed{\quad}.$$

which in turn is the shape of the measurement formula.

Hereinafter the difference formula, if deducible from the measure-formula, which itself can be derived from the fundamental formula, can be regarded as the more general of both, and how it has emerged from them, can also give it back.

In the use of the difference formula it is necessary to agree on the meaning of the signs, which may take the difference $\gamma - \gamma'$.

The value of $\gamma - \gamma'$ is positive or negative, depending on $\beta > \beta'$ or $\beta < \beta'$. A positive value of $\gamma - \gamma'$ indicates naturally that the sensation γ , which belongs to the stimulus β , predominates, a negative, that the sensation γ' outweighs that which stimulus β' listened. Thus, the opposite of the signs generally means a contrast in the direction of the sensation difference, where both sensations may be above the

threshold, or both below the threshold, or one above, and the other below the threshold.

This meaning of the signs is to be held as the universal one for the sensory difference; but not to interpret the antithesis of omens in general as the antithesis of the consciousness and unconsciousness of sensory differences. Only in the special case where the difference formula is reduced to the measure-formula by putting $\gamma' = 0$ or $\gamma = 0$, does the contrast of the sign before the absolute feeling, which is now the sole remaining, automatically assume the meaning of the opposition between conscious and unconscious. because this opposition refers only to the relation of a sensation to the null-sensation, but not to other sensations.

If one thinks that the mathematical consequence does not permit one to understand the antithesis of the sign in such a special way before the absolute value of a sensation, without generalizing this meaning for the difference in sensation, then again it will only be necessary to remember one earlier to recall a used parallel example from analytic geometry in order to see the reservation lifted. Before the absolute value of a radius vector in the system of polar coordinates, the opposite of the sign signifies an opposition of the real and the imaginary; but this meaning can not be generalized for the difference between two Radii vectores r, r' ; rather, the sign of $r - r'$ in general only the direction of a difference between the two, whether one is greater or smaller than the other, and the opposition of the real and the imaginary only if $r' < r$ or $r = 0$. This is quite the analogue of our case. The representation of the positive and negative sensation values by positive and negative ordinates leads to the same view, while the stimulus values form the right-angled abscissa. We can take the difference of two positive ordinates equal to $\gamma - \gamma'$, and it will be negative according to our difference formula if $\beta' > \beta$. But this negative difference between two positive ordinates has, in the spirit of analytic geometry, a completely different meaning than the equally great negative difference of a single ordinate of zero, which is nothing else than a simple negative ordinate itself Space that represents consciousness, this space entirely, which represents the unconsciousness; and the meaning of the unconscious, which is the latter difference, can not therefore be transferred to the former, but it does not contradict it, but both cases are special cases of a more general conception of the sign-contradiction. Our conception is thus entirely in the spirit of mathematics, and there would be no connection between the formulas and the facts with a different conception.

Incidentally, one can see that the shape of the difference equation is the same as that of the measurement formula, if we for the sensation difference $\gamma - \gamma'$ set a single letter, except that in place of the threshold value of the measurement formula takes the value of the stimulus, against the we look at the other, and at the place of the interpretation of the sign on conscious and unconscious the interpretation on the direction of the difference. Under this consideration, all laws and relationships that can be deduced from the dimensional formula for absolute values of feeling are also transferable to differences and vice versa.

Well there

we are the difference between two sensations comparable n -facht see if the ratio of the stimuli, which belong to the feelings of the n increases th power, as we comparable sensation n found -facht if the ratio of the stimulus for threshold values to the n - th power increases.

In the same way we can transfer everything that is said about the relative course of sensation and stimulus to the relation between sensation difference and stimulus, by referring only to the fundamental stimulus value as relation value to the threshold, but to the stimulus, in relation to which the difference is considered take.

A noteworthy sentence, which was already asserted earlier (chapter 17) in just a slightly different way of expressing the measure-formula, results when we construct a series of stimuli $\beta, \beta', \beta'', \beta'''$. no matter whether arranged according to the order of their size or not, taking the differences of sensation from one to the next, and summing up these differences. The sum of these sensory differences is equal to the difference in sensation between the extreme stimuli of the series. In fact, we only have to convert the sum of the logarithms of , etc., into the logarithm of the product

from this quotient in order to find this sentence confirmed.

The formula for sensory differences can easily be generalized into a formula for differences in sensory differences.

If we set the sensation difference $\gamma - \gamma' = u$, the stimulus ratio $= \varphi$, another sensation difference $\gamma'' - \gamma''' = u'$, the corresponding stimulus ratio $= \varphi'$, then we have

$$u = k \log \varphi$$

$$u' = k \log \varphi'$$

therefore

This formula is more general than the formula for simple differences in sensation, by going into it by setting $u' = 0$, which implies $\varphi' = 1, \beta'' = \beta'''$.

No less does one arrive at a generalization of the fundamental formula by using the difference formula

$$u = K \log \varphi$$

differentiated, which gives you

$$\boxed{\quad}$$

which by integration the same general formula

$$u - u' = k \log \boxed{\quad},$$

which we just received in a different way.

A generalization of the difference formula in a different sense is obtained if, instead of equating the absolute sensitivity and therefore the value b with the action of the two stimuli β, β' , different thresholds, respectively b, b' , take place. Then the thresholds do not disappear from the formula, and we get

$$\boxed{\quad} \quad (1)$$

$$\boxed{\quad} \quad (2)$$

$$\boxed{\quad} \quad (3)$$

$$\boxed{\quad} \quad (4)$$

These are merely different forms of the same formula, which we may briefly call the difference threshold formula. The expression (2) teaches us that the perception difference is generally proportional to the logarithm of the quotient of two

fundamental stimulus values $\boxed{\quad}$ and $\boxed{\quad}$, of which the former by this dividing the

product $\boxed{\quad}$ is. The expression (3) that it is proportional to the logarithm of the

quotient obtained by dividing the ratio of the stimuli $\boxed{\quad}$ with the ratio of the

associated thresholds $\boxed{\quad}$. Finally, the expression (4) that the difference in sensitivity decreases or increases due to the difference in sensitivity, depending on the

threshold b or b' the larger one is, at first $\log \boxed{\quad}$ positive, later negative. If we now put β as the stronger stimulus, then the threshold value b' of the weaker stimulus must be greater in order to increase the positive sensation difference, and if we put β' as

the stronger stimulus, the threshold b be greater for the weaker stimulus, so that the negative sensation difference grows. In general, therefore, the difference in sensibility increases or decreases as the threshold of the weaker or stronger stimulus is greater, hence the greater or lesser stimulus is perceived with greater sensitivity. If the thresholds are in the same proportions as the stimuli to which they belong, the sensory difference disappears altogether.

Thus, with regard to sensory differences, it is not the same as we previously found for the sensory sums, that it does not matter whether the sensitivities for the stronger and weaker stimulus are reversed.

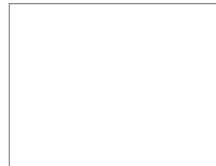
Incidentally, the same formula shows that even if b and b' differ, the difference in

sensation becomes noticeably independent of both if $\log \frac{b}{b'}$ disappears noticeably against $\log \frac{\beta}{\beta'}$, that is, if the stimuli β, β' are strong, and the thresholds b, b' are low differ.

The difference threshold formula can be reduced to the form of the measure

formula by denoting the sensation difference $\gamma - \gamma'$ by u , the stimulus ratio $\frac{\beta}{\beta'}$ by φ ,

the ratio of the threshold values $\frac{b}{b'}$ by F ; by changing the shape of the difference threshold formula



hereafter translated into



If we now call the quotient $\frac{\beta}{b}$, that is the ratio of the stimuli divided by the ratio of the corresponding threshold values, in short the fundamental difference ratio, we can say that the difference in sensations depends in the same way on fundamental differences as the sensation depends on the fundamental stimulus.

XXIV. The difference measure formula.¹⁾

After the discussion of the 22nd chapter on the distinction between sensory differences and perceived differences or contrast sensations, our difference formula, which serves the measure of the first one, can not at the same time afford the measure of the last. In fact, it contains only a dependence of the sensory difference on the size

of the stimuli, but no dependence on the circumstances, on which the magnitude of the perceived difference still depends, and the fact of the difference threshold is not included in it, according to which it is not a vagina between conscious and unconscious perceived differences, which in reality consists no less than for absolute sensations. To measure the perceived differences, on the contrary, we have to serve another formula which satisfies these requirements.

¹⁾ In the matter of p. 9. 11. Revision p. 185 ff., Psych. Massprinzipien p. 194. 200th

In view of the fact that perceived differences have their threshold as well as absolute sensations, one can first of all justify the difference-measure formula for an analogy with the measure-formula as follows.

Let us denote, as before, a difference in sensation, so now a perceived difference

between the sensations γ and γ' with u , and the corresponding stimulus ratio with φ , and give the value of this stimulus ratio at which the perceived difference comes to the threshold, ie the ratio constant or Ratio threshold v has the same relation to φ as the simple threshold b to the stimulus β in the measure formula, we obtain

$$\boxed{\text{[Redacted]}}$$

Here, as is always the case, it is assumed that the greater stimulus is related to the value of φ , hence $\varphi > 1$, and $\log \varphi$ is positive; which is essential if, in the previous form of the formula, positive values should correspond to u conscious values of perceived difference. After all, they wanted to use the smaller stimulus as a counter, it would $\varphi < 1$, and therefore $\log \varphi$ are negative, and u so gain greater negative values, an ever larger proportion of a stimulus to the other would receive, however, but the sensation of the difference hereby rises higher above the threshold.

In itself, however, nothing hinders the use of the smaller stimulus in the numerator, but in this reversed position of both stimuli one has to reverse everything in the previous formula, namely, by reversing the stimulus ratio φ into the

reciprocal $\varphi_1 = \boxed{\text{[Redacted]}}$, also the value of v in the reciprocal $v_1 = \boxed{\text{[Redacted]}}$ to operate, and the position of φ_1 and v_1 , to act against those of φ and v , that is, to write the formula

$$\boxed{\text{[Redacted]}}$$

$$\boxed{\text{[Redacted]}}$$

which has the same value with the previous one, provided

In the following, however, the assumption $\varphi > 1$ and accordingly the position of the greater stimulus in the counter will always be recorded, according to which, if, for example, a stimulus applied in a certain way becomes ever larger and smaller than the other according to circumstances, its place as counter and Denominator has to change in the value of φ .

The above formulation of the formula also generally presupposes the normal case that when the two temporally or spatially distinct stimuli, the difference of which is to be understood, interchange the magnitude, the greater stimulus takes the place of the smaller, and vice versa, only the direction, not the size of the perceived difference changes. This normal case is by no means the general case of reality, since on the contrary, in all cases where so-called constant errors occur in experiments on the sensitivity of difference, the conception of a difference depends on the spatial and temporal position of the compared quantities (compare Th. that the sensation of difference is different in magnitude with equal proportions of stimuli, as one makes the one or other stimulus greater).

However, constant errors can always be eliminated by trial and error, and thus the cases with constant errors are reduced to the normal case; in many cases constant errors are too small to need to be taken into account; finally, those can, after the basic formula is given for the normal case, then be given special consideration in a suitable way (see chapter 27); according to which the formulation of the formula for the normal case always remains what one has to assume.

To the same form of the difference-measure-formula, which appears here merely by analogy and thus does not yet appear to be strictly justified, including the rule concerning the change in the form of the formula, according as one makes $\varphi > 1$ or < 1 , can be made more strict on the basis of the weaver. law and the fact of the threshold of equivalence for an analogous course as the measure-formula, in the manner indicated in the following interposition.

The fundamental formula based on Weber's law gives in particular for two sensory differences



hereafter



Now that γ and γ' are two sensations whose difference is $\gamma - \gamma'$, the differential of this $d\gamma - d\gamma'$ can be regarded as the element of a sensation difference, the value of

which [redacted] is. But if the addition of a constant to an integral does not

change anything in the differential, $d\gamma - d\gamma'$ is more generally the element of a

constant (di of φ or \square independent size) increased or decreased sensory differences. Now, according to Ch. 22 the difference in sensation is identified with the particular case of perceived difference, where at the smallest possible difference of stimuli β, β' a difference is perceived, and perceive a perceived difference as the more general case, where at some definite value the sensation of difference begins waning. By integrating the above value of $d\gamma - d\gamma'$ and determining the constants in the manner to be indicated in the same way, we obtain the expression for this more

general case, and herewith the difference measure formula. \square

In fact, we put $d\gamma - d\gamma' \pm du$ (if there is no reason in itself to apply one sign in front of the other), then we have

$$\int \pm du = K(\log \beta - \log \beta') + C$$

This is achieved through integration using natural logarithms

$$\pm u = K(\log \beta - \log \beta') + C$$

$$= K \log \varphi + C$$

where C is the integral of integration, or substituting natural by common logarithms (see Chapter 17), and thus replacing K by k

$$\pm u = k \log \varphi + C.$$

If we now define the constant C by setting u equal to zero, if φ takes the value v , then we have general

$$o = k \log v + C$$

hence

$$C = -k \log v.$$

And this value, substituted into the general equation, gives

$$o = k \log v - k \log v + C$$

Using the upper sign, we have

$$o = k \log v - k \log v + C \quad (1)$$

applying the lower and reversal of the sign on both sides

$$o = k \log v - k \log v + C \quad (2)$$

The formula (1) corresponds to the condition that $\log \varphi$ is positive, and thus the larger stimulus is set in the counter, the form (2) is just the condition that $\log \varphi$ is negative, hence the smaller stimulus is set in the counter because only under this condition can u grow in a positive sense with the growth of the absolute value of φ , as long as the normal case which we presuppose exists. Let us distinguish the two cases in which the greater and the smaller stimulus are placed in the numerator, in that at first the letters φ and v , secondarily φ_1 and v_1 so far as both cases refer to the same sensation u , and thus their measure can only be formally different



therefore



which presupposes that $\varphi_1 = \square$, that also $v_1 = \square$ is.

If the normal case did not take place, but u assumed different values, as the position of the larger and smaller stimuli is reversed, equations (1) and (2) would still be usable for the formulation of the difference measure, in so far as the constant error is Weber's law, according to which the perceived difference must remain the same for the same φ for which one, and for the opposite position of the greater and lesser stimulus in particular, could exist. Then one would need only the constant v to determine differently for the opposite time and space situation of the compared quantities. But if in this case it should happen that, owing to the constant error, the smaller stimulus appeared within certain limits than the larger one, and the perceived difference grew, if the difference of stimuli diminished instead of increased, one would follow this rule by observing the rule to use greater stimulus always in the numerator, to apply in those limits the equation (2) instead of (1), or to have the rule to use the larger stimulus in the counter, exceptionally to have the opposite in order to still have the equation (1) apply so that always positive values correspond to the conscious values of perceived difference.

As with the earlier formulas, in the difference-measure formula the meaning of the sign-contradiction, which the value of sensation can assume, needs special clarification.

For the full determinateness of the value u , we must pay attention not only to the sign of u itself, but also to the sign of the sensations between which the difference exists. The perceived difference u , after derivation, assumes the value 0 as the limit between conscious and unconscious values for the value $\varphi = v$ only if the ratio φ between stimuli is above the threshold, for only then does the empirical determination of the constant v whereas, when both stimuli and, with it, the associated sensations fall below the threshold, the whole concept of a perceived difference is lost, and if only one stimulus is above the threshold, the other on the threshold or

below the threshold, it is so good as if one were dealing only with a single sensation, as the difference of a null-sensation, or of an unreal sensation.

This is therefore necessary to remember because, according to the formula $u = k (\log \varphi - \log v)$, the value of u may be positive, even if both stimuli β, β' are below the threshold, and therefore nothing is felt, by affirming that $\varphi > v$, which may well be the case, if both β and β' are below the threshold, if only β has a great relation to β' . One may then in this positive values of u not yet find the sign of consciousness, because the precondition to it lacks, the consciousness of the values on which u depends.

If against this different interpretation of the sign of u , depending on u function either way beschaaffener values β, β' is, there are still a concern, it is again, as before so many such concerns, by reference to an analogous case of analytical geometry. In this too, the sign of a value u , which is the function of two values β, β' , can assume a very different meaning, depending on whether the values β, β' are such or such.

In fact, we take a square divided into four smaller squares by means of a cross parallel to the sides, divided by its center, divided by $r.o, l.o, r.u, l.u$ (upper right, upper left, lower right, lower left) may be called, and let us search for the analytic expression u for the 4 small squares. Emanating from the center of the right arm of the cross will measure its claimed by $+\beta$ designated, then the left by $-\beta$ are referred to; the arm of the cross going from the middle is denoted by $+\beta'$, the arm going downwards is indicated by $-\beta'$ be designated; and we are obtained by multiplying these positive and negative measures with each other as analytic expression u for

$$\begin{array}{lll} r.o & \text{the value} & +\beta\beta' \\ l.o & -- & -\beta\beta' \\ r.u & - & -\beta\beta' \\ l.u & -- & +\beta\beta' \end{array}$$

So the dimension expressions of the squares, which are very opposite to the center, have $r.o$ and $l.u$, one of which is a function of only positive, the other of negative values β, β' , but the same sign, and we can not conclude from this sign alone, whether the square to the rooms of positive or negative factors and belongs to what position it has in relation to the center, if we do not go back to the sign of the factors themselves, whose function it is. So we can also from the sign of u as a measure of a perceived difference, but not conclude what relationship the perceived difference has to consciousness, if we do not refer to the nature of the values; which enter into consideration, and in principle it does not change anything, that here in the realm of sensation we have rather to do with the function of a quotient, as a product. But as we get a full determination for the squares, if we with the sign of u at the same time the sign of β, β' considerate, so it is with the perceived differences in the case when we u, β, β' for use these.

Instead of establishing the difference measure formula as a function of the stimulus ratio and the ratio threshold, we can also establish it as a function of the relative stimulus difference and the difference constant as follows.

If one is different from the other by the quantity α and the ratio threshold v by 1 is different by the quantity ω , then we have

$$\boxed{\quad}$$

$$\text{and } v = 1 + \omega$$



Here is ϑ the relative stimulus difference, called φop short, and ω the difference constant in the sense given in Th. IS 244. After which the difference measure formula takes the following form

$$u = k [\log(1 + \vartheta) - \log(1 + \omega)].$$

In the case where ϑ and ω are small values whose squares can be neglected against the first power, after the i. Cape. 14 indicated substitution this formula over in

$$u = k M(\vartheta - \omega) = K(\vartheta - \omega)$$

which is the measure expression for a perceived difference, which exceeds the just noticeable little, provided that the difference just noticeable corresponds even to little different stimuli, according to which such a difference is proportional to the relative differences of excitement diminished by the difference constant, but a smaller one in the sensation rising sensation difference is proportional to the undiminished relative stimulus difference 2).

2) If in chap. It is said that a small difference in weight of twice the size is perceived to be appreciably twice as great, that this is correct to the effect that a small difference in weight of twice the size carries twice the sensation of difference, only *a priori* can be inferred from the mathematical auxiliary principle, but not that this difference is also perceived as twice as great, as indeed a small difference in weight and twice the size of the above formula by no means twice the perceived difference, so long as not the limit the relative sensitivity of difference is assumed. However, that only incidental careless confusion has no influence on the derivation of the fundamental formula and measure formula, which has been done with the correct application of the mathematical auxiliary principle.

The difference measure formula is to be regarded as the more general of the difference formula, and herewith also the measure formula and fundamental formula, insofar as these themselves are special cases of the difference formula. In fact, it passes into the difference formula for the case that $v = 1$, ie that the felt difference in equality of both stimuli comes to the threshold, and thus the smallest possible deviation from the equality would be felt, which according to i. Cape. The remark

made may be regarded as the extreme or the limiting case of the relative sensitivity to difference, and with which the perceived difference becomes so great as the real difference of sensations expressed by the difference-formula.

In the normal case to which our formula is based, v is always larger than 1 unless the limit of difference sensitivity is reached. But where the stimuli are, under favorable conditions, to perceive their difference, and the sensitivity of difference is great, v differs only little from 1; B. has shown in the experiments on the difference

sensitivity for the light, where according to Volkmann was [redacted] found. Since then $\log v$ deviates little from zero, the difference-measure formula also coincides closely with the simple difference-formula, and this can approximate serve as long as not even φ to a value very close to unity, and thus $\log \varphi$ descends to a value close to zero.

The ratio threshold v appears in the difference-measure formula quite in the place of the stimulus threshold b in the measure-formula, and is just as decisive for the degree of sensitivity with which a given stimulus-relation is conceived as the constant b for the degree of Sensitivity with which a given stimulus is conceived. As

well as [redacted] a measure of the absolute sensitivity, can [redacted] serve as a measure of the relative sensitivity of difference. Everything has to the value of v the perceived difference is modified influence, which at a given stimulus conditions, and it is therefore v to be regarded as a constant for constant conditions of conception.

In addition to the temporal and spatial differences of the stimuli, the difference of which is to be understood, the condition of what intervenes, as well as what is temporal and spatial, is one of the influential circumstances of the value of v . This influence may be such as to give rise to constant errors in the conception of the difference to be considered by experiment and calculation in the manner indicated in the methods of measuring difference and in Chapter 27.

The degree of absolute sensitivity with which both stimuli are apprehended has, insofar as it always remains the same for both stimuli, no influence on the value of the perceived difference; but an unequal value of them establishes a constant error for both stimuli, which necessitates the considerations to be taken for it.

Just as any change in the constant b in the measure-formula can be represented by a reciprocal change of the stimulus-effect β , the same applies to the change of the constant v , as long as every change of the same can be represented by a reciprocal change of φ .

The expression for a fully conscious sensation in the chapter. 22 sense given is, if they can be grasped as particularly pointed preconceived difference a sensation above the threshold of a sensation on the threshold, that is, from a zero sensation, naturally found when we in the Unterschiedsmaßformel the smaller stimulus β to which we others considered in the ratios to the threshold value b reduced, while at the same

time we sensation γ' reduce to zero, hence for $\varphi = \boxed{\quad}$ substituted $\boxed{\quad}$, and u substitute γ . So we get this formula

$$\boxed{\quad},$$

If we call b the full threshold, b the threshold of sensation as hitherto, then the relation between the full threshold and the threshold will be given by the ratio constant v . If we exclude such irregularities of the absolute sensitivities and the temporal and spatial position of the stimuli, which can make a greater stimulus

appear than the smaller one, then v will always be greater than 1 if $\boxed{\quad} > 1$, and thus the stimulus of the value b even in proportion to v must grow in order to convert the start of the semi-conscious state of sensation in the fully conscious.

Insofar as the basic formulas of the psychic measure are first of all to be established for the simplest assumptions, and everything that presupposes, as a deviation of small order or complication, the establishment of the basic forms, at first ignored and taken into account only at night, is also in the formulation of the difference-measure formula and the adjoining discussion has hitherto disregarded a circumstance which is to be regarded as such a deviation or complication, and consists in the fact that the existence of a stimulus has an influence on the sensitivity with which a neighborly stimulus is perceived unequal stimuli, as they go into the difference measure formula, is unlike for both stimuli. So when white and black are next to each other, the whites appear brighter, *in continuo* without the unequal neighboring stimulus, which is called the elevation of impressions by contrast. It is undeniable that this elevation of impressions from a certain point of view is only a matter of comparative judgment, namely, that we consider black to be white, white to be black, or one to be a plus, the other a minus for the other; and, to that extent, no special consideration is necessary in the formulation of our formulas, since this judgment is based first on the relation of the absolute sensations to the magnitude and direction of the perceived difference, but this does not depend on it. Yes one might be inclined to make the whole elevation of the impressions dependent on the contrast. In the meantime, I shall later provide experiential facts which do not permit this, but rather require to assume that contemplated *in continuo* alone, so that both of them themselves have their own effect with these modified values for determining the comparative judgment. This circumstance will undoubtedly likewise have no influence on the preparation and use of the difference-measure formula, if we substitute it for the stimulus for the psychophysical movement thereby induced (according to which instead of β in the formulas to be substituted), because the altered sensitivity for a stimulus itself may be represented by another magnitude of the same triggerable psychophysical movement, and, presupposing, the basic formulas of the psychic measure a pure and strict validity with respect to those of the psychophysical movement have dependent sensations. And even without the decline in the psychophysical movement, which must first be preserved in internal psychophysics, if we knew only the laws according

to which the sensitivity to the stimuli changes as a result of its proximity, it would suffice, accordingly, to change the values of β , β' and consequently φ or, what comes to the same thing, to substitute v into the difference-measure formula to then use it as before; There is also an important need to study these laws. I will go into this study later. But as long as they are not known, we must be content to use the difference-measure formula as an approximately valid one in cases where there is no reason to ascribe a considerable influence to the circumstance given, such as: For example, when estimating the perceived differences between stellar luminosities and, incidentally, the direction of the influence can only be taken into account in general, for there are undoubtedly many cases where the influence in question is greater than could easily be neglected.

XXV. Apply the difference measure formula to the estimate of the star sizes.¹⁾

The subsequent application of the difference measure formula may serve as an example of the more general applicability of this formula in the simplest cases at all.

¹⁾ Revision p. 160 ff.

For the sake of brevity we call lightness the measure of sensation of light, intensity the measure of the physical stimulus of light which causes the brightness, and always take the brightness differences as specially conceived, the measure of which is determined by the measure of difference.

Let p be the intensity of the part of the celestial ground on which a star appears, without a star, i the intensity of the star passing through it, so that $\beta = p + i$ is the intensity of the star plus the ground, v the ratio constant, ω the difference constant

(compare Th. IS 244). We call i the own, $\beta = p + i$ the whole, \square the relative intensity of the star.

Hereinafter the difference *brightness D* of the star against the ground, whereby it rises above the ground, is determined by

$$\begin{array}{c} \boxed{\text{ }} \\ \downarrow \\ \boxed{\text{ }} \end{array}$$

The last form is due to the fact that v deviates little from 1, so that for $\log v$ we can set $M\omega$, where M is the modulus of the logarithmic system.

The intensity of the ground p is composed of two parts, a part a , which is to be regarded as constantly constant, which is represented by the intensity of the eye-black, and a variable part z , which depends on the external light, in particular the scattered light of the stars.

By substituting $a + z$ for p , the formula then goes into



This formula, with the formulas derived from it, is of particular interest insofar as it can be obtained under the following consideration of the size of the stars.

According to the usual order of the star-sizes, the numbers of the stars are allowed to rise while the intensities descend, which, however, complicates the conception of the relation between magnitude and intensity. Accordingly, let the quantities with the intensities rise below, and assume the zero value of the size, where a star basically loses its indistinguishable value, then the size of the star falls with its difference *brightness D* from the ground up, and we can immediately see the above formula as the general expression for the functional relationship between star magnitudes and intensities, and we still have the freedom to choose the units of star magnitudes and intensities so that the formula simplifies as much as possible below. So the previous formula leads to the following conclusions.

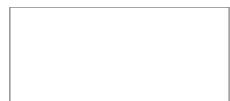
1) The size of the star depends not only on the star's own intensity, but is essentially dependent on the intensity of the ground $p = a + z$, and decreases more with given own intensity, the more the intensity of the reason grows, as the most intense stars disappear in the daytime sky, that is, show no noticeable brightness difference from the bottom. In this respect, it is useful to distinguish true and apparent size; In true size we mean the difference in brightness of any reason ordinarily fixed, and of apparent magnitude that of some other reason, which for general comparability must first be reduced to the difference in brightness from the true ground.

The normal intensity of the reason should be considered here as the possibly attainable minimum, ie the intensity a of the black of the eye. A completely night dark sky will approach the, and especially seen through telescopes where the zutretende to Black intensity for the scattered light sky weakens in accordance with the magnification, appreciably coincide therewith.

2) If the intensity of the star itself is so small as that of the reason that the higher



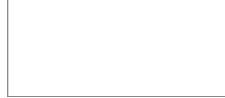
powers $\frac{1}{\text{intensity}}$ can be neglected from the first, that is, $\frac{1}{\text{intensity}} \approx \text{constant}$ to cap.15 = M



ie proportional to the excess of the relative intensity of the star \square over the difference $\chi_{\text{ov}\sigma\tau\alpha\tau\omega}$.

If i has become large enough to neglect p , then $D = k \log \square$, and finally i is large enough to neglect $\log vp$ against $\log i$, then $D = k \log i$.

The two formulas



and

$$D = k \log i$$

determine the limit cases of the dependence of the size of the star of p and v . On the upper limit, size becomes independent both of the intensity of the ground and of the relative sensitivity of difference, so that stars of equal, only sufficiently strong, intrinsic intensity appear to be of equal magnitude on different intensities, and of different degrees of relative sensitivity.

3) For telescopic viewing, the following is considered. The own intensity i of a fixed star is increased with sufficient opening of the ocular and, apart from the light absorption by the glasses, in the ratio of the area size of the lens to the area size of the pupil. In general, F is the ratio in which it is amplified by the telescope. From the intensity of the celestial ground $p = a + z$, the part a remains unchanged by the telescope, the part z increases in accordance with the area enlargement G which gives the telescope intensity, in that, as a spot of the sky gives a larger picture in the eye, the light of this spot is more thinned. Hereinafter is using the

telescope i in Fi and p in $a + \square$, over, and if we obtain D_f is viewed through the telescope size

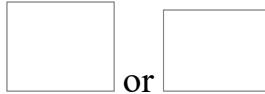


for which we can set at not too insignificant magnification and dark sky



if then z is negligible against aG .

If now a star of its own intensity i' with the telescope and another with its own intensity i without a telescope are considered, they appear the same size when



When the sky is very dark, p will not deviate significantly from a where it can be set, whereas if the sky is so dusky without a telescope that it is z . For example, if

the intensity of the eye-black is twofold, one would find that the ratio according to this equation would be only half as large as it really is.

If the brightness enhancement through the telescope is so great that a can be neglected against F_i , we obtain the formula

$$\boxed{\text{Equation 1}}$$

after which the gain by a given telescope all stars, weak and strong, an equal increase in size $k \log F$ inflicts. Conversely, if the gain so weak and i so small that F_i against a disappears, so the telescope would not act for reinforcement, and would at last such that a and F_i have a coming into consideration relative to each other, the increase in size would be variable by the same telescope.

4) If we take the simple difference of two quantities D, D' , which stand on the same ground p , then v vanishes, with which, however, one returns only to the difference in brightness of the same arising in the sensation. In order to gain the particular or perceived difference of the same, one has, after direct application of the difference measure formula

$$\boxed{\text{Equation 2}}$$

where, however, v may not have the same value as if we consider the difference of a star from the surrounding ground.

This formula shows that the size difference of two stars depends not only on the ratio of their own intensities, but on their total intensities, and hence on the intensity of the ground p ; according to which, when the sky is completely dark, two stars must differ less in their own intensity than in the dimness, in order to offer the same difference in size. The difference in this respect, according to the nature of the ground, will be strongest in the weakest, imperceptible in the case of very intense stars, so that not only the absolute size of the intervals between the apparent magnitudes, but also the ratios of these intervals will vary with the intensity of the Change reason.

The expression for the perceived difference in size of two stars when using the telescope is

$$\boxed{\text{Equation 3}}$$

From this it can be seen that the difference in size with a telescope depends on the amplification factor F as long as a can not be neglected against F_i and F_i' . However,

if the amplification factor F is large enough, the difference in size merely depends on
 the conditions just as it does on strong intensities without a telescope.

5) The arithmetic series of the star magnitudes is given a geometric of the total intensities of the stars, provided that the same difference $D - D'$ between the

successive members of the series corresponds to an equal ratio , the corresponding series of intensities. Let the exponent of the intensity series belonging to the arithmetic star series $0, 1, 2, 3, \dots, E$, change from the quantity $D = 0$ to the quantity 1, the intensity vp at which the zero size is assumed will have to multiply by E to find the corresponding total intensity β . Substitute now in the general expression

1 for D and Evp for β , we get

$$1 = k \log E$$



from which it follows that one can substitute k and thus write

6) The series of its own intensities i , which belongs to an arithmetic series D , is not strictly geometrical but corresponds to:

$$\begin{aligned} D &= 0, 1, 2, 3, 4, \dots, n \\ \beta = i + p &= vp \cdot Ev^2 \cdot p \cdot Ev^3 \cdot p \cdot Ev^4 \cdot p \dots \cdot Ev^n \cdot p \\ i &= (v 1) p \quad (Ev 1) p \quad (Ev^2 - 1) p \quad (Ev^3 - \\ &\quad 1) p \quad (Ev^4 - 1) p \dots (Ev^n - 1) p \end{aligned}$$

However, from such great intensities that 1 can be neglected against Ev^n , the series of own and total intensities noticeably coincide, and the exponent E of the last can at the same time hold for the first.

7) The unit of magnitude can either be determined as a fundamental unit such that $k = 1$; or in such a way that the size intervals assumed since then are met, and therefore the exponent of the associated series of total intensities is reproduced thereby, ie only the output and the direction of the previous magnitude sequence, but not the distances of the magnitudes of each other and ratios of the associated intensities change.

It is extremely strange that by using natural logarithms both conditions are sufficiently close in combination that one can not be sure of the deviation from real accuracy.

In fact, after the first condition must be in the printout for the size



the value $\boxed{}$ of the unit of magnitude of the basic number of applied logarithms should be the same (see Chapter 16), and this basic number should at the same time be the general exponent of the series of total intensities belonging to the order of magnitude with the difference 1, since it is the exponent of the first ratio of these Intensity series at $D = 0$ and $D = 1$. Now the basic number of natural logarithms = 2,71828 ..., and according to the compilation given in Th. IS 161, the exponent of the intensity series, which belongs to the quantities assumed today, has almost this value. The deviations of the previous provisions of this can depend on points, which I in a treatise in the reports of the sächs. Soc. (1859, p. 58 ff.).

To hereafter also to simplify the formula by appropriate choice of unit intensity as possible, you have as a unit intensity vp to take that as v differs little from the unit, with the intensity of the heavens reason p and when this on perfect night darkness or normal eyes Black Reduced thinks with a near-by agreement. The simplest possible formula is thus

$$D = \log \beta = \log (p + i)$$

according to which the number, which measures the size of a star, is equal to the logarithm of the total intensity of the star.

This formula corresponds to the natural size phenomenon, but appears to be uncomfortable insofar as we do not measure the total intensity $p + i$, but know its own intensity i and therefore know. But if one takes into account that in the bright star classes, say the 3 highest, p is against i can be neglected, and not only the invisible, but also weaker visible magnitudes of the telescope to be considered, whereby by sufficient strengthening of the star intensity, the intensity of the ground can also be brought to disappear visibly against the own intensity of the star, so you will, If, in principle, the sizing is carried out everywhere with sufficient natural or telescopically intensified intensity, that the intensity of the ground is no longer noticeable, the formula $D = \log i$ with $D = \log (p + i)$ can hold) noticeably equivalent and generally used for linking the sizes and intensities after having previously only reduces the telescopically certain intensities and sizes to the non-specific



telescopically, to which the above expression $D_f = k \log \boxed{}$ granted indication. For let us set the intensity enhancement through the telescope strong enough that a is negligible against Fi and $\log va$ against $\log Fi$, and $k = 1$, so

$$D_f = \log Fi = \log i + \log F$$

that is, to reduce the telescopic intensity F_i in the ratio of F , in order to bring it down to the true i , but to deduct $\log F$ from the telescopically estimated quantity D_f , in order to bring it to that belonging to the true i .

Nor does it then prevent anything from assuming, as a unity, the pure intensity of the black celestial ground or normal eye-black a , in which the zero size takes place, instead of the intensity of the ground vp increased in proportion to the ratio threshold. Since, according to the discussions (chapter 21), the intensity of the eye-black is not unlikely to be e - times the threshold, and e is the exponent of the intensity series, the zero point of the star size would be just one size higher than the absolute zero of the light sensation and, if you wish, could be brought into coincidence with it.

However, in the systems proposed here, the lower classes of the still visible stars will no longer differ by the same distance for the free eye, but with a telescope, which in itself seems more practical, since they are usually observed with telescopes for astronomical purposes.

It is indisputable that one should estimate the size distances in such a way that only the own intensities of the stars become decisive, which everywhere demands that the intensity of the ground become infinitesimal against the natural or artificially intensified star's own intensity. and, especially in the case of the smallest telescopic stars, so far only incompletely fulfilled, and without clearly having in mind the principle of fulfillment; Also, astronomers may not be sufficiently interested in elaborate determinations of this relationship. However, apart from the difficulties of a comparable estimate by the eye, this explains the variations in the size of the small stars found in astronomers; and the exponents of the series of intensities flowing from the various examinations will in some way be influenced by them and be less favored in accuracy. Without new investigations in the light of the above principles, it seems to me that this matter is not clear and clear, but to leave such an investigation to the astronomers, if they should have interest enough for them.

XXVI. The higher difference measure formulas. ¹⁾

Secondly, if we accept as equal the thresholds for the differently applied stimuli, a possible difference of the same, we have allowed a generalization in a double sense, once we have considered differences between differences rather than simple differences which considers a change in the size of the stimuli to have an influence on the result. The difference-measure formula permits a corresponding generalization in a double sense, extending once again from simple differences to differences between differences, secondly from the case where the change in size of the stimuli does not change the result to the case where it changes the same, The generalization in the first sense is described in this chapter,

¹⁾ Revision p. 186.

If a conscious sensation γ can take place only to the proviso that the corresponding stimulus β (or the internal psychophysical activity it represents) exceeds a certain finite size b , and a perceived difference $\gamma - \gamma' = u_1$ only in accordance with the



corresponding one If the stimulus ratio exceeds \square a certain finite quantity v_1 , where we denote the letters u , φ , v with an index because of the relation to the following, then it must be presupposed and confirmed by experience that there is also a difference between two sensory differences $u - u' = u_2$ can only be perceived in accordance with the proviso that it is possible to come into consciousness more



consciously than the corresponding higher stimulus \square ratio \square, \square ie the ratio between two relations, exceeds a certain finite size v_2 , etc., so that we, under any arbitrary conditions Continuing to have this increase



etc

Of these, the formula for u_1 corresponds to the simple difference measure formula ; the others, which we may call higher difference-measure formulas, can be derived in an analogous way as these. Let us confine ourselves here to consider only the perceived differences of the second order u_2 of the closer.

Their consideration is not idle because they are really eligible. The recognition of the impurity of a sound interval is perhaps the simplest and most simple explanation of a perceived difference u_2 , In fact, the perceived impurity of a sound interval is nothing other than the perceived difference between two intervals, the pure and the impure; however, each of these intervals felt as the perceived difference between two absolute pitches. If the impurity is really to be felt, then the difference between the pure and the impure interval must exceed a certain magnitude. In addition, it goes without saying that, in order to perceive a difference between differences, we ourselves must feel these differences; but, in addition, they must in turn exceed a certain size; But at last the height of each sound must exceed a certain magnitude for itself, if it is to be perceived as sound, and thus the sensation of a difference be possible.

Not only the sensation of the impurity of a tonal interval, but also the musical impression made by the sequence of pure intervals in the melody and more of its

complexes in harmony, is a matter of perceived differences of a higher order, and indeed differences are much higher than the second Order a role with.

It is no less important to add meaning to differences of higher order perceived in the strength of sensation. The impression of *crescendo* and *decrescendo*, of the multiplied change between the *piano* and the *forte* of the music, is based on this and supports the impression of melody and harmony, even if, for some unknown reason, it is not capable of producing a corresponding aesthetic impression, as melody and harmony for itself. The field of the sensation of light gives us other examples. If we have three stars β , β' , β'' of different brightness or so-called size, one may ask, for example, if the difference between β and β' are greater than the difference between β' and β'' , or, for 4 stars, whether the difference between β and β' is greater than between β'' and β''' . To decide, the difference between the differences one compares will again have to exceed a certain magnitude which, even at star intensities, we again do not know why, must be comparatively much greater than pitch; but the astronomical estimation of stellar differences requires such comparisons.

Now let us draw the second-order difference-measure formula valid for the perceived differences of the second order



taking into account the most general case that we have 4 stimuli, pitches, star magnitudes or whatever it is, β , β' , β'' , β''' ; that between the two differences from β to β' and from β'' to β''' the difference is to be understood, that $\beta > \beta'$ and $\beta'' > \beta'''$, we shall thus explain the formation of this formula of the more can.

The perceived difference of first order between β and β' is



The perceived difference of the same order between β'' and β''' is also designated by a dash below, considering the same order, but in consideration of the other stimuli between which it is distinguished by a dash above the former, and thus be



Thus, first and foremost, the difference between the two perceived differences, which arises in the sensation, will be the simple difference between them, ie



In fact, a difference between perceived differences may be as well felt as not felt, the latter, for. For example, if the two perceived differences are found in two different

people, or if there is too long an interval between them in the same person, or if they differ too little. Shall now the sensation difference



become the perceived differences, the value of the second-order stimulus ratio must reach a certain size, we V will call in which the zero value of the perceived difference in second order occurs, which for the expression of the perceived difference u_2 are



But by $\frac{1}{\text{[]}}$ putting φ_2 and for the single letter we get



This formula leads to a generalization of Weber's law in one of its expressions. According to Weber's law, a difference between two stimuli is felt to be equal if the ratio between the stimuli that make the difference is the same. According to the previous formula, a difference between two stimulus differences is perceived to be the same if the ratio between the associated stimulus conditions is the same. For φ_1 and φ'_1 , which form the quotient φ_2 , represent the stimulus



conditions $\frac{1}{\text{[]}}, \frac{1}{\text{[]}}$. It must not be overlooked, however, that the validity of Weber's law, like this generalization, is bound by a condition. Weber's law presupposes a constancy of the threshold v_1 , as the present generalization of it presupposes a constancy of the threshold v_2 .

The field of music, on the other hand, presents to us a remarkable example of the validity of this generalization of Weber's law, as well as a departure from the validity based on the variation of v_2 , which find their common representation in our second-order difference-measure formula,

In fact, the impurity of a sound interval is easily recognized in different octaves; This corresponds to our generalization, insofar as it is part of the conception of impurity that the difference between two tone intervals, for which two different vibrational relations belong, is recognized. If the pure vibrational ratio n , the



impure v , be the impurity will be recognized, if $\frac{1}{\text{[]}}$ the value v_2 attained; but just as



well, if $\frac{1}{\text{[]}}$ the value v_2 is attained; therefore, the absolute size of $2v$ and $2n$ does not matter, since v_2 does not depend on it.

On the other hand, the deviation of one fifth from the purity is recognized relatively more easily than that of any other interval of the same octave, and in general there are differences between the various intervals (compare Th. IS 261). This corresponds to a deviation from the generalization of Weber's law, and proves that, while the constancy of v_2 is for the same intervals of different octaves, this constancy does not exist for the different intervals of the same octave, as there is no aprioristic necessity for this.

If we substitute our values of second order for φ_1 and φ'_1 , then we have

$$\boxed{\text{Equation for } \beta' = \beta''}$$

and here we set $\beta' = \beta''$, which corresponds to the case that we reduce the 4 stimuli to three in order $\beta, \beta' \beta''$, and the difference from β to β' with that from β' to β'' compare, so we have, by introducing instead of β''' now β'' :

$$\boxed{\text{Equation for threshold comparison}}$$

which shows that the perceived difference between two such differences comes to the threshold when the quotient from the square of the mean stimulus to the product of the external stimuli acquires a certain value v_2 .

It can be inferred from our higher formulas, which confirms experience, that the higher the order, the higher the order the differences which are to be grasped by it, so that, for example, a difference of the second order can enter consciousness only with an intensity which reaches or exceeds that which belongs to a simple sensation at the value $\beta = bv_1 v_2$. Because one must not think that the perceived difference u_2 , by taking the value $\varphi_2 = v_2$ occurs the threshold, always at all occurs on the threshold with a zero value of consciousness, but only with a zero value of the second order on the threshold of the second order consciousness, whereas the awareness of differences u_1, u_1' where there is between it, whether the higher difference between them is felt or not, the threshold at v_1 may already have exceeded. This exceeding or at least reaching, as that of the stimulus threshold b is, as already discussed above, in any case the presupposition of the consciousness of the higher order u_2 . It can, however, be shown as follows that indeed a corresponding degree of consciousness belongs to it, as if a simple stimulus or the corresponding psychophysical activity reaches the value $bv_1 v_2$.

Express the formula for u_2 as follows



In order for u_2 to be consciously perceived, and therefore to exceed the threshold of the second degree, the size below the logarithm must be greater than 1, and consequently



But it is also necessary that the differences of the first degree are both consciously

felt, and therefore not only $\boxed{}$, but also $\boxed{}$ if v_1 is the common denominator of the corresponding threshold, which gives for the preceding inequality



and therefore

$$\beta > v_1 v_2 \beta'$$

Finally, each of the stimuli β , β' must have exceeded the threshold b , which gives for the previous inequality

$$\beta > b v_1 v_2$$

Just as the difference-measure formula of the first degree implies a measure-formula for the full consciousness of a simple first-order sensation as a special case, we can also derive from the second-order difference-measure formula a measure-formula for a simple second-degree consciousness; and as the first is characterized by the fact that we not only have the sensation, but can also become aware that we have had it, the second will be characterized by the fact that we can become aware that we have had this consciousness. We obtain this formula by first considering the perceived difference u_2 as the difference between a conscious difference u_1 and



consider a zero difference that $\boxed{}$ occurs in the value of the stimulus ratio ; what gives



Secondly, let us consider the difference u_1 as the difference between a conscious sensation and a null sensation, which belongs to the stimulus $\beta' = b'$, whereby we obtain



then, in accordance with what we found earlier, we see that a simple sensation, to rise to the same level as a perceived difference, inclines the product of all thresholds up to this stage. must exceed.

XXVII. The ply formulas. Application of the same to the assessment of the ratios of constant errors. ¹⁾

In the following, if two stimuli in different temporal or spatial positions are to be referred to each other, then the stimulus applied in a manner with β , which is otherwise indicated with β' , their size relation with φ or φ' , will be designated in such a way, that the larger stimulus is always used in the counter, after which the letters β , β' to exchange their position in the numerator and denominator, if the two stimuli given change their position at the same magnitude, but if they change their size while the position remains the same, which comes to the same thing, if both stimuli differ in nothing but size, as is assumed here.

¹⁾ Revision p. 130 ff. On the Measures of Spatial Intellect, Abh. Of the Royal Saxon Ges. D. W. Math. Phys. Cl. XIII, p. 273 ff.

The ratio $\frac{\square}{\square}$, which thus on the previous $\beta > \beta'$ is intended in particular

with φ , the ratio $\frac{\square}{\square}$ where $\beta' > \beta$ is, with φ' called and the symbol for both common Φ are needed.

In what follows, I will refer to my previously discussed weight tests several times, the smaller stimulus is represented by the simple emphasis P , the larger one by the main weight plus the additional weight, ie by $P + D$, according to which the stimulus

ratio $\varphi = \frac{\square}{\square}$, or $\varphi' = \frac{\square}{\square}$ is $\frac{\square}{\square}$ given by the way that D has the opposite position than otherwise. However, if the weight tests below merely serve as examples for explaining general conditions, under P and $P + D$ stimuli of any other kind can also be understood as weights.

Insofar as the two stimuli, the difference is considered to be construed there are different according to their temporal or spatial mounting manner is also found in

general that the difference between them at constant ratios Φ is still perceived as different sizes according to whether it at a constant position, the size or, if the size remains the same, the position changes or the excess of one falls over the other stimulus to one side or the other, which according to the above are only expressions for the same thing.

Thus, in the weight tests which have been mentioned in the first part, there is a difference in the size of the perceived difference as to whether the weight supplement with the same main weights P is in the first or second-lifted vessels, in the left or right vessels. In spite of the fact that the stimulus ratio Φ does not change in this case, the perceived difference precipitates from other values than otherwise, or, what it says, one weight seems to us to outweigh the other one more or less than otherwise.

Even without the existence of an additional weight D , this influence asserts itself; for if I compare two equal weights without D , I find on average so many attempts that the irregular coincidences balance each other, one weight constantly heavier or lighter than the other; depending on the room or time situation of the cancellation. But I am able to compensate for this influence by giving the weight, which seems lighter, with a sufficient added weight, and thereby at the same time being able to determine the influence of the position of its magnitude and direction, by giving it to the necessary for compensation D equivalent in size, position opposite. But if another D is placed in a different position, it will always be seen as if the influence of the temporal and spatial situation in its turn were represented by that ideal, but a real, equal and equal weight, by which it was measured which, however, adds as additive or subtractive to the effect of the real extra weight D , according as it has the same or opposite position as D , and justifies the different value of the perceived difference according to the position of D .

The size, by which, by the influence of the temporal or spatial position or the combined influence of the same, apart from D , the weight P or any stimulus seems to be exaggerated or diminished, this ideal, but a real, equal, positive or negative addition to it, forms that which is called the constant error, insofar as it really asserts itself as an error in the comparative estimation of the stimuli and, if the influence of the temporal and spatial position of the stimuli is constant, it is made constant, or, if this influence is altered by irregular coincidences, averaged out by a multiplicity of experiments. How the constant errors and thus the extent of the influence of the time and space position are to be determined exactly, has been stated in the presentation of the measurement methods of the difference sensitivity.

It is easy to see from the above that the constant error does not depend neither on its existence nor on its size and direction on the size and position of D , but rather on its independence, and only in so far as there is a difference in the perceived difference according to the situation of D ; when, in one position, it works with it in the same way, in the opposite, in the opposite sense, that is, at first increases, and at other events reduces, the difference dependent on D , which falls into the sensation.

The case itself may occur, and occurs often enough in experiments on the sensitivity of difference, that by virtue of the influence of time and space the smaller

stimulus appears greater than the larger, and the perceived difference increases rather than diminishes when D is reduced, and herewith both stimuli are approaching equality, which I shall call a perceived difference in the wrong sense. As is easily understandable, such a case necessarily occurs when the constant error, as a positive increase, is added to the smaller stimulus, and the D of the greater stimulus predominates so much that the difference just noticeable is exceeded.

Thus, in my weight experiments with sufficiently heavy weights, the weight that was first lifted, that is, with respect to the time, apart from accidents, always appeared to be the easier, even if the extra weight D was there, as long as this additional weight did not rise above a certain limit. If, of course, one increases the excess weight sufficiently, the constant error dependent on the situation is thereby outweighed, and instead of the wrong sense, the right sense of perceived difference occurs. But as long as the wrong sense exists, there is also the circumstance that the perceived difference grows rather than diminishes when the stimuli of equality are more near.

It follows from the condition that the constant error as a positive increase of the smaller stimulus must exceed the D of the greater stimulus by more than the just noticeable difference, so that the difference is perceived in the wrong sense, that it does not necessarily result in a wrongly perceived difference. When a positive constant error in the smaller stimulus exceeds the D of the greater stimulus, because not only D but also the difference must be exceeded, otherwise the sensation of the difference, instead of acting for the consciousness, remains unconscious.

The reason that the perceived difference may appear larger or smaller, or even in the wrong sense, depending on the different position of the stimulus excess, can be twofold. By grasping the two stimuli β , β' from different parts of a sensory organ, or by dropping them successively into different times, they can be conceived of as having different absolute sensitivities, and thus given different thresholds b , b' . Now, however, we have seen earlier (chapter 23) that the true difference of sensations in the case of difference of b , b' , $\alpha\sigma$ determined by the difference- $\tau\eta\rho\epsilon\sigma\eta\lambda\delta\phi\rho\mu\lambda\alpha$, is the same for Φ is larger or smaller as the greater or lesser stimulus is perceived with greater sensitivity (corresponding to a smaller threshold), after which, under the same circumstances, it will fall more or less into the sensation afterwards. Apart from that but could also z. For example, an earlier stimulus, although regarded with the same sensitivity in the present, as the present, but in comparison with the present increased or diminished by memory, enter into the perceived difference, where at first the perceived difference would be smaller or larger, ever after the former stimulus was smaller or larger, the latter vice versa. No less could the relation in the spatial position of the greater and lesser stimulus,

For the sake of brevity and in the absence of more fitting terms, the reason that φ is perceived to be different from φ' , if it is based in the first sense on a difference of absolute sensitivities for β , β' , is to be called absolute, provided it is in the second sense on the temporal or spatial relation of β , β' , apart from the relations of b , b' based, the relative. The existence and the efficacy of the absolute reason is fact, as far as the relative is concerned, it is now still in the hypothesis, and it still requires

experimental investigations, which are not yet available to decide whether it exists at all.

In fact, it may still be very questionable whether there really is, according to a law for the memory, a constant tendency to compare the earlier or later stimulus as the larger one, if not the difference, whether the preceding or the following Irritation is the larger, if at all only indistinct, so that it may appear to be magnified by remembrance rather than diminished, which does not establish a constant error, but only an influence on the magnitude of the relative susceptibility, which is indisputably dependent on the time-distance would mean. Still less can one overlook the extent to which the relative reason for a change in the spatial position of the larger and smaller stimulus could be considered, if complete security were therefore necessary, β , β' fall to the conviction that the constant errors can be covered by ratios of these sensitivities.

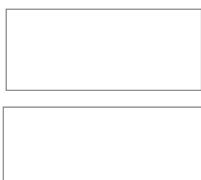
For the following, the question as to whether the first or second reason is preferable or at play, is not at all material in so far as the following considerations and formulas remain equally valid for one cause and another, without making a distinction but also allow for the introduction of the distinction, if such should be based on experience.

If the difference between two stimuli appears to be of different magnitude, depending on the two different stimuli applied, one or the other forms the numerator in the ratio Φ , then, which is also the measure of this sensation, there will be a sensation of medium magnitude between the two sensations, which U is. The positive and negative growth $+a$ and $-a$, To what this mean sensation depends on the change in the position of the greater and lesser stimulus, will be what depends in sensation upon this change, and on the middle sensation itself, which we shall call the normal sensation, as a change of position the stimuli independent, the difference measure formula can be referred to in the earlier lineup. Your measure according to this formula is



as we here formerly used in the measurement formula φ and v by Φ and A replaced. Inasmuch as A is the value of the ratio Φ at which the normal sensation disappears, we may need the term normal threshold for it. Below will be shown how it is to be determined by experience.

Now let u and u' be the changes in dependent sensations, u or u' , depending on whether it is the stimulus β or β' , which enters the numerator as the larger one, so u and u' grow with growth of Φ , ie the perceived difference in the right sense takes place²⁾, which is always the case with sufficiently large Φ ,



2) The establishment of the difference-measure formula itself presupposed this meaning.

Now nothing prevents the size of a to give any other desired shape. If we then put $a = k \log B$, giving B the appropriate size, we obtain the following formulas, which we briefly call the layer formulas:

$$\boxed{\quad} \quad (1)$$

$$\boxed{\quad} \quad (2)$$



Or, by putting $\boxed{\quad}$ and $BA = v'$:

$$\boxed{\quad} ; \boxed{\quad}$$

As we can see, we have hereby come back to the form of the difference-measure formula, except that, depending on the opposite position of the great and the small stimulus, the ratio threshold has assumed a different value v and v' , of which the former is to be applied, as long as $\beta > \beta'$ the latter, when $\beta' > \beta$. We call them the sleepers.

The ply formulas are more general of the difference measure formula, in that they represent the particular case where $B = 1$, which corresponds to the trap where the effect of ply change disappears. Also, the layer formulas with their special sleepers, as in Ch. 24, can be deduced immediately from general basic equations, without first having shown the special case of the difference measure formula.

The normal threshold A is found as a geometric mean of the two position

thresholds v, v' , provided that $v = \boxed{\quad}, v' = BA$, hence $v v' = A^2$ and $\boxed{\quad} = A$. This gives the experiential means to the hand, A by experiments on difference sensitivity to determine constant errors. One can see at which values φ, φ' the perceived difference disappears as the one or opposite position of the larger stimulus takes place, and takes the geometric mean of these two values.

In more detail, it can be seen that each of the positional thresholds v, v' consists of two factors, the factor A or the normal threshold, which remains constant when the

time and space position of the stimulus excess is confused, and another $\boxed{\quad}$ or B which may be called the error threshold, and which assumes the reciprocal value when changing the position. If $A = 1$, which corresponded to the maximum of the normal sensitivity, then the latter alone would form the value v and v' .

The in such a direction correctly perceived difference that β is greater than β' is displayed, according to formula (1) will begin to be noticeable when $\boxed{\quad} > v$ to be starts the correct felt in the opposite direction according to formula (2) when $\boxed{\quad} > v$ ' to be begins; hence the first if $\beta > v \beta'$, the second if $\beta < \boxed{\quad}$. In the interval from $\beta = v \beta'$ to $\beta = \boxed{\quad}$ or, which comes to the same thing, in the interval of $\beta' + \boxed{\quad}$ until $\beta' = v' \beta$ or finally, which is again the same thing, in the interval from $\beta = \boxed{\quad}$ to $\beta = \boxed{\quad}$ the perceived difference remains in the unconscious.

If a difference is perceived in the wrong sense so that the greater stimulus appears as the smaller, and with the growth of Φ the value u decreases, with decreasing Φ , then the above positional formulas are just as useful, except that then the sign What they interpret as the perceived difference is to be interpreted in the opposite sense. This follows partly from a closer examination of the way in which the wrongly perceived difference is connected with the right feeling, partly, and with rigor, in deriving the positional formulas from the basic equations (see Chapter 24).

The closer it is with it.

All cases in which only properly perceived differences are possible are, according to our formulas, covered by the fact that both v and v' are greater than 1, in that the correctly perceived difference presupposes that β αππεαρσ greater than β' , as long as β is greater than β' , hence $\varphi > 1$, and that β' appears larger than β , as long as β' is greater than β , hence $\varphi' > 1$, until the threshold value of Φ is ρεαχηδ; from where the perceived difference becomes unconscious; therefore, all values of φ , both as φ' and attaining v and v' , and v and v' itself as a limit, must be greater than 1. On the other hand, the cases in which a difference can be felt in the wrong sense are covered by the fact that only one of the two thresholds v , v' has a value greater than 1, while the other at the same time has a value less than one.

In fact, let β be the stimulus which may appear greater than the other, in spite of the fact that it is smaller, it will, of course, appear all the greater if it is equal to it, or if it is somehow larger, according to which a threshold of $\boxed{\quad}$ at all can not be reached at any values above 1 and not even at 1 itself, which equals the equality of β with β' ; the stimulus β' must first become greater than β , so that seeming equality occurs. Thus, the threshold v , which is valid as long as $\beta > \beta'$, must be less than 1, the value v' , which corresponds to the value $\beta > \beta'$, be greater than 1, which satisfies the condition that that value can not be achieved, which can be achieved.

Even in the present case, however, the limits of the interval in which the sensation of difference becomes unconscious are determined by the values $\beta = v \beta'$ and $\beta =$

. Since $v < 1$ and β also < 1 (because $v' > 1$), β is at both bounds $< \beta'$, and the interval of the unconscious values of the perceived difference falls entirely on the side where $\beta' > \beta$. As long as $\beta > v \beta'$, if the perceived difference has a conscious

value in one direction, β drops below β' , then it assumes the opposite direction with conscious value; the interval in which the perceived difference takes wrong values is that of $\beta = \beta'$ to $\beta = v \beta'$. For in this interval, $\beta < \beta'$, because $v < 1$; but in spite of this the difference still appears in the first direction in which it appears in case of overweight of β over β' .

In order to obtain the measure of the wrong sensation values in the interval where β seems erroneously greater than β' , we have to use the formula (2) valid for φ , because really $\beta' > \beta$, but the negative sign of u' , what we get here is to reverse in the positive, or rather to point to unconsciousness to indicate awareness of a sense of perverse sense, for although the perceived difference in this interval really in the sense of u' is unconscious as the but corresponds to the interval of conscious values of opposite meaning.

This is not an arbitrary rule, because the fundamental justification of the formulas (Chapter 24) shows that the formula (2) in the case of wrong sensation is even given by the formula

$$u' = k (\log v' - \log \varphi')$$

which directly contains the expression of our rule of sign meaning.

If, in the formulation of the formulas, we pay particular attention to the change of timing and spatial position, then, after a corresponding derivation, the error

threshold B , or β' which as a factor in the position threshold v , v' enters, for its part, into two factors, a time-dependent z , which β' assumes the reciprocal value when the time is confused, and a dependent on the spatial position r , which assumes the reciprocal value when the spatial position is confused, so that instead of just two

Error thresholds B and β' now, according to the fourfold possible confusion of the time and space position of the larger and smaller stimulus, as explained by the four main cases of our weight tests (Th. IS 113), four error thresholds are obtained, with which the normal threshold A is to be multiplied to give to each position of extra weight or underweight (which of course are related) ply threshold. Be F_1, F_2, F_3, F_4 , these four error thresholds, and their common

name F , so we have if one of these thresholds zr is, for others β' , v' , v so that

every two of them are reciprocal. Of course, it does not matter which of these we want to designate as F_1 , F_2 , etc., just as it does not matter in which case we want to use one or the other of these general terms, except that we use the others consistently in that, whatever the mode of use of the values z , r ; we may always let them be determined so as to satisfy the experience. Let us therefore set the following for the 4 main cases³⁾:

$$F_1 = \boxed{}; F_2 = \boxed{}; F_3 = \boxed{}; F_4 = zr$$

Thus, with these values of F_1 , F_2 , etc., we have to multiply the normal threshold A in order to obtain the 4-layers of the larger and smaller weights, relative to each other, of ply formulas; after which the sensation *and* relative to the four major events takes the following values:

$$\boxed{}; \boxed{}; \boxed{}; \boxed{} \quad (3)$$

³⁾ It would undoubtedly be formally more appropriate (if indifferent in substance) to arrange the values F_1 , F_2 , etc., according to their indices, so that two reciprocal values stand behind each other. However, I have adopted the above order in order to relate them to the one observed in the weight tests of the first part, p. 113, which was chosen by me before I clearly had the views of an election to be made, and later, after all many series of experiments were treated according to this order, could not be abandoned without evil, and without too much danger could be translated by mistake into another.

By adding these four sensations, and dividing them by 4, after transforming the sum of the logarithms into the logarithm of the product, we again obtain the sensation independent of time and space

$$\boxed{}$$

Among the previous position formulas, those which correspond in time and space to opposite positions of the additional weight are characterized by the fact that they contain reciprocal values of the error thresholds, that is, those for u_1 and u_4 , as well as for u_2 and u_3 . They may be called conjugate to each other.

Instead of thinking, as before, of the stimulus ratio Φ unchanged in all positional changes and of relating the influence of the position to a change of the normal threshold value A by multiplying it by the error threshold, one can say after the remark (chapter 32) and the form of the formulas (1), (2), (3) think the influence of the situation just as well on changing the stimulus ratio Φ by multiplication with the reciprocal values of the error threshold, while the normal threshold A retains as unchanged threshold. In the first place, we think of a stimulus-ratio unchanged by the

position of the stimuli, with different sensitivities, depending on the position of the stimuli, and, lastly, a relation of stimuli which, depending on their position, have a modified effect, with a sensitivity independent of the situation. Both modes of presentation are connected by the viewpoint that a sensitivity to a stimulus ratio, which is altered to the normal case, is always represented by a modified ratio of the stimuli in the normal case, and even by a changed ratio of psychophysical movements caused by the same stimuli can be made.

Instead of multiplying the normal threshold A by the 4 error thresholds F_1, F_2, F_3, F_4 as before, we multiply the stimulus ratio Φ by the reciprocal values of these error thresholds , which we refer to as F_1, F_2, F_3, F_4 generally denote by F , so that

$$\mathbf{F}_1 = zr; \mathbf{F}_2 = \boxed{}; \mathbf{F}_3 = \boxed{}; \mathbf{F}_4 = \boxed{}$$

which of course leads us back to formulas (3) only in a different form, the further explanation of which may be based on our weight tests.

In these experiments, where the stimulus ratio Φ is generally given, D

has only a small value against P , and z and r , as well as \square and \square deviate little from unity, the former in one, the latter in the opposite sense, because of the constant Error the true weight ratio but changed only in small proportions appears. So if we set $z = 1 + \zeta$, and $r = 1 + Q$, then ζ and Q only small positive or negative Zuwächse to 1, the

higher powers and products are negligible, and $\underline{\underline{L}}$, $\underline{\underline{R}}$ by $1 - \zeta$, $1 - Q$ can be

represented, in that, when executed by \square , and \square displayed Division and neglect of the powers of ζ and q , which exceed the first, the value $1 - \zeta$ and $1 - Q$ as the quotient remains⁴⁾. Let us now substitute in the expressions for u_1 , u_2 , etc. the

value $\boxed{\quad}$ for Φ and the values $1 + \zeta$ and $1 + Q$ for z and r , the values $1 - \zeta$, $1 - Q$ for $\boxed{\quad}$, $\boxed{\quad}$ so we get:

Etc.

4) For the same reason, it is possible \square to substitute through \square
 and \square through \square , if c is small to P , of which there are many opportunities to make use of it.

But if we can neglect the product of the quantities ζ, Q because of their smallness, this is done by executing the multiplication in

etc. of the kind that the values for u_2, u_3, u_4 differ from u_1 only by other signs before ζ, Q .

Let us now remember that if there had been no influence of the temporal and spatial situation, the sensation would have been the measure of difference

Thus, $(P + D)(\zeta + Q)$ is the quantity by which the weight $P + D$, or, what comes to the same thing, by this influence, changes the extra weight D in its effect on the sensation; whereas the weight P appears to be constant, this is nothing else than the constant error of the weight, in which D is dependent on the time and space position.

The constant error, according to its double dependence, is composed of the time-dependent parts $(P + D)\zeta$ and the space-dependent parts $(P + D)Q$, which we have designated earlier by p, q and which we also refer to want. They can be components of the constant error; but in so far as they are called constant errors themselves, the error of which they are a part is to be called a constant total error. For the sake of brevity we may distinguish it as time error and space error.

By substituting p, q for $(P + D)\zeta$ and $(P + D)Q$ we get the following equations instead of equations (3):

;

(4)

;

Since it is possible to determine p and q by experiments, since A according to Chap. 27 is determinable and P and D are given, k can finally be set arbitrarily = 1, because the unit of u is arbitrary, then everything is given here which is necessary for measuring the perceived difference in the case of constant errors.

If we call the constant total error no matter what it depends on and whether it is positive or negative, generally c , then the preceding 4-position formulas are only special cases of the general formula

(5)

where c , depending on the 4 times possible time and spatial position of the stimulus to which D enters, assumes a fourfold different value, respectively c_1, c_2, c_3, c_4 , corresponding to the 4 error thresholds and position factors. In particular, we have hereafter

$$c_1 = p + q ; c_2 = -p + q ; \\ c_3 = +p - q ; c_4 = -p - q ; \quad (6)$$

according to which c_1 and c_4 , as well as c_2 and c_3 , have an opposite sign for the same size. They can be called conjugate with respect to each other, provided that they conform to the conjugate equations in Chap. 27 belong.

It should not be forgotten, by the way, that equations (6) are valid only in so far as z and r deviate little from the unit, hence ζ and Q are small fractions, ie if the time and space error is only slightly in proportion to $P + D$ is; otherwise, in the expression of c_1 , c_2 , etc., we also take into account powers and products of p , q ; as one easily finds when one carries out the previous developments; without neglecting anything.

In the experiments presented for explanation, which are made and treated according to the scheme of my weight tests, the extra weight D is brought successively into the 4 possible positions, so that it enters in each case of positive sign to the main weights whose position is envisaged, and the constant error c is always related to the thus increased main weight. In itself, not only does nothing prevent, but it may also perform formal services under certain circumstances, as will soon be shown to refer the constant error to the smaller weight, which is in the opposite position to the large one, that is, has an opposite c , then what is only necessary, the greater weight as the main weight P to introduce into the denominator of previous formulas, and to take the D in the counter negative, since of course the smaller weight just as much underweight against the larger, than this overweight has against the smaller. In this case, in cases where the positive excess weight D maintains the same position as is the case within one and the same experiment, as in the case of the main experiment, one always has the choice of arbitrarily applying one or the other of the conjugated equations, one of them then always to the greater weight, the other to the smaller weight, where the whole value $D + c$ for the same size assumes an opposite sign for the larger and smaller weight, and the value of P between the values of smaller and larger weight changes.

If one then makes the rule of always applying to each of two conjugate equations that for the determination of the value u , in which $D + c$ is positive (which is the case with negative D , if c is at the same time positive and $> D$), this occurs $P + D + c$ everywhere to the place of the larger stimulus, P to the smaller stimulus of the difference measure formula; and you can look at it quite as if u undetermined by this formula, which makes no special rule necessary for the reversal of the sign in the case of perceived differences. On the contrary, we obtain in each case a positive sign of u for a conscious, a negative for an unconscious value. The cases perceived in the wrong way, however, then differ from the right ones, in that the wrongly felt ones correspond to the application of the negative D , the right ones to the ones of the positive D .

If both stimuli are equal, the previous formulas would still be able to determine the value of the sensation according to the time and space of the weights, setting D equal

to zero, and placing the stimulus in the counter, its constant error is positive to find positive values of u conscious values of sensation.

After what has been said, the situation formula for one and the same perceived difference can u under three different shapes up, whichever you the influence of the position by the position threshold F , or its reciprocal location factor \mathbf{F} , or

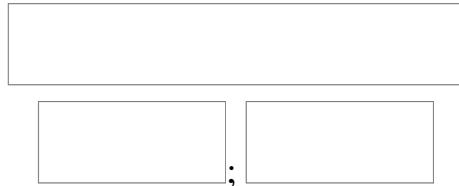
functionally related constant error c represents, namely considering that [redacted], by



From the equivalence of these equations, the functional relationship between results in c and F or \mathbf{F} . Because you have it



therefore



For the four main cases, these formulas specify that, if F , \mathbf{F} accepts the values F_1 , \mathbf{F}_1 , etc., at the same time c assumes the value c_1 , etc.; which according to Chap. 27 given by $p + q$ is usf

These functional relations remain equally valid, though the influence of the situation may be considerable or insignificant, and thus c may have a great or small relation to $P + D$; except that only with a small ratio of c to $P + D$, which corresponds to a slight deviation of the values F and \mathbf{F} of 1, the simple composition of c , given by Equations (6), takes place. In the case of a small c , one can also write for the

expression (after chapter 27, note ⁵⁾): [redacted]



⁵⁾ By considering $P + D$ as a large value instead of P .

After introducing the constant errors into our formulas instead of the position-dependent error thresholds and the positional factors, we also use the normal, just noticeable difference, ie the value of D , instead of the normal threshold A independent of the position. where the perceived difference, apart from the influence of the situation, steps on the threshold, which is called d , by setting



Taking into account that in the experiments we are considering here, D and c , as well as the sum of the two, are always small compared to P , the formula (5) can be simplified as follows.

For brevity's sake



thus E and ω are small fractions, and the formula (5) gradually passes into consideration



(A)

$$= k \log (1 - \omega) (1 + E) \quad (\text{b})$$

$$= k \log (1 + E - \omega) \quad (\text{c})$$

$$= k M (E - \omega) \quad (\text{d})$$

$$= K (E - \omega) \quad (\text{e})$$

For (b) follows from (a) when we perform the division and neglects higher powers of ω in the quotient, where



= 1 - ω

It follows (c) from (b) if we perform the multiplication $(1 - \omega)(1 + E)$, neglecting the product of the small quantities ω and E ; it follows (d) from (c), in that $E - \omega$ is small compared to 1, so that the control (Chap. 14) is applicable, if we for a set $E - \omega$; finally it follows (e) from (d) as we kM in the constant K contract.

Let's solve the so definitely found formula

$$u_1 = K (E - \omega)$$

again, by setting their values for E and ω , we find



(7)

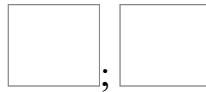
which formula is disaggregated into the position formulas corresponding to the different main cases by substituting for c the values and signs associated with the different positions.

Among these formulas we then always have to apply the one in which $D + c$ is positive in order to obtain generally positive values of u conscious, negative unconscious values of sensation; and here, too, perceived differences correspond to the case where D is negative, whereas $D + c$ is positive, ie, where the smaller stimulus, by its constant error, becomes overweight.

In Chap. 24 we had as a measure of difference-measure in the case that a perceived difference exceeds the barely noticeable little, which presupposes a small D , and that the just noticeable difference, which is itself small, is the formula

$$u = K(\vartheta - \omega)$$

found. Now consider that according to the meaning of ϑ and ω



So this formula goes over in



after which one sees how, as the particular case, it comes under the position formula, where c equals zero; and immediately overlooks how c can be understood both as a modification of D and of d .

If the error thresholds and location factors F , \mathbf{F} at different absolute size of the stimulus P remained constant, the influence of the situation would not prevent the Weber's law through experiments on differential sensitivity of different P confirmed directly from detention one and the same location. But according to my weight experiments, in general, z , r ; hereby change F , \mathbf{F} and hereby the factor which multiplies the value $P + D$ in the expression of the constant error by (s, o) with the size of P , and this requires, once, that in order to obtain a confirmation of Weber's law in such modified P experiments, one should eliminate the constant errors, and thus make the case by calculation, as if the differences perceived were merely of the difference-measure formula, not the *ply* formulas, depended; secondly, to use the position formulas to the extent of perceived differences, the values z , r , F , \mathbf{F} , as well as the values dependent thereon in the constant errors at changed values of P with changed values, generally as a function of P , in which relation it is important to introduce the dependency ratios of these values of P to examine more closely, to what I in my, in the "measure methods" of special to be communicated, attempts to supply some contributions, in the main, however, must refer to still to be arranged investigations.

The above implies that if, after (s.o), the constant error c is generally given by the factor $P + D$, then c is generally not found to be proportional to $P + D$ by the other

factor $\mathbf{F} - 1$ or also depends on it.

Since then, I have always taken into account only a dependence of error thresholds, positional factors, and hence also constant errors on the temporal and spatial position

of the compared quantities; but also the manner in which the quantities are made for comparison, that is, the manner of manipulation in the experiments, may unequally meet the quantities compared, and from this an influence may arise which comes under quite the same points of view as that dependent on the situation that the reason here can be sought less easily, and in part certainly not in variations of the absolute sensitivity to the stimuli.

In fact, under certain circumstances, a dependence of the constant error c on the position of the sizes and also on the method of production of the sizes may occur. Thus, in the method of just noticeable differences, a constant error of opposite sign may arise, as we bring the greater stimulus by diminution, or the smaller stimulus by magnification, to the apparent equality with the other; and in the method of mean errors, a constant error is that we always subject the defect, but not the normal size of the alteration, to apparent equality with the other.

Several of my series of experiments with the method of mean errors with self-application of the circles show a very considerable constant error, which remains after elimination of the time and space error, and for this reason alone seems to be attributable; when the compass was applied by an assistant but was missing or ambiguous.

Wherever other dependencies of constant errors occur than of temporal and spatial conditions, this does not change anything in the principles from which the previous formulas are developed; and thereafter nothing in the formulas which c included, it explicates itself merely c different from what can be easily overlooked by mere analogy, and growing the number of able formulas.

The contemplation of the mode of operation of contingencies, which, as Th. IS 76 was asserted, plays a major role in all methods of sensitivity to difference, and at the same time justifies the rule which has been given, measures of differential sensitivity only comparable insofar as one can presuppose an equal scope of contingencies.

In short, the effect of the accidents is represented as an increase in the normal threshold A increasing with the size of the margin of the same, which averages out on a plurality of trials and does not balance in this means, and as a modification of the error threshold F or Position factor F in each individual experiment, which on average takes place just as often and strongly in plus than minus, and which on average balances, or what says the same thing, as an increase in value d increasing with the scope of contingencies and as a mean-balancing one alternating magnification and reduction of the value c .

In fact, the greater the latitude of the randomness of the experiments, the smaller the de facto level of difference-sensitivity which can be obtained from a means of many experiments, as Th. IS 77 has argued, turns out to be de facto; These experiments necessarily compensate for each other by the fact that, if they are not, they are no longer regarded as accidents but as constant errors.

The details can be explained as follows:

If one starts from the ideal case that a difference under the most favorable possible conditions falls into the sensation, then, since an absolutely small difference can not at all be felt to be special, but absorbed in the sensation, a certain value d as a noticeable difference, which, moreover, does not prevent anything from being set to zero in the limit, without this changing anything in the following analysis. The most favorable case, however, can not be absolutely met at all, because the coincidences soon produce deviations from the most favorable conditions in this, now in that sense. Whatever the meaning of these deviations, their influence, as a deviation from the most favorable state, can always only be that of a diminution of the sensitivity, hence enlargement of A or of d which increases with increase in a margin of deviations; but by virtue of the fluctuations of the accidents by a mean value, even by an average value, which variations can be taken as enlargements or reductions of A or of c in the individual experiments.

XXVIII. Comments on the measurement methods of sensitivity.

Without wishing to go into all the explanations to which this subject might give rise, I make some of the discussion and formulas of the preceding chapter, while maintaining it, which may serve to explain and, in a sense, widen the previously discussed methods of sensitivity but I will try to show that the validity of the principles at issue here and the rules governing them extend beyond the validity of these formulas, which should be noted insofar as the methods of measurement of the Sensitivity must also be used for cases where Weber's Law, on which the previous formulas are based, does not or does not apply with sufficient approximation.

As in Chap. 27, the influence of the temporal and spatial position of the compared stimuli in the experiments on difference sensitivity can be interpreted twice. It is certain that variously situated stimuli can be understood with different absolute sensitivity (absolute reason); questionable, whether the temporal or spatial relation of stimuli does not bring another reason (relative reason) into play.

In fact, influence the timing may very well be based on the fact that the stimulus for two incoming hits the sentient body already changed by the first stimulus, if on the one hand a certain Nachdauer takes place each irritant effect, on the other hand, a dulling by any irritation¹⁾ Influences that work in opposite senses, and out of their conflicts and relative predominance over circumstances, the proteus-like variability of the time error may be explained by circumstances that I have observed in my weight and tactile experiments. Both influences, however, can be regarded as the most general version of the concept of absolute sensitivity. For if an irritating effect persists in an organ, afterwards it requires only a lesser stimulus than usual, in order to produce the same sensation-size; but the concept and the measure of absolute sensitivity can only be based on the fact that it is in the inverse relationship of the stimulus, which produces the same sensation. With regard to blunting, traceability is

a matter of course for a change in sensitivity. Which, incidentally, does not hinder both, since every change in sensitivity can be translated into a modification of the irritating effect of doing so here too, and which not only does not exclude the investigation, but in any case leaves to what extent one or another circumstance is to blame to the change of sensitivity or irritation.

(1) What is termed fatigue after lifting weights is rather to be reckoned on the former as the latter circumstance, since in the fatigued state, even without load, the fatigued limbs are felt to be heavy, and the same burdens heavier than usual; whereas what one calls the fatigue of the eye after seeing the light, will be more likely to be written on the latter circumstance, if an eye fatigued by light sees less brightly than an unwearied one.

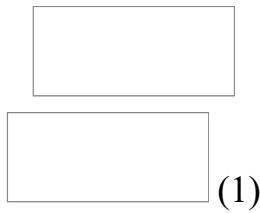
The influence of the spatial position, it is self-evident that different organs or parts of a sensory organ or the same parts in different spatial positions, when they are associated with changes in state of the parts, may be associated with different sensitivity; and that, therefore, if the two stimuli compared are not always taken uniformly in the same parts and in the same state, then their influence may be influenced by their estimation, if in the weight tests I weight one with one hand and the other with the other hand or move from one to the other with the same hand, turn the wrist left or right, depending on whether I go in one direction or the other, give the hand a different position for the two different weights.

Just as every stimulus in the organ on which it operates has a certain endurance and leaves behind a dullness that comes into conflict, so also every stimulus works in a certain way, radiates on the one hand to other parts, and on the other agrees with the sensitivity of others Part antagonistically, influences that can be complicated with the previous, if the stimuli are understood by different organs or parts of organs.

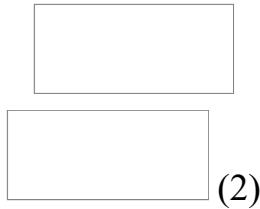
Insofar as in one way or another the different temporal and spatial positions of the compared stimuli influence the absolute sensitivity with which they are perceived, the threshold values b , b' , whose reciprocal value is the measure of the absolute sensitivity for these stimuli, become thereby is, modified; and the meaning of these amendments will soon be considered on the basis of our previous formulas, and more generally.

The in the chapter. The formula of difference-thresholds given to us gives us the value of a true difference of sensation in relation to the difference of the thresholds b , b' , whereby this difference may have arisen; The positional formulas of the previous chapter give us the value of a perceived difference in dependence on the same difference of the thresholds b , b' , under the assumption that the influence of the situation is based only on this difference, and therefore on the absolute ground is assumed to exist. Let's put it in the layer formulas $A_{\text{below}} = 1$, which corresponds to the limit of difference sensitivity, we perceive the difference as it is, and must therefore return here from the position formulas to the difference-threshold formula.

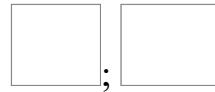
If we consider at first merely a simple dependence of the perceived difference on the situation, we obtain by setting $A = 1$ in the corresponding positional formulas



however, the difference threshold formula in the previous lineup, as we put β' or β in the counter, gives:



The comparison of the formulas (1) and (2) thus shows that



from which the important result flows, that we have in the error thresholds B , \square the position formulas or the thus-reciprocal position factors the relation of the absolute sensitivity with which the stimuli are conceived according to their position; where a

value $B = \frac{\square}{\square} > 1$ means that the sensitivity for the stimulus β is greater than for β' , but a value of $B < 1$ means that conversely the sensitivity for β' is greater than for β .

In the case of a compound dependence of the error thresholds on time and space, we



can substitute for the simple ratio \square and \square a composite ratio of the form \square with a 4-fold confusable position of the values therein, denoting the ratio of the absolute sensitivities to this composite dependence the position of the

values F_1, F_2, F_3, F_4 or their reciprocal values F_1, F_2, F_3, F_4 occurs. Generally



it will \square or \square called, so that \square the values of F and \square with F matches.



In a simple dependency is reduced \square and \square on \square and \square , and what general



, \square it is proved is therefore considered by itself also \square .

If, with greater sensitivity for one stimulus, it appears greater than the other, if it is already equal to it, a positive, constant error arises for it, while with a lower sensitivity it is a negative, constant error. Now the constant errors can be determined very precisely by our measurement methods of sensitivity; the dependence of the

$\boxed{\quad}$ or $\boxed{\quad}$

value $F = \boxed{\quad}$ or $F = \boxed{\quad}$ according to the differences in the position of the stimuli from the constant errors is also determined in the previous chapter, and afterwards the constant errors obtained in experiments on the difference sensitivity can serve to find the ratio of the absolute sensitivities for differently located stimuli, in this respect the absolute cause of the position influence alone can be considered valid, which, though not everywhere, will in many cases be After this we have to this provision:

$\boxed{\quad}$; $\boxed{\quad}$

and in cases where $D = 0$

$\boxed{\quad}$; $\boxed{\quad}$

Constant errors that allow this application are occasionally won partly by the method of right and wrong cases, partly by the method of mean errors. But where one deliberately wants to compare the relations of susceptibility of two different organs or parts of organs, it will be convenient to use the method of equivalents, which is given in Th. IS 131, and which is explained as follows by our formulas.

Take the layer formula (1)

$\boxed{\quad}$

so, according to ch. 27 does not feel any difference as long as $\beta \eta \alpha \sigma$ values

between $\boxed{\quad}$ and $\boxed{\quad}$, or the value falls $\boxed{\quad}$ between $\boxed{\quad}$ and $\boxed{\quad}$. Now, in the

method of equivalents, we $\boxed{\quad}$ always reduce the relation to these limits, and make a greater number of experiments of the kind, the probability of being hit at random

$\boxed{\quad}$ being $\boxed{\quad}$ equal for all values of x between those limits, so that the value $\boxed{\quad}$ and $\boxed{\quad}$

the value $\boxed{\quad}$ and $\boxed{\quad}$ are taken on average equally often, if x any size; which

is smaller than A , called. Let's multiply all values of $\boxed{\quad}$, which we obtain in this way,

and extract the geometric mean from these values, the factors $A - x$ and $\boxed{\quad}$, and we

keep the value $\boxed{\quad} = \boxed{\quad} = \boxed{\quad}$ alone, which tells us that the thresholds are direct, hence the sensitivities are the reverse Equivalent stimuli β , β' to which they belong, behave, which is in fact the statement of the method of the equivalents. From this it is evident at the same time that, in principle, it is not the arithmetic, but the geometric

mean, which has to be taken between the various relations \square in which equivalence

has been found; but if the values are not too different \square , the difference between the two remedies is negligible.

If in the equivalence experiments the time position and mode of production of the variables also gain influence, then one will obtain the relation depending on the

spatial position \square or \square always purely in the previous way, if one attempts at the same time with confused timing and method of production of the quantities Both parts sets, and the geometric mean of the product of all equivalence ratios thus obtained draws by the timing and manufacturing-dependent factors also compensate here.

Although the previous proof of the usability of the constant errors and equivalences for the comparison of the absolute sensitivities has been based on formulas which presuppose the validity of Weber's law, this usability is quite independent of the validity of this law; and in every other law there is the same dependence of the

relation F or \square of c , which is given by the formulas (see above), and the method of equivalents can be used in the same way. This overlooks the details so:

Two similar but differently applied stimuli, which here may be called P, P' , would also be perceived as equal without the influence of the situation. Due to the influence of the situation of the one, z. B. P greater than the other; but according to the principle (chapter 27) we can restore the equality of sensation by increasing P' by a certain value c , which is at the same time the measure of the constant error in P , as long as it serves to compensate it. Now P and $P' + c$ equally strong sensation. But according to the notion of absolute sensitivities, these stand in the reciprocal relation and the perturbation thresholds B, B' in the direct relation of the stimuli, which give an equal sensation; so we have

$$\square = \square$$

or, if $P' = P$,

$$\square = \square \text{ thus } \square = \square$$

where c is to be regarded as a constant error of the stimulus to which B refers.

Since these formulas generally valid for any value of P are, so you can it

for P set $P + D$. Thus one obtains all expressions for \square and \square again which have been given (without any need to go back to the position formulas).

As far as the equivalents are concerned, it is largely independent of Weber's Law; that, when two stimuli are conceived of two parts with different sensitivities,

and in repeated experiments one [] always brings their relation to the point where

the difference for the sensation disappears, this [] proportion [] varies by a certain mean proportion , which by chance is the same often and in the same proportions as

diminished, and as the geometric mean of all values [] that you get so can be found. This average ratio is considered to be that of stimulus magnitudes, which would appear to be the same regardless of coincidences, and according to the concept of absolute sensitivities, this is at the same time the ratio of the absolute sensitivities for these stimulus magnitudes.

With the measure methods of difference sensitivity, given the time and space conditions of the stimuli, we always obtain only the constant error c , complicated by space and time error , either in itself, as in the method of mean error, or even complicated with D , in the form $h (D + c)^2$, in the method of right and wrong cases; and then it is necessary to derive the simple time and space errors from this.

²⁾ The M Th. IS 112 agrees with what is called c here .

How to do this with the method of right and wrong cases is already Th. IS 113 f. discusses what the method in the method of the average error substantially matches. But the analysis of the constant total error like this method are explained here subsequently a little closer and it catered to the really occurring in the experience regarding case that c except by p , q also is in response to a third value.

Let us lay down for the sake of ours, Th. IS 120 et seq., Generally discussed, and Th. IS 211, partial measurements and tactile experiments.

In these experiments, the error distance with the normal distance, which here represents the value P , would be found equal in the average of the experiments, and apart from the constant error, so that one has to set on average $D = 0$ ³⁾ . The deviation, which shows the mean error distance from the normal distance, is entirely accounted for by the constant error c , and represents this itself, which, however, varies according to the position ratios of the normal distance and the error distance from each other, differing from p , q and according to circumstances still a third value s composed.

³⁾ The D of the measures of proportionality Th. IS 211 follows is, as the normal distance important, not to be confused with the D of this and the previous chapter, but rather compares itself to the P .

If a separate determination of these components of the total error c takes place, the experiments must be made with strict distinction and methodological alternation of opposite time and space, and the different values of c thus obtained should be combined by calculation in the manner to be indicated in the same way.

An opposite time position to be designated as I and II, with which the time error $+p$ and $-p$ as a component of the constant total error c . In the case of the position I, whenever we place the normal circle first, then the misreading, and thereafter the change of the misreading circle, if its range is perceived as different from that of the normal circle, in position II but each time first puts on the crescent, then the normal circle, and thereafter modifies the crescent, if the normal circle does not appear to correspond to the previously placed crosstalk. I have complied with this methodical procedure with a special distinction of the cases obtained in my tactile tests in general. The same could be said for the measures of correctness, in that instead of making the change in the wrong distance after irregular turning back and forth, as has always happened in previous attempts,

As opposite spatial position R and L , or O and U , with which the error $+q$ and $-q$ can be related, one can introduce: in tactile tests holding the normal circle once in the right, the othersal in the left hand, or with upper and lower Parts of the hand⁴⁾, while the misreading is always taken in the opposite way; in the case of the measures of correctness, the position of the normal distance on the right and left, up and down against the wrong distance; of which the first ratio for horizontal, last for vertical distance comes into consideration.

⁴⁾ Such a different attitude comes into consideration, if you hold both circles in the same hand to z. B. Try to do it on the other hand. I understand the details of O as the stem of the normal circle between the thumb and forefinger (which I call the upper part of the hand), the circle of error between the other three fingers and the vola of the hand (which I mean the lower part of the hand to name); below U , if the inverse ratio of the socket takes place.

Perhaps it is true that the different ways of keeping the circles in tactile experiments are rather than a spatially different production method as different spatial position of the compared quantities; however, this does not change anything in the mathematical treatment of the dependent errors.

Now suppose we have in the 4 main cases, which result so in our experiments,

$IL, II L, IR, II R$

or

$IU, II U, IO, II O$

If the four constant errors c_1, c_2, c_3, c_4 are found to be special values of the error c , we have, if these errors depend only on p, q - but whether it is the case, the following treatment will itself result - the equations for it as chap. 27 to set:

$$c_1 = +p + q; \quad c_2 = \\ -p + q; \\ c_3 = +p - q; \quad c_4 = -p - q$$

and can now (respectively by adding or subtracting each of these two equations of one another and dividing by 2) p and q , each of these values in fourfold ways, as follows:

(1) (2) (3) (4)

| |
|--|
| |
| |

These four determinations must not differ further than can be postponed by probability to unbalanced contingencies; if really only a dependence of p, q takes place, and the experiments remained comparable in all 4 positions. If there are more substantial differences between these four modes of determination, one has either to assume that a sufficient comparability has not taken place; rather, in certain situations the accidents have had a different scope, or the influence of time and space, than in other situations, or that apart from those constant influences, from which depend p, q , another has acted, which then can be determined, as stated.

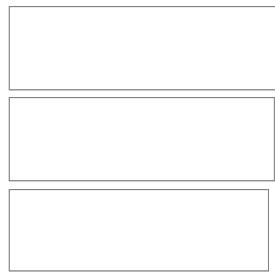
It is easy to overlook the fact that the mean of the values (1) and (2) agrees with the mean of the values (3) and (4); so that one arrives only at the middle determination of p, q with the equations (1) and (2) only the same as with the equations (3) and (4), as well as vice versa.

As we have seen in Chapter 27, the method of mean error is sometimes accompanied by a constant error, which shows that only the missing quantity to which we refer the constant error is not subjected to the normal size of the modification. This error, which is called s , retains the same value and the same sign in the opposite order of time and space of the error variable. Although I have not always found it to be of considerable size, it is always necessary to examine whether it has one, and to consider the equations for the constant error in the case of an analysis of constant errors More general method of mean errors:

$$c_1 = p + q + s; \quad c_2 = -p + q + s; \\ c_3 = p - q + s; \quad c_4 = -p - q + s.$$

This gives:

(1) (2)



Thus in this case there remain only two equations for the determination of each component, which must give sufficiently unanimous values, if the assumption of these relations of dependency should suffice, or if sufficient comparability of the experiments has taken place.

To differentiate the two values of p , q , s , which is obtained by (1) and (2), the same can be prepared by the corresponding indices as p_1 , p_2 distinguished etc. and their agents or circumstances their sum of Letters without index are needed.

General Comment now earned that when the values p_1 , p_2 well agree with each other, this is also necessary with the values of q_1 , q_2 and s_1 , s_2 is the case, conversely, and just as dependent non harmony the doubles of all three solidary together. The close union of small double values, however, need not be sought in that their relation is close to that of unity, but that both differ little from 0; by, if a constant error p , q or s it is very small against one of the others, or the other two, but it can only be ascertained to such an extent that its small size is even apparent.

The values of the constant error components p , q , s , which is obtained from the above equations remain, at all affected by the more coincidences, the less the adjustment is effected by numbers and comparison of tests.

Where an error p , q or s nature does not consist of the case, he can not find, therefore, because of such unbalanced contingencies but generally zero by the above equations, but so small that be ejected by these equations value of probability be supplied only on contingencies pushed or regarded as quite insecure. The probability calculus gives rules for a more accurate assessment in this regard, which, however, can not be discussed here.

In not a few of my experiments with self-application of the circles I have received not only the double values of p , q , but also of s so large and consistent that the existence of all three errors under the circumstances of these experiments do not doubt, but in other circumstances one or the other error remained ambiguous. More about it in the "measurement methods". The measures of gauging have hitherto not been made to permit a complete analysis of the constant errors, but merely in such a way that the spatial error is particularly pronounced, the constant error being dependent on the spatial position and independent of it, the composition of which remained unknown; decomposed.

If one does not intend a complete analysis of the constant errors, but only one or the other component of the same, z. B. wants to determine the dependent on the spatial position q , so it is sufficient to make experiments in confused spatial position,

while the timing and method of production of the compared sizes remains the same average. Then one gets only two constant errors c_1, c_2 , for which the equations are stated as follows:

$$c_1 = q + C$$

$$c_2 = -q + C$$

from which results



Here q is the space-dependent, C is the component of the constant errors, possibly still composite, independent of the spatial position.

If the experiments are made with sufficient modifications, then p and q may be subjected to the experiment for further analysis. So one can examine in experiments with modified main sizes, whether p or q let it be divided into a part that is constant and a part that depends on the main quantities according to some function. In a trial and error series, I intentionally varied the setting of the circles so that I always took the normal compass always on the pedicle, the crescent on the thigh, the other way round, and compared the success of these positions with that where both circles are always on the pedicle, and where both are always caught by the thighs, and so on. All these alterations had an influence on the constant mistakes. More specifically, however, I must save on the "measurement methods".

While the constant errors obtained in carrying out the dimensional methods of the difference sensitivities may be used to compare the absolute sensitivities insofar as the absolute reason is valid, these methods, as previously indicated, result in the measure of difference sensitivity by eliminating the constant errors. how it is independent of the position change of the stimuli. We either bring the value D to a point such that D becomes equal to the just noticeable difference d existing independently of the constant error , which is the method of the just noticeable differences, or we determine a value in the mean error ε of the method of mean error which with d is in direct proportion, or in the value $t = hD$ of the method of the right and wrong cases, a value which is in reciprocal relationship with d , if h is inversely proportional to the difference sensitivity directly proportional to d . It is to be considered that d , depending on the range of randomness, is larger or smaller, if not alone dependent thereon, except at the ideal maximum of the difference sensitivity, so that, as repeatedly recalled, the measures of difference sensitivity are only comparable insofar as they presuppose an equal scope of contingencies.

XXIX. Relationship between contrast sensations and sensation sums. ¹⁾

Our soul is so much determined by perceived differences, contrast sensations, as absolute sensations.

¹⁾ About the contrast sensations, Ber. der Kgl. Saxon Ges. d. W. Math. Phys. Cl. XII. 1860, p. 71 ff. In the matter of p. 107 ff.

Contrast sensation, as the sensation of difference, is a sensation *sui generis*, which, without being somehow self-explanatory as a sum or function of a sum of absolute sensations, adds to the sum of sensations afforded by the components of difference, and thereby increases the total effect on the soul ,

The absolute sensation is, according to the measure-formula, to judge the difference between absolute sensations, in short difference of sensation, according to the difference-formula, the sensed difference of sensation, briefly perceived difference, the sensation of contrast, according to the difference-measure-formula and its generalizations, the position-formulas, and the hereafter to add a certain contrasting effect to the cumulative effect determined by the measure formula and the empirical formula (Chapter XX), in order to have the overall psychic effect.

To grasp this, we are compelled by the fact that everywhere, where the uniformity of a stimulus is occasionally or temporarily interrupted by a diminution, cessation, intermission of the same, the soul finds itself more excited than if the stimulus is uniform throughout space or Time fortrestretched. Since, as a result of the occasional diminution or cessation of the stimulus, the sum of the absolute sensations dependent thereon diminishes in such a way that the stimulus continues continually, the intensified effect in the soul must be based on an effect of the contrast which does not the sum effect of the stimuli coincides or rises.

The consideration of the lifting effect of contrast (chapter 24) does not change anything in this regard; because through them the sum of absolute sensations as a whole does not grow. If the white is growing by contrast with black brightness, the Black takes the other hand at the same time the brightness down, yes I will continue ²⁾ empirically demonstrate and explain that and why the deepening of the black by the contrast effect is generally noticeable when the illumination of white. Insofar as an elevation of the impressions takes place through the contrast, this only reinforces the sensation of the difference which is to be added to the sum effect, but does not establish it in the first place, and the sum of absolute sensations does not gain anything thereby.

²⁾ Either in a later chapter or in a treatise of the Saxon law books, since my observations in this respect are not yet edited.

Facts for explanation and evidence of the above offers the ordinary life in abundance.

If, on the one hand, one sees a whole white surface of paper, the other one with a black disk in the middle of the eye, the sum of the absolute impressions of light, such as the sensations of light, is smaller than at first; but the soul finds itself, by virtue of the oncoming contrast, more strongly affected, at first, than the first, and the more so, if one even considers a paper with multiple alternations of white and black, such as black and white. B. considered a checkerboard pattern, when even the sum of the absolute light impressions is even more reduced here, since this multiplies the contrast effect.

On my very sensitive eye, certain bright sunspots in the room make such a strong impression that I can not stand them well, but I can walk in the full sunshine on the street, even through snow, or see the bright sky without feeling annoying ; notwithstanding, in this case the whole retina is irritated with the same or greater intensity than, at first, a limited place.

A sudden pause in a rushing music or a sudden bang after a pause makes an impression that can not be explained merely as the sum of the impressions of the components, since at first the effect of one component is broken off, at least the impression at the moment of the onset blow incomparably stronger than at every moment of the progressive tympanic vertebra. The latter may be explained by the fact that the first bang meets a fresh sensitivity, which becomes more and more dull as the vertebra continues; and undoubtedly, this also depends on something; but the same circumstance can not be asserted at first, and therefore, indisputably, does not necessarily determine the main effect.

Some apparent anomalies can be explained by the double determination of the soul, respectively, by absolute and contrast impressions.

Weaker sensation of light than gray, and yet makes a stronger impression in the soul than gray. How does this rhyme? Distinguish the absolute sensation of light of black from the contrasting sensation of its difference against the previous, the surrounding or the medium brightness which we remember. Absolutely, black always remains a positive sensation of light, and we will allow that to happen if we hold it against the nonsense of the finger; and a weaker sensation of light than gray, which we will no less concede. But the difference of the black from the medium brightness is greater than that of the gray, which may even coincide entirely with it; and this greater difference makes a greater impression of their kind in the soul.

Cold is different from black, and there is only analogy, not equality of both cases. Whereas the absolute strength of the sensation of light, with diminution of the light-stimulus, resolutely diminishes through all degrees of the deepening of the black, and only the contrast-impression intensifies, the sensation from a point where we find it neither warm nor cold, grows absolutely with increasing cold ; and it can just as strongly affect us, but only very differently sensually, than strong heat. But this does not prevent that in the field of temperature sensations just as well as contrasts of the same character assert themselves, as in the field of the sensation of

light. And so a warm temperature can be cool against a warmer one and a cold one against a colder one.

For the first sight, it seems that the principle of adding the sensation of contrast, calculated according to the measure of difference or positional formula, to the sum of the absolute sensations calculated by the measure-formula, in order to have the total effect of the stimuli, does not suffice for experience, if the fact follows can not conclude that by contrasting a stronger and weaker stimulus one can achieve a greater overall psychic performance than if both stimuli were equal to the stronger one. Because the molecular formula founded on the measurement formula is for two stimuli β , β' with the threshold values b , b' the sensation sum

$$\boxed{\quad}$$

The difference measure formula or location formula gives for the perceived difference

$$\boxed{\quad}.$$

placing the greater stimulus in the counter³⁾, where v is always greater than 1, as long as we have no wrong feelings (chapter 27). If we add both expressions, we get that

$$\boxed{\quad}.$$

whereas the value obtained by the mere empirical formula in the case that both stimuli are equal to the larger β is

$$\boxed{\quad},$$

$$\boxed{\quad}$$

However, this value is greater than $\boxed{\quad}$, if v is greater than 1.

³⁾ The Resultat does not change, if one puts the small stimulus in the counter,

$$\boxed{\quad}$$

and then the perceived difference by $\boxed{\quad}$ in the sense of chap. 24 expresses,

$$\boxed{\quad}.$$

Now, the principle of combining both measures simply by addition, in order to obtain the total psychic power of sum and contrast, is not in itself so obvious that no other functional mode of connection could be accepted if it were better suited to experience; but we shall not need to respond to distant assumptions in this respect, since a simple, quite obvious presupposition suffices to produce the missing correspondence with experience; namely, that the effect of contrast is not simply to be

calculated between both stimuli, but across and over, since it indeed exists over and over, 4 and thus for two stimuli is no less composed of two members than the sum effect.

4) In gravitation, for instance, the square of the distance which enters into the law can be conceived by taking the distance over and over into consideration.

Provided this, so far as the sensation depends on the sum

insofar as it depends on perceived differences

as a whole

That is, the total psychic achievement attained by the entrance of the contrast to the

sum effect is stronger than that obtained by the mere empirical formula for the case; that both stimuli are equal to the stronger β .

It will be useful to note that by setting the perceived difference here , while we set in the chapter on the difference-measure-formulas and

position-formulas , we do not set anything contradictory,

by regarding the former value only as the one-sided difference, or the k of those formulas have to be given twice the value as the k of the measure formula. In

fact, the terms are different and only in that a term is twice the

other, since $\frac{\text{one}}{\text{two}} = 2 \frac{\text{one}}{\text{two}}$ is that it makes no difference whether we use one or the other, as long as we have merely to do with the comparison of perceived differences among each other, without considering them in relation to the sum effect, since the ratios of perceived differences do not change, may we measure it by one or the other expression. For this very reason, too, no basis of determination could be found in our list of the difference-measure formulas and the position-formulas, and the two-sided ones are to be preferred to the one-sided conception of the contrast. But

such is now in the cited fact, which relates to the combination of sum and contrast, and it is therefore essential to add a fundamental meaning to this fact.

Just as sensations above the threshold and below the threshold are not to be added after previous discussion, but are to be taken into special consideration insofar as they exist as special, so even in the case where the perceived difference falls below the

threshold, it is possible to that v becomes too big or \square too small, no longer makes use of the combination formula of sum- and contrast-sensation, but, where such a case occurs, it means that the difference not felt now contributes nothing to the state

of consciousness, and it remains \square alone left to represent the positive sensation.

A consequence of this is that when a stimulus changes continuously in space or time, the contrast between close points can be neglected, and the total effect, where the change does not occur too rapidly, is reduced to the sum effect at all then it is negligible even between distant points, which is of importance when one tries to use sensations as a function of elementary movements or changes by means of the methods described in Ch. To construct 16 given formulas.

In the past, when we obtained the result that a stimulus with the most uniform distribution above the threshold gives the maximum of the sensation-sum, it follows from the above that it does not grant the maximum of the sensation-power, if in such a nonuniform distribution that a contrast is asserted Contrast adds a new sensation to the sensation sum.

In the foregoing we have confined the consideration to the simplest case, that one has to deal with only two differentiated stimuli, which sufficed in general to overlook the conditions which apply to the combination of the contrast effect with the sum effect. Another question is how to judge the relations of the total effect, where contrast effects between more than two stimuli are asserted; where, therefore, it is necessary to sum up contrast sensations in addition to the absolute sensations. Since it is here z . For example, with three stimuli β , β' , β'' not merely the contrast of $\beta : \beta'$ and $\beta' : \beta''$, but also of $\beta : \beta''$, and in the case of n stimuli the number of relations $n(n - 1)$ to be taken into account is, if we calculate every relation over and over, that is, twice, (otherwise half as large), I wonder how the summation is to be effected, for which I have until now had no obvious principle, but I suppose the following will be authoritative, since it seems rational and compatible with experience.

Since none of these relations has any other precedence over sensation than that given by the ratio threshold, one must first of all sum up all perceived differences which belong to $n(n - 1)$ relations one by one. This sum is expressed by Σ . But only n points of time or space are present, upon which sensation falls, or which

contribute to sensation; consequently, that sum will have \square to be reduced in

proportion to the divide $n - 1$; therefore have the value $\boxed{\quad}$. Let's do this for three stimuli, β, β', β'' , taken in descending order of magnitude, and giving k the double value against the k of the measure-formula, to merely introduce any relation simply, we have

$$\boxed{\quad}$$

if v, v', v'', v''' are the three conditions associated ratio thresholds, whose indices are taken according to the indices of the stimuli, for which they apply. These thresholds may be set equal to 1, and may be assumed to be equal, as in the case of three lights which, on a uniform basis, form the vertices of an equilateral triangle. In the general case but are v, v', v'', v''' as different from 1 and from each other. No matter what their values are, by transforming the sum of the logarithms into the logarithm of the product, the above expression is transformed into

$$\boxed{\quad}$$

Now, without adding the middle stimulus β' , the perceived difference would have been

$$\boxed{\quad}$$

which, in the case that $v, v' = v''$, agrees with the above expression; according to which, in the case of three stimuli, whose ratio thresholds have this relation, the sum of contrast would be just as great as in the case of two without addition of the middle. On the other hand, where all three thresholds are equal, for which there are examples, as noted above, the sum of contrasts is smaller for three stimuli than for the two extremes.

If one passes on 4 stimuli, calls them by descending order of size $\beta, \beta', \beta'', \beta'''$, and the product of the 6 thresholds which come into consideration here, ω , then the central stimuli no longer disappear from the Expressions of the contrast sum and we receive for it

$$\boxed{\quad}$$

In some attempted application of these formulas is to be considered in consideration that, where it is z . For example, it deals with the sum of contrasts which stars grant in the sky, and has to consider not only the contrast of the stars against each other, but also the black background of the sky, which indisputably gives the chief effect.

If points of light flow together into areas of light, their contrast sum necessarily diminishes against the ground, because the strongest contrast effect, and thus the

smallest ratio threshold, indisputably exists between each point of light and the nearest part of the black ground, but which is equal for the points inside a surface of light Light points is replaced. After all, the distribution of the contrasting stimuli against each other has to have a great influence on the sum of contrasts.

However, I will not go into further details and calculations here, since it remains to be admitted that the principle of calculation used here is neither *a priori* nor sufficiently established by experience.

It is not without interest that Heaven, which has previously provided us with the most beautiful and simple evidence of the fundamental facts and laws of psychophysics, also provides the most beautiful and simplest example of both sum and contrast. In fact, we will not be able to obtain a purer and more exalted sum effect of sensation without contrast than through a purely blue day sky, and no simpler and loftier contrast than through a starry night sky. In addition, the alternation of clouds, mornings and dusk also give an inexhaustible alternation of contrasts that evolve over time.

XXX. Question about sensory products. Relationship between height, strength and periodic element in the tone scale. ¹⁾

We have taken into account sentiments and sensory differences; The question arises whether meaning should also be attached to the concept of a product of sensation.

¹⁾ In matters p. 165 ff.

Let us first understand the concept of a product and, in order not to lose ourselves in unclear abstractions, use as a clue a specific example of geometry.

If we have a rectangle of which one side is 2, the other four are long, these numbers are relative to some linear unit, then the product does not give both sides, for there is no such thing as ²⁾ but of the numbers, indicating their length is measured, the measure of the rectangle with respect to a unit area, which is related to the linear unit.

²⁾ At least not according to the convention of strict mathematical usage; although it is only a matter of definition to call product of two sides the area-space, which to the extent has the product of the measures of both sides, as happens often enough.

If one lengthens or shortens the rectangle by the direction of one side alone, while leaving the other constant, then the relative size changes of the whole rectangle coincide with those of the side in the direction of which the change occurs, and in reality with none If we can operate on absolutely simple lines, then what is ideally said about linear relations will in reality only be applied to rectangles, cylinders, and the like. Like. Be proved of constant thickness.

Now one wonders whether even a sensation can be attributed to two sides or dimensions quantitatively determinable in different senses, according to which each of them is independently capable of increasing and decreasing, independently of the other, according to which each one is measured by a unit homologous to the dimension in question can be, and whether the sensation result, what both sides give in the meeting, can find its measure just as well in the product of the measures, the two sides in particular belong, as the rectangle in the product of the measures of its sides.

In favor of such an idea, the strength and height of a sound appear to be the sides of it. And first I want to quote what can be asserted in this sense.

Both strength and height is subject to the measure by our dimensional formula in particular. However, the qualitative difference of strength and height makes it necessary to refer each to a unity of their kind, and this justifies a difference from the geometric product, where the same linear unit is at the root of both perpendicular sides. But since it is not the various qualities that are to be multiplied, but only the abstract measures related to them, it seems to me that the less a fundamental obstacle lies in the fact that the different directions of the sides of a rectangle are represented by the different qualities of strength and height of the sound can hold. If the unity is chosen arbitrarily for both sides of the sensation, then nothing will hinder

The essential, the main question is only whether both sides really give such a common feeling result, that the measure by the product of the measures of the sides means something and corresponds to the connection of the facts. If this is the case, then mathematical concerns can no longer take place.

In fact, many things seem to be cited for this.

It is certain that the overall impression of a high tone is increased by its strength, and the total impression of a strong sound is in a sense increased by its height. The sound becomes more drastic, the higher it gets³⁾. The circumstance deserves attention, too, that it is well known to judge of the equality of the strength of different tones at different heights, as the judgment seems to fluctuate between the measure of the overall impression and the pure measure of strength.

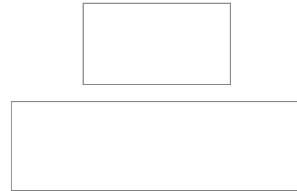
³⁾ Hereby I occasionally recall attempts by Desprez (Pogg, Ann., LXV., 445), which prove to be a strong and even annoying impression the still highest vocal sounds of very short vocalizations can make.

Thus, in the overall impression of a sound, there really seems to be something measurable, the measure of which is determined by the interaction of both sides, strength and height.

For the sake of a more definite distinction, we shall always mean the magnitude of the impression, insofar as it depends only on the amplitude of the vibrations, as strength, the magnitude of the impression, insofar as it depends only on the duration

of oscillation or the number of vibrations, as height, but the size of the impression, provided that both at the same time, as intensity or as the size of the overall impression.

According to them, the measures of the perceived sound intensity and sound levels s and h are taken separately



where β is the physical amplitude dependent on the amplitude, n is the oscillation number, τ is the period of oscillation, b , n_1 , τ_1 are the associated thresholds, k , k' are constants, then the measure of the intensity or of the overall impression would be the previous one



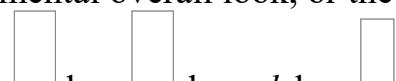
or, if we set the thresholds 1

$$sh = kk' \log \beta \log n$$

which expression by analogy could extend to colors.

Insofar as we look at the physical strength of a light or sound by the square of the amplitude measured which a hot, will be a^2 for β can be substituted for in the previous equations, and, since $\log a^2 = 2 \log a$, the previous expression pass into $2kk' \log a \log n$, or, assuming $2kk'$ by choosing the appropriate units equal to 1, it is easier to $\log a \log n$.

However, I think the previous view not only not binding, but for not convincing, and after once reasons to be discussed as a measure of mental overall look, or the

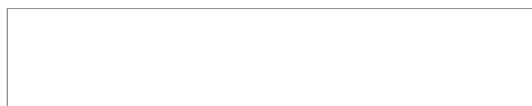


intensity of a simple tone instead of the form $2kk' \log \square \log \square$ shape $k \log \square$ for cogent if with L the, amplitude and vibration frequency or period of oscillation at the same time dependent, living force of the vibrations and l whose threshold value is understood. For colors special considerations apply, which I will come to below.

Now, L are considered to be measured by the square of the product of or the



quotient \square , for which purpose the threshold values $a_1 n_1$ and \square are; according to which the expression would be the measure of the total psychic strength of the impression produced by a simple tone



or choosing such units, whereby $2 k, a_1, n_1, \tau_1$ become 1

$$\log an = \log a + \log n$$

or



Thus, instead of the product obtained earlier, the logarithm of the values a, n , the logarithm of the product of these values, or, what is the same thing, the sum of the logarithms of these values would appear as a measure of the psychic overall impression.

Grailich in his otherwise estimable essays on the formation of composite colors in the reports of the Vienna Academy in 1854. XII. P. 783. XIII. 201, the living force of the light vibrations, from which the sensation effect is derived, is proportional to the quotient of the simple duration of oscillation in the square of the amplitude, or what is the same, the product of the simple number of oscillations to the square of the amplitude, that is, the value $a^2 n$ while Seebeck, in his treatises on the relations of sound (Poggend, LXII, 872. LXVIII, 461), just as it happens here, sets the living force of the vibrations proportionally to $n^2 a^2$. The latter is undeniably more valid⁴⁾, and the point where Grailich was wrong to specify easily.

4) The fact that Grailich deals with vibrations of light, Seebeck with sound vibrations, can understandably make no difference in the relevant point of view.

The living force of a vibration is set by Grailich (XII, p



where τ is the duration of an oscillation, \square the velocity, t is the time, which gives by integration



if we substitute \square as velocity the function of time t , which takes place in a vibration, if a is the amplitude, π the Ludolfian number. But the living force of a vibration can not be decisive for the living force, which is developed by vibrations during a given time, what it is when the living force of different tones and colors is compared; but it must also be taken directly from the number of oscillations in this time, ie, with τ , so that, instead of τ , τ^2 is in the denominator, or n^2 , which is thus reciprocal comes in the counter.

It is a pity that the arduous calculations concerning the intensity values in Grailich's essays (Reports Th. XIII., Pp. 230 ff.) have thereby lost their validity. But his general principle of explaining compound colors is not affected by it.

The reasons to prefer the last view of the first are the following:

It is not disputed that we have to regard the strength and height of a sound as something externally related; but the task in the nature of things is to derive the impression of strength and height in connection with the basic relations of sensation to movement; and the simplest possible conditions in this respect are our Chapter 32 rather than a Maßausdruck the overall impression of a note on the form $\log on$ as $\log a \log n$ lead.

Apart from that, the experience speaks directly against the form $\log a \log n$. According to this form, there is a fixed point of strength at which the sound ceases to be audible, no matter what height it has, and a fixed point of altitude, where it ceases to be heard, whatever its strength. For if a or n has fallen to the threshold value, which is set to be 1 in the form $\log a \log n$, then the product $\log a \log n$ is in any case zero, just as the other value behaves. Not so with the form $\log on$. Here strength can be represented by height and vice versa as to audibility; it is within the limits of the height, which are able to be perceived at all after the establishment of our organ of hearing, for every other oscillation number n another amplitude a , at which it becomes audible, and vice versa. The sound is heard when the product of the, briefly = one set, threshold $a_1 n_1$ reached. This will be at low a when n is large and vice versa. But that's the experience.

In fact, low notes require a large amplitude of vibration to be audible, and high notes can still be heard at very low levels.

Dove has emphasized this fact, in connection with a fact relating to the colors, which will be discussed below, but which must at least partly have another reason. In order to stand still in what concerns in the tonal field the compensation of small strength by increased height, or lower height by increased strength, Dove recalls "how the strings of the contrabass must vibrate farther than those of the violin ... as we speak in a higher tone, when we want to be heard without great effort, as when the deep, reinforced by the mouthpiece voice of the sailor dies in the storm, nor the shrill sound of the boat whistle through the roar of the waves and the sound of the wind penetrates, and as Savart has shown by means of the spoke siren,

The following circumstance is also incompatible with the form $\log a \log n$, while it enters the form $\log a + \log n$.

When the sensation of thickness or height without regard to the other element alone is comparable m -facht, so this can be according to any requirement by $m \log a$ or $m \log n$ represent. Now, in the product $\log n \log a$, the factor $\log n$ or $\log a$ takes the place of m , and according to this we would have to expect, if there is another mathematical consequence, that the sensation of the strength in the ratio of $\log n$ and that of the height Ratios $\log a$ growth, that is, a mutual increase in strength and height occurs, so that with increased height of a sound at the same time an

increased impression of strength, and with increased strength the impression of an increased height, but this is not the case. In the form $\log a + \log n$ this difficulty does not occur.

However, the form \log conflicts with the difficulty that, as one goes deeper into the sound, there is no amplification of the sound sufficient to make it audible, and thus even too high sounds are no longer audible while but, according to the form \log , every reduction of n is compensated for by a magnification of a , and the impression of the note with increasing height would have to increase indefinitely.

To be sure, this is to be regarded as a deviation from the validity of the formula $\log an$ at the lower and upper limits of the audibility of tones, as we are already accustomed to find a lower and upper limit to the validity of our basic formulas, which limits are nevertheless presupposed exist only for the external, not for the inner psychophysics, insofar as the external stimuli only within certain limits, in which the ordinary sensory use holds, trigger proportional psychophysical movements, to which the basic formulas are actually to relate, and thus only within such limits can represent.

In fact, man's hearing apparatus is undoubtedly suited only to absorb vibrations within certain limits of height and to produce them to certain limits of strength, and the inaudibility of such deep or high notes is not due to the fact that very slow or rapid psychophysical Oscillations are inaudible even at the greatest amplitude, but that they do not come in human beings in the required strength, even if there are external vibrations to it.

Even the eardrum with its annexed parts can fail the services if they are too high or too low⁴⁾; indeed, by a means given by Wollaston, even made artificially deaf to low notes⁵⁾. Moreover, it is not improbable that the nerve keys which are struck by the notes, or accessory instruments by means of which they appear to be struck by recent investigations, reach only to a certain height. In fact, there are many reasons, which I will discuss in Chapter 33, to suppose that the apperception of tones of different heights involves different nerve fibers.

⁴⁾ Comp. about this point in theoretical relation especially Seebeck in Pogg. Ann. LXVIII. P. 458.

⁵⁾ Philos. transact. 1820. p. 307. "I remarked that, when the mouth and nose are shut, the tympanum may be exhausted by forcible attempt to take breath by expansion of the chest, that the pressure of the external air is felt upon the membrana tympani, and that "In this state of tension from external pressure, the ear becomes insensible to grave tones without losing any degree of perception of sharper tones."

Many people are not able to perceive high notes at all. Well known in this respect are the observations of Wollaston, 6 according to which certain high whistling sounds

of the insects, and indeed even the chirping of sparrows, are no longer heard by some persons, who, however, hear lower notes. I myself was very astonished when, on one occasion, I made a foot-trip with Professor Ch. H. Weisse, who is very hard of hearing on an ear, that he does not care of the very lively squawking of crickets and other insects surrounding us on a hot summer's day heard the slightest thing, and never heard anything like that, even though he heard the far weaker appearance of a distant carriage. And Bonafont 7) draws the general result from his observations about dove, "that as the sensitivity of the ear decreases, it loses the audibility for the high notes, while the deeper ones still clearly perceive." A person could not $\text{h} \parallel$ still $\text{a} \parallel$ still a hear, but e took II fairly and $\text{c} \parallel$ perceive very clearly. Bonafont even believes that thereafter, he can judge the curability of various degrees of deafness. Also Wollaston 8) noticed by hearing impaired people: "that they usually hear sharp sounds much better than lower ones."

6) *Philos. transact.* 1820. p. 306.

7) *Compt. rend. T. XX.* p. 1498. Pogg. Ann. LXV. P. 448.

8) *Philos. transact.* 1820. p. 306th

This result, however, seems to require a limitation, and in certain types of deafness higher tones are better heard than deep ones; In the "rational Otiatrik" by Erbard (1859), p. 65, I find the following passage: "I have remarked that almost all nervously hearing-impaired people hear relatively high notes better, easier than lower tones of equal intensity, without one Acoustically deaf persons can be found by combining the *tensor tympani* relatively much better comprehension for high notes than for deep, and for the very simple reason that a taut eardrum has more the property for high notes Further, my pathological observations indicate that in the absence of the eardrum, deep sounds are heard relatively better, perhaps because the *stapedius* resonates more easily to low tones."

Not without interest is the following remark by Wollaston [†]:

I have heard from the numerous instances in which I have heard that I am in the hearing of different friends in the affirmative, although the lower is heard distinctly."

†) *Philos. transact.* 1820. p. 312th

Incidentally, the upper limit of the audible tones has more and more expanded by the successive observers, and it wonders if the limit has already been reached. Comp. in this regard Th. IS 258.

It may be noted that the form $\log a + \log n$, or, to reintroduce the thresholds, \log



+ \log \square with the form presented in the sum formula



$\log \square + \log \square$

$\log \square + \log \square$, which takes place when we have two stimulus quantities β, β' act on two different points with different sensitivities. The meaning of this form is generalized thus; that not only that which belongs to the same side of sensation, on two different points, but also that which belongs to two different sides, are united in the same point under this form. And this has the coincidental success: that, just as the stimuli can be subjected to a separate conception on two different points, while they nevertheless remain in a common spatial intuition, so strength and height on the same point, while they conceive in a common sound sensation stay.

\square

However, in the case of the otherwise complete agreement of the form $\log \square +$

$\log \square$

$\log \square + \log \square$, the difference can not be overlooked that in the final form b, b' are independent of each other, but in the first a_1, n_1 by the equation $a_1 n_1 = \text{Const.}$ are linked. This implies that the perceived difference in height of the notes is altered just as little by their different strength as the height

\square

itself. For if one tone is $\log \square$, the other $\log \square$, then a_1 is indeed of a'_1 and n_1 are different from n'_1 , but $a'_1 n'_1 = a_1 n_1$ and the total tone difference

\square

In spite of the fact that a low-pitched and a high-pitched tone may have a measure of equal size, the qualitative impression or character of the two is different according to the composition of this measure. The first seems to us relatively serious, worthy, heavy, broad, the second pointed, thin, shrill.

Given the validity of the form $\log an$, the threshold strength of a tone is constant only to the extent that the height is constant, and the height threshold only to the extent that the magnitude is constant, and, generally speaking, the threshold the oscillation number, on which the height depends, in the inverse ratio of the amplitude of the oscillation, and vice versa the threshold value of the amplitude of the oscillation in the inverse ratio of the oscillation number, in the direct oscillation period.

It is probable that there are great differences between different creatures (as Wollaston has specified) with regard to the limits of audibility of sound, in that each creature, according to its mode of life, is provided with receptors and nerve keys for a certain greater or lesser, higher or lower part of the tone scale. We will always assume that faster vibrations and smaller amplitudes belong together. If what applies to tone vibrations should be generalized to all the vibrations on which sensations depend, then we have, so to speak, two so different creatures in the eye and the ear, since the vibrations of light, with tremendous smallness, are tremendously fast, the vibrations of sound much greater Slowness are much bigger, insofar as it can be considered

probable that the ratio of the external vibrations translates into the interior. Of course, as will soon be discussed, the form $\log t o$ apply no direct application to colors, if we wish to measure the dependence of the sensation on the external color stimulus; yet this does not preclude the possibility that, if a final analysis of the internal oscillatory motions which are subject to the sensation of light would be *at our disposal*, the dimensional form \log would also be decisive here.

One might think of systems in which movements of such a long period as the movement of the earth around the sun still conveyed sensory phenomena; if at the same time the amplitude would be correspondingly large; we also can not know if the world itself is not such a system. Only it would be useless to pursue such possibilities here further.

The previous combined, the strict justification of the form \log depends *on* the Maßausdruck for the intensity of the sensation of sound and the possible transferability this form to other sensations on two conditions: 1) that the Weber's law for strength and height it applies in particular as really found himself in tones like that; on this depends the logarithmic form of the measure expression and its decomposability into two independent members; 2) that the intensity of Toneindruckes the same at a constant kinetic energy $a^2 n^2$ and thus the same vibration product *of remain*, thus reducing the audibility of reduced amplitude by a corresponding increase of the oscillation frequency and conversely, the reduction in the audibility of a reduced number of vibrations by a corresponding increase of the amplitude can be compensated for, which can be regarded also at tones in so far as confirmed when, after The general failure of experience, as such (see above) can go.

In the meantime, however, the latter does not yet suffice for an exact proof, and in this respect the following remark is important. Both the validity of Weber's law for strength and height, and the compensability of power for height, and vice versa, with regard to the audibility of the sound in general, insofar as it has hitherto been established by general and indeterminate experiences, would be equally ascribed to forms of power Maßausdruckes of the form $\log t o^2$ or $\log a^2 n$, when the log shape *to* tolerate. So that is decided by experience not between these different forms, and the form $\log on$ it is only because of its greater simplicity and simpler relationship of the magnitude of sensation to the size of the living force that it may presumably be preferable as long as there is no direct decision.

Such a decision would be gained through experiment, which, as I show below, lacks all prospect, but would be of the utmost importance. It is apparent from the discussion of a future (of the 32) chapter that the shape $\log on$ is required when the intensity of the sensation of the size of the speeds, the shape $\log t o^2$ but if they (the size of the speed change speeds second order), which take place in the course of a vibration; in the sense of the measure formula, which is a very fundamental question for psychophysics, which could be decided in this way. And notwithstanding I the previous lack of such a decision in the form of $\log on$ when the simpler ones have been preferred and will soon be preferred, I still put it quite well whether this preference will prove itself⁹⁾. Incidentally, the difference between the two forms

does not apply both in general conclusions and in the relations of the measures of strength and height to which they attach themselves.

9) In Th. II., P. 32, I have already preached a preference for the presupposition on which the form \log is based *on* 2, but, on closer consideration, can no longer find the reasons for it to be resounding and make the decision entirely to the success of future experiential investigations.

The experiment, what I have in mind as possibly driving to decision, is this:

Supposing that the same hammer is always dropped from the same height to the same horizontal string, but at different tension, or the same pendulum strikes the same elongated vertical string at elevation by the same angle of elongation, the string will always be more vivid with the same moving force, but the more it is tensioned, the more a decrease, n increase, they do will oscillate in ever smaller amplitude, while at the same time obtains an increasing pitch, the product $a^2 n^2$, and therefore also a will remain the same,

Is now on the Maßausdruck \log *on*, so the sound always at the same height of fall will begin to be heard and stop acting like you abändere the tension of the string; or, if the experiment is carried out with two identical but differently tensioned strings and two equally constructed hammers or pendulums at the same height (reversing the experiment with both), which would undoubtedly facilitate the comparison, the sound of both at the same distance of the hearer start and stop being noticeable.

If, however, the shape of \log *to* 2 trifftig, the audibility by magnification is n increase more than by magnification of a .

If the form $\log a^2 n$ holds, which presupposes, however, no theoretical reason, the reverse would apply.

For the moment, I am unable to do this experiment with enough precision to make the necessary modifications, which may perhaps be possible in the future; if not meanwhile, as I wish, others have taken care of it. There is no doubt that more could be expected of it, if not for a circumstance which must greatly affect its decisive power. Its result would be simple and unambiguous if the earpiece were to take each n equally easily, ie corresponded to the amplitude of the external vibrations with proportional amplitude of the internal, but according to the facts communicated this is not the case; and the more n to the limits of audibility approaches, the more must at constant values of audibility decrease, even if the form \log *on* should be correct with respect to the inner movements, which is to examine the main interest. The question remains to what extent the changes in the audibility of different high notes with the same living force depend rather on the fact that the equality of the living force of the external vibrations does not transfer itself to the interior, or if the inwardly same living force contributes to it different n and a equal intensity of sensation heard. In the meantime, perhaps by combining the results of experiments 1) against the lower

limit, 2) against the upper limit of audibility, 3) a binding conclusion could be drawn about the middle between the two; especially since it is not improbable that the tension of the eardrum can be accommodated in such a way that the perception of tones of different heights is equally easy within certain limits.

If, however, the attempt to solve the problem by reason of an irresolvable complication of the conditions does not yield a sufficiently decisive result with regard to the main question which is inherent in internal psychophysics, it would nevertheless be useful to have established its composite result for external psychophysics.

Like after all the Maßausdruck *log on* or *log on*² prove to be the more cogent, he can be but based on available general experience only in the territory of the sounds, do not take the colors to complete. Because for color IS remark made 175 there after already Th Weber's law not just as as for pitches, so even the first condition of the form *log. On* or *lied to*² does not apply here; and there is a fact that the second does not apply either.

This, if I am not mistaken, first noted by Purkinje,¹⁰⁾ by Dove¹¹⁾, which in turn was self-constantly discovered and more closely followed, by

Grailich¹²⁾ occasionally stated by Helmholtz^{†)} The most sharply defined and formulated fact, according to which at dawn one recognizes the blue longer than the red, which makes a stronger impression during the day, is pronounced by the latter in the following sentences or laws. "Two colored sets of light, which appear equally bright at a certain absolute light intensity, generally cease to do so when the quantities of light are both doubled or halved, and in the first case the less breakable of the two colors, in the last case the more refractile the brighter become."

¹⁰⁾ Purkinje, N. Contrib. 109.

¹¹⁾ Reports of the Berl. Akad. 1852. 69 or Pogg. LXXXV. 397.

¹²⁾ Meeting. the Vienna. Acad. 1854. XIII. 251.

^{†)} Pogg. XCIV. 19th

Helmholtz says that the phenomena found by Dove were very well observed in my experiments on the homogeneous colors, and I let two colored amounts of light penetrate the gaps in the screen in such an amount that they immediately cast dark shadows Heliostats and the first cleft a single or multiple layer of a thin white tissue that retains some of the sunlight without altering the ratio of its various constituents, the shade of the less breakable color then appearing darker than that of the more breakable ones very small, as long as I took both colors from the less breakable half of the spectrum, red to green-blue, much more striking between those of the more breakable half, and the strongest, if you put Violet in one of the less breakable colors.
"

As we have probably done, this fact must not be treated as equivalent to the fact that a larger number of oscillations can compensate for a smaller amplitude of perceptibility; because while the latter sufficiently stated in tones that fact in the form of $\log on$ or $\log on^2$ into it occurs and is required by contradicts the fact contained in the Helmholtz theorem, which is stated up to now only in color, not with sounds, this form, as any shape which a same visibility to a same living force or the equality of a product as in^2 or $a^2 n^2 = a'^2 n'^2$, hence $an = a'n'$, then $2an = 2a'n'$ must remain; and therefore neither the logarithmic nor any function of $a^2 n^2$ or, as a measure of the intensity of the sensation, is compatible with Helmholtz's theorem. Corresponding to functions of an^2 or $a^2 n$. If, therefore, blue outweighs red at twilight, it ought, after such a form of measure expression, to prevail over even the greatest daylight; whereas Dove's experience and Helmholtz's theorem are the opposite.

If one examines whether, for example, the form $\log a \log n$ would be more suitable for giving Helmholtz's sentence as an inference, it turns out that one would rather drive worse with it; in that, if two magnitudes equal in magnitude $\log a \log n$ and $\log a' \log n'$ increase the amplitude a and a' in the same ratio, not only no equality of the intensities can remain, but contrary to Helmholtz's law Color with the larger vibration number must come in excess weight.

In fact, the intensities will $\log a \log n$ and $\log a' \log n'$ by multiplying the values of a and a' with the same values m into

$$\begin{aligned} & \log ma \log n \text{ and } \log ma' \log n' \\ &= (\log m + \log a) \log n \text{ and } (\log m + \log a') \log n \end{aligned}$$

according to which the value $\log a \log n$ increases by $\log m \log n$, the value $\log a' \log n'$ increases by $\log m \log n'$, and consequently the value with the larger oscillation number increases by more than the other.

So you can see the indisputably held in common the fact of colors and tones that smaller frequencies are demanding greater amplitude to be noticeable, but not to be confused with a community of Helmholtz's law for both, which is not set so that¹³⁾, and I think it is not improbable that Helmholtz's law is related to colors with so many other deviations, which represent the ratios of colors to those of tones, and which I will especially put together in chapter 33, and thus only for colors. not for sounds, in which respect, of course, direct experiments, in connection with the one suggested above, would still be very desirable.

¹³⁾ This is already Grailich in the session. d. Vienna, Akad. XIII. 1854. p. 253 attentive.

Incidentally, it is not to be overlooked that the experience result contained in Helmholtz's theorem is confirmed only in separate colors, and that it behaves differently when the colors are mixed into white light than what remains white, given

the strength of all its components weakens in the same proportion, as well as that the result does not become very clear even with separate colors, as long as both colors are taken from the less breakable half of the spectrum, proving that there is no relation valid for all values of n , Probably the anomaly that applies here for more refractive colors, ie high values of n shows, together with the other abnormality, which Helmholtz has noted that the colors refrangible preferably before less breakable at a modified starch at the same time change the shade 14); however, is not known; that higher tones are preferably subject to a lower dependence of the oscillation number on the amplitude. Finally the object remains to be clarified.

¹⁴⁾ Pogg. XCIV. 13th

After that, two very important questions remain.

First. It has been shown partly as certain, partly as probable, that the sensations of color do not depend in the same way on the frequencies of vibration as the sensations of sound, for otherwise Weber's law would likewise have to be confirmed for them. What can be the reason of the difference, after they actually depend on it? To this question I enter more closely in the 33rd chapter, in which, if nothing is absolutely certain; but many of the greatest likelihood about this object will be said.

Secondly. According to the earlier investigations on the strength and height of sound (Th. I. Chapter 9), the impression of both depends on the same law, that of magnitude on amplitude, on height on the number of vibrations, and afterwards it would appear that All conditions must be equated to the sensation of strength and height. But it is not like that. The scale of the heights carries a natural measure of the feeling which the scale of the strengths does not carry, and besides the impression of the progression in the ascending scale of the heights, we also have the impression of a periodicity as we ascend in the scale of strength do not have. Because every step of the way to an octave in the first scale tells us the feeling

The feeling for the octave is naturally related to the feel of the octave divisions. The scale of the strengths is infinite for the feeling, of which there are no finite proportions at all, whereas the finite interval of the octave delimited on the scale of the heights permits also finite proportions. Let us think of both scales as pillars that run to infinity. But on the pillar of the heights the feet are divided and afterwards we easily estimate the toll. Nothing is broken down on the Pillar of Strengths, and so we have no basis for estimating subdivisions.

From where does this difference between the scale of sensation of the strengths and heights of the tones with the same mathematical representation? with which one can immediately connect the question which enters into the previous question, from where does the difference which the tones in this respect offer of the colors, which after all depend on the number of vibrations, just as they do? For the colors offer nothing to the musical impression of the octave interval and its subdivisions analogous. Although the color spectrum by Violet at the breakable end seems to indicate a return to the red at the least breakable end, about which one may read more

in the 33rd chapter; but a sense of proportion of the intervals between red and violet is thus not in the least;

Does not show itself, one can ask, here an inadequacy of the theory?

In my opinion, not an insufficiency inasmuch as the previous theory is erroneous, but an incompleteness, as long as it still requires a supplement. Before attempting to give these, however, I want to communicate the ingenious graphic construction and exposition, whereby Drobisch has already lately reconstructed the course of progressive ascension together with the periodic return of the sound impressions as it traversed the scale of tones, a representation which one certainly can not do without Will find interest here¹⁵⁾.

¹⁵⁾ This construction is first in the derivation of Drobisch: "On the mathematical determination of musical intervals" in the treatises of the Jablonowski Society, 1846, p. 113, and later, only formally, somewhat differently, in his treatise: "About musical tone determination and temperature" in the Abhandl. d. Saxon Soc. d. Wiss., Math.-phys- Cl. Vol. II. 1855, p. 35. The above description is literal, only with the disregard of the, easily reconstructed, figures and their explanation, taken from the last source. Drobisch points to the conclusion of the above quotation on an earlier similar construction of Opelt, which is not known to me in the original, whereas he himself, according to the remark on p. 181, has attached his concept to Newton's circle of colors.

"If one thinks of the interval 1 of the octave with the fundamental tone as the

circumference of a circle whose  radius must therefore be 0.15915, all other intervals arc of this circle, whose corresponding center-point angles can be easily determined the angle corresponding to the interval $x = w$,

$$360^\circ : w = 1 : x ; \text{ so } w = x \cdot 360^\circ.$$

According to this, the following values of w result for the thirteen main intervals , to which we add under w' the values which correspond to the intervals of the keyboard instruments expressed by twelfths of the octave.

| | <u>w</u> | <u>w'</u> |
|-----------------|-----------------------|------------------------|
| 1) Prime | $0^\circ 0' 0''$ | |
| 2) small second | 33 31 30 | |
| 3) big second | 61 10 60 | |
| 4) minor third | 94 10 90 | |
| 5) major third | 115 53 120 | |
| 6) Quarters | 149 24 150 | |

- 7) excessive fourth 177 42 180
- 8) fifth 210 36 210
- 9) little sexes 244 7 240
- 10) great sorts 265 19 270
- 11) minor seventh 298 50 300
- 12) major Septime 326 29 330
- 13) Octave 360 0 360

"These values of w and w' with their corresponding arches represent figs. 1 and 2 (of the original). One can see in them the radius according to its different positions as the image corresponding to the position of the tone against the fundamental. .. Incidentally, here the designation of sixths and sevenths justifies vividly than the reverse thirds and seconds. after allowed to the radius after he described the entire circumference of the circle, turn back, so are the seconds and thirds, which he then from the Octave out, the sevenths and sixths of the root note, as well as the fourth described by this reverse rotation coincides with the fifth of the root note 16). "

¹⁶⁾ A passage in Newton's Optics (*Lib., I. Pars. II. Prop.* .

"This rotation of the half-knife, however, gives only an incomplete picture of the change which the note undergoes when it gradually passes from the fundamental tone to the octave, for the octave, despite its kinship with the fundamental tone, is a sound distinguishable from it indeed, although it is the fundamental tone in a higher position, but without providing any definite information, it is close enough to remark that, since the change of the tones is a gradual one, this higher position does not occur suddenly, first with the octave. can occur, but a steady transition must take place. "

"We obtain a completely sufficient explanation of this by giving the equation $y = 2^x$, which represents the relationship between the relative vibrational number y of a tone and its interval x with the fundamental tone, an appropriate geometric interpretation, namely, the values of x through Arc of a circle, the values of y can be represented by straight lines that are perpendicular to the plane of the circle in the endpoints of those arcs, which are obviously the values of y representing straight lines in the curved surface of a cylinder, which has that circle as its base, its end points in a logarithmic spiral winding around the cylinder. Since for $x = 0$, $y = 1$, the distance of the point corresponding to the fundamental tone of this spiral from the base of the cylinder = 1; and since for $x = 1$, $y = 2$, the distance of the point corresponding to the octave is twice as large. Any intermediate sound, for which $1 > x > 0$ and $2 > y > 1$, has its corresponding point in the spiral. Hereinafter, put x and y is the coordinates of a logarithmic spiral on the face of a straight cylinder, and y can be called the absolute height of the sound, x its deviation from the direction of the fundamental. "

"If $y - 1 = u$, then u expresses the relative height of the tone given by the relative vibration number y with respect to the height of its fundamental tone, or shorter the elevation of the tone above the fundamental tone, and so

$$u = 2^x - 1.$$

The values of u are represented by the distances of the points of the spiral from the plane of the circle which is laid parallel to the plane of the base by the point of the spiral which corresponds to the fundamental tone; or x and y are the coordinates of the spiral which refer to this base parallel section of the cylinder "

According to this illustration (explained by Fig. 3 and its exposure in the original), the image corresponding to the continuous succession of tones is not both the logarithmic spiral on the cylindrical surface, but rather the helical surface, which describes a radius of the cylinder when in the axis of the cylinder rises and at the same time revolves around it, and between elevation and rotation of the relation $u = 2^x - 1$, or what happens the same, $x = \log_2(1 + u)$. Sound sequence c, d, e, f, g, a, h , chappens, only a certain number of tones, with skipping of the intermediate ones, so the lines corresponding to them give the picture of a spiral staircase. The terms "scale" and "tone steps" are indeed very aptly chosen, if one thinks of the turn of the ladder at the same time "

"As far as I know, W. Opelt (On the Nature of Music, Plauen, and Leipzig, 1834, p. 43) first used the above cylindrical spiral to make the sound sequence more sensual, from the helical surface, which seems to complete the picture first. he does not use. "

As far as the representation of Drobisch, which is indisputably very suitable to give a vivid idea of the connection of the progressive and periodic element in the tone series.

Let us first show how, by choosing only other units, this construction is related to our previous measure-expressions.

Let $n' \beta \varepsilon$ the vibrational number of any fundamental tone, n that of another tone

considered against it, $\boxed{}$ = y its ratio, x the sensation of the difference between n and n' , ie the sensation of its interval, k our ordinary constant, then gives the difference formula

$$x = k \log \boxed{}.$$

Since an arbitrary value can be added to the k by the arbitrary choice of the unit of sensation, to which n' by arbitrary choice of the unit of time for which the oscillation number is determined, we provisionally take the circular construction $k = 2\pi$, where π is the Ludolf means number; Further, taking into account the fundamental importance which the oscillation ratio 2 has as a standard of comparison with all other oscillation ratios, the fundamental number of the oscillations n' and of the logarithmic system are at the same time given by this ratio



(which expression would still have to be divided by $\log 2$, if one wanted to use the usual instead of a logarithmic system with the basic number 2).

If we now represent the values of x , which correspond to given values of n , by arcs of a circle of radius 1, which are taken from a certain starting point, then 2π is the circumference of this circle and at the same time representative of the octave interval. Whenever n becomes a power of 2, that is, when the tone rises to a higher

octave; \log becomes $\frac{1}{2}$ an integer, hence x is a multiplier of 2π after an integer, ie equal to an integer number of cycles, or returns x in the construction to the output, which takes place when $n=2$, ie equal to the oscillation number of the fundamental tone. Let's put the oscillation ratio at the same time

$\frac{1}{2} = y$ by straight lines, which are perpendicular to the plane of the circle in the end points of the arc x , and so on, like Drobisch, we have completely its construction.

Also, the mathematical expressions underlying both sides can be easily reduced to each other. After Drobisch one has $y = 2^x$, thus



or, if, as Drobisch himself suggests for the application of the logarithms in the pitch domain, 2 is taken as the basic number of the logarithmic system and at the same time as the fundamental number of notes

$$x = \log \frac{1}{2}$$

according to which only the difference between Drobisch's and our formula remains, that the same constant k , which we set = 2π , is set by him = 1, which implies that in

him the radius of the circle = $\frac{1}{2}$, the circle = 1, in ours the radius = 1, the radius = 2π is set. Since the octave interval is represented by a circle circumference, it has the value 1 for Drobisch and the value 2π for us of which the first seems more appropriate inasmuch as the octave is the natural measure of the intervals of sound. On the contrary, since this is not a representation of numbers in terms of numbers, but of geometry, it has something in it to express the radius by 1 as usual, and the circumference by 2π ; Finally, the choice of units remains the same for the design.

By the way, after looking at our formula, it is easy to see that the course of the sound impressions can be represented more simply than by a spiral wound around a cylinder, by a plane spiral, if one uses the equation

$$x = 2 \pi \log \frac{1}{2}$$

is represented by polar coordinates, where x is regarded in particular as an angle, and

either $\log \frac{r}{x}$ or $\frac{r}{x}$ radius vector, of which the first gives an Archimedean spiral, the latter a logarithmic spiral. In either case the angle at which the radius vector forms against its starting position at $n = 2$ gives the measure of the perceived deviation from the fundamental tone or from any octave of the fundamental tone; first case (in the

case of Archimedean spiral) in the radius vector $\log \frac{r}{x}$ the measure of the perceived

height above the fundamental tone, if $x = 2 \pi \log \frac{r}{x}$ proportional to $\log \frac{r}{x}$ remains

second case (in the case of the logarithmic spiral) in the radius vector $\frac{r}{x}$ the measure of the real or objective height above the fundamental tone, if the relative ratio of the numbers of vibrations of the tone and fundamental tone concerned is so called. In both cases, as Drobisch prescribes, the radius vector can then be raised during its

rotation, and by the elevation at $\frac{r}{x}$ first the real height above the fundamental tone,

and secondarily by the elevation $\log \frac{r}{x}$ to represent the perceived height above the ground tone; so that both the perceived deviation from the fundamental tone, or an octave of it, at the same time, only in different form, are at once perceived as the perceived height above the fundamental tone, and the true height above it, which may be a small advantage of completeness. Through both constructions we obtain the spiral-leaf of a snail, through the first a relatively more elevated, finally ending in the snail's axis, and through the second one more asymptotically stretched with infinite turns of the axis.

Interestingly enough, a spiral leaf in a few turns is one of the most important parts of our auditory organ, the bearer of a part of the end of the auditory canal. One has even been inclined to keep the snail nerves preferably in front of the labyrinth nerves for the sensation of the pitch; but this does not rest on anything positive; and should a more accidental meaning be added to that encounter, the abalone would have to show just as many turns as we can hear octaves, which is not the case, if we do not suppose that the labyrinth nerve is the scale of the Schnek sounds continues. Anyway, there would be some interest in finding the exact shape of the spiral leaf of our abalone, and more, to be able to give teleological account of its form; but up to now there should be no prospect, and that does not concern us here too much.

The above, after all, is only a little essential transformation of the original representation of Drobisch, for which there is no weight, and which is cited here only in so far as it has, of itself, presented itself as the most natural expression of justification of the circumstances presented which I come now.

First of all, one must not overlook the fact that all these constructions are only empirical, which faithfully represent the experiential conditions without, however, teaching us something of the basis of the circumstances presented. A higher or lower

octave is of paramount importance when a number of oscillations is doubled or halved, hence the number 2 is introduced as a fundamental constant in the formulas on which these constructions rest. But why could not $3, 4, \sqrt{2}$ or any irrational number, this constant, according to which then, instead of the octave, some other interval would have the decisive meaning, which in reality has the octave. The sound impression in a sense returns to the starting point of each octave, hence the circular function $2\pi i\sigma$ introduced into our formula as a second fundamental constant and represented by polar coordinates of ours; but what reason in the nature of the matter brings with it? From the formula based on Weber's Law



starting; For k , we could just as well substitute any value other than 2π , and instead of using polar coordinates just as well use rectangular coordinates to represent the

size relation between x and \log , where we would then obtain a usual logarithmic curve, but no spiral Expression of periodicity would be omitted. Furthermore, why does the periodic element concern only height, not strength, why does it appear decidedly only in the domain of tones, not of colors? For all this, the construction gives us no answer, but rather demands the answer.

It surprised me a little, what seems to me to be an answer to, to receive unsought as I was looking for something else, but related, namely, only went out the common dependence of the tone impression of vibration and amplitude, which according to the The above discussions, as called for by experience, seem to be found by deduction from elementary presuppositions, without thinking that the dependence of the periodic octave impression might be in solidarity with it, as has been shown; a result, which I consider important from the fourfold point of view, as the entirety of the measure expression for the tone impression thereby the stamp of the validity is expressed, as the profound principle of elementary derivation, by which this result was found, Proved to be a psychophysical riddle with it, and as a reason to be presented by other, future (Chapter 33) already probable, but only likely to be made, view of the simplicity of the vibrational motions that are inwardly subject to our hearing, and thereby lessening the simplicity of those who are subject to seeing, thereby preparing the inner psychophysics in a certain direction. Only under the condition that the sound stimulus triggers the simplest possible form of vibration in our sensitive hearing aid does the following explanation arise. View of the simplicity of the vibrational motions that are inwardly subject to our hearing, and of the lessening simplicity of those who are subject to seeing, thereby supporting the inner psychophysics in a certain direction. Only under the condition that the sound stimulus triggers the simplest possible form of vibration in our sensitive hearing aid does the following explanation arise. View of the simplicity of the vibrational motions that are inwardly subject to our hearing, and of the lessening simplicity of those who are subject to seeing, thereby supporting the inner psychophysics in a certain direction. Only under the condition that the sound stimulus triggers the simplest

possible form of vibration in our sensitive hearing aid does the following explanation arise.

This subject will be dealt with in more detail in Chapter 32; But I raise from the somewhat extensive discussions which the more general version of the task will make necessary there, anticipating and summing up that which pertains especially to our present question.

In the 32nd chapter it will be shown that the measure of the overall impression of the strength and height of a tone of the form $\log on$ or $\log to^2$, between which, after the above discussion, is still the choice, can be found by summing the measures of elementary sensory contributions. which are generated by the individual moments of vibration, when each elementary sensation contribution from either taking place at that moment speed (which is the form of $\log to$ exist) or speed variation (which $\log at^2$ there) depending thinks than the whole sensation in the same manner depends on the whole amplitude and oscillation number.

In this derivation, not only that which in the dimensional expression for the tone depends on the magnitude of the amplitude and what depends on the magnitude of the oscillation period, but also finds in the measure expression a value which is independent of the magnitude of the amplitude and size of the oscillation period merely dependent on the periodic recurrence of the same oscillation period, and for simple vibrations of each amplitude and each oscillation period remains the same, in the forms of Maßausdruckes $\log on$ or $\log on^2$ but why not come to light because he, his constant Naturally, in the constant 1 set constant k and $a_1 n_1$ or $a_1 n_1^2$ of these forms¹⁷⁾ with, as can be seen from the following derivation. This value is a function of both fundamental constants 2 and π , of which the importance of the octave interval dependent, namely it is without regard to arbitrary determination of the units, and the constant k , likewise by two conditions, between which is still the

choice absolutely by optionally , which corresponds to the above values of x for an oscillation number n set equal to the unitand can be regarded as the pure expression of the periodic element of the pitch sensation, which depends on the periodicity of the movement. It arises exclusively from the summation of a periodic function, in which the period of oscillation or oscillation number, not the amplitude, can therefore be related only to the first (ie pitch), not the last, but, as you can see, not even the duration of oscillation; this and the amplitude enter from another side in the Maßausdruck the entire tone impression.

¹⁷⁾ Recall that their evolved value is actually $k \log \square$ or $k \log \square$.

The course of the calculation, by which this result turns out, led on the assumption that the sensory contributions depend on the speed of the vibration in every moment,

is in brief. In the 32nd chapter, the calculation for this assumption will be executed a little more, partly also for the other condition (dependence on the speed change).

In a simple rectilinear oscillation of the amplitude a , oscillation duration τ or thus

reciprocal oscillation number $n = \frac{1}{\tau}$ the velocity v at the time t , this calculated from the maximum of the deviation, is known to be¹⁸⁾

$$\boxed{\quad}$$

where π is the Ludolfian number, or the half circle periphery, the radius = 1. By making the sensory contribution in each moment dt of the velocity v , or what essentially emerges from the logarithmic form of the expression, dependent on living force v^2 , it becomes through

$$k \log \boxed{\quad} dt \text{ or } k \log \boxed{\quad} dt$$

given what the first term might be based on, considering that $\boxed{\quad}$ always is to be taken as positive. Here **b** is the value of v , at which the sensory contribution comes to the threshold (the elementary threshold), and k is the ordinary constant. Hereinafter, the sensation sum $S \tau$, which is generated during the duration of a vibration, given by

$$\boxed{\quad}$$

¹⁸⁾ For example, see B. Herschel on the light §. 569 with regard to the value $\boxed{\quad}$.

Since the unit of velocity is arbitrary, we set the value $\boxed{\quad} = 1$ (to express in simple terms the expressions that matter here), decompose the logarithm of the product into

a sum of logarithms, and substitute n for $\boxed{\quad}$ which we receive the sum of the following three terms:

$$\boxed{\quad}$$

of which the first represents that of the amplitude, the second that of the oscillation number or oscillation period, the third that of the periodicity of the oscillation

dependent part of the measure expression. If you set the phase $\boxed{\quad}$, the last link goes in



But the definite integral $\boxed{\quad}$, which represents the part of the measure expression, which is purely dependent on the periodicity and independent of the magnitude of the period of oscillation, multiplied by the constant factor $\boxed{\quad}$, is



after which the whole Maßausdruck for the sensation sum $S \tau$ during one oscillation from the time τ is



If one divides this expression by τ , whereby one obtains the intensity of the sensation instead of the sensation sum, and sets $k = 2 \pi$, one obtains as measure of the intensity



or, if $k = 1$ and $b = \pi$ are used in the derivation, the simplest expression

\log on .



How to $\log k \boxed{\quad}$ is given in chapter 32.

The second presupposition that the sensation depends on the change of velocity (second-order velocity) leads, after a corresponding course, to the same expression



$2 \pi \log \boxed{\quad}$ for the periodic element, in particular, as the previous presupposition, and gives as definite value for the whole measure expression



which can be obtained by setting $b = 8 \pi^2 a$ and $k = \pi$ in

$2 \pi \log \boxed{\quad}$

can transform, according to which the same construction can be linked as after the previous assumption.

XXXI. Generalization of the measure principle of sensation. ¹⁾

The measure-formula, difference-formula, and difference-measure-formula, which have served us to the measure of sensation, sensory differences, and perceived differences, are based upon Weber's law and the fact of threshold (threshold and threshold of difference), and remain true as long as this law and these The fact remains true.

¹⁾ Psych. Maßprinzipien p. 179 ff.

In the meantime we must acknowledge that Weber's Law, albeit probably of unlimited universality and validity in relation to the inner psychophysical movements, is valid in its relation to the external stimulus only in the limits of medium excitability, and many disorders and complications, even losing its validity under certain conditions.

From this point of view the assertion and utilization of an earlier remark is important, that only those formulas, but not the principle of our measure, base their validity on the validity of Weber's law, but on the same principle only as well with other formulas a measure of sensations, sensory differences, and perceived differences can be obtained, in that the essential on which our principle is based in its full universality is only the possibility of establishing the equality of small changes, increases in sensation for given stimulus increases in different parts of the stimulus scale for which not only one, but three good methods are available to us. By constant from Zuwüchsen the whole sensation $d\gamma$ from zero, which are determined as a function of associated stimulation increments $d\beta$ in the different parts of the stimulus scale, we obtain the measure value of the whole sensation γ by summing its gains from zero to the value γ , which corresponds to a given stimulus β , more generally, the difference $\gamma - \gamma'$ of two sensations γ, γ' , which correspond to the stimuli β, β' , as the sum of the increments falling in the corresponding interval. The details are as follows:

Suppose we have found that the same only distinct difference is sensed if we take the stimulus, which is generally β , from the size β' an to $d\beta'$, from the size β'' to $d\beta''$ u. s. f. Let $d\beta', d\beta''$ denote very small, after the place of the stimulus scale in which the observation happens, ie the change of stimulus variable according to the size of β ;

$$\mathbf{F}(\beta)d\beta = c$$

where \mathbf{F} denotes an initially unknown function and c denotes a constant, and determine the function \mathbf{F} such that when the related values β' and $d\beta'$, β'' and $d\beta''$ usf in $\mathbf{F}(\beta)d\beta \alpha\rho\varepsilon$ substituted that a constant value c is actually obtained everywhere, on whose absolute value depends on the

choice of arbitrary units. In the case of Wber's law, the equation will suffice if β maintains a constant relationship to $d \beta$, therefore



to be taken, ie to take $F(\beta) = \boxed{\quad}$, where K is an arbitrary constant. If, with increasing stimulus β , the stimulus difference $d \beta$, which is necessary to give an equally noticeable difference, would be in inverse rather than direct relation to β , then $F(\beta)$ would be $K \beta$. If, in all parts of the stimulus scale, there were an equally large difference in stimulus $d \beta$ of the same feature, then $F(\beta)$ would merely refer to K to reduce. These three exemplary cases thus correspond to the three equations:



$$\begin{aligned} K \beta d \beta &= c \\ K d \beta &= c. \end{aligned}$$

But it may also be the case now that there are no so simple or unique for the whole stimulus scale relationship between $d \beta$ and β is a constant value. Then it is always possible, by means of one of the known interpolation formulas $F(\beta)$, for each given part of the stimulus scale for which the measure is sought, to find the mutually corresponding values β' and $d \beta' \beta''$ found in this part by observation. and $d \beta'$, etc. so as to determine; that condition

$$F(\beta) d \beta$$

is equal to a constant is enough.

What can be observed as a constant value on the side of sensation is, strictly speaking, not a true sensation difference, but perceived difference, if we adhere to the distinction between sensory differences in the narrower sense and perceived differences introduced since Chapter 22. But insofar as the sensation differences are understood only as the special case among the perceived differences that the sensitivity would be a perfect, we can at the same values of β and $d \beta$, where the perceived difference is constant, also view the associated sensation difference to be constant, so the equation $F(\beta) d \beta = c$ in solidarity for small sensory differences and perceived differences, and replace $d \gamma$ as a small sensory difference for c in previous equations. This solidarity may not be entirely *a priori* quite evident, but its condition is that which makes the measure possible on the one hand and the experiential results on the other.

If you have now the equation in such a form

$$d \gamma = F(\beta) d \beta$$

with the determination of $F(\beta)$, it will be considered as a differential equation and integrated as such; by understanding a very small constant sensation difference under $d\gamma$, under $d\beta$ a very small with β variable stimulus difference. Thus one obtains the finite difference of two sensations γ, γ' , which belong to two values β, β' , under the following form

$$\boxed{\text{[]}}$$

and the sensation γ alone under the mold

$$\boxed{\text{[]}}$$

if b is the stimulus value at which the sensation becomes zero, which value generally speaking could be zero or have a finite value of which the latter is valid in experience.

The three formulas given above, for example, give the following result:

$$\boxed{\text{[]}} \quad \text{where } k = \boxed{\text{[]}}$$

$$\gamma = k(\beta^2 - b^2), \text{ where } k = \boxed{\text{[]}}$$

$$\gamma = k(\beta - b), \text{ where } k = K.$$

In order to ascend from the sensory difference to the perceived difference, one will then have to follow the same course, which (chapter 24) on the functional form

$$\boxed{\text{[]}}$$

has been explained, without this will require further execution.

It can be seen from the foregoing that Weber's law is in fact not an essential condition for the principle of the measure of sensation; only the most important applications of this measure will always have to be based on this law.

Taking the above into account, the foundation of our measure should be assured by a turn of two pages in full generality. If we are to be objected to, the fundamental formula based on Weber's law, upon which we based our measure of sensation from the beginning, is not strict everywhere, and in some cases not at all, if we refer to the external stimulus, we reply that they are true in wide limits of the experiment, and especially in those in which the sensations are on average; and that it would indisputably be necessary to refer them, instead of to stimuli, to the psychophysical movements that are triggered thereby, in order to always find them exactly correct. And if we are persuaded that we get into the field of hypothesis, we reply,

Some examples may serve to highlight this more specifically.

In the field of the sensation of light, the validity of Weber's law has a lower limit, which we have written on the fact that the sensation of light does not merely depend

on the external light-stimulus β , but apart from that already consists of the constant sensation of the black-eye, which can thus be regarded; as if it were produced by an inner light stimulus, which forms the equivalent of a small quantity of external light stimulus. However, regardless of this mode of thinking and assertion of Weber's Law, we will find the facts met when we set

$$\boxed{a}$$

where a means a constant quantity to be added to the external light stimuli. By integrating this value, we get as sensation difference

$$\boxed{a + \int \beta dt}$$

and with such large values of β , β' that a noticeably disappears

$$\boxed{\int \beta dt}$$

Another example:

I have given Th. IS 205 that, according to my experiments, the sensitivity to temperature differences against the freezing cold back in without comparison more rapid ratios decreases as corresponding to the Weber's law, and that for lower temperatures t the just noticeable in Reaumur'schen degrees Temperature difference D obtained by multiplying $(14.77 - t)^3$ by 0.002734 or by dividing it by 365,7. The values calculated according to this condition are given (see chapter 32) in combination with the observed values.

Now I am by no means inclined to the formula

$$D = (14.77 - t)^3 \cdot 0.002734$$

for more than one, within certain limits of temperature, and perhaps for the particular individuality of the observer and the attempts to hold approximately empirical empirical. But the better it can serve us to show that we are in fact not bound by the principle of our measure to any general legal relation between stimulus and sensation. It represents, in any case, the course of the sensation of temperature in my experiments.

The value D here represents the value $d\beta$ and t the value β . So, by putting short, we have $14.77 = T$

$$d\beta = (T - \beta)^3 \cdot 0.002734.$$

therefore

$$0.002734 = \boxed{\frac{1}{(T - \beta)^3}}$$

and, since 0.002734 is constant, general

That we here $d\gamma$ introduce a negative sign depends on that the nature of the case, depending on growth of β increases the sensation or decreases, $d\gamma$ with the same or opposite sign as $d\beta$ is to be introduced. Insofar as we are concerned here with sensations of coldness in which the latter holds, a negative $d\gamma \mu\nu\sigma\tau\alpha\lambda\sigma\omega\beta\varepsilon$ associated with a positive $d\beta$. If we now integrate the previous equation from $\beta = t'$ to $\beta = t$, we obtain the corresponding sensation difference

It may now be remarked that if one wanted to take t or $t' = T$, $\gamma - \gamma'$ would assume a positive or negative infinite value; which is connected with the fact that in the transition between the sensations of heat and cold, which is indisputably to be assumed in T , the discontinuity of the function which gives it its measure must occur. In addition, the empirical validity of the formula does not extend to the value of $t = T$. In the limits, however, where they are considered valid, one can solve them by means of the same tasks as follows: At 5° the sensation of coldness is less than at 0° , and the difference between the two sensations is of a certain magnitude. Of course, the difference is greater between the sensations at 0° and 10° . The formula gives the ratio of these two or any other such differences. Here is a table on the relative size of these differences, reduced to the perceived difference between 0° and $1^\circ R$ as a unit.

| Sensation differences $\gamma - \gamma'$ | between the temperatures |
|---|--------------------------|
| 1 | 0° and 1° |
| 2.24 | $0 - 2$ |
| 3.82 | $0 - 3$ |
| 5.85 | $0 - 4$ |
| 8.55 | $0 - 5$ |
| 12.26 | $0 - 6$ |
| 17,36 | $0 - 7$ |
| 24,99 | $0 - 8$ |
| 36,90 | $0 - 9$ |
| 57.06 | $0 - 10$ |

After this is z. For example, the difference in temperature sensation from 0° to 10° ($= 57.06$) between 6 and 7maI is as large as between 0° and 5° (where it is 8.55), and the difference between 5° and 10° ($= 57.06-8.55$) to the difference between 0° and 5° such as 48.51 to 8.55, or over 5 times as large. If one takes the differences of the successive values of $\gamma - \gamma'$, one obtains the sensory differences for the successive temperature intervals of 1° each as follows:

| Sensation differences $\gamma - \gamma'$ | between the temperatures |
|---|--------------------------|
| 1 | 0° and 1° |
| 1.24 | 1 - 2 |
| 1.58 | 2 - 3 |
| 2.03 | 3 - 4 |
| 2.70 | 4 - 5 |
| 3.71 | 5 - 6 |
| 5.10 | 6 - 7 |
| 7.63 | 7 - 8 |
| 11.91 | 8 - 9 |
| 20.56 | 9 - 10 |

Thus, the temperature difference between 9 and 10° R is felt to be more than 20 times greater than between 0° and 1° R, provided that the law really remains valid until 0° , although it has not been pursued so far by experiments. And thus, the increase in the sensation of cold against the frost point slows down extremely.

Incidentally, this is already obvious from the test table itself. For if, according to her, a difference of 2° , 8 is required at 4° , 6°, in order to be as noticeable as, for example, If, for example, at 9° , 15R is a difference 0.48, then one must proceed at 4° , 6, 2°, 8 (the temperature 4°, 6 being thought to be in the middle of the step) to sensation to obtain a temperature change of the same magnitude as when proceeding at 9° , 15°, 48°. However, the magnitude of this necessary progress is not to be regarded as a measure of the sensation of temperature change, since there is no simple proportionality with it, but only a functional relationship expressed by the above formula.

Volkmann has convinced himself by experiments that the sensitivity of the skin to distances caused by cold is greatly weakened. Now it is interesting to see that cold, so to speak, weakens the sensitivity for itself.

XXXII. The oscillatory stimuli in general.

Attempt of an elementary construction of the measure of sensation.

a) Preliminary discussion.

The most important sensory stimuli, the stimulus of light and sound, are of an oscillatory nature, and, as they rest on oscillations, they indisputably excite oscillatory processes in us whose amplitude and period are related to that of the external oscillations. This gives the consideration of this kind stimuli a special importance.

Light and sound stimulus are considered to be constant, as long as the oscillation number n or thus reciprocal oscillation time τ and the amplitude a of the underlying

vibrations, hence the product $n^2 a^2$ or \square , di the living force of the vibrations through which we the physical Intensity of light, sound, measured, constant. Also, according to the experiences on which our formulas of psychic measure are based, we introduce these stimuli as constant as long as the constancy of n and a is constant. But it wonders if the values n and a the last are where we can go back and have to go back to represent the fundamental dependence of psychic on physical values.

The velocity and thus living force of a vibration is not really constant during its duration, but grows from zero at the limits of the oscillation to the maximum when passing through the equilibrium position. Likewise, the changes in velocity in successive equal time periods are not the same during the duration of the oscillation; but passing through the equilibrium position, the change in speed is currently zero, and a maximum at the limits of the oscillation.

To go back to the elemental, we would have to think that every moment of the vibration gives its elementary contribution to the whole sensation, which can only be distinguished from itself, and that the finite magnitude of sensation resulting therefrom in finite time is the sum of all elementary contributions to represent; more generally, that the quantity of each sensation, the quality of which is linked to a certain form of motion, is to be found by summation of the quantitative according to a general principle, which the moments of motion entering into this form contribute, no matter what form the whole movement and sensation has, how the volume and weight of an entire house can be determined as the sum of what all the individual stones contribute to, regardless of the shape of the whole house.

Whether such a view is valid and useful seems *a priori* to me certainly can neither be asserted nor refuted; but one must try with it, see what comes out of it, and tie the decision to the two points, first, whether we also, through the propositional summation of the elementary, maintain the same dependence of the whole sensation

extending through a finite time from that through this time Secondly, whether we gain something we do not gain by remaining with the empirical laws and facts which directly affect the sensations and movements in finite time that is, whether we are better guided by the facts, learn more of their interrelations, gain a source of new derivatives;

In spite of the still great deficiency of the following investigation, I believe that both the affirmation and usefulness of this decline can already be answered in the affirmative. It turns out that a very simple, functional relationship can be established between the elementary determinations of vibration and elementary contributions to the senses, which by summation leads back to the result of experience for the whole vibration and a whole series of vibrations Both Weber's law for strength and height, and the compensability of power for height, and vice versa for the perceptibility of sound, as the fundamental importance of the octave interval, are partly explained in the 9th and 30th chapters are, *on* or \log_2 (depending on the choice between two conditions, between which is yet to decide) for the dependence of Toneindruckes of thickness or height, and the form $2 \pi \log_2^1$ for the meaning of the octave interval. Also, it has already been shown (Chapter 30) in an outline shortly how this will happen. But if a direct correspondence of the results of the calculation with the experience in this respect takes place only in tones, not in colors, then this is not a contradiction to the validity of the principle of calculation, except by other reasons to be discussed in the following chapter, which suggest that only the Sounds, not the colors are attached to such simple conditions, as here subjected to the bill. The different ratio of the two sensations to the results of the calculation itself makes such an interpretation in itself very well possible.

But now we are not reduced to experiential results merely by this elementary construction, but at the same time we continue to be guided by it. Experience tells us nothing about the cause of the combination of strength, height, and periodic elements in the scale of sound impressions, and leaves us still some doubts about their connection; our elementary construction shows their common dependence on the fundamental relations of the vibration and demands a certain form of their connection. However, in this case, if we find the elementary construction satisfactory on one side and on the other side conducive to it, we are at the same time giving an example of the fact that something can be gained with it at all, and can expect to see it also in cases, where it is no longer about simple vibrations or vibrations at all, to find usable, thus establishing a common bond for all psychophysical movements. For although in outer psychophysics we can at first only keep to the stimulus, what we find in our present way will ultimately be related to the psychophysical movement triggered by the stimulus, and even to the external stimulus only insofar as it finds its pure application insofar as corresponding conditions for it and the movement thereby induced can be presupposed.

It is undisputed that we have a similar case here, as in physics. So long as we can not derive the phenomena from the elemental, we retain special laws for particular phenomena; the farther we are able to go back to the elementary, the more special

laws combine as special cases under general laws, which determine success for any combination of the elemental.

Meanwhile, we are not hitting the success that has been achieved so far. I must acknowledge that a satisfactory treatment of the problem has so far been achieved only to a very limited extent, and that the attempt to find a more general solution to it encounters difficulties which would require more in-depth investigations than are available here, and for what purpose, as far as I can tell, the funds are available so far.

Before going into the detail of the following investigation, the principle and course of it will generally be explained.

b) General course of the investigation.

In terms of experience, the height and strength of the sound and the overall impression dependent on it, what we call intensity, are a function of the amplitude and the number of oscillations or the duration of the oscillation. But these are, as has been remembered, for all the vibrations. Now if the task is set to produce the measure expression of the sensation by summation of what the individual moments of the oscillation contribute, we must ask what changes in each individual moment of the oscillation, if the amplitude or oscillation number or both changes; and must make the elementary contribution to the sensation dependent on this. Should we now find something in the individual moments, which is in direct proportion with the amplitude a and the oscillation number n or a potency of these values, of which the sensation depends on one and the same law, we must also make the elementary contribution to the senses dependent on it, because only under this presupposition, by summing up the elementary contributions to the senses, can the result be experienced for the whole Sensation can be found again.

What we can think of here is the first-order velocity v or the second-order velocity \mathbf{v} , both distinguished according to the following interpolation, of which, according to the formulas given under d), the first is the same for each oscillation by a certain phase of the oscillation referred torque in simple proportions to both the amplitude and the oscillation number, the latter in simple proportions to the amplitude, in the square to the number of oscillations.

Under speed of first order or velocity par excellence, always following v , I understand the well-known concept of proportion between the size of the space, which is traversed in any motion, and the time used, that is, the speed in the ordinary sense, which is constant. if at the same time, taken arbitrarily large or small, the same spaces are always passed through, changeable, if not, of which the former is uniform. The latter takes place in the non-uniform movement.

By second-order velocity, to be denoted by \mathbf{v} , I understand the concept of ratio between the change of the first-order velocity in terms of the direction of force and the time in which this change takes place, which is the measure of the accelerating force in terms of physics and mechanics. and as constant, as long as the velocity in the direction of the direction of force arbitrarily large or small taken in the same time by the same amount grows or decreases, as changeable, if it is not the case, of which

the former in the uniformly accelerated or delayed, the latter in the Non-uniform accelerated or delayed movement takes place.

*In order to avoid any ambiguity about the relation of the terms used here, I quote the following passage from Poisson's *Traité de Mécanique*. TI p. XIII. (Table de Matières) or p. 268 (of the text) to: »Source que soit la Variation de vitesse d'un point matériel, en grandeur et en direction, pendant un temps infinitésimement petit, il ya toujours une certaine direction pour la source l'augmentation de vitesse est la plus grande , et perpendiculairement à la source les composantes de la vitesse ne sont augmentées ni diminuées. Cette direction est celle suivant la direction of the force qui agit sur un point matériel en mouvement; en partant de cette définition, on démontre que l'accroissement de la composante de la vitesse suivant une direction quelconque, pendant un instant, est uniquement du à la force qui agit suivant cette direction, et le même, que si les autres forces n'existaient pas. «*

If the change in first-order velocity, without reference to the direction of force sharply defined in this definition, should be in the measure of the accelerating force or of our first-order velocity, it would have to be set to zero for the circular or circular motion, since the velocity v here, in absolute terms, remains constant. But \mathbf{v} This is not zero after our identification with the measure of the accelerating force, but constant, in that the motive body is accelerated by the force to the center of motion at every moment so much that the centrifugal motion (dependent on a decomposition of the tangential motion) compensates for it which would otherwise take him away from the center of the movement.

Now, according to the following investigation, it turns out that, if we take the assumption of a dependence of the elemental working-order of v or \mathbf{v} on Weber's law for the dependence of the height as strength of the sensation of oscillation number and amplitude, as the periodic Element in the tone scale is found again, so that there is nothing to distinguish from here. But, however, the dependence of v to a Maßausdrucke the intensity of the sensation of the form $\log on = \log a + \log n$ performs, performs the function of v to a Maßausdrucke of the form $\log at^2 = \log a + 2\log n$. Now, in the Thirtieth Chapter, we have taken the first measure expression as that which is more probable because of its greater simplicity and simpler dependence on the living force; and this should be done here too, and accordingly the first condition for the following should be accepted. If, nevertheless, the second assumption proves to be more conclusive, which would undoubtedly be decidable, if not by simple experiments such as the one (chapter 30), but which can be decidable through a combination of experiences ¹⁾, then the course of this would be After all, the first one can easily be transferred to the other, and this will itself happen here for the first and most important of the cases to be treated here.

¹⁾ That I have the in Ch. I have already taken back in 16 chap. 30 noticed.

Let $\mathbf{F}(v)$ be the function of v , which expresses the dependence between the psychic intensity and the velocity v in each moment.

If v remained constant during time t , then $\mathbf{F}(v)$ and thus the psychic intensity would remain constant during this time, and the sum of sensations during this time would remain constant by $\mathbf{F}(v)$. t be given. Alone v and therefore $\mathbf{F}(v)$ changes from moment to moment during an oscillation and can only be regarded as uniform during an infinitely small time element dt in which the infinitely small time sum or elementary sensation contribution is $\mathbf{F}(v) \cdot dt$. We now summing these size-variable contributions, which have had during an entire oscillation instead, as we v for every moment of the vibration with his demgemäß size, so as a function of t , to determine the sensation contribution $\mathbf{F}(v) \cdot dt$ applied, we obtain the time sum of sensation throughout the vibration di extent to the perceived effect of the whole vibration during its duration, and the vibrations of the same nature in the period $t m$ repeat times, the total time is during the time t the m -fold the previous one. In order to obtain the mean intensity of the sensation during the time t , we have then to divide this sum merely by t , or, insofar as t should enter into the sum of sensations as a factor, as will be shown, to delete this factor.

The form of the function $\mathbf{F}(v)$ is given by the fact that the dependence of the strength on the height of the sensation γ has the expression



let it be that under β we understand the amplitude or oscillation number of the whole oscillation with associated threshold values b . Is now the elementary sensation contribution equally from v than the corresponding to the whole vibration sensation from the extension v proportional β depend, we have v for β and a to v corresponding threshold b hot for b in previous formula to substitute²⁾, and to multiply this expression by dt to obtain the infinitesimal sum of sensation during the time element dt , to obtain the elementary sensory contribution, the measure of which will be hereafter

$$\gamma dt = k \log \boxed{\quad} dt$$

Here γ denotes the intensity of the sensory contribution during the time element dt , v the velocity during this time element, b the threshold value of this velocity, ie the value of v at which the sensory contribution enters the threshold, k the usual constant.

²⁾ In Chap. 16, the letter b was retained for this.

This formula is called the elementary formula and the value b is the elementary threshold.

The concept of the elementary **threshold** b can not be linked to the fact that, if the velocity v momentarily rises above the value b , the sensation which we find attached to the whole vibration arises momentarily, but that only a contribution to the

formation of this sensation arises which is to be considered more positive in the construction of the measure expression for the intensity of the whole sensation, while the contributions which are denoted by v below b are to be supplied as negative, as will soon be considered. In essence, therefore, one will only have to see in it a mathematical auxiliary which is necessary to introduce the relation between the elemental and the whole, and which will eventually be eliminated, as will be seen. If one wants to tie more than this abstract meaning to it, then one should see in it a value of v , which, as it is transgressed, gives a positive determination of consciousness, which, however, can very well enter into general consciousness without being considered special. To assert sensation if the transgression does not reach a certain size; how, indeed, will it become clear that a certain amount of transgression is necessary for this.

Perhaps the principle according to which the function valid for the whole sensation is transferred to the elemental contribution is not quite evident. Nor is it necessary to seek evidence in this regard; you can put it this way. At any rate, that transference presents itself as the one which first deserves to be tested; since, according to the following analysis, it leads back to the experiential results, one must stand by her; how, in fact, the basic principle of the whole course set here is to make those assumptions which are necessary to reproduce the experiential results, and in this respect to examine the most simple and natural assumptions before all others.

The first order velocity changes its sign with the direction of the oscillation, and the second order speed, as it relates to an increase or decrease in first order velocity in a given direction. According to this, the following signs for the first-order velocity v and the second-order velocity v take place in the four main divisions of a rectilinear oscillation :

| phase | v | v |
|-------------------------|-----|-----|
| $0^\circ - 90^\circ$ | + | + |
| $90^\circ - 180^\circ$ | + | - |
| $180^\circ - 270^\circ$ | - | - |
| $270^\circ - 360^\circ$ | - | + |

Now we have no reason to attribute to the vibration in the divisions with opposite signs of v or v different effects on the sensation, and this compels us, the sign of v or v , to introduce some value into the elementary formula than to assume

indifferently, that is, if we stop at v , to understand the expression $k \log \boxed{}$, or to put it so that it retains the same value for every sign of v .

We achieve this either by the fact that we b always with v can also change the sign, $\boxed{}$ which then $\boxed{}$ retains the same positive value, may v be positive or negative, or that

in consideration that it is immaterial whether we write k or $2k$ for the first constant, the form $\boxed{\quad}$ as a mere transformation of the form $\boxed{\quad}$

consider as actually valid, in which case the value under the logarithmic sign remains as actually quadratic in any case positive. Since, in any case, we have attached the measure of the whole sensation to the logarithm of the living force rather than the velocity, this conception is only consistent with the earlier ones. It will, however, be

immaterial whether we wish to adhere to the first or second conception; if we only keep positive in every case, v may somehow change its sign.

It would prevent nothing in itself to go back in the preparation of the elementary formula instead of to the measurement formula, to the fundamental formula by instead of in the time element dt taking place from v dependent sensation contribution of propagation velocity v would prefer dependent proliferation of such contribution into account; but only to be reduced back to the already established elementary formula by the integration of

Regarding γ just the formula $\boxed{\quad}$ reproduces.

The nature of the case remains in simple linear vibration v needed during part of the vibration below the threshold b , because the speed lifts in each linear vibration during round Herganges twice of zero and must be only up to certain limits increased to reach the value b . So long as b has not yet been reached, and hence $v < b$, the

whole value $k \log \boxed{\quad} dt$ and thus the elementary sensory contribution negative. Each such oscillation thus includes positive contributions which are at the same time negative, or may itself consist entirely of such if, because of too small a or n , the elementary **threshold b** is not reached even at the maximum of v , i.e. when passing through the equilibrium position. Since, in the following, an oscillation will often be referred to, in which a , τ , n are such that in Maximo the elementary **threshold b is** only given by v reached, then such a vibration should be given the name of the fundamental, and the amplitude, duration and frequency of vibration thereof, as basic thresholds, respectively referred to

as α , ϑ , v . Thus, as $\boxed{\quad}$ or in excess of the value $\boxed{\quad}$ or αv , a positive contribution to the sensibility begins, according to this definition, by exceeding the

elementary threshold b , without it being remarkably sufficient to show the characteristic sensation attached to the oscillation, for which, according to the result

following analysis of the value $\boxed{}$ or a only higher in a certain assignable relations

value as $\boxed{}$ or $a \nu$ must attain. The values of a, τ, n , which must be attained in order that the characteristic sensation may step to the threshold in the usual earlier sense, where we have not yet gone back to the elementary, shall be treated as before with a_1, τ_1, n_1 and this threshold sensation threshold (or tone threshold, light threshold, depending on the sensory areas) are called.

Now the important question arises as to how to offset the negative contributions in connection with the positive ones. Here a distinction is necessary. According to the principle established by Th. II, p. 61, the positive or conscious sensations which arise by exceeding the threshold of sensation in a certain time can not be compensated for by the negative, unconscious, which arise in another time, and if both are equal a great amount of time, no zero state of sensation being produced thereby. Thus, for a certain time, the sum of sensations should not be drawn by the algebraic summation of the positive and negative sensations that took place during this time, but the positive sum should be taken especially without the negative, to know how much sensation you have ever really had. This is evident.

In the meantime, it is not a matter of discrete feelings, as previously formed, but of contributions co-operating in solidarity, of the value with which a sensation of a certain quality, depending on the circumstances of the contributing moments, rises above the ground of the general consciousness; and here it is no longer evident that we have to take the positive contributions into account without the negative ones; rather, it could be thought that the greater in each oscillation the sum of the negative contributions is in proportion to the sum of the positive, the less the particular sensation rises above the ground of the general consciousness; and that positive and negative contributions contribute in solidarity to the determination of the form and size of the particular sentiment attached to the vibration,

It seems to me again difficult or impossible, in this respect something *a priori* to decide. But the subsequent investigation gives the decision insofar as corresponding results can be found by calculation only under the last condition of experience established here as possible. It turns out that, if we want to measure the magnitude with which the sensation as peculiar enters into consciousness, the positive and negative contributions, and, taking the latter into consideration, merely measure them according to the sum of the positive contributions, they do not satisfy the experiential Weberian law could be; which, however, is the case if we take the algebraic sum of the positive and negative contributions as decisive for the size of the senses to be compared. At the same time we gain by including the negative contributions in the composition of the sensation itself,

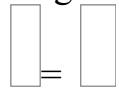
I therefore believe that until further notice, unless to fall all the elementary construction of sensation measure or take a significantly different turn when under

the I endure to represent them, the algebraic summation of the positive and negative contributions to a comparable Empfindungsmaß necessary³⁾.

³⁾ For this conviction, after having been of the opposite opinion, I have arrived at a new revision of this subject, and must thereafter not deny the expression used in Th. II. P. 63 that the sum of the negative contributions is simple explain more effectively.

The following study is limited to the following 4 cases:

- 1) Simple rectilinear vibrations.
- 2) Simple circular vibrations.
- 3) The composition of two rectilinear oscillations of equal amplitude a and oscillation time τ , which fall in the same direction and meet in any phase.
- 4) The composition of two rectilinear oscillations of different amplitude a, a' and oscillation time τ, τ' or oscillation number n, n' , but of equal living force, so

that, although a is different from a' and τ from τ' , then n of n' that is  and $an = a'n'$.

In the event that any number of oscillations of the same period of oscillation but any amplitude coincide in the same phase and direction, it is not necessary to treat special, since such a composition of a simple oscillation with an amplitude equal to the sum of the composing amplitudes without changing the oscillation period and Phase in every respect.

c) Overview of terms used in the following.

α) General terms.

γ the intensity of a sensory contribution during the time element dt ;

v the velocity of the oscillation in the usual sense (first order) during the time element dt , on which γ depends;

v the speed of the second order in the sense indicated above;

b is the elementary threshold of v or v in the sense given, as the elementary sensory contribution is made dependent on v ;

$S \tau$ or $S_{t is}$ the sensation sum developed during a vibration of duration τ or a number of vibrations during duration t , whereafter the mean intensity of the sensation during time t can be obtained by dividing S_t by t ;

π sets the Ludolf's number or length of the half circle periphery the radius = 1;

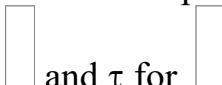
k is the usual constant.

β) For a simple rectilinear or circular vibration:

a the amplitude;

τ the period of oscillation;

n is the frequency of oscillation which is reciprocal in duration in such a way



that everywhere n can be set for \square and τ for \square ;

G is the maximum velocity when passing through the position of the equilibrium with a simple rectilinear oscillation, or the same constant velocity at the same amplitude with a circular oscillation;

α, ϑ, v are the fundamental thresholds of a, τ, n in the sense given above; that is, the values of a, τ, n at which, when they occur, the velocity G just reaches the elementary **threshold b** ;

a_1, τ_1, n_1 are the sensory thresholds of a, τ, n in the ordinary sense, ie the values of a, τ, n , in which, when they take place, the particular sensation tied to the whole vibrations comes to the threshold.

γ) For a compound rectilinear oscillation.

In the case of the composition of two rectilinear vibrations into a single one, the previous designations for both composing vibrations are distinguished by being used above for one with a dash, for the other without such. Let A be the amplitude, G the maximum velocity of the resulting vibration, while G is the maximum velocity of a composing vibration. Then α, ϑ, v and α', ϑ', v' are the values in the composing vibrations at which, when they occur, the maximum velocity G the resulting oscillation of the elementary threshold b becomes equal, a_1, τ_1, n_1 and a'_1, τ'_1, n'_1 the values in the composing vibrations, in which, if they occur, the whole, the resulting oscillation knotted, sensation comes to the threshold.

At the moment from which time t is counted, let c be the time that has passed without a dash since the beginning of the oscillation, and c' the one which has been streaked since the beginning of the oscillation, when the beginning of each oscillation has passed the divergence is believed the maximum situated on the same side, after



which \square and \square the phases of both composing vibrations at the time $t = 0$. Finally be



half the phase difference of both vibrations.

d) equations for the oscillations, which are based on below.

For a simple rectilinear oscillation one has (see chapter 30)

The beginning of time is set at the point where the particle is at the limits of the oscillation.

You asked for a circular vibration

For a composition of two rectilinear oscillations of the amplitude a , a' and oscillation

time τ , τ' , which fall in the same direction and in the phases and coincide one has

The value v for a rectilinear oscillation, such as the composition of rectilinear

oscillations, is obtained by the equation $v = \sqrt{a^2 + a'^2}$, that is, for a simple rectilinear oscillation

For a circular oscillation

e) Formulas and results that emerge from the study.

On the basis of the previous principles, designations and formulas etc., provided that the first-order velocity v is substituted into the elementary formula ⁴⁾, the following formulas and results flow from the following derivation:

1) For a simple rectilinear oscillation one has

 (1) (2)



(3)

For a simple circular oscillation:



(4)



(5)



(6)

For a composition of two rectilinear oscillations that fall in the same direction, in which not only $an = a'n'$, but also in particular $a = a'$, $n = n'$, and in which the half phase difference, if they coincide, is D :



(7)



(8th)



(9)

⁴⁾ The result of the substitution of \mathbf{v} is found with the derivation of the same for a simple rectilinear oscillation at the end of the section (see below).

For a composition of two rectilinear oscillations which fall in the same direction, in which $an = a'n'$, but a is different from a' and n from n' , irrespective of a particular phase difference at the meeting:



(10)



(11)



(12)

Is important in the comparisons of the Maßausdrücke found for the four cases investigated to remember that \mathbf{b} is an absolute, not only of a , τ , n is, but also on the waveform independent value, whereas αv as $a_1 n_1$. Although of αv depend independent but from the waveform. Therefore, if one wants to compare the magnitude value of the sensation S_t for certain a and n for different modes of vibration, one has only to apply the formulas in which except k , t , π merely a , n , \mathbf{b}

are received; however, the formulas into which αv and $a_1 n_1$ enter can only serve to compare the magnitude value of the sensation for modified values of a and n for the same mode of vibration.

2) In all cases examined, is found according to (3), (6), (9) and (12) of the experiential required expression of sensation measurement, to which the discussion of the 30th chapter led again when S_t with t divided, or sets $t = 1$, and takes into account that k in the present chapter is twice the value as in Chap. 30 has. Here Weber's law regarding a and n and the compensability of a by n in the multiply discussed sense are self-contained.

3) The expression for the periodic element of the tone scale [redacted] is not visible in the given formulas for the reason given in (chapter 30), but occurs in the manner already indicated in the derivation of the measure expression for itself.

4) According to the established meaning of α and v (see above) achieved the elementary threshold at a simple linear vibration when *at* the value αv assumes after emerging from our calculation formula (2) reaches the threshold of sensibility, that is S_t disappears if *at* the value $2 \alpha v$ assumes di when the number of vibrations $\alpha v \delta$ at the same to α increased by an octave.

5) In the case of a circular oscillation, the value of the sensory thresholds a_1, τ_1, n_1 coincides with that of the fundamental thresholds α_1, τ_1, v_1 .

6) After comparing the expression for the rectilinear and circular oscillation (in consideration of the above remark), the sensation result of the circular oscillation coincides in magnitude with that of a rectilinear oscillation of equal amplitude and double oscillation number or of equal oscillation number and double amplitude ; but in the measure expression for the circular vibration no value dependent on the periodicity is involved, and it can not be concluded from this that the quality of the sensations is the same. According to this, the vibrations of the sound can not inwardly be bound to circular vibrations, as, indeed, in a uniform circular motion, nothing is that delimited a period.

7) Of the two cases of the composition of two rectilinear vibrations, which are taken into account, and in which $an = a'n'$, the first, where at the same time $a = a'$ and $n = n'$, appears only a special case of the second to be where a of a' , n of n' and consequently τ of τ' is somehow set differently, as long as the generality of the second case seems to permit this difference to be arbitrarily small, and therefore zero, and unless it is clear why a phase difference can gain influence in the first particular case, if it is in the second general case not in consideration.

On the other hand, a look at (so) teaches that the formulas for the first case can not really be deduced from those for the second by equating a and a' , n and n' ; for in the

formulas for the first case, half the phase difference D , which does not enter into the formulas for the second, and considering the formulas of the first case for $\cos D = 1$, where both composing vibrations meet in the same phase, has you



But give those of the second case



According to the formulas of the first. So the case is true, the psychological result of the composition of its size by the vibration of a simple match, the vibration product 2 to be, for those of the second with a simple oscillation whose oscillation product only to be.

The contradiction that seems to lie here, however, is only apparent.

It must be borne in mind that the formulas given for the second composite case presuppose, in their generality, after their subsequent derivation, that the phase difference of the interfering vibrations does not remain constantly the same, as is the case when $\tau = \tau'$, hence $n = n'$, so that this case is expressly to be excluded from the generality of the second composite case. Now, for the first sight, there is something extraordinarily disturbing in the fact that even the slightest deviation between τ and τ' . The psychic result of the composite vibration can at once be reduced in such considerable proportion to the case of the equality of τ or τ' , as it is stated above, and follows from the comparison of the formulas of the first and second composite cases. It seems almost inconsistent with the principle of continuity, and I thought for a long time that there must be an error of calculation in the derivation of the formulas, which, after careful revision, is certainly not the case. However, a careful consideration also shows that there is nothing irrecoverable here. It must be remembered that when the vibrational durations τ , τ' yet, in the course of many oscillations - for which the summation is indeed presupposed in previous results - it is necessary to gradually pass through all degrees of deviation and opposition of the phases, while maintaining the same phase difference Equality between τ and τ' is linked, this can not be the case.

Even with regard to the physical intensity, which has its measure in the living force of the vibrations, the interference leads to a correspondingly paradoxical result, as we find here with regard to the psychic intensity. According to the known inference rules two go in the period of oscillation matching rectilinear vibrating beams of the same phase and amplitude of a composite beam, the physical intensity is twice as large as the sum of the intensities of its components, ie $4i$ is, when the intensity of each component i is, If, however, the two rays deviate so little in the period of oscillation, the sum $4i$ drops to $2i$ and, in general, the sum of the physical intensities of two rectilinearly vibrating beams of equal amplitude, but different duration of oscillation, to which the intensities i , i' come, is $= i + i'$, the phase in which they coincide being indifferent.

This result has been rigorously proved by Grailich,⁵ and the peculiarity that lies in it has already been emphasized by saying:

"The intensity of the beam (resulting from two rectilinearly vibrating beams of equal amplitude and different duration of oscillation) is equal to the sum of the intensities of the composing ... This sentence is strange because in the interference of two homogeneous beams of equal phase and amplitude Intensity of the new beam is twice the sum of the intensities of its components, the mutual delays arising from the inequality of the wavelengths consume just half of the applied force, the relative length of the waves is always which."

⁵⁾ Meeting reports of Vienna. Akad. 1854. p. 805 ff. - The physical intensity or living force of the ray, which is dependent on amplitude and oscillation duration or length, is determined by Grailich by the given expression, and the error indicated here can not be considered in the derivation of the above result,

8) If instead of the algebraic sum of the positive and negative sentiment contributions only the positive contributions to the measure of the time sum of the sensation were to serve, one would have to subtract the particularly determined sum of the negative contributions from the value S_t in the above formulas, in order to receive positive ones as rest. This sum of the negative posts is now at a simple linear vibration for the particular case of the fundamental

where $t_0 = \alpha v$, by $kt \log 1/2$ given what from $kt \log$ [] would be deducted, be as

Maßausdruck $kt \log$ [], But as far as the basic threshold is exceeded, necessarily the sum of the negative contributions changes; Therefore, with increasing a and n , other sums would always have to be subtracted, which Weber's law could not withstand, and the negative sum for other cases would be as far as the limiting case with the present means of analysis, as much as I can overlook; not particularly determinable.

f) Derivation of the formulas.

I give this derivation first for the assumption that the first-order velocity v for β should be substituted for the measure-formula in order to obtain the elementary formula, hence this is:

$$[]$$

In case of a simple rectilinear oscillation we have (s. O)

$$[]$$

after which $S \tau i\sigma$ given by

By decomposing the logarithm of the product into the sum of the logarithms of the factors, this expression goes into

if we denote the two integrals into which $S \tau$ decomposes kp, kQ .

The integral P is

To find Q , we transform the integral by setting

 therefore

That's how we get

what can be substituted for

because the whole vibration is divided into 4 equal parts.

The definite integral is the same as after Euler Thus we obtain the factor dependent on pure periodicity and

So:

If we now think of an oscillation of such amplitude α and duration ϑ , or number v , that the elementary **threshold b** takes place at the maximum velocity, then we have

and since the maximum occurs when the sine = 1, then this maximum value

of and this value is substitutable for b , giving us:

A time $t = m \tau$, which deals with m vibrations of duration τ , will give m times the value of $S \tau$; what you have

Finally, by giving the value of at , where S_t vanishes, the threshold product $a_1 n_1$, it agrees with $2 \alpha v$ and can be substituted for it, so that finally one has

In case of a circular oscillation we have (so)

For the value b , the value v can be substituted in a circular oscillation whose values α , τ , $v \alpha \rho \varepsilon$ such that v is equal to b . In such a vibration is

What

The values of α , ϑ , v fall here with the threshold values a_1 , τ_1 , n_1 directly together so that they can be substituted in the previous formulas it.

In the case of the composition of two rectilinear oscillations of the amplitudes a , a' and oscillation durations τ , τ' , which fall in the same direction and in the

phases and coincide, one generally has the value (v . I do not generally

integrate the equation when substituting this value v ; but it can happen for the main cases indicated on (see above) under 2) and 3).

So if first $a = a'$ and $\tau = \tau'$, then the value v in turns

$$\boxed{\quad}$$

According to the known trigonometric equation

$$\boxed{\quad}$$

but this expression can be transformed into the following

$$\boxed{\quad}$$

$$\boxed{\quad} \quad \boxed{\quad}$$

if D is half the phase difference $\boxed{\quad}$ and $\boxed{\quad}$. Since the beginning of time is arbitrary, we shift it backwards so far that the time calculated by the new starting point is $t' = t + C$, hence $t = t' - C$, whereby C rises in the value of v . By exchanging t with t' again, since the designation is indifferent, we obtain

$$\boxed{\quad},$$

The sensation sum during time t is hereafter

$$\boxed{\quad}$$

If this expression is treated like the previous one, then one has

$$\boxed{\quad}$$

Let us now consider a resulting oscillation with such values a, τ, n of the composing vibrations that the elementary **threshold b is** reached in Maximo, and we call these values as before α, ϑ, v , so we have

$$\boxed{\quad}$$

hereafter

$$\boxed{\quad}$$

Let us finally consider the case that a is different from a' and τ from τ' , but

still $\boxed{\quad}$ and mitbin $an = a'n'$; according to which the maximum velocity $G = \boxed{\quad} = \boxed{\quad}$ is equal for both, so is

$$\boxed{\quad}$$

If we turn the sum of sines back into a product of sine and cosine, we get that

wherein

Then, in the printout, we transform the logarithm of the product into a sum of logarithms, and set

 .

that's how we get

We integrate this expression from $t = 0$ to $t = m \ t \ \pi$, as we m take so that both $m \ t$ a $m \ t$ is an integer, which for exempted size of m is always accessible by any approximation, it is the first Link directly

The integral of the second term is to be taken from $\xi = C$ to $\xi = 2 m \ \pi \ t + C$, as we

find when substituting 0 for t at the first boundary 0 , at the second $m \ t \pi$. But since $m \ t$ is an integer, thus $2 m \ t \ \pi$ is equal to an integer full circumferences so true, if ξ is regarded as a circular arc, the nature of the circuit functions, of $\xi = C$ to $\xi = 2 m \ t \pi + C$ taken with that taken from $\xi = 0$ to $\xi = 2 m \ t \ \pi$, and we can delete C . This leaves the second member

Since we can now continue to set the nature of the circular functions

So does this link over in

which with respect to the previously specified value to

reduced. The third term, after equal treatment, gives the same value, bearing in mind that the value is the same . If we then add the three integrals thus obtained and replace the expression for the time $m \cdot t \cdot T$ by t , we obtain

considering that $2 \log \frac{1}{\sqrt{1 - \cos \varphi}} = \log \frac{1}{\sin \frac{\varphi}{2}}$.

It should be noted that if $\tau = \tau'$, the value $t = \frac{1}{2} \tau$ zero and hereby the third

term, which goes into the sum, be omitted, so instead of $2 \log \frac{1}{\sqrt{1 - \cos \varphi}}$ only $\log \frac{1}{\sin \frac{\varphi}{2}}$ would be obtained, which is the difference of the now treated conditioned by the above-mentioned case, of which (so) the speech was.

If we now think of a composite vibration while retaining the equality of the living forces of its components in such a way that the threshold **b is** reached in the maximum of their velocity , we can again substitute this maximum velocity for **b** . Let α, ϑ, v and α', ϑ', v' be the amplitudes, oscillation durations and oscillation numbers of the components of this oscillation. The maximum of the velocity v takes place when the sines in the printout of the same (so) at the same time become 1, and hence for **b is** to be substituted

and since

so we get now

or, since $an = a' n'$, $\alpha v = \alpha' v'$

Now let us make the second assumption that the velocity of the second order v must be substituted for the elementary formula for β , thus

is to be set by limiting ourselves to the case of a simple rectilinear oscillation, where

If we now apply the same treatment to it, as we did earlier to the substitution of v into the elementary formula, we obtain

Here **b** is the value of the second-order velocity v , at which the sensory contribution comes to the threshold, and when α , ϑ , v denote the amplitude, oscillation duration, and oscillation number of a vibration at which v reaches this

value at maximum, we have Placement of in the above printout of v :

$b = \boxed{\quad}$; hereafter

g) More general considerations.

Insofar as legal relations between body and soul are established by the previous formulas and results, they are principally to be referred to the movements directly underlie the sensations, that is to say psychophysical movements, and to that extent would rather belong to the inner as well as the outer psychophysics. But they are directly based on experiences belonging to external psychophysics, insofar as the elementary formulas on which they depend are only a translation of the measure-formula which has been gained in external psychophysics, into the elemental, and they can have direct validity only in the external Looking for psychophysics, by comparing it with the external movements, whereby the inner ones are stimulated, since we can not observe the inner ones directly,

Of course, a direct proof of formulas and results, which refer in principle to the inner movements, to the outer movements, can only be expected and sought in accordance with the proviso, as a consensus of both movements takes place. The

study of the extent to which direct verifiability exists can therefore be done from a dual point of view.

On the assumption that the internal and external movements are absolutely identical, such an investigation would be nothing other than the investigation of whether the preceding formulas, and hence the principles from which they are derived, are in the first place valid. For if they were, all relationships between sensation and movement that flow from the previous formulas must be confirmed already in the relations of sensation to outward movements, and if this were not the case, then it would be the falsity of formulas and principles from which they flow, proved. On the other hand, assuming the certainty of these formulas and principles, it would be the study of how far the external and internal movements match. Now the first condition can only be set from the beginning to a certain extent. The excitement of the sensory organs by the stimuli with which we are dealing here, comes under the general view that a vibratory motion in the media of the outside world causes movements by propagation to the media of the inner world, which we suppose to be even under the form have to think of oscillatory movements. The vibrational movements in the media of the outside world, before they reach the medium of the nervous system - but previously they are not able to arouse sensation, - nor to penetrate the medium of the external sense organs. Now, according to the most general laws of motion, the nature of the vibrational motions that are aroused in a medium, that vibrations are transplanted from one another to another, though from the quality of the awakening to the other, and under certain circumstances even correspond exactly, as the facts and circumstances of the resonance prove, but not alone, since rather the nature of the medium under which Interaction and on which the message is made has influence on it. We know the nature and closer conditions of the excitement of our sensory nerves by no means sufficient to be able to say *a priori* how the excited ones must behave everywhere to the exciting movements; but we know so much that the conditions are more complicated than in the simplest cases of resonance in the external world; however, even with the most perfect resonance in the outside world, the transmitted vibration frequency does not leave the shape and amplitude of the transmitted vibrations unchanged, but is determined by the particular conditions of the resonating system and the mode of transmission. So on the first condition can not be based absolutely.

From the other side, however, the principles from which the previous formulas and results are derived are not so *a priori* that they do not need the support of experience, but they are only concerned with the external movements on condition of correspondence let the inner win.

It can not be denied that this results in a solidary difficulty in securing our principles and in ascertaining the relation between external and internal movements, which will not be completely overcome at the first attempt. If psychophysics did not offer more difficulties than physics, it would have always been the same step with her. In my opinion, however, one may oppose the present difficulty in this way.

It is first examined whether the experience which can be made of the external motions is to the results of the theory relating to the internal movements, which up to now has been made only with regard to very simple cases (in previous formulas), something in There is something analogous to this, that the coincidence of theory and experience can not be regarded as coincidence. If this finds itself, as I believe, to be in the domain of tones, one finds at the same time that what is said of the physical and physiological conditions. Knowing the transference of external movements into the interior, a favorable one of the external and internal movements here is so far favorable, as the correspondence is to be presupposed for the confirmation of the theory, as I believe that it also finds here, In this way the correctness of the theory and the correspondence of the external and internal movements according to the relations in question are at the same time found to be fundamentally justified, and it is now sought by which extensions or secondary determinations of either the theory or which possible or probable deviations between the theory Correspondence of external and internal movements is to cover the cases where there is no such direct correspondence between the results of theory and experience. It is finally considered whether any other theory in all these relationships is more adequate or achieves more than the one stated. So you become, if not absolutely certain,

But whereas the agreement of theory with what we find in the tonal world seems to me to be great enough to give confidence in the fundamental points of the theory from the first point of view, the deviations which the field of colors presents between theory and experience call for one Examination from the second point of view, in which, in particular, the deviation of the colors from Weber's Law (Th. IS 175) and Helmholtz's Law (Th. II., P. 176) call our attention. I will talk about this in the next chapter. But I want to discuss one point here.

The living force of a circular oscillation of amplitude a and duration τ is twice that of a rectilinear oscillation of equal amplitude and duration and is equal to the living force of a rectilinear oscillation of amplitude $\boxed{}$ and duration τ ⁶⁾. Also, according to the interference rules, a circularly vibrating beam of the amplitude a may represent a rectilinear oscillating of the amplitude $\boxed{}$ with respect to the brightness. However, according to our above formulas (formulas 1 and 4), the sensation effect of a circular vibration of the amplitude a is equal to the sensation effects of a rectilinear one not of the amplitude $\boxed{}$ but from the amplitude $2a$; and, with the same living force of the vibrations, sensation-effects of different magnitudes, depending on the different form of the vibrations, can arise at all, while, as far as is known, an equal living force of light-vibrations of the same duration and of different forms grants a similar sensation-effect.

⁶⁾ This is found when one considers the living force, which is developed during a vibration of duration t , according to the formula

determined, and substituted for v the p 212 indicated values. One thus obtains for the rectilinear oscillation $\boxed{\quad}$, for the circular one $\boxed{\quad}$.

If we think firstly of a modification of the theory which might possibly be necessary for the elevation of this difficulty, then, generally speaking, we might think that the assumptions on which the theory was based in the construction of the sensation effect of rectilinear and circular vibrations, in so far as it would be valid, that for every form the correct relationship of a and n would come out, and only one assumption would be correct, which is necessary for the combination of both effects. In fact, this requires a certain precondition; indeed, in order to relate the effect of differently shaped vibrations to each other, the assumption has been made that the sensation depends on the velocity in the same way, may it maintain a constant direction in space, as in rectilinear vibrations, or its direction change continuously, as with circular vibrations. This presupposition is not only the simplest, but seems to me the most probable even now, just as the calculation of the living force of the vibrations does not take into account a changed direction of the same, but it is not self-evident, and if another was necessary and sufficient to link the facts, it would be possible to do so. Only I confess that I did not succeed, such a thing which at the same time appears rational and in accordance with the facts; just as little could I gain by substituting v for v ; and I find it more likely that the deviation between theory and experience is not due to a mistake of theory, but to a lack of correspondence between the form of external and internal motion.

In fact, there is no physical or physiological principle at all, which in any case, in any case, guaranteed us an unaltered transference of the form of vibration from the external to the internal; and even with sounds it will not be acceptable. Thus, we do not see the form of the violin bow as being translated into a corresponding vibrating string; and if a string were already in motion, the encounter of a rectilinear oscillation would produce a rectilinear oscillation in the same direction only in the single case, if the direction of movement of the string coincided with that of the oscillation; otherwise the movement would generally become elliptical, or circular, or rectilinear with direction changed. Our nerves, especially optic nerves, But they are already active in a certain way without any external stimulus, and so are comparable to a moving string. So also the movement awakened by the light stimulus will only be able to intervene modifyingly into the already existing one.

Now, if a circularly polarized ray of amplitude a expresses a similar effect on the sensation of light as a rectilinear polarization of amplitude $\boxed{\quad}$, this in my opinion means nothing else than it expresses a physically equivalent physical impulse in terms of the evocation of that Type of internal movements on which the sensation of light is based; and, in general, when rays with different forms of oscillation are equivalent according to the laws of interference, this equivalence is valid only for the

physical impulse which the nerve receives to produce the forms of motion peculiar to it, without it being said that these forms follow those of the excitatory Straighten the beam.

This assumption is sufficient to cover all the deviations that might be found between the results of our principle and those of the interference formulas.

After that, I turn to some other points of general importance.

After the input of plowed discussions, the quantitative of the sensation is connected with the quantitative of the relation of which the quality of the sensation depends. Insofar as this connection is concerned with whether equal or unequal moments of motion follow, and according to which law, what function of time they follow, it seems to be a difficulty that we distinguish the present sensation by a series of moments which not having to fall into the present, having to keep a certain degree, for in the moment of the present only one moment of vibration can fall at once.

In the meantime this difficulty can only be a difficulty of the imagination and is outweighed by the impossibility of making the quality of the sensations dependent on individual moments of movement. For this would explain neither the constancy of the sensation in the course of a vibration, where the moments of motion change continuously, nor the difference of the sensations, insofar as all movements contain similar moments of motion of different composition. It is undisputed that the feeling of the present is itself psychophysically grounded in a certain sequence of moments, or does the soul summarize in this feeling a physical sequence of time, and hereby links the feeling of the moment to several real moments of time. The soul, it can be said, actually fulfills the time with its activity, as the body through its expansion the space; or psychophysically, the form and magnitude of the soul activity is a linking function of what happens in successive time elements, as the form and size of the body is a linking function of what falls into juxtaposed spatial elements; and there is nothing inherent in the concept of the extension of time, which prevented it from being psychologically as well as physically enclosed with this analogous position. In fact, everything is successively linked in our soul in a unity of consciousness, which in no way can depend on individual moments, but is necessarily regarded as a linking function of that which falls into the succession. But if this must be granted to the whole unit of consciousness through the whole life-span, nothing hindered, it is rather only consistent,

If one wants one can also say that every moment of an oscillation leaves an aftereffect in the soul, and in that all moments leave such an aftereffect, a compound aftereffect arises, which the sensation gives. But in other words, in other words, we just say the very same thing we say when we say that the soul, with the effect of the present moments, at the same time summarizes those of the earlier ones; but it may be more convenient for some modes of the nature of the soul to use one language than the other, which we do not dispute.

In the meantime, one might also be inclined to substitute something else for the former, which, in my opinion, is more to be connected with it, because this connection raises difficulties which would remain if one wanted to keep to the former

alone, but others and others probably would introduce greater difficulties, if one wanted to substitute the same.

After all, our soul not only connects successive things, but also simultaneities, albeit in a different sense. Everything which in our psychophysical system acts at the same time as the foundation of phenomena of consciousness, and this is undoubtedly a great connection of movements, gives so well a psychologically uniform consciousness result, as the temporal succession of these movements, and all the moments which occur during the duration of the oscillation Particles occur successively in the nerve or brain, appear within the length of an undulation at the same time on the series of particles understood in the Undulationslänge and contribute in solidarity to give the sensation, since their performance can not actually be distinguished.

According to this, the difficulty which exists for the idea of grounding the formation of a sensation of a definite character upon a combination of successive moments, can be quite simply lifted by making it dependent on the simultaneity instead of the successive, provided that What the majority of the particles encounter at the same time, corresponds to what the same particle successively encounters, except that it is spatially and temporally explicated. We would therefore have to find the same formulas, which we have found by a summation of the time, by a spatial summation.

In the meantime, it must first be remarked that, after the connection of the successive in a unified consciousness remains a fact, and only the solidary consideration of this connection between the successive and the simultaneity allows the soul-life to be represented as a whole, there is no reason for the special phenomena of consciousness merely to consider the connection of the simultaneity. In addition, the full replacement of the successive moments of motion by simultaneous ones in our case would only be strictly possible, if one could think of matter as continuously fulfilling space, as a particle fulfills time with its motion. But exact science has good reason to prefer the atomistic view that it is not possible that in the length of one and even so many undulations, all states of motion that successively occur in the course of an oscillation on the same particle, find themselves at once, even if they can be so close to one another, that the discontinuity is replaced by continuity for an approximate calculation can think. But it seems to me very awkward to base basic ideas on approximations and, if a circular function contains the exact expression for the movement to which a sensation is attached, the circle is actually replaced by a finite number of discontinuous points want what the view in question would amount to. Rather, I believe that if a continuous function gives the strict expression to the movement in question, s common, therefore the number of the same proportional comes out of it, instead of a mere sum time S_t a period sum S_{ts} introduce, and in our formulas instead of factor t the interpreted in that way factor st apply.

From this point of view, the intensity of the sensation largely depends on the number of contributing particles, and a greater amplitude of the vibration can be

replaced by a larger number of particles oscillating at a smaller amplitude; just as with regard to the generation of objective physical sound power, a strong sounding instrument can be replaced by a majority of weak sounding of the same kind, and even a single, struck, large bell sounds so strong in invisibly small movements of its particles only because so many particles do Perform movement.

This is undoubtedly one of the most important means of producing great psychic achievements with the invisibly small movements in our nerves and brain. If only a nervous particle were to vibrate internally, it would undoubtedly have to vibrate in tremendous amplitude in order to reproduce the bell-tone in the same intensity as we hear it now, but as it would for every bell-particle itself, if the tone were to be equally strong, when he gives the whole bell.

It seems a miracle that imperceptibly small vibrations in our nerves can sound like cannon thunder, howling of the storm, etc., in our soul. In part it is explained, in so far as there is any explanation at all, from the fact that the effect of the vibrating nerve particles on the sensation is not weakened by a factor reciprocal to the squares of the distance from us, since they are not far from us, but belong to the sentient organs themselves. But it is partly explained by the fact that there are many particles that contribute to the same sensation.

Now one may ask whether a sensation quantity with less expenditure of physical means, ie of lesser living force, can be increased to a given degree by increasing the number of vibrating particles or by increasing the amplitude. In this respect the same formulas which have been developed in the twenty-first chapter concerning the distribution and concentration of the sentiment stimulus to more or less points may be decisive, for the distribution of the sentiment of sensation to a larger number of points of the feeling organ itself is nothing but a larger number Sensation contributing psychophysically active points represents. Except that it is not self-evident and not yet proven that the magnitude of the intense sensory results, to which a number of non-discreetly sensed points interact, determined by the number and magnitude of action of these points in the same way as the magnitude of the extensively-explored sum of sensation provided by a number of discretely-sensed points, in which case those formulas actually referred; but, on the other hand, it is perfectly conceivable that the case of discrete and non-discrete points differs from one another only in that the same amount of sensation is extensively explicated, which otherwise sums up intensely. in which case those formulas actually referred; but, on the other hand, it is perfectly conceivable that the case of discrete and non-discrete points differs from one another only in that the same amount of sensation is extensively explicated, which otherwise sums up intensely. in which case those formulas actually referred; but, on the other hand, it is perfectly conceivable that the case of discrete and non-discrete points differs from one another only in that the same amount of sensation is extensively explicated, which otherwise sums up intensely.

If the sound of a bell can objectively be summed up as summed up by the sound of the particles of the bell, it must be borne in mind that the particles could not have been individually involved in the motion in which they were by virtue of their

connection. Accordingly, it will be in our psychophysical systems. One particle alone would not be able to obtain any other than uniform motion at all; In order for a state of vibration to arise and to be sustained, several particles must be determined by interaction, and it is indisputable that the solidary interaction of the particles is also related to the same sensation, insofar as it exists in our psychophysical system. But now different cases can occur. Either all parts of the system, which co-operate in solidarity to a sensation, perform movements of the same kind, except that at the same time they find themselves in different phases of the same form of motion, as in the external world in the propagation of light, sound in uniform media, and as I suppose it with the movements on which the sensation of sound depends in us, because it is really possible to depict this sensation on the repetition of the motion-form even of a single particle, without it being said that the particle would also this motion-form as single could accept. Or, at the realization of the sensation, there is a solidarity of particles with motions of various kinds, and we are free to think of such sensations,

All the formulas developed in the preceding offer only expressions of measure for the quantitative side of the sensation, without saying anything about the quality, so that the same values in different forms of motion therefore do not mean the same sensations, but only the same quantitative values of these sensations. It is indisputable that the form of the sensations depends on the form of the function, which links the moments of movement which contribute to the sensation; but as those formulas draw the quantitative conclusion for the whole series of moments of motion to which the sensation is attached, the description of the mode of connection of these moments of motion is lost in it, and it is rather the form of the function of t , which represents the incoming v in the elementary formula , to be regarded as an expression of the form of motion, whereby the form of sensation is determined.

Thus the quality of the sensation, which is linked to a simple rectilinear vibration, is not at the same time as the quantity by the expression



which we have definitely come to regard as given, but through the expression



In the latter, the disintegration appears in three moments, a moment dependent on a , on τ , and on the periodic recurrence of the same moments of motion, while the last moment in the first print has been lost.

A circumstance which might in a certain sense directly suggest that the sensory contribution in the sense of the elementary formula depends on the velocity of the second order v as the first order v , is as follows: It is known that a mere passage of electricity through the Organs produces no, or by far less conspicuous sensation, than the change of current, and especially the entrance and exit of the current, which may be regarded as the strongest and fastest changes of current, respectively, in increase

and decrease, and that it is essential at all the speed of increase or decrease of the electric current, in short, depends on the magnitude of the second order speed⁷⁾, However, the sensation is generally not entirely silent during the closing of the chain; but it is quite possible to make these moderately persistent sensations dependent on the same principle as the stronger ones upon entry and exit of the flow. For it must be remembered that the periodic fluctuations within the organism, which must already carry the pulse of the blood-run, indisputably also produce constant fluctuations in the flowing-through electricity, and conversely must somehow be altered. At the end of the chain on the eye one sees not only a flash in the moment of closing, but also a faint light phenomenon during the period of being closed. But we have to remember that, even without electrical stimulation, one has in mind a perpetual sensation of the face, the eye-black, which at times even changes into vivid phenomena of the face. So much as the tongue of a reed, which is capable of oscillation, can be put into constant vibration under the influence of a constant stream of air, a vibration in the appropriate visual apparatus can be maintained under the influence of a constant electrical stimulus Including speed.

⁷⁾ Cf. Dubois Unters. Bd. IS 258 ff.

In the meantime, it seems to me to be decided by that fact only against the possibility, which can not be determined anyway, of making the sensory contribution dependent on an absolute speed of the first order, but not against the dependence on a first-order relative speed. It is not disputed that for the inner sensations of every psychophysical system, such as our nervous system, only relative movements of its parts and consequently only relative velocities are considered. Otherwise, if man moves with the earth sooner and later more slowly around the sun, changes in his mental state must occur after the changes in speed, whether first or second, which occur in this case. Now if the galvanic flow is uniform, Thus the acceleration and deceleration of the particles, but at the same time the relative movement of them against each other, cease to exist here; however, on entry and exit, and any change in the flow, which is always excited from certain points, relative velocities occur until the velocity of all the particles has equalized. By the way, it always remains to admit that the experience is not yet between v and \mathbf{v} decided and the question is still floating.

If the elementary formula [] or [] should show generally adequate for the movements in our nervous systems so that it might not yet be proved that each of v and \mathbf{v} in the world a sensory contribution in the sense of this formula may depend on it possibly still preconditions or conditions might be present, as they exist in our nervous system, but elsewhere could be absent, while of course from the other side that we are no sensations of movements outside of our nervous system, nor can we establish any empirical evidence that they are absent outside of us, and that sensations are only possible by means of a nervous system. To discuss these

possibilities in detail is not the place here and would not have any particular success. Only the following point will be commemorated.

We would not be comfortable thinking that a facial sensation, auditory sensation, so to speak, hovered in the void, that is, existed without a more general consciousness that had the same. And so it is natural to believe that a simple vibrational motion can arouse sensation only insofar as it intervenes in a more general system of movements, such as that which carries our general consciousness, and could not arouse any sensation in the void. Only that it could not exist in the void, since its creation itself already has a connection, an interaction of parts whose movements take place in connection with each other.

However that may be, our consciousness is active during waking, apart from external stimuli, which presupposes in us a psychophysical activity independent of external stimuli. And whatever its nature may be, the velocity of it for any point in the process (decomposed in any direction) may be represented by Fourier's theorem by a series of periodic terms plus a constant. Let its value be V , and add the value v to the stimulus .

If we were to determine the conditions of general consciousness, to find a measure of its intensity, of its rise or fall below the threshold, this would probably have happened (insofar as we can only follow the movement in one direction) if we did $V + v$ instead of previously substituted v in the elementary formula and integrated. It would not be possible to prove *a priori* that, in order to obtain the measure expression for the sensation which is in particular connected with v , v apart from v can be treated; but only the success of this treatment teaches it. In the derivation of our formulas, we have regarded it as if v alone existed, have not taken V into account, and have thereby arrived at results which correspond to the experience.

Special investigations on some sensory areas.

XXXIII. About sensations of light and sound in relation to each other.

The discussion of chapter 30 has given us many reasons to consider the psychophysical relation between tones and colors, and to suggest the task, where possible in the actual conditions of physical conformity and diversity that prevail in them, the reason for the to discover psychic.

Let us, in the following examination, which is led in this respect, proceed in part to the consideration of some conditions which concern the colors in particular, to which the investigation is partly to refer.

a) On the limits of the visibility of the colors and the causes of the limitation of this visibility.

It is well known that the visibility of colors is within certain limits of refractability, hence vibrational speed and the associated length of undulation, and it will be a matter of specifying some of these limits, of examining them on the basis of which they depend, whether or not oscillations under and over a certain degree of rapidity according to the nature of the light sources at our disposal and of the device of the eye, and not to the retina, or of the fact that they can not be perceived by the retina below and above a certain degree of refrangibility, even if they get to the same. This study can only be considered with regard to the intensity ratios of heat and heat in the spectrum and the question whether there is a material identity or non-identity of both agents; which question will therefore be necessary to consider here.

As is generally known, it is presumed that in a prismatic spectrum formed of homogeneous colors dark lines appear, which, for each type of light of definite origin, always lie between rays of the same refractoriness, and hence can serve for the characteristic of rays of given refrangibility. The most characteristic of these lines is marked in the series from red to violet and in the ultraviolet in large, by Stokes, however, and earlier also by Helmholtz in the ultraviolet with small, Latin letters.

Of these, ¹⁾ *A*, *B*, *C* in red, *D* in orange, *E* in green, *F* in blue, *G* in indig ²⁾, *H* in violet. *I* is referred to by Fraunhofer as the violet border of the spectrum.

¹⁾ Herschel, about d. Light. §. 419.

²⁾ This statement according to Herschel. After comparing the two tables below rail *G* rather still belong to violet, and is Fraunhofer's spectrum drawing *G* midway between the designated indigo and violet spots. Because of the gradual transition of the colors and the nuance of the breakable spectrum part varying with the intensity of the light (Pogg. XCIV, 13), no sharp determination will be possible here.

Illustrations of the Fraunhofer spectrum from the red end to the line I can be found in Gilb, among others. Ann. LVI. Plate IV; Biot's apprenticeship Vol. V. Taf. XXI; Herschel on the Light, Plate VI et al. 0. - An illustration of the outermost violet and ultraviolet spectrum part with the solid lines is given by Stokes in Pogg. Ann. 4. Supplementary B Plate I. Fig. 1 (explanation p. 200), a picture of the entire spectrum from red to the last ultraviolet Esselbach in Pogg. XCIV. Plate V. Fig. 6 (explanation p. 514 ff.). Although in Stokes' spectrum the lines of the ultraviolet part are denoted by small letters, in Esselbach's by large letters, the same letters correspond to the same lines, as not only from the comparison of the spectra, but also from an indication of Esselbach's in Berl., Ber. 1855, p. 788.

In several respects useful reference to the following will be the following two tables, the first of which, Esselbach ³⁾, which differs from the usual spectrum to the ultraviolet with extensive determinations thereof over the wavelengths corresponding to the solid dark lines in the spectrum, compiled with the includes Fraunhofer provisions which extend only to the violet, and the second, of Helmholtz ⁴⁾ which was

founded in Esselbach's provisions with the concurrence of some of their own rules on the limits of the range, combination of colors with pitches when the line A to the Tone G and the wavelength of the tone $c = 1$ is set, while the wavelengths of the colors are expressed in millimeters, as in Esselbach's table.

Table of Esselbach.

| lines of the spectrum | Wavelengths in millimeters | |
|--------------------------|----------------------------|----------------------------|
| | to Esselbach | according to Fraunhofer |
| A | 0,0007617 ⁵⁾ | |
| B | 6874 | 0.0006878 |
| C | | 6564 |
| D | 5886 | 5888 |
| e | 5260 | 5260 |
| F | 4845 | 4843 |
| G | 4287 | 4291 |
| H | | 3929 |
| L | 3791 | |
| M | 3657 | |
| N | 3498 | |
| O | 3360 | |
| P | 3290 | |
| Q | 3232 | |
| R | 3091 | |

³⁾ Pogg. XCVIII, 524.

⁴⁾ Reports of the Berl. Acad. 1855. 761 ·

⁵⁾ This provision for A is added here after Helmholtz, since it is not included in Esselbach's determinations.

Table according to Helmholtz.

| | | |
|--------|---------------------------------|----------------------|
| volume | wavelength the tone of color | nature the colors |
|--------|---------------------------------|----------------------|

| | | | |
|------------|-----------------|-----------|---------------------------|
| <i>Fis</i> | $\frac{64}{45}$ | 0.0008124 | End of the red |
| <i>G</i> | $\frac{4}{3}$ | 7617 | red |
| <i>Gis</i> | $\frac{32}{25}$ | 7312 | red |
| <i>A</i> | $\frac{6}{5}$ | 6721 | red |
| <i>B</i> | $\frac{10}{9}$ | 6347 | Red orange |
| <i>H</i> | $\frac{16}{15}$ | 6094 | orange |
| <i>c</i> | 1 | 5713 | yellow |
| <i>cis</i> | $\frac{24}{25}$ | 5217 | green |
| <i>d</i> | $\frac{8}{9}$ | 5078 | Green Blue |
| <i>it</i> | $\frac{5}{6}$ | 4761 | cyan |
| <i>e</i> | $\frac{4}{5}$ | 4570 | indigo blue |
| <i>f</i> | $\frac{3}{4}$ | 4285 | violet |
| <i>fis</i> | $\frac{32}{45}$ | 4062 | violet |
| <i>G</i> | $\frac{2}{3}$ | 3808 | About violet |
| <i>gis</i> | $\frac{16}{25}$ | 3656 | About violet |
| <i>a</i> | $\frac{3}{5}$ | 3385 | About violet |
| <i>b</i> | $\frac{5}{9}$ | 3173 | About violet |
| <i>H</i> | $\frac{8}{15}$ | 3047 | End of the solar spectrum |

Further, the general fact of fluorescence is presumed to be known, according to which some substances (such as acidic quinic acid solution or paper coated therewith) reduce the refractability of the light rays passing through or reflected from them, which facilitates the visibility of those rays exceed the violet limit of the usually visible spectrum in refractability, thereby transforming it into rays which enter the limits of ordinary visibility.

The prismatic spectrum of colors known by Newton and visible without peculiar precautions covers only about one fifth.

J. Herschel ⁶⁾ gives the undulation length of the outermost red as 0.0000266, that of the outermost violet as 0.0000167. Inches in air (corresponding to 0.0004242 and 0.0006756 mill.), The number of vibrations in 1 sec. For the former to 458 trillion, for the latter to 727 trillion. However, these limits have already been extended by Fraunhofer, who has observed at least one octave, as from the comparison of the following statement of the same with the determinations of the wavelength and the

view of the spectrum he has recorded, from the line *I* as the border of the violet to a little goes beyond the line *A*, emerges.

⁶⁾ About the light. §. 575th

"At A, the red is the purple end, at I the violet end of the color picture, but a certain limit can not be stated with certainty on any side, lighter even in red than in violet."
"If all sunlight reflected directly or through a mirror is excluded, it seems on the one hand, the boundary to fall approximately between G and H, on the other side to be in B. With sunlight of very large density, the color picture is almost half longer⁷⁾ but in order to be able to see this greater extent, the light from the space between C and G must be prevented from entering the eye, because the impression that the light makes on the eye of the boundaries of the color image is very weak and displaced by the rest. In A a well-defined line is clearly visible; but here is not the limit of the red color, but it is noticeably over it."

⁷⁾ If I understand this right, it means an extension nor *I* addition.

That the sunlight, beyond the red and violet border of the spectrum visible without special caution, still contains rays of lesser and greater refractoriness, was long known by the warming effects of the rays beyond the red and the chemical effects of the rays beyond the violet. Of these rays, invisible in ordinary spectrums, the first are nowadays often called ultra-red, the last ultra-violet or violet.⁸⁾ Also, the visibility of ultraviolet rays by fluorescence can be facilitated by transformation into less breakable ones.

⁸⁾ Helmholtz, from whom the name derives from violet rays (Pogg. XCIV, 13), does not clearly state from where he calculates them, and it is common ground that a boundary could only be determined conventionally, since the nuances without them merge. According to the given table, it calculates a wavelength of 0,0004062, which lies between *G* and *H* after (so), nor violet, and 0,0003,808, which is very close to the line *L*, to the violet. By placing the end of the violet at *I*, the beginning of the violet would be calculated from *I* or *K*, whose wavelength has not yet been determined.

More specifically, the new research shows:

1) The ultraviolet rays can be up to the limit of the refractive power, in which they are present in the solar spectrum and by fluorescence for perception, according to the consistent experiments of Helmholtz⁹⁾ and Esselbach¹⁰⁾ without this aid (ie without reduction of Breakability) are perceived by such measures that the ultraviolet rays pass as completely as possible through the media used to create and view the spectrum, which is better with quartz (rock crystal) than with glass¹¹⁾ and when, in part, the neighborhood of the brighter spectrum part, whereby the eye is dazzled, is partially excluded admixture of irregularly scattered light to the ultraviolet light regularly refracted by the prism, a purpose generally attained¹²⁾, taking the ultraviolet part out of the Spectrum designed by means of a quartz prism isolated by a

screen with a column and viewed through a telescope of quartz lenses with an advanced second quartz prism.

⁹) Pogg. XCIV, 12. 208.

¹⁰) Pogg. XCVIII, 513.

¹¹) However, Helmholtz also succeeded in using mere glass prisms (Pogg. XCIV, 1 ff.).

¹²) Comp. Helmholtz in Pogg. LXXXVI, 501. XCIV, 1 . 205. Reports d. Berl. Acad. 1855. 757. Esselbach in Pogg. XCVIII, 515.

With regard to the extreme ultraviolet limit, Esselbach notes Pogg. XCVIII, 523); "behind R only one line S was very weakly seen during the summer."

If, therefore, no more colors are perceived by the eye beyond a certain degree of refraction in the solar spectrum, the reason is that none are present in this spectrum; and therefore not directly inferring a limit of visibility from observations on the solar spectrum which is in itself for the eye to this side.

Now Stokes ¹³ has made the observation that the electric light gives a spectrum which contains much more refractile rays than the solar spectrum, so that about one octave in height is added to this ¹⁴⁾. So far, however, this spectrum seems to have been observed only by the use of fluorescent substances, which reduces the refractive power, and I find neither an indication that the part which is added to the solar spectrum by this spectrum could be perceived without this aid , another statement which expresses the opposite, so that it would still be possible to determine by the attempt whether a limit of visibility did not directly show itself here.

¹³) Pogg. LXXXIX, 628.

¹⁴) After Esselbach's remark in the Ber. d. Berl. Acad. 1855. 760.

As long as the existence of ultraviolet rays could be recognized only by their chemical effects and by fluorescence, it was reasonable to suppose that they would be invisible because they were absorbed by the media of the eye, and attempts by Brücke on the effects of diffused white light after his passage through the transparent ocular media to a thin layer of dried guaiac tincture, ^{15 he} concluded, "that the lens absorbs most of the most refractile rays (guaiac), less so the cornea and the vitreous body, but most of all Lens with these two media together ", to which he added later confirming others ¹⁶⁾ ,according to which the ultraviolet rays of a prismatic spectrum after passing through the lens, vitreous body, and cornea of an ox-eye, no longer had an effect on sensitive photographic paper, while the violet rays still had a lively effect. Meanwhile, apart from the fact that the visibility of the ultraviolet rays is now directly established by the above observations of Helmholtz and Esselbach, Donders ¹⁷ , too, obtained opposite results as a bridge by another method, according to which the ultraviolet rays are not only transmitted by the eye media but just as easily as the more breakable ones.

¹⁵⁾ Müller's Arch. 1845. 263.

¹⁶⁾ Müller's Arch. 1846. 379.

¹⁷⁾ Müller's Arch. 1853. 459.

The principle of Donders' experiment was this:

How easy it is to check whether ultraviolet rays pass through the ocular media, to design only a spectrum on a screen coated with acidic acid solution of quinine (which is a fluorescent substance), and to see if they pass through Fluorescence visible ultraviolet rays also remain visible when interposing the transparent eye media. If it does, then of course they can not be absorbed by these media. Donders now filled the first vials of various sizes with the bodies of some beefy eyes and brought one or the other between the sulfur screen, to which only the rays of the spectrum beyond the violet were allowed to pass (so that they became more visible to themselves), and between the light source , They appeared just as well and to the same limit as without this intermediate contribution, only with as much weakening as when the less refractile rays of the spectrum were subjected to the same experiment. Then the other mediums of the eye, the cornea, the lens, the retina, were each hung by themselves in a glass filled with an ox-ophthalmoscope, as was the whole anterior half of an eye; in which the cornea, aqueous moisture, lens, and vitreous body were united, applied in a similar manner, and obtained substantially different results, except that when the lens and the half-eye were used, the appearance was somewhat altered by the lens action in the mold. if one subjected the less breakable rays of the spectrum to the same experiment. Then the other mediums of the eye, the cornea, the lens, the retina, were each hung by themselves in a glass filled with an ox-ophthalmoscope, as was the whole anterior half of an eye; in which the cornea, aqueous moisture, lens, and vitreous body were united, applied in a similar manner, and obtained substantially different results, except that when the lens and the half-eye were used, the appearance was somewhat altered by the lens action in the mold. if one subjected the less breakable rays of the spectrum to the same experiment. Then the other mediums of the eye, the cornea, the lens, the retina, were each hung by themselves in a glass filled with an ox-ophthalmoscope, as was the whole anterior half of an eye; in which the cornea, aqueous moisture, lens, and vitreous body were united, applied in a similar manner, and obtained substantially different results, except that when the lens and the half-eye were used, the appearance was somewhat altered by the lens action in the mold.

The result obtained by Donders has later also been confirmed by Kessler ¹⁸⁾ in the following way. Prismatic spectra were presented in the dark room with all the precautions needed to exclude extraneous light, and it was examined whether such individuals, who had been deprived of the crystalline lens by surgery, perceived the spectrum on its most refractile side to the same extent as persons with normal vision apparatus. There was no significant difference. A person who was able to see a double image of the spectrum due to laterally displaced crystal lenses, and with the aid of a lens both images in the same sharpness, saw the violet in the same extent.

18) Gräfe's Arch. 1854, p. 466; here after Liebig and Kopp Annual Report for 1854. p. 188.

2) Of the ultra-red rays is not the same as the ultraviolet; Up to now, they have made themselves perceptible (beyond the limit indicated by the table above) by no means to the eye, but only by their warming effects.

With these rays, however, it can still be considered doubtful whether their lack of visibility is merely due to a strong absorption by the eye media, or whether a lack of perceptibility of the retina has a part in it. Certainly, the lower the temperature of the heat source, and the thicker the layer through which the rays are to pass, the less the water, protein, and other transparent liquids pass relatively less from the dark heat rays than from the luminous ones. However, they nevertheless allow a fraction of the dark ultra-red rays of the solar spectrum to make a not inconsiderable contribution. After the direct attempts of Franz¹⁹⁾ On the ultra-red rays of a solar spectrum generated with a flint glass prism, which had its maximum heat in red, the temperature of the next dark red zone (each zone of 3 mill) only from 11.81 to 5.93, the following from 8.77 to 1.66, the third from 6.11 to 0.83²⁰⁾ while the humiliation for the red itself went from 15.11 to 10.00. (Even less was the reduction in the dark portion with saline or alcohol instead of water.) After which it is hard to imagine that the much watery and protein-like ocular media, with their much smaller thickness, should not transmit much of the ultra-red rays, especially after Melloni's statement²¹⁾ Protein in water does not appear to deviate significantly in the Diathermanity, and in a flint glass spectrum the ultra-red rays are already reduced by absorption of the glass. And after that, however, a lack of sensitivity of the retina for ultra-red rays would be a cause of their invisibility; however, it will only require direct experiments on the patency of the eye media for ultra-red light, in order to be able to make a reliable judgment in this regard.

19) Pogg. Cl, 51.

20) The numbers are degrees of the thermo-multiplier.

21) Pogg. XXXV, 282.

However, Bridge²² has made direct experiments, according to which, through the cornea and lens of a fresh ox-eye, applied singly or in conjunction, nothing for the thermomultiplier transpired anything remarkable of the dark heat, which by a lamp of oil quite high, but by far non-heated for annealing black iron plate cylinder stemmed, however, the free light from the lamp through the cornea alone 8° to 9°, by the lens alone 1 1/2° (by both together nothing) gave, and meanwhile a water layer of 18 Mill. Thickness between mica plates of the lens same cross section and a calcite crystal of 3.7 Mill. Thickness combined with each other 2° when irradiated the dark heat gave. But the dark heat of the lamp makes no conclusive conclusion on solar heat, which is composed of warming and luminous rays in other proportions. And a later attempt of bridge²³ with sunlight can not be regarded as sufficiently proving

without a closer examination of the mode of action of the thin layer of soot, with which the rays had to penetrate.

22) Müller's Arch. 1845. 271.

23) Müller's Arch. 1846. 382.

3) According to the determination of Helmholtz²⁴⁾, the whole, without the help of fluorescence visible, part of the solar spectrum from the outermost red to the outermost violet, using all measures that can facilitate the direct visibility, about one octave plus a fourth (see above); Namely, according to Helmholtz, the wavelength of the outermost visible red (in a spectrum from which all light except the outermost red was dimmed by employing two prisms and two screens) is 0.0008124 mill., that of the outermost ultraviolet is 0.0003047; where, between them, the wavelengths of the dark lines determined by Esselbach line up in the manner indicated above.

24) Berl. Ber. 1855. 760.

4) The latest experiments of J. Müller²⁵⁾ led him first to the conclusion that the wavelength of the extreme ultra-red rays of the solar spectrum was 0.00183 mill., And later, according to another method of calculation, that it was 0.0048 mill. And as long as the wavelength of extreme ultraviolet rays 0.0003047 Mill., The former would be about $2 \frac{1}{2}$, giving the latter even 4 octaves together for the expansion of the entire solar spectrum, the visible and invisible part. However, partly the lack of homogeneity of the spectrum used for the experiments and partly the doubts about the validity of the principle applied to the calculation²⁶⁾ make both statements still doubtful.

25) Pogg. CV, 337. 543.

26) See here the remarks by E. Eisenlohr in Pogg. CIX, 340.

5) One could ask whether the visibility of the ultraviolet spectrum part without artificial aid of fluorescence might not be based merely on the fact that the retina itself by a fluorescent property transforms it into less breakable rays, since the ultraviolet rays show a blue color?

Helmholtz²⁷⁾ first examined this question on the retina of a man who had died 18 hours earlier, and found that the retina, however, due to its weak fluorescence, dropped the ultraviolet light on it into a mixture of not quite pure (greenish blue) white which, in addition to a relatively large proportion of unaltered ultraviolet light, also contains the less frangible rays of the spectrum (except the red), but that weak fluorescence (weaker than paper, canvas and ivory, stronger than porcelain) is insufficient to keep the visibility of ultraviolet rays dependent on fluorescence.

27) Pogg. XCIV, 205.

"The fairly saturated blue color of the over-violet rays for the living eye and the almost wholly white color of the dispersed light of the dead retina were too different,

he says, for the retina to survive the over-violet rays only after their transformation in less breakable light."

Sezenov²⁸⁾ has found in the fresh retina of rabbit and ox eyes the results obtained by Helmholtz. In addition, it also examined the transparent media of the same animal eyes for their fluorescence in ultraviolet light. The vitreous showed only traces of fluorescence, whereas the lens fluoresced strongly white-blue, the cornea much weaker, but in the same way, the watery moisture did not. This fluorescence can also be detected in the eye of living man by bringing the eye into the focus of the ultraviolet rays of the apparatus used by the author. The cornea and lens then begin to shimmer with white-blue light, and the cornea much more strongly than in the cut-out state.

²⁸⁾ Gräfe Arch. 1859. V, 206.

Meanwhile, this fluorescence of the transparent ocular media can do nothing to make the ultraviolet part of the spectrum visible, but rather to prevent this visibility, because the transparent media disperse the light that suffers the fluorescence in them, dispersing, as if they would be self-luminous; so that no image of the ultraviolet spectrum part in the eye could be generated by this dispersed light.

From what has been said above, it can not yet be directly decided by experience that limits of retinal perceptibility for colors with too fast and too slow vibrations take place, according to what is said (above), the most refractile (ultraviolet) rays of the solar spectrum have still been directly perceived, and after the discussion (see above) the possibility is still not entirely excluded that the at least breakable (ultra-red) rays are invisible only because they are unable to penetrate through the ocular media in sufficient quantity to be visible to be.

Nevertheless, a different perceptibility of the retina of the type that color rays of equal living force at different frequencies or wavelengths are perceived with unequal lightness or strength, and are not perceived beyond certain limits remains predominantly likely, once, because of the effect of fluorescence secondly, because the only explanation given is the difference in the distribution of heat and brightness in the prismatic spectrum, a substantial difference between the principle of light and heat, or a different sensitivity of the retina to rays of different refrangibility to make a statement; of which the former has become more and more unlikely due to the recent investigations,

These points will be discussed in a little more detail.

As for the first, the fact is that the ultraviolet rays, although not mediating fluorescence for visibility, are not necessarily needed, but are easier to see when they are transformed by fluorescence from more refractile to less refractile rays, though not to be presumed that the living force is increased by fluorescence.

Thus Helmholtz²⁹⁾, observing from the ultraviolet rays, that their "objective brightness" is not so slight as one would like to infer their small effect on the eye; this is evidenced by the fluorescence, "and although the living force of the

vibrations of light is certainly not increased by the process of fluorescence, the light of prolonged oscillation produced by it affects the retina vividly enough to be seen."

29) Pogg. XCIV, 13.

However, it was thought that facilitating fluorescence visibility was due to the fact that the rays within the normally visible spectrum were easier to pass through the ocular media than the ultraviolet ones, and the experiments of Brücke (so) seemed to prove this directly, but contradicted them very determined the (so) reported observations of Donders and Kessler.

In order to discuss the second point, it will be first of all to state the differences in the distribution of light and heat in the spectrum, which are important for us, after a number of relationships, and to determine them as far as possible according to previous investigations.

The maximum of the luminosity of the solar spectrum, which is produced by a prism of any colorless transparent substance, is known to lie in the yellow between the lines *D* and *E*³⁰⁾, and the distribution of the intensity is from Fraunhofer³¹⁾ on a spectrum produced with a flint glass prism from homogeneous beams. However, the numbers given by him do not express the true intensity ratio of the color rays contained in the sunlight because they are relatively more dispersed in the more refrangible portion of the prismatic spectrum and thus more dilute than in the less refrangible what differs in the interference-generated Fraunhofer. " grating spectrum³²⁾, where the distance of each color from the middle white stripe is proportional to the associated wavelength. To have the true intensity ratios of the colors in the sunlight; Therefore, the intensities of the prismatic spectrum must first be reduced to those which would occur in the grating spectrum. This reduction is made by A. Seebeck³³⁾ by means of an interpolation according to the relative distances of the dark lines in both Spektris. According to this, the light intensities of the prismatic spectrum according to Fraunhofer and the lattice spectrum calculated by Seebeck for the parts of the solar spectrum corresponding to the dark lines are as follows:³⁴⁾

| firm lines | Intensities. | | wavelength in mill. |
|---------------|--------------|-----------|------------------------|
| | Prismat. Sp. | Gittersp. | |
| <i>B</i> | 0.032 | 0.02 | 0.0006878 |
| <i>C</i> | 0.094 | 0.06 | 6564 |
| <i>D</i> | 0.64 | 0.57 | 5888 |
| Maxim. | 1.00 | 1.00 | |
| <i>e</i> | 0.48 | 0.56 | 5260 |
| <i>F</i> | 0.17 | 0.28 | 4843 |

| | | | |
|----------|--------|------|------|
| <i>G</i> | 0.031 | 0.08 | 4291 |
| <i>H</i> | 0.0056 | 0.02 | 3929 |

³⁰⁾ "The brightest spot - says Fraunhofer - Siegt by about $1/3$ or $1/4$ length *DE* of *D* to *E* to exactly the location of the place is not indicated.."

³¹⁾ Gilb. LVI, 301.

³²⁾ Denkschr. d. Münch. Akad. VIII.

³³⁾ Pogg. LXII, 374.

³⁴⁾ The intensity curve of the prismatic spectrum according to Fraunhofer can be found in the pictures of the same (see page 239); the derived grating spectrum to Seebeck in Pogg. LXII, Plate III, Fig. 4.

Of course, the numbers for the intensities in this table do not signify intensities of the sensation produced by the different spectrum colors, but objectively measured intensities of white lamplight, with which the different parts of the spectrum of equally strong impressions were found on the eye; a comparison, which, however, is somewhat difficult, but has been made possible by appropriate experimental measures and practice, which, as Fraunhofer observes, makes the comparison immensely relieved, and has attained only a modest degree of certainty, according to the degree of agreement of the individual Observations (Gilb, LVI, 301), and according to which the determination is relatively safer for the larger intensities than for the smaller ones.³⁵⁾

³⁵⁾ For the lines *D*, *E*, *F* with a sum of the intensities = 1.29, the simple error sum is found after every 4 attempts on each line in the whole 0.676, for the lines *B*, *C*, *G*, *H* with a sum of the intensities 0.163 in total 0.228.

Melloni also remarks in an Abhandlang (Pogg. LXII, 24) of the need to first reduce the directly observed light intensities of the Newtonian spectrum to that of the lattice spectrum in order to obtain the correct ratios of the luminosity of the different color rays in the sunlight, makes the following message.

In order to preserve these relationships, Mr. Prof. Masotti has computed the data that contribute to the formation of the lattice spectra, in which the elementary colors propagate side by side by mere interference, and thus occupy spaces that depend solely on their period of vibration or length of unduction. For this spectra free of the indicated defect, Mr. Masotti has found the brightest point exactly in the middle of the yellow, and this, in turn, equidistant from both ends, so that the red and the violet border are the least bright points of the spectrum and both have the same luminous intensity M. Masotti has finally proved that the colors of these two boundaries consist of ether waves whose length is in the ratio 2 : 1. "

Unfortunately, there is no indication of where Masotti's work can be found nor on what data it is based. Their result differs somewhat from the Seebeckian to Fraunhofer datas in that it finds an equal intensity for colors whose wavelength is in the ratio 1 : 1.75, whereas Masotti gives the ratio 1 : 2.

As far as the distribution of heat in the prismatic spectrum is concerned, the position of the heat maximum varies, partly according to the substance of the prisms, by which the spectrum is produced, partly by the thickness of the prism through which the rays pass, partly by the homogeneity or non-homogeneity of the spectrum, and finally finally of the nature of the transparent substances still interspersed by the rays. When using a hollow prism filled with water, alcohol or turpentine oil, it has been found in yellow, glass prisms depending on the type of glass and other circumstances in orange, red or beyond the visible red (in the ultra-red), with a rock salt prism always beyond the red Variability depends essentially on the fact that the ultra-red dark heat rays from the transparent substances,

But, according to Melloni's experiments, rock salt is a substance which allows the dark and visible heat rays to pass easily; and in order to have definite determinations of the heat intensity of the whole spectrum, both in its dark and light parts, one must therefore apply a rock salt prism for the design of the spectrum, which is not so essential, if only the heat intensity in the visible part of the spectrum from violet to red, since, according to the data to be communicated below, the most diverse transparent substances show an equal patency for all rays of this spectrum part. In addition, strictly speaking, a homogeneity of the spectrum would have to take place, for which the existence of the dark lines is considered characteristic. But since you have to use a very narrow light beam,³⁶⁾, so that one does not yet have pure and on certain dark lines related intensity determinations of the heat of the spectrum.

³⁶⁾ Comp. Franz in Pogg. CI, 50th J. Müller in Pogg. CV, 339.

Recalling from Helmholtz's study directed against Brewster (Pogg. LXXXVI, 501), what are the important errors of diffuse light dependent on impurities of the substance, imperfect polish of the prism, and multiple reflections between the surfaces of the prism in the evaluation of the color relations of the spectrum and considers that it is not at all excludable in the case of a spectrum produced with only one slit and only one prism, as it has been the subject of previous investigations on the heat conditions of the prismatic spectrum, least of all in a rock salt prism not so easily of such perfect polish, and as pure as a glass prism is to be obtained, so here too a notable cause of the impurity of the spectrum and of the results obtained therefrom may be sought, However, as far as I can see, it seems that from this only a nearly uniform change in the temperature of the visible part of the spectrum, but no influence on the position of the maximum, can arise.

Meanwhile, the following data should be given. In any case, using a rock salt prism, the maximum thermal intensity is significantly beyond the visible limit of red in the ultra-red.

According to an earlier statement of Melloni's (Pogg. XXVIII, 377), "it lies so far from the red end that the distance between it and the red was just as great as the distance between the red and the violet as the whole length of the red Spectrum." According to a later statement (Pogg. XXXV, 307), the distance of the heat maximum from the red end is at least as great as that of the green-blue from the red, and then the intensity decreases rapidly, and at a distance from this point, which accounts for one third of the red Length of the color spectrum is the same, stops all noticeable heat effect. According to a third statement (Pogg. LXII, 22), Melloni finds the heat maximum "quite apart from the colors at a middle distance equal to that which, on the opposite side, exists between the red and the yellow."³⁷⁾ gave a result which coincided with the second of these data with regard to the maximum position, ie, the distance of the maximum from the boundary of the red approximately the same as the distance of the transition from green to blue from the red border of the spectrum Sun spectrum over the red but occupying a space almost as long as the whole usual visible spectrum to violet, and found that a crown glass prism in this thermal extension agreed with the rock salt prism, but gave a nearer to red maximum. Line B in the crown glass spectrum was approximately midway between the violet end of the spectrum and the outermost dark heat rays of the spectrum

Measurements of the intensity in the individual parts of the (admittedly not homogeneous) spectrum have been given by Franz³⁸⁾ and J. Miiller³⁹⁾, the former by using a flint glass prism and interposition of a glass bottle to make comparative experiments with and without transmission of the rays by liquids, the second with comparative application of a crown glass and a rock salt prism. Using the rock salt prism, the latter found the following intensities of heat (forces acting on the thermo-multiplier), where the indication 1 "", 2 "", etc., for the ultra-red indicates the distance from the visible red end.

³⁷⁾ Pogg. CV, 352.

³⁸⁾ Pogg. CI, 46.

³⁹⁾ Pogg. CV, 337. 543.

Center of Ultrared

| | | | | | | | |
|------|--------|------|------|------|-----|-----|-----|
| Blue | Yellow | Red | 1 " | '3' | "4" | '6' | " |
| 3.7 | 7.9 | 10.0 | 13.2 | 15.9 | 13, | 2 | 1.7 |

With the Crownglasprisma (because of greater purity of this prism) in the visible part of the spectrum absolutely stronger, but noticeably the same, ratios for the different colors showed numbers, namely (with reduction to the same value with red)

Blue Yellow Red 1 " " 2" 40) 4 "
6" 4 7 10 12 11 7 2

however, as you can see, the conditions in the invisible ultra-red were very different from those of the rock-salt prism.⁴¹⁾

40) The rock salt prism here is 3 "", probably 2"" is printed.

41) The comparative curves of the rock salt and crown glass prism s. Pogg. CV, Plate III, Fig. 1.

However, even with these determinations, made on a prismatic spectrum, it must be taken into account that the heat rays in the more refractile part of the spectrum are more dilute, and therefore to have their true intensity ratio in which they are contained in the sun's rays. first a reduction to the grating spectrum is necessary, as has been found by Seebeck with respect to the brightness. After such a reduction of a prismatic rock salt spectrum J. Müller finds the maximum of the intensity of the heat just as it applies to the light, lying in yellow, and this determination receives the more weight in that Draper⁴²⁾ previously found the same by direct experiments on a grating spectrum generated by reflection without the inclusion of dioptric media. However, the distribution of the heat in the spectrum is by no means in agreement with the distribution of brightness (as Draper assumes), as follows, of course, that the brightness, but not the heat, vanishes beyond the red; and also from the comparison of Seebeck's brightness curve (see above) with Müller's heat curve for the grating spectrum⁴³⁾, which we will return to below.

42) Philos. like. 1857. XIII, 153.

43) Pogg. CV, plate III, Fig. 4.

If one asks now for the reason of this different distribution of light and heat in the spectrum, it is obvious that, if one regards light and heat as essentially different agents, nothing prevents one from thinking that the intensities of light and heat of equal friability in the spectrum do not go in proportion to each other. Meanwhile, the view of the essential identity of light and heat, though not yet proven to be absolute, can only be met with weak doubts, and that difference in the distribution of light and heat in the spectrum does not justify a binding counterpart because it partly of different patency of the rays of different refractive power through the eye media, and sometimes different sensitivity of the retina can be made dependent on it.

Melloni, who has made the most extensive investigations in this field, having previously declared against the identity of light and heat,⁴⁴⁾ and has cited several facts as firm evidence, has himself arrived there by subsequent investigations, all the facts he observes to keep the identity view compatible, and has just as decidedly

declared this view.⁴⁵⁾ Masson and Jamin⁴⁶ do not agree with this opinion, according to their experiments.

⁴⁴⁾ Pogg. XXXVII, 486.

⁴⁵⁾ Pogg. LVII, 300. LXII, 18, as well as his work: "La thermochrose 1850. 327."

⁴⁶⁾ Compt. rend. XXXI, 14.

To sum up all the newer facts, the whole difference of the dark rays of visible rays, visible by no means, seems to be reduced to the fact that they have a lower refractive index and thus faster vibration, greater length of undulation, with less continuity most media are related; and it does not seem that rays of identical refractoriness can still be distinguished as light and heat rays. Not only do the dark heat rays follow the general laws of propagation, reflection, simple and birefringence, polarization, interference, absorption of light, but Melloni⁴⁷⁾ lately finds, too, "that the colors of the spectrum are so intimately linked to their temperature, that they lose just as much heat as light when passing through not quite clear substances, so that the relation of these two agents always remains undisturbed the same."

⁴⁷⁾ Pogg. LXII, 28.

The new investigations of Franz⁴⁸⁾ about the diathermy of dyed fluids. "Wherever absorption of light is recognizable, a decrease in heat intensity is also detectable The minimum of light loss in the case of radiation of the spectrum by a liquid, he concludes, must be with the minimum of heat loss in the same zone otherwise, the identity of heat and light is impossible, indeed the blue solutions of sulfuric copper oxide show the minimum of heat loss after radiation of a spectrum through them in the blue zone, the green solutions of sulphate of iron oxide in the green zone. When red solutions are used, it is found that of all the colored rays passing through red solutions, the red rays lose the least light and heat,

⁴⁸⁾ Pogg. CI, 46.

Whatever seems at first glance contrary to the first view of identity, and which Melloni asserted earlier (Pogg. XXXVII, 486), is the above-mentioned circumstance that, depending on a prism made of rock salt, flint glass, crown glass, water or the spectrum produced by a rock salt prism can be irradiated through this or that transparent medium or layers of the same medium, the position of the heat maximum and the heat distribution at all, hence the intensity ratio of the heat rays of the spectrum changes, while the intensity ratio of the color rays unchanged remains; otherwise these substances would appear colored in the continuous light. But after Melloni's later attempts⁴⁹⁾ this applies only to non-homogeneous spectra in which dark heat rays are still mixed with the colored rays at the red end; whereas, "with the greatest possible avoidance of all sources of error the temperatures of the prismatic colors constantly asserted the highest temperature at the red end, whatever the colorless substance one was applying, either in prismatic form,

the sunlight in his Dissect elementary rays, or in slab form, to explore the body's absorbing effects on these rays. "

49) Pogg. LVII, 302. LXII, 28.

Masson and Jamin⁵⁰ also conclude from their investigations that all heat rays between red and violet pass through rock salt, rock crystal, alum, glass, and water evenly, that is, the considerable differences in the diathermy nature of these substances only in the different absorption of the dark Rays have their reason. Finally, the above results of the comparative experiments of J. Müller with a crown-glass and rock-salt prism⁵¹ are also in the same sense. According to which, instead of proving counter-evidence against the view of identity, these relations are rather among the most important proofs for the same.

50) Compt. rend. XXXI, 14.

51) Pogg. CV, 349. 351.

As far as I can see, there is only one class of facts which seems difficult to reconcile with the view of identity, namely that there is light of considerable luminosity, or that it can be produced by special methods of action, which shows a barely noticeable or no noticeable warming effect. Even the moonlight is light whose heat can only be detected by the most sensitive apparatus. Particularly striking, however, is the following experiment, which Melloni⁵² has earlier cited as a cardinal attempt against the identity view, with respect to the passage of sunlight, as terrestrial firelight through a system consisting of a layer of water between glass plates colored green by copper oxide.

52) Pogg. XXXVII, 486.

"The pure light, says Melloni, which extends to this system, contains much yellow, but still has a blue-green color, does not warm the most sensitive thermoscopes, even if it is concentrated through lenses so that it is just as shiny as the dark sunlight. "

It is to be regretted that Melloni, after his conversion to the concept of identity, did not come back to the discussion of this attempt, which he briefly mentioned, just as little has he, as far as I know, been repeated by others, even though he is everywhere a main objection the identity view is cited; but it must be concluded from the fact that he did not prevent Melloni from later turning to the view of identity, that this attempt later did not appear to him as proving as it once did.

These facts could only be a resounding blow to the concept of identity if they were accompanied by measures which were particularly directed at the question, but which are not yet available. For, at any rate, it is sufficiently proved that the heat of sunlight, as well as earthly fire, is by far the greatest proportion of dark heat, which is more easily absorbed by transparent media than by visible matter, so that if all the dark rays and, moreover, one absorbed much of the luminous, as happened in Melloni's cardinal attempts, the rest can express only a very low heat effect at all; if it always

remains unexpected that it should not be noticeable even after concentration by a lens up to strong luminosity.

If, according to the foregoing, the unequal distribution of light and heat in the spectrum can not with probability be made dependent on a non-identity of light and heat, it might be thought from the other side that the unequal absorption of the rays of different refractive properties on the part of the ocular media another intensity ratio of parts of the spectrum perceived as luminous in the eye than those measured outside the eye thermometrically. Such an unequal absorption now also occurs indisputably, when one compares the visible and invisible heat rays, and must be considered. Just after the above-mentioned experiments by Melloni, Masson, Jamin and J. Müller finds within the visible part of the spectrum from violet to red no uneven absorption of different color rays through colorless transparent media instead; or at least such is unlikely insofar as the most diverse transparent media with very unequal absolute absorption capacity for the heat can still find the same heat conditions of the passing spectrum rays.

It has also been noted above that, according to the present facts, the ultra-red rays of sunlight are very unlikely absorbed by the ocular media.

The only supposition left behind is that, if the colors of the spectrum do not appear bright in the same proportions as they are warm outside, this depends on a nonuniform sensitivity of the retina to the colors, of the kind after which of the spectrum of color vibrations with the same living force with which the retina is hit by them, yet they are perceived less easily and strongly than they are felt around the middle, and beyond certain limits no longer noticeable.

Given the identity of light and heat, one can keep the objective intensity, ie the living force, of the rays in the different parts of the spectrum measured by their heat, and in the colorless transparency of the ocular media, which does not alter the ratio of the visible rays of color. suppose also that the rays reach the retina with the same proportionate intensity which they have by heart; where we are no longer able to measure their warmth, but rather their luminosity, ie the intensity of white light, which makes an equally strong impression on the eye (see above). Both would have to be proportional to each other, unless the unequal sensitivity of the retina for the different colors changed this ratio.

If we had a curve of heat as accurate as the luminosity of the spectrum, more definite conclusions about the sensitivity of the retina could be drawn from the deviation of the two curves; insofar as these deviations would then have to be pushed only for the account of the differing sensitivity of the retina for the different color rays. But if this is not the case, then the comparative view of the Seebeck curve of luminosity (Pogg. LXII, Plate III, Fig. 4) and the Mullerian curve of heat (Pogg. CV, Pl. III, Fig. 4), which was already mentioned, give a certain general support in this respect.

According to this, and as already noted above, the maximum of luminosity coincides with the maximum of heat in the yellow from which one must conclude that the maximum of the retina's sensitivity coincides markedly with the maximum of

the intensity of the rays reaching it; Rays appear to be the most luminous for the double reason, because they are the most intense and because they are perceived with the greatest sensitivity. From the common maximum coordinate, the Seebeck curve of luminosity falls almost convex on both sides almost symmetrically against the abscissa axis of the wavelengths, the Müller curve of the heat concave against the axis of abscissa, completely asymmetrical on both sides, slowly becoming red and ultra-red , much faster to violet, F (ie in the blue), so that indigo-colored, violet, ultraviolet rays, which lie beyond the line F , correspond with their ordinates to ultraviolet rays, and thus those are still visible in a living force in which they are invisible; to interpret as meaning that the sensitivity decreases from its maximum value for the yellow much more rapidly to the sides of the red than to the sides of the violet.

This result seems to me to be drawn, in so far as the compilation of previous observations can be considered authoritative. But, of course, it would be necessary for the complete assertion and precise determination of this result, that the investigation should be directed toward it, and that certain points should be more precisely determined and settled, which could only be asserted here as probable or not rest on any sharp determinations.

Insofar as the pitches have a lower limit and probably also an upper limit of perceptibility, it may in any case not be improbable if something similar takes place in the area of the colors. Assuming that the laws of resonance, according to which vibrations outside the eye communicate between elastic media, are also applicable to the communication of the light vibrations to the retina, it may even seem necessary that the retina be easiest of color It sounds the most consistent with resonances under otherwise identical circumstances, in which they vibrate independently, and from this point of view J. Herschel, Melloni, and A. Seebeck have grasped the subject. The only difficulty that seems to me to exist here is that the retina does not sound in a certain colored light, but in white light, provided the black of the visual field is colorless, and the ordinary, with the eye closed, which represents a slight degree of sensation of light Flicker of light in case of morbid irritability of the eye, as I can tell from myself, is white or, at the most, quite ambiguously yellowish, which can not quite be distinguished by flickering points. On the assumption, however, the retina, without external stimulation, would have to vibrate decidedly in the color for which it is most susceptible. if the black of the field of vision with the eye closed, which represents a slight degree of sensation of light, is colorless, and the usual flicker of light with morbid irritability of the eye, as I can assert on myself, is white or at most quite ambiguously yellowish, which is due to flickering points can not quite distinguish. On the assumption, however, the retina, without external stimulation, would have to vibrate decidedly in the color for which it is most susceptible. if the black of the field of vision with the eye closed, which represents a slight degree of sensation of light, is colorless, and the usual flicker of light with morbid irritability of the eye, as I can assert on myself, is white or at most quite ambiguously yellowish, which is due to flickering points can not quite distinguish. On the assumption,

however, the retina, without external stimulation, would have to vibrate decidedly in the color for which it is most susceptible.

Although I do not consider the resonance theory of seeing adequate, it may perhaps be applicable to a certain extent, and I think it useful to show how it has been attempted so far; therefore, the essence of the view of Herschel, Melloni and Seebeck may follow here.

W. Herschel in his work on the light, §. 567 is expressed as follows:

which are exactly the same as the oscillation time thereof, can be set in vibration, or as a solid elastic body may also vibrate when vibrated by another remote body, by virtue of its propagation through the air, when both are in unison We also assume that the coarse nerve fibers of the retina are set in motion by the incessant repetition of the etheric strikes, and that only those will move which, by virtue of their size, shape, or elasticity, will be able to complete their vibrations in the periods in which the Repeated shocks. In this way one can easily see how a limitation of the visible colors must result; because if there are no nerve fibers with vibrations that are more or less frequent than certain fixed boundaries, but such vibrations, though reaching the retina, will not produce any impression. Thus, even a single or an irregularly repeated impact produces no light, and in this way the vibrations produced in the retina may continue for a considerable time, even though the active cause has ceased, thereby prolonging the sensation of light. "

Melloni develops his ideas in a letter to Arago in the *Campt. rend.*, T. XIV, p. 823, resulting in a translation into Pogg. Ann. LVI, 574 (see also LXII, 25) under the heading: "Observations on the Coloring of the Retina and the Crystal Lens," with reference to a paper read in the Academy of Sciences in Naples, where he expressed the same opinion. He says:

"According to the principles developed in the treatise just mentioned, the vision would be due to the extremely rapid vibrations which the nerve molecules of the retina undergo under the influence of a certain series of aetherundulations." These vibrations, considered in relation to the various undulations composing the solar spectrum, would not but depend on the greater or lesser ease with which the particles of the retina follow this or that ether vibration, it would, acoustically speaking, be a kind of resonance of the retina excited by the chord or harmonic relation between the tension or elasticity of its molecular groups and the period of the incident wave. "

"The undulations lying outside the two limits of the spectrum could not induce a vibratory movement on the retina, and would therefore be invisible, because every kind of chord would leave them with the molecular elasticity of this membrane of the eye." Between yellow and orange, that is, according to Fraunhofer On the other hand, the undulations corresponding to the maximum of the light intensity would provide the most homogeneous vibrations with the mentioned elasticity of the retina, and communicate to the molecules of this skin the most pronounced vibratory movement. "

"It is self-evident that, according to this theory, as with any other thought for the explanation of vision and optical phenomena in general, the amount of light depends on the intensity of the radiation, which, for us, is the breadth of the molecular vibrations. For under the same circumstances, for example, the blue ray of the sun's spectrum might very well develop a ten times smaller amount of light than the yellow ray because of its weak chord with the tension of the retinal molecules, but the luminous effect of both rays would apparently be the same when the vibrating atoms in the blue undulation undergo a ten times larger space than those in the yellow undulation."

"The relations between the intensities of these different vibratory movements of the ether would, according to our view, be supplied by the different temperatures, which a well-coated Kienruß thermoscopic body under the influence of the radiations adopts."

Melloni concludes from the circumstance that while temperature and luminosity increase from violet to yellow, the temperature from yellow to red increases, while the luminosity from yellow to red decreases, the need for retinas has less consonance the orange and red, as with the yellow rays, which conclusion no longer seems to be binding, if in the equally reduced spectrum of heat and light the maximum for both heat and brightness lies in the yellow (see above), but in something else. Form after the uneven decrease of heat and brightness from the maximum can be restored only in slightly different form.

Further, Melloni puts forward the proposition that the retina best agrees with the yellow in relation to a yellow coloring of the retina, which is directly observable in the so-called Sommmering yellow spots, and, according to Melloni, the rest of the retina too under certain precautions, according to which, and other circumstances, he concludes that it is more easily visible in the yellow spot because of the greater thickness of the nerve layer.

"For a body, according to Melloni, is red, green, or blue, according as the tension of its particles is more consonant with the period of oscillation of red, green, or blue undulations, and it necessarily follows that a substance whose particles are under the action of this or that light-undulation swing better, is necessarily colored."

A. Seebeck gives his opinion in a letter to Poggendorff under the headline: "Remarks on resonance and on the brightness of colors in the spectrum" in Pogg. Ann. LXII, 571, with reference to an earlier paper (in the same volume, p. 299), in which he examined how an air-vibrating elastic plate behaves at resonance.

"From that theory of mid-tones, he says, it has been found that a plate, as I assumed it there, has its own amount of vibration n , hit by a wave-train of the form $a \cos(m t + \Theta)$ always after some time into one movement passes, which by $\alpha \cos(+mt\Theta)$ is presented, where the oscillation amplitude α the larger in proportion to a is, the less m of n is different."

"The following is very easily derived from the formula found for a . The following sentence⁵³⁾ :" If two equally strong notes are applied to the plate, then the midtone is

of equal intensity, in the case of the higher tone the same tone interval above the tone of the plate like the deeper below it, z. For example, if that is higher by a fourth, this is one fourth lower than the original tone of the record. If one therefore draws a curve of resonance strength by taking the wavelengths as the abscissa and the intensities of the midton as the ordinate, then this curve does not become symmetrical on both sides of its maximum, but falls faster on the side of the shorter ones. (It would become symmetrical if, instead of the wavelengths, they took their logarithms as abscissa). "

After referring to the curve of these intensities recorded in the original (Pogg LXII, Plate III, Fig. 3), Seebeck continues:

"I shall now try to apply these considerations to the so-called resonance of the retina under the not guaranteed assumption that the theorem that has been found for the longitudinal vibrations of the sound waves may, with certain limitations, be transmitted to the transversal waves of light . "

"Let us imagine that the retina consists of particles which, by themselves, make their own vibrations, just like the plate, and the subjective light which we perceive upon excitation of the eye by means of shock or electrical discharge then becomes Suppose that the value of n is the same for all the particles of the retina, that is, that that subjective light is homogeneous, or what comes to the same thing, we consider only those particles which no matter n If we let light waves of any length act upon these particles, the vibrations of the retina must, after some time, become isochronous to those of the exciting wave, but the stronger the less the wavelength of the incident light from that of our own (subjective) light of the retina is different. If we let waves of different lengths, but of equal magnitude (equal values of am), act on the retina after each other , their resonance and the resulting sensation of light must be of unequal strength, and the effects on our organ would be affected by a resonance curve similar to what I have drawn for the plate, where only the value of n and b should be determined from experience. "

53) The formula given by Seebeck (Pogg. LXII, 299. LXVIII, 459)



where α is the oscillation amplitude of the resonating plate, a is the amplitude of the vibrations which cause the plate to resonate, n is its own oscillation number of the resonating plate, m is the excitatory vibration, b is a constant dependent on the resistance of the movement. The above theorem follows from the fact that α takes

the same value if one substitutes for $m xn$ and \square which number is also x . Besides, it will be easy to deduce the proposition that if n and n' are their own vibrational numbers of two different plates, α is equal for them when they are linked by the relationship

$$n^2 + n'{}^2 = 2 m^2.$$

"If this curve could be made identical with another, representing the observed magnitudes of the color spectrum, by an expedient choice of b and n , one might surmise that the waves are of equal strength (living force) in the whole extent of the spectrum but an unequal distribution of this strength would have to be concluded if these two curves can not be reconciled."

"The latter is indeed the case, which I have already convinced myself some time ago by comparing Fraunhofer measurements."

Seebeck now gives the reduction of the prismatic spectrum as already reported on p. 281 to a lattice spectrum, also gives a curve thereafter (Pogg. LXII, Plate III, Fig. 4) and continues:

"If one compares this curve with the previous one (Figure 3), one notices at once from the very unequal course of the two, that - among the prerequisites mentioned at the beginning - the true intensities ($a^2 m^2$) can not extend uniformly over the entire extent of the spectrum, in that the maximum has a completely different position between every two points of equal brightness than would be possible with the resonance curve for equal wave strengths. If the wave strength is unequal for different parts of the spectrum, the brightness curve must become a function of it and of the unequal resonance capacity of the retina, so that in order to judge the latter one would have to know the former (the wave strength). The maximum of brightness must depend on the nature of these two variables. If, for example, the wave intensity decreases continuously from red to violet - as seems to be the case under the assumption of the principle of identity, if here too the unequal propagation in the prismatic picture is brought to bear, then the retina already fall into cyan or blue⁵⁴⁾. This is a very different result than that to which Melloni arrived, without question from completely different premises, by putting the greatest resonance capacity where the greatest brightness is perceived."

⁵⁴⁾ "If perhaps this is why the green color is so beneficent to our eyes, then the subjective light would probably also be green or bluish, which, I believe, is not confirmed."

"I have performed this calculation under the unilateral assumption that all parts of the retina no matter n have, because it did not seem to be of no use to me, the analogy to which one is rejected even in this subject, carried out on such a simple examples. However, I do not consider this assumption to be likely, but may several n s will be appreciated, it will be possible to reconcile any given brightness scale with any given distribution of wave strengths. In this way, assuming the principle of identity, it will be possible to capture the idea of a retinal resonance, or perhaps of several such resonances, just as one may find the distribution of heat in the spectrum or the retinal part of it, But whether the values of the n , which have to be assumed in order to

reconcile the heat scale with the brightness scale, are really grounded in the nature of the eye, are likely to give the subjective facial appearance some insight."

b) Points of agreement and difference between the areas of sensation of light and sound.

In particular, the following points should be asserted.

1) Sensations of light and sensations of sound are sensual sensations, both, albeit in different senses, the chief underpinnings of our higher spiritual development, both of a great variety of modifications, alterations, and decomposition by contemplation into different, if not really divorced, sides (Strength and color in light, strength, height and sound in tones).

2) Both depend on the vibrations of an elastic medium as external stimuli, but can also arise without external stimulus for internal reasons. They are probably also subject to internal vibrations, which are excitable by the external.

3) In both, a sensory organ, usually double-sided, inserts itself between the external stimulus and the sensory nerves, whereby the form and mode of action of the external stimulus is influenced in its action on the nervous system.

4) The quality of the tones, such as the colors, depends on the duration of the oscillation or the number of oscillations, the intensity of which depends on the amplitude of the exciting oscillations. With regard to the amplitude and the intensity of the sensation dependent thereon, Weber's law applies to both.

5) Different tones, such as different colors, can produce an impression in the meeting, which corresponds to that of a simple tone, a simple color. In terms of tones, I refer here to the so-called Tartini or combination tones.

6) As there are limits to the audibility of sounds, so too limits the visibility of colors, and on both sides still subject to the discussion of the extent to which these limits are due to lack of perceptibility of the nerves for very fast and slow vibrations, or because of the The mechanism of our external sense organs is that vibrations above and below a certain degree of rapidity are unable to reach the nerves. Of what applies in this regard to sounds, Th. I, p. 258 and Th. II, chap. 30, have already sufficiently spoken of what applies to colors in the preceding section of this chapter.

7) The approximation, which shows the color impression of the violet at one end of the ordinary solar spectrum to that of the red at the other, can be compared (in a certain sense only) with the periodic return of an analog tone impression after the interval of one octave.

Although proliferates in the transition from the usually visible violet to ultraviolet rays by no means the approach to the impression of the red (due to expected purple inks), as one would assume by analogy with tones, but the blue returns⁵⁵⁾. The ultraviolet part of the spectrum (beyond Stokes' group *I*) appears at low intensity indigo blue, at strong intensity white-blue, but concludes Helmholtz from his experiments (Pogg XCIV, 210), "that the reversal in the color series, which takes place in the ultraviolet light, can be explained so that a faint sensation of violet color

which directly excite these rays of light, associate the perception of the greenish white light produced in the retina by fluorescence (*supra*), and both color sensations combine to give the whitish indigo blue coloring which the overviolet rays present when seen directly."

⁵⁵⁾ VgL Pogg. XCIV, 14. 206. XCVIII, 514.

to see them in greater light. I have shown the overviolet light to several other persons so as not to be deceived by a peculiarity of my eye, and all designated the color in the way I have stated. Among all these breakable color tones, there is faint purple, for example from the region of line A.⁵⁶⁾ closest to the purple; but even this is separated from the outermost red by a wide interval in the color series. By combining violet and red one can form in my apparatus a very large number of distinguishable purple shades, which can all be placed between the colors of the two extreme ends of the spectrum. "

⁵⁶⁾ This must be printed (for H?), Since A belongs to the red.

Elsewhere (Pogg XCIV, 208) he says (with respect to a spectrum obtained by means of a quartz crystal apparatus): "The eye did not appear to have a lesser degree of sensitivity to the outermost ultraviolet rays of sunlight than to those of the m I could not see the change in the color from the first to the last, except that the fainter spots showed an indigo blue more like violet, but all the indigo-blue rays are but at lower brightness it was more like violet, but at the same intensity of light the color of the violet rays seemed to be whiter than that of the ordinary indigo-blue ones. "

Esselbach (Pogg XCVIII, 515) says (with respect to a spectrum designed with a rock crystal apparatus): "The physiological impression is in the part of the ultraviolet from N to R of the same" "lavender gray" "as between the lines L and N. Mostly the lines appear very sharp on dull greyish blue ground, at lower brightness the ground appears shining indigo blue and in even greater diminution of light sometimes, especially at the limits of the field of vision, in decided violet. This colorful play of colors observed during observation agrees entirely with Helmholtz's explanation Color, according to which their short waves are perceived partly directly as a little intense violet, partly by mediating a white, greenish blue fluorescence. "

8) Normally, we just see with both eyes and just listen with both ears.

9) As according to Ch. There are 30 individuals who are unresponsive to the sounds of a certain part of the normally audible tone scale, such as those who are unresponsive to some of the normally visible gamut.

A. Seebeck already draws this comparison (Pogg. LXVIII, 461). A compilation of the manifold forms of inadequate sense of color can be found, *inter alia*, in Rüte's Ophthalmologie p. 179 ff.

The main points of difference, on the other hand, are the following.

1) Light and sound sensations have a different basic character.

2) The nature and relationships of the external vibrations, which serve as stimuli for the awakening of the sensations of light and sound, and the sensory organs by which they are transmitted to the nervous apparatus, are very different in light and sound, according to which differences are also aroused thereby internal processes in our nervous system, of which the sensation is functionally dependent, may be considered probable.

3) The light, which awakens the sensations of light, is due in particular to very fast and rapidly propagated oscillations of very small amplitude in an imponderable, very thin medium, the ether; the sound, by which the sensations of sound are aroused in us, on comparatively much slower and slower propagated vibrations of much greater amplitude in a weighably denser medium, the air. These are due to mere displacement of the particles of ether against each other, without condensation and dilution of the ether, to the approximation and removal of the particles with compaction and dilution of the air. The light vibrations are transversal, di in their direction of propagation, that of the light beam, perpendicular and can be rectilinear, circular, be elliptical and have the most varied composite forms; the vibrations of the air are longitudinal, that is, they coincide with the direction of propagation of the sound, the direction of the sound-beam, and are indisputably uniform in direct air.

(4) When arranging the eye care is taken that rays of light emanating from a point also meet again in a point of the nerve-skin struck by the rays of light, and the impressions of light juxtapose in a similar manner on the retina, as in the external world that a picture of the external things arises on the retina. In the device of the ear no such device is taken, and there may be no sound image of the outer objects in the ear. On the other hand, other peculiar arrangements have been made in the ear, the interpretation of which with respect to the perception of the sound is partly clear, partly unclear. Particular attention should be paid to certain fine key apparatuses with which, according to new anatomical discoveries, the ends of the auditory nerves are related, as will be recalled below.

5) The various auditory nerve fibers can not at all preserve the impression of spatial juxtaposition, as is the case with the various optic nerve fibers, in that the simultaneity of different sounds makes a different impression than that of spatial coordination, a difference that exists independently. that the sound rays do not produce an image of the sounding objects in the ear; for if rays of light emanating from a point disperse over the retina, as is the case with a lack of accommodation, they nevertheless appear spread out in an area, spatially explicated.

6) The perception of light has the ability to be spatially formed, in common with the tactile sensation, while the sound sensation is no closer relationship with another sensation.

7) Even without external light-stimulus, we normally have a sensation of light, that of the black field of vision, which, according to earlier discussions, indeed joins the sensations of light, whereas normally we have no sonic sensation without external sound-stimulation; according to which the psychophysical activity of vision, but not

that of hearing in our nervous apparatus, is above the threshold without external stimulus.

8) The scale of visible colors is, according to the discussion in the previous section of this chapter, about 1 octave + 1 fourth, while that of the audible tones is a whole number of octaves.

9) Through the psychic act of attention, under certain restrictions, a mixture of sounds can be decomposed into its components in such a way that we can become aware of one another alternately; whereas, in terms of color mixtures, attention is not given to such assets at all.

On several sides it has been doubted or denied that with pure clay mixtures a real distinctness of the individual tones takes place, and in this there is a substantial difference between them of color mixtures. If musicians can hear a false note in a concert and even designate the instrument that gave it, this is only due to the fact that they recognize the character of the whole clay mixture, but without it, in particular to hear how one can well recognize the blending of a nuance of color with white, and that the practiced eye of the painter can even decide on what kind of admixture it is based, without, however, being able to consciously raise it with the elimination of white.

Now it can not be denied that the distinctness of sounds in pure clay mixtures has its limit determined by the degree of practice and attention; If, however, I am inclined, even with my very bad musical affections, to submit to such a view, musicians with educated obedience are definitely opposed to it. The music director Hauptmann in Leipzig explained to me in the most definite way that he was, however, able to hear one or the other from a chord of simultaneously struck notes, and not only when he was unclean, but also when he was whole chord is pure. In the same sense Helmholtz expresses himself in several places, among others⁵⁷⁾ "Now that experience teaches that wherever the mathematical-mechanical investigation proves compound wave motion, a practiced ear can distinguish sounds corresponding to the simple wave motion contained therein, etc"; and elsewhere⁵⁸⁾ in relation to sounds in which a root is accompanied by overtones. "In the immediate sensation, however, the individual simple sounds are always separated from each other, with attentive attention, while they flow together in the imagination into the sensory impression which the sound of a certain sounding body makes on our ears, and it usually involves an artificial sound. Attention to divorce the individual elements of composite sensation, just as special observation methods require, for example, in order to convince oneself that the intuition of the corporeality of a considered object is due to the merging of two distinct images of the same based on both eyes. " Helmholtz (see below) shares this

⁵⁷⁾ Pogg. XCIX, 502.

⁵⁸⁾ Pogg. CVIII, 282.

10) Whereas sensations of light and sensations of sound in the strength dependent on the same physical circumstance (the vibrational amplitude) have a common psychic side, the color and pitch, which are no less dependent on the same physical circumstance (the number of oscillations), is psychic in both. It is incomparable, and in this way gives both feelings the qualitatively different basic character which we have to recognize in them. Apart from the immediate feeling of difference, the following conditions are different in this respect.

11) In the case of sounds, the height increases continuously with the number of vibrations, and only in relation to each other do they show the peculiar impression of the third, fourth, fifth, octave, etc. In the case of colors, as the number of oscillations increases, nothing resembles the continuously increasing perception of height, but a change of characteristic impressions, Red, Yellow, Blue, the same are linked to the rate of vibration itself, not only about relationships and what is no analogue in the clay-rich place than about the sound of that but here depends only on sympathetic vibrations of higher order⁵⁹⁾. Conversely, the impression which the contrast ratio of the colors makes on each other shows no analogy to the relations of the third, fourth, fifth, octave, etc., in the realm of tones.

59) "The musical timbre depends only on the presence and strength of the side notes contained in the sound, not on their phase differences" (Helmholtz in Pogg, CVIII, p. 289). However, some limitations are mentioned.

Moser, in a treatise "On the process of seeing and the effect of light on all bodies" in Pogg. Ann. LVI, 177, in which the effects of light on the retina are not both identified and compared with the daguerreotypic light effects, is expressed (p. 192) as follows: "the colors make, so to speak, a complete one, not one another. It is not confused with very high and very low tones, but the easier it is with a normal ear when sounds are closer, and at any rate includes a particularly fine and musically formed ear to be able to specify a tone of the usual name, while the eye does not know a difficulty of this sort when determining the colors. Rather, one might be inclined to compose the height or depth of a tone with the intensity of a particular color, and contrast the different colors with the sound of the tone. I have seen few people who would not have confirmed the latter if asked."

12) The periodic return of the same color impression as the number of oscillations, which is indicated by the violet and red at both ends of the spectrum, can, besides the fact that the approach to the first impression already occur after the interval of a fifth, and that this approximation on the contrary, progress towards the octave interval is diminished again rather than increased (which may have the already stated reason), only to be compared improperly with the periodic recurrence which the octave interval presents in tones. For in this case all tones with intermediate numbers of the vibration are also for the feeling between the fundamental tone and the octave; so it creates a real distance between the root and the octave for the feeling whereas the colors between the two boundaries of the spectrum do not seem to lie between red and violet, and even less between red and red, if these were the colors corresponding

to the interval of the octave. Thus, in the case of colors for the interval of the octave, the progressive element is absent, which occurs with tones.

13) For the comparison of all colors, sensation as a common starting-point is the white, the most composite color, under, if all colors can be regarded as deviations in different directions, whereas the sensation as a starting point for the comparison of all tones is only a simple one Sound as a fundamental tone is useful.

14) Even without regard to a physical measure, the pitch differences are comparable to each other in a purely psychic way by reference to a common unit of measure, the octave interval. the differences in color have no relation to such a measure of sensation.

15) The difference of pitches appear the same size with the same proportions of the respective frequencies in the higher and lower parts of the tone scale, not as the difference of colors in different parts of the color scale, like that of Helm holtz⁶⁰⁾ based on Esselbach's measurements compared teaches which Th. I, p. 175 was mentioned, and which one can also employ according to the table in section a) of the chapter itself. In other words, Weber's law applies to pitches, but not to colors by their dependence on the number of oscillations.

⁶⁰⁾ Reports of Berl. Acad. 1855. p. 760.

The following explanations from Helmholtz in Pogg. XCIV, 17. "In the wide space from the end of the red to the line C, the tone of the red hardly changes noticeably, just as the tone of the violet does not change from the line G to L. Also in orange and blue it changes Sound slowly, but already much more noticeable On the border of yellow and green on the one hand and blue and green on the other hand, the transitions are so fast that they seem to be completely absent, if one looks at a pure spectrum without strong magnification, and here rather green It seems to be amazed at the extraordinary richness of the magnificent shades of color that these regions of the spectrum unfold,

16) Regardless of the corresponding physical dependence, we would by no means be inclined to compare the red of the spectrum to the lower tones, the blue and violet to the higher tones, but conversely, regardless of the red as the lower tones slower, the violet and Blue as the high notes corresponds to faster vibrations.

Grailich⁶¹⁾ believes that the lively impression of the red can be deduced from the fact that, because of the slower vibrations, the particles remain insane longer from the rest position, which causes greater irritation, against which, in my opinion, a great deal can be objected.

⁶¹⁾ Session the Vienna. Acad. 1854. XIII, p. 258.

17) The aesthetic impression of the color combinations depends on quite different conditions than that of the tones. If one divides all the notes of an octave into two parts and strikes both halves together, one has physically but not psychologically the analogue of two complementary colors which complement each other in white. While

the colors are pleasing to each other and give a pleasing composition, there is a discordant note in the notes.

The repeated attempt to establish a harmony of colors on the basis of an analogy with the Tonhar monie, which does not exist, seems to me in vain from the outset.

18) By the composition of simple colors a color can be produced, which in turn makes an inseparably simple impression in which the composing impressions are canceled out. If, on the other hand, we combine simple tones, the Tartinian tone produces a resulting simple impression which resembles that of a simple tone; but the composing impressions continue at the same time.

19) In the case of colors, it is possible to create an impression corresponding to the mixture of all colors, white, by means of two simple complementary colors; not such a sound by combining two simple sounds.

According to Helmholtz's experiments (⁶²⁾ and Grassmann's theoretical discussions (⁶³⁾ , for every simple homogeneous color ray there is another homogeneous complementary ray which, mixed with it, yields pure white. The following is the table given by Helmholtz on the wavelengths of the complementary colors belonging to each other, in millionths of a Paris tariff.

⁶²⁾ Pogg.XCIV, 1.

⁶³⁾ Pogg. 1853.Nr. 5

| To dye. | Wavelength. | Komplemen-tärfarben. | Wavelength. | Ratio of W. |
|---------------|-------------|----------------------|--------------------|-------------|
| red | 2425 | Green Blue | 1818 | 1, 334 |
| orange | 2244 | blue | 1809 | 1, 240 |
| golden yellow | 2162 | blue | 1793 | 1, 206 |
| golden yellow | 2120 | blue | 1781 | 1, 190 |
| yellow | 2095 | indigo blue | 1716 | 1, 221 |
| yellow | 2085 | indigo blue | 1706 | 1, 222 |
| Green yellow | 2082 | violet | from 1600 onwards. | 1, 301 |

In the violet, because of his lack of light, the outermost rays of the wavelength

1600 had to be combined. For green, which does not appear in the table, the complementary colors in the ultraviolet rays are to be found.

The ratio of the wavelengths of complementary components varies between that of the fourth and the minor third; it is smallest for golden yellow and blue. - Strange is the distribution of complementary colors in the spectrum. While the golden yellow stands quite far from the outermost red, its complementary colors greenish-blue and cyan-blue lie close together; while the outermost violet and indigo occupy a wide space in the spectrum, their complements are greenish yellow and pure yellow only in very narrow stripes; this is due to the conditions mentioned under 15).

Two complementary colors generally do not enter white in the same light intensity. To measure the ratio, Helmholtz measured the width of the slit through which the brighter color penetrated, after the whiteness had been made to the utmost perfection, then reduced this width until a rod held in front of the field designed two equally dark, colored shadows measured the width again. The two widths gave approximately the ratio of the brightness of both components in white. Incidentally, the results, as was to be expected according to the facts given in (Chap. 30) concerning the altered brightness ratio of pigments in different degrees of illumination, differed with unequal absolute luminous intensity. At lower light intensity, the more refractive colors are relatively overweight.

For strong In low
light. Light.

Violet : Green Yellow 1 : 10 1 : 5

Indigo : Yellow 1 : 4 1 : 3

Cyan : Orange 1 : 1 1 : 1

Green Blue : Red 1 : 0.44 1 : 0.44.

With regard to white composed of the simple complementary colors red and green-blue, Helmholtz notes that the eye is very sensitive to admixtures of very small amounts of simple color to white. If you do not make it pretty faint from both blended whites, it always retains a spotty and changeable reputation. "Then the color of the mixture also changed somewhat with the place of the retina, which received its image." Purkinje has already pointed out that the side parts of the retina have a different sensitivity to colors than the place of direct vision, the yellow spot - says Helmholtz - red and green-blue so well-connected that the field they light up together seemed to be as white as possible, and rather outweighed the red, it immediately became decidedly green, when I fixed a point of paper beside the bright field. The same was the case when I brought the eye so close that the field of mixed color covered a very large part of the visual field, so besides the yellow spots many other parts of the retina also took the picture. In this experiment the dispersion of color in refraction in the eye in the middle of such a large field can have no effect. "

20) The characteristic impression of the colors disappears more and more and approaches the white, if one multiplies the intensity of the vibrations depending on the amplitude of the vibrations, or subjects them to constant observation; conversely,

white can become colored by constant observation, whereas the impression of the pitches nothing corresponding shows.

In my experiments on the influence of strength, I made experiences of colors in my experiments on the afterimages⁶⁴⁾:

"If one lets the sunlight (sunk into a dark room through a hole in the store) fall through a colored glass onto the opposite wall of a gloomy room, it is clear that the color of the glass is clear Whichever glass one may use, the sun picture appears only slightly colored, almost white or yellow, and at most in a slight degree it nuances itself by the color of the glass, with such intensity, but only weakly As a rule, the first phase of the afterimage also appears in colored light, although at other times it also bears the color of the glass more clearly at first."

⁶⁴⁾ Pogg, L, 465.

Corresponding experiences with spectrum colors, which are produced by a prism, have Helmholtz in his essay against Brewster⁶⁵⁾ made known and given some details. He explains it for the fact that, with dazzling brightness, all the colors seem to whiten or approach, which is easiest to do with violet, and most difficult with red. Violet goes through a bluish gray-white in white at a very tolerable degree of brightness, blue in a slightly higher by blue-white in white. Gray also approaches green yellow with increasing brightness, and yellow with yellow white approaches a dazzling white. Red only turns pale yellow at its highest gloss. One sees these changes just as pure, isolated colors of the solar spectrum as on the more composite of the colored glasses. See also the information given in pogg, p. 269, in Pogg. XCIV, 13.

⁶⁵⁾ Pogg. Ann. LXXXVI, 501 ff.

It is well known that colors become inconspicuous through prolonged observation, and consequently the color impression of them becomes more and more extinguished. Particularly interesting and instructive in this respect is the following experimental form, which Moser (Pogg LVI, 194) after Brewster⁶⁶⁾ for it leads.

⁶⁶⁾ The original information from Brewster is unknown to me.

"Most decidedly, an interesting experiment, owed to Brewster, can be confirmed easily enough: consider the spectrum of a flame of light through the prism, so first the red and green disappear, and some of the blue, one sees on and on, without dislocating the eye, even the yellow disappears, turning to white, so that, instead of the prismatic colors, one sees only a uniformly white, elongated picture of the flame. "As I said, this remarkable attempt succeeds without any difficulty, and, like me have observed the fastest if one fixes the upper eyelid with the hand and prevents the down-beat. if one has the white picture after about $\frac{1}{2}$ Minute is reached and you drop the eyelid, by opening the eye immediately, so appears for a moment the spectrum with its colors, and then quickly make room again for the white light.

Moser puts this experiment together with the fact that even in the otherwise divergent daguerreotypic effects of the various color rays, "a uniform effect of all colors, including yellow and green, certainly takes place on the silver iodide in one case, if they have a lasting effect They then bring the iodide to condense the mercury vapors and blacken it with continuing continued action. "

The gradual fading of colors on prolonged observation is all the stranger than, on the contrary, white becomes colored by constant observation.

In this connection I recall the following observations made by myself⁶⁷⁾:

a transitional stage through green could have perceived, finally red-violet or red. The yellow phase is the shortest; the blue often lasts a long time before going on to the next one. After the red or reddish violet, I could not perceive any more; although I continued the experiment to the great effort of the eye. Even in the common light of day, I have often perceived the indicated succession of colors, though once with greater decisiveness than the other; I usually recognized the last two shades lighter than the first yellow one. The red-violet or red ink of the last phase is often seen in green, especially in broad daylight, and on closer examination, it is found that these are the shaded areas of the paper,

⁶⁷⁾ Pogg. L, 306.

Szokalski⁶⁸⁾ has made a corresponding observation by saying: "We lay a square piece of white paper on a black ground, illuminate the whole by a white light and direct our eyes attentively to the square, assuming such a position that the light does not directly meet our eyes If we have looked at the paper for a few seconds in this way unrelated look, it will be a yellow color, and if we continue the experiment, gradually take a greenish, then a blue color and last quite stop being visible. "

⁶⁸⁾ About the sensations of colors. P. 11.

This experience, independent of mine, seems to me all the more noteworthy in respect of its essential agreement in the change of color with mine, as the same agreement between Szokalski and me does not find itself in the manner in which the after-image of Weiss subsides, about which I here in no more detail included. But he gives an intermediate of green, which I could not notice, and the apparition did not thrive with him until the last, the red, phase.

21) The impression of the colors gives in the eye the impression of the complementary colors and leads them in the neighborhood; of which nothing similar is found in the domain of tones.

22) Colors that strike corresponding areas of both retinas may, under appropriate measures, give the impression of the same mixed color (complementary colors, for example, to white), as if they coincide in an identical place, whereas tones separate to enter into both ears (according to Dove's experiences⁶⁹⁾ unable to give the same combination sound which arises when they are produced before the same ear.

⁶⁹⁾ Pogg. CVII, 653.

"Of two tuning-forks giving a perfect fifth, one was held in front of the right ear, the other in front of the left, and the Tartini sound emerging as the lower octave from the combination of the two oscillations was not heard, but very clearly when both forks stood before the same ear."

It has been denied that complementary colors can combine on corresponding retinal sites to the impression of white, and in fact, the impression of one, and sometimes of the other, of the composing colors easily prevails alternately, giving the appearance of the so-called competition. Meanwhile, combine to white is especially by the experience of Dove⁷⁰⁾, Foucauld and Regnault⁷¹⁾ and own set no doubt mean by appropriate measures and likewise other as complementary colors are able to connect to corresponding locations to pure mixed color when the Competition can be ruled out or the same has calmed down.⁷²⁾

⁷⁰⁾ Berl. Monatsber. 1841. p. 251 or Pogg. LXXI, 111.

⁷¹⁾ L'Instit. XVII, 1849. p. 4th

⁷²⁾ VgL Völckers in Müller's Arch. 1838. p. 64; Prevost in Pogg. LXII, 1844, p. 566; A. Seebeck in Pogg. LXVIII, 1846, p. 455; Bridge in Pogg. XC, 1853, p. 606; Dove in Pogg. CI, p. 147.

23) We are not able to arbitrarily produce a double hearing as a double vision.

24) When the sound penetrates into one ear alone or more strongly than the other, we are able to distinguish very well which of the two ears is alone or preferentially affected; but we can not distinguish from which of the two eyes an object is seen.

I have a compilation of the facts and circumstances here in my treatise "On some conditions of binocular vision" in the Abhandl. the Saxon Soc. Mathematics and phys. Cl. Vol. V, p. 548 ff.

c) assumptions that seem necessary to explain the previous points of agreement and diversity.

The task has been set to correlate the psychic and the different of the senses of light and sound with the physically matching and the different, and psychophysics can not escape this task. But only the external physical conditions are directly accessible to our observation and therefore could be taken into account only in the preceding; but a sufficient psycho-physical theory will eventually have to go back to the internal relations, and the principle of this decline will only be that we look from one side to the external physical conditions on which the inner depend, from the other side to infer the conditions of sensation that depend on the inner physical conditions;

As long as this addition still leaves gaps or doubts, what we thus open up remains only a hypothesis, and in this respect we are here more or less in the position of the hypothesis everywhere; but it may be useful, before attaining certainty, to seek out the most probable, for the way to certainty in this region can go everywhere only by testing the most probable, and a sharp line between the most probable hypothesis and

certainty will not be everywhere here. To reject this way of finding the true is to refrain from finding it here.

Moreover, it is not the psychophysical interest alone that leads to certain presuppositions about the nature of psychophysical activities, which are subject to our sensations, but at the same time a physical and physiological one; and even the most exact investigators have been induced, as can be seen from the following quotations, to supplement the observation in this field by hypotheses which seem necessary.

From this point of view, I now set forth some hypotheses, some of which were previously considered necessary by others, others appearing necessary to me for the purpose of further examination, some of which seem necessary to me through my own investigation of the circumstances. The number of these, there are five of them, must not frighten, for the last four are merely further determinations of the first, the basic hypothesis, which are held together by a nexus of facts, so that they are based not upon each other, but together upon this nexus , No one is ever so sure that she could enforce recognition; but no one is easily put up for a single consideration.

The first, the fundamental, hypothesis is that the activities in our nervous systems, which are triggered by the stimulation of light and sound, and of which the sensation of light and sound functionally depend, no less than the stimulus itself in the form of vibrational motions to think about.

In order to justify this hypothesis, it should first be pointed out that an idea of the nature of the motions to which our sensations are attached is necessary as the basis of all further investigation, so that it can only concern those who set up the facts and facts Need of explanation best suits. Now the light and sound stimulus are oscillating, and since there is no theoretical or empirical reason to assume intermediary means of transmission, whereby an oscillating motion can also be converted into a progressive one, the oscillating nature of our and sound sensation underlying, movements likely. Even if one wants to grasp the changes aroused by light and sound stimulus as chemical, what they might be, or at least be connected with, will in the last resort be reduced to changes in the molecular relationships, which, insofar as they are excited and sustained by vibrations, can hardly be thought of other than even in the form of oscillatory motions ; For the time being, however, most of these questions can be left to do with how far they relate to the weighable or imponderable parts of the nerves. It is undeniable that according to the force relationships between the weighable and unpredictable particles of both movements, only a certain connection can take place, although under certain circumstances the wobbled particles might behave as a relatively strong centra against the imponderable. in the last resort, these will be reduced to changes in the molecular ratios, which, insofar as they are excited and sustained by vibrations, can scarcely be conceived otherwise than even in the form of oscillatory motions; For the time being, however, most of these questions can be left to do with how far they relate to the weighable or imponderable parts of the nerves. It is undeniable that according to the force relationships between the weighable and unpredictable particles of both movements, only a certain connection can take place,

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What appears to be probable from one side seems to be necessary from the other side, as long as it would not be possible at all to put the relations of sensations into functional relation with the conditions of a progressive movement, but with conditions of an oscillating movement such as the 32nd chapter has shown. Incidentally, the hypothesis with diligence is from the outset so general as to permit, according to the needs of what it is to represent in particular, and the facts in particular, to admit even the most varied of detailed provisions.

Even the most thorough investigators, insofar as they refer to the nature of the movements triggered by the stimulation of light and sound in our nerves, which sometimes can not be circumvented in physical and physiological questions, are always familiar with the same hypothesis Part already on more detailed provisions of the same.

It is particularly noteworthy that even Newton, notwithstanding the whole objective theory of light according to the emission system, found himself compelled to think of vibrations in the nerves as the basis of the sensation of light, using only the expression question (quaestio) for our expression of hypothesis; by saying (Optica, lib. III):

"Quaestio 12th Annon radii luminis, incidendum in fundum oculi, excitant vibrations quasdam in tunica retina, quae quidem vibrationes, propagatae inde solidas nervorum opticorum fibras in cerebrum usque, sensam ibi videndi excitent?

Nam, quandoquidem corpora densa conservant calorem suum diutius, et ut quaque corpus densissimum est, ita calorem suum diutissime conservat; utique vibrationes partium suarum natura sunt durabili, adeoque propagari possunt in longinqua usque spatia per solidas materiae uniformis ac densae fibras, ad transmittos in cerebrum videlicet motus sensuum omnium organis impressos ,

Quaestio 13. Annon radii diversorum generum vibrations excitant diversa magnitudine; quae scilicet vibrations, pro sua cujusque magnitudine, sensus diversorum excitent colorum; simili fere ratione, ac vibrations aëris, pro sua itidem ipsarum diversa magnitudine, sensus sonorum excitant diversorum? Et nominatim, annon radii maxime refrangibiles, vibration excitant brevissimas, ad sensum movendum coloris violacei saturi; radii minime refrangibiles, vibrations longissima, ad sensum coloris rabri saturi; et radii generum omnium intermediorum, vibrations comparate intermedias, ad sensum colorum diversomm intermediorum eicitandum?

Quaestio 14. Annon fleri potest, ut harmonia et discordia colorum oriatur e proportionibus vibrationum propagatorum per nervorum opticorum fibras in cerebrum; similiter ac harmonia et discordia sonorum oritur e proportionibus vibrationum aëris? Sunt enim alii colores, si juxta se invicem positi simul inspiciuntur, oculis grati, ut auri et indici, alii autem minus grati. "

Grailich, in s. Abhandl. over d. Theory of mixed colors XIII. says:

p. 247. "Each of the individual movements (of the aether) finally encounters a nervous element, to which we may as well attribute with the same right transversal vibrations as the etheric point itself, it would indeed be difficult to see why in the visual apparatus the transmitted movements of another kind should be as in the medium mediating the movement hitherto, etc. " And p. 259: "The decision could not be drawn from the calculus, and I had to go back to the act of seeing, but it seems that, as one assumes, the movement of the ether shares in the nerve elements and puts them into a similar swinging motion , it also follows with necessity "

The composition and design of the hypothesis by W. Herschel, Melloni and A. Seebeck has already been reported above.

From the outset, one could doubt that the hypothesis of the condition of physically representing the relations of sensation will suffice if one grasps the task in the generality which nature gives to the object. For one seems to have to despair from the outset that, with the relations of the correspondence between the areas of sensation of light and sound, they can also represent those of the differences which we have discussed. In the case of vibrations, what is at issue for us on which differences of sensation can be made functionally dependent, as differences in the nature of the vibrating medium, differences in the amplitude of vibration, duration of oscillation, and form of vibration; but can such fundamental distinctions be made dependent thereon as between face and auditory sensation? If ether and light vibrations belong to quite different media, and if it were conceivable that they communicate only to the unpredictable, these to the weighable in the nerve, it would be unfortunate that differences of matter would be such *Qualitas occulto* conclude that differences of sensation may depend on it unless different modes of movement depend on it. If the

amplitude and period of oscillation of the vibrations of light are infinitely smaller than those of the air vibrations, and it is not improbably the case that the vibrations thus excited in the nerves take place, this does not give any explanation for the fundamental difference in the quality of both sensations. For by reducing the amplitude and the duration of oscillation in tones and colors, only the strength and height of the sound sensation, the brightness and the quality of the color sensation change, but there remains sound sensation, color sensation, and the slightest tendency to transitions between the two remains. What finally reaches the form, light vibrations can be outwardly straight, circular, be elliptical, there are light vibrations. Sound vibrations can be outwardly rectilinear, circular, elliptical, sound vibrations remain, and if we have no right to assume an unchanged transference of the external form of oscillation to the interior, there seems to be no ground from another side, certain forms of vibration on certain nerves to limit one more principle, qualitative quality differences in form differences of the vibrations to make.

And hereby all paths seem closed, by means of our hypothesis to fulfill the task set in the generality in which it is to be set.

I confess that the difficulty in this respect has for a long time seemed to me to be almost insoluble, so that I believed in its possible solution because I believed in the possibility of a general understanding of psychophysics rather than have any way of knowing it succeeded. Nor should such a one be easily found by considerations of a general nature. But when I deal with the special conditions of the two sensations and the circumstances in which they arise, it seems to me that by a certain necessity we are led to ideas of such a fundamental difference between the relations of the oscillatory movements that underlie them that difficulty, though not fully exalted, but so diminished, that their complete uplifting may be considered possible, ideas which, in the case of a merely general consideration of the possibilities, could not only not be justified, but could not even be offered. Such representations appear in the following as closer determinations of the previous hypothesis.

The second hypothesis, which I accordingly, again not as the first, makes is that while in fact all the color rays of the spectrum can be perceived by each optic fiber, the tones of different heights resonate inwardly through various fibers of the auditory nerve, so that each one as a string with only one tone, or rather for so small a range of sounds that they can not be distinguished from the hearing, may hold.

Although nothing seems more improbable at first glance than this hypothesis, since there is no reason to add to the various auditory nerve fibers a different tension such as different strings, there still seems to be something that denies vibrations of any pitch access to all acoustic fibers. The most recent anatomical investigations on the ear-tool have since taught that special elastic structures (the so-called Corti's fibers in the snail, peculiar bristles in the atrium) are connected with the special auditory nerve fibers, which seem suitable according to their different dimensions and dimensions Elastizitätsverhältnissen vibrations of different speed and record these to the Hörner nerve endings, about which one can read some notes in the following activation.

A treatise of the M. Schultze, who has earned a lot of money for the anatomy of this subject (on the way in which the auditory nerves in the labyrinth terminate in Muller's Arch, 1858, pp. 343), concludes p. 380 like this:

The peculiar position of certain nerve cells in the angles of forked rods, or pinched between lamina spiralis and bent fibers, may justify such an assumption, which, of course, is entirely in the field of hypothesis, as long as the anatomical conditions are not further investigated belongs. But where neither the experiment comes close, nor, as here to be presupposed, experiences about pathological conditions may soon give an explanation, such may, when it quakes the structure in question from the state of pure curiosity, be in the right place. "as long as the anatomical conditions are not further investigated, it belongs entirely to the field of the hypothesis. But where neither the experiment comes close, nor, as here to be presupposed, experiences about pathological conditions may soon give an explanation, such may, when it quakes the structure in question from the state of pure curiosity, be in the right place. "as long as the anatomical conditions are not further investigated, it belongs entirely to the field of the hypothesis. But where neither the experiment comes close, nor, as here to be presupposed, experiences about pathological conditions may soon give an explanation, such may, when it quakes the structure in question from the state of pure curiosity, be in the right place. "

It is impossible, without detailed description and assistance of figures or schematic figures, to give a reasonable idea of the complicated device which the Corti's apparatus in relation to the snail-nerve endings has in the lamina spiralis, and difficult everywhere to exactly do so orientate. An overview of the results of previous anatomical examinations, with the exception of the latest work by Deiters, is provided by Funke's Lehrb. of physiology. 3. Aufl. 1860. Bd. II, S. 90 ff. The most complete investigation has however (after an earlier essay in Siebold and Kölliker's magazine) Deiters in the small writing, "investigations over the Lamina spiralis membranacea, Bonn 1860", delivered.

Very instructive and facilitating for the understanding of these writings was a model of a piece of Lamina spiralis with Corti's organs in wood and paper, executed by Rüte on the basis of Deiter's writing. One is astonished at the amount of particularities that present themselves here at a glance, and is convinced that these can not be there in vain.

In order to designate, according to the instructions of Deiters' writing, at least the points of the device which seem to be the most essential, the lamina spiralis is known to consist of a bony inner, to the modiolus of the snail, and a membranous outer, to the snail's wall attaching, parts. This membranous part is, however, essentially doubled, that is to say, between two plates, one lower, or the basal membrane, membrana basilaris, which is an immediate continuation of the periosteum of the scala vestibuli, and one upper, the covering membrane or Corti's membrane, one against the Labyrinth water enclosed cavity now considered as a third scale, Scala media, between the Scala tympani and Scala vestibuli. In this Scala media lies the complicated apparatus,

In order to visualize the organ of Corti, consider a kind of vaulted arch or roof placed on the basilar membrane, formed by the fact that two parts of the basilar artery collide in an oblique direction against the arched parts or thighs above the basilar muscle but not both fused at the point of meeting, and joined together by means of a joint, a kind of ginglymus (Deiters, p. 39), by means of special connecting parts which form the ceiling of the arch. These thighs are called the Corti fibers, and that more according to the modiolus of the snail up to the M. basilaris rising up there fixed as inner or ascending fiber or fiber 1st row, the more after the Schneckenwand to itself to the M. basilaris adherent, as outer or descending fiber, Fiber 2nd row distinguished. The whole arch is obtained by attachments and proppants in its position. Such arcs are innumerable next to each other along the whole lamina spiralis ranked. As it seems (Deiters p. 30), they are surrounded by fluid in the scala media, and these are not filled with cell parenchyma (as Claudius has stated), but only in some places of the scala media, so that the Corti's Organ remains free.

According to Deiters (page 27, 29), the inner fiber is essentially a homogeneous, solid, flat, much less thick than wide structure, more rigid, less pliable, brittle, more elastic than the outer fiber. The strength of the substance of the inner fiber gradually increases from its beginning to the top. "In its normal bent position it will be maintained in a certain tension, which it strives to deliver in the straight direction." The outer fiber, on the other hand, is, according to Deiters, a round, tubular structure in which a shell and a consistent content are to be distinguished next to each other; the strength of the outer fiber is the same everywhere, the elasticity is less, the flexibility is greater than in the case of the outer fiber, its end, which rests on the basilar membrane (Deiters 37), "

It is not clear to me from this description whether the mouth of the funnels is openly closed against the labyrinth water or through the basilar membrane.

The distribution of nerves in the organ of Corti and its pertinence is very complicated, and in the relations and final endings of the same many still unclear. Here can not be further discussed.

The peculiar bristles with which the ends of the atrial nerve are related have, as shown in Funke's Lehrb. II, p. 91 f. a different length and protrude freely into the labyrinth water. I am not familiar with the details of the anatomical investigations.

An execution of the hypothesis, as far as it should be possible, is in the first place to be left to the anatomists, who have more exact knowledge of the circumstances which come into consideration; but the whole investigation does not yet seem to have reached the point of permitting such a thing.

The same hypothesis has not only been put forward several times, even before that anatomical discovery was made, but also recently Helmholtz has repeatedly advocated it; and I am not reluctant to assert the authority of this thorough and brilliant researcher for the same.

The official report on the 34th Assembly of German Naturalists and Physicians in Karlsruhe, 1859, p. 157 (see also p. 225) contains a lecture entitled "On the physical cause of harmony and disharmony", to which I borrow the following passage:

"In general, the air movement produced by a musical instrument is mathematically represented as a sum of air movements corresponding to different simple tones of n , $2n$, $3n$, etc. This composition of the air movement, however, is only a mathematical fiction, and we also find in the ear, with sufficiently observant observation, that all the tones corresponding to the individual members of that series are felt, namely, that of n vibrations as the fundamental tone, the others as its higher harmonic overtones. Shape of the oscillatory motions can be accurately determined, for example when the strings are worn, convincing that the ear hears all those overtones, whose corresponding members are present in the mathematical expression, the missing does not hear. "

"This most striking and peculiar faculty of the ear, on which it is also based that the different notes of a chord can be distinguished, would find their explanation, if we suppose that the peculiar elastic platelets and hairs, which in recent times are at the ends the auditory nerve fibers are found sessile, each tuned to a particular tone, so that each auditory nerve fiber only senses when the corresponding simple tone is given and its elastic appendage vibrates. "

Elsewhere (Pogg. Ann. CVIII, 1859, p. 290) he states as follows:

"I have already hypothesized in another place that every nerve fiber of the auditory nerve is destined for the perception of a particular pitch, and comes into motion when the sound hits the ear, which corresponds to the pitch of the elastic entity connected to it (Corti). Thereafter, the sensation of different timbres would be reduced to the fact that, simultaneously with the fiber which senses the fundamental, certain others are set in motion which correspond to the side-tones. "

The main reason for our hypothesis asserted by Helmholtz lies in the different behavior of the attention to the facial and auditory impressions. When colors penetrate mixed through the same optic fiber, we can not, by any force of attention, raise awareness of one over the other. If, on the other hand, tones penetrate through the same ear, we are able, to a certain extent, to divide them by the direction of attention now to the one, now to the other tone, and to particularly understand the constituents of the composite sound. If all the sounds heard at the same time were perceived together by each acoustic fiber, the difference of the effect of the attention could not be explained; which is probably the case,

A very simple and striking attempt comes to the aid of this view:

Hold a pocket watch in front of each ear, you will hear the beat of both watches, and, depending on whether one's attention is drawn to one ear or the other, the beat and beat of each watch can be understood as one different from the other. Should attention be able to do what it can do, where the beats of both clocks are perceived by two different nerves, even if they are perceived by the same nerve, then the beat and beat of both clocks would have to be adjusted more appropriately Mood of attention

can also be regarded as a special, if you hold both watches in front of the same ear. But this is after a well-known experiment by EH Weber⁷³⁾ not at all the case; The blows of the two clocks combine to form a sound in which one now only perceives the common periods of amplification and weakening, which, conversely, one does not notice when one holds both clocks in front of the different ears, while one finds it quite impossible to strike and tact of both clocks still separately. By the way, you can use instead of the sound of two clocks with the same success any other noise, eg. As the noise, which is generated by rubbing the hair between two fingers in front of one and two ears before.

73) S. his Abhandl. about sense of touch and common sense in Wagner's Wörterb. P. 489.

If noises are very different, nothing prevents them from being distinguished and separated by attention, even if they penetrate into the same ear, and every day we neglect them by For example, pay attention to the words of a speaker, and focus our attention entirely on others' accompanying noises. This may in part be due to the fact that our attention is able to accommodate the peculiar rhythm which many sounds, such as the mill rattle, have in a corresponding change. Moreover, the possibility of separation depends so much on the difference of the sounds, that one may well assume that it takes place only to the extent that the various acoustic fibers are affected in unequal proportions, so that the attention gains a special attack on it.

The following is related to the above reason: if different optically simple colors act through the same optic fiber, they sink in an impression which again has the character of one produced by an optically simple color, and even close to the impression of one optically simple color of the average frequency of vibration agrees; which can be explained by the fact that the vibrations of different periods of oscillation, superposing in the same fiber, interfere with each other according to Grailich's principle. If all tones were to penetrate through the same acoustic fiber, it would not be possible to explain why they should not be destroyed by interference in a tone impression, which has the character of a simple tone. and close to that of a middle simple sound. In fact, when we strike different notes together, nothing of the kind takes place; the composite sound does not have the character of a simple and can not be confused with a middle tone between the troubled ones.

However, the development of new tones by interference is also possible with tones, as the formation of the combination tones proves; but it can also be proved that the combination sound is already produced by the interference of the air vibrations outside the ear, has an objective existence like the sounds to which it owes its origin.⁷⁴⁾ If Tartini's tone produced by its interference in the air penetrates with two notes at the same time, then it is perceived by its special acoustic fiber, and can therefore also be distinguished from the composing tones, which would not be possible if it were accompanied by would be perceived by the same acoustic fiber at the same time.

74) Comp. Helmholtz, Pogg. XCIX, p. 539.

If one attempts to produce a Tartini sound by two tuning forks in front of two ears instead of one ear, then according to the (above) mentioned experience, it is no longer heard by Dove, because the vibrations of each fork then penetrate distinctly into each ear, and Thus, the objective Tartini sound does not arise, but the soul itself, after this experience, does not have the power to form it subjectively from its components.

In connection with this it can be further explained how it is possible that in the domain of tones one can distinguish three sides, strength, height, sound in one and the same impression, in the realm of light only two, strength and color. With the sounding of an acoustic fiber main tones, a mixture of higher side tones can echo through others, and thereby create an admixture to the main sound, which is felt as a sound; whereas this is not the case with the face, inasmuch as the different colors penetrating through the same optic fiber are again and again the result of a simple one which appears penetrating through other optic fibers but spatially discreet.

Perhaps the peculiar circumstance noted by a very general experience that hearing-impaired persons as a rule hear musical sounds much better than sounds, is related to our hypothesis.

Concerning the fact, which is very well known, I casually cite the following passage from the rational Otiatrik of Ehrhard (1859):

p. 41. "My pathological observations show that the musical sense agrees with the sharpness of the hearing in both ways: I have found it pronounced in the most varied degrees of deafness, even twice in deaf-mutes, and it is often wonderful to find that hearing-impaired people, who do not hear my box clock, hear my repeater only a few inches, attend a concert with satisfaction, and feel the subtlest nuances of a symphony. I saw in Cologne a deaf-mute who sang in the church, although his voice was, of course, soundless; I came to know another, who carved his pipes and tried their purity, the various pathological conditions of the organ of hearing, both the acoustic and the nervous apparatus, even up to central paralysis,

A sound can be regarded as a mixture of many tones of different heights, which are weak in themselves, only in the sum strong. In the ear the sound of apperception breaks down into its components; and if these do not exceed the threshold, or only a little for themselves, then the noise is not heard, or only weakly heard, while an objectively equal sound is strongly heard, because in apperception it does not decompose, but remains concentrated in the same fiber.

Next meets with the previous reasons together. The meaning of the octave interval for the periodic side of the scale of sound sensation can be mathematically justified only for simple vibrations, and therefore, if the vibrations for different high tones could be composed in the same acoustic fiber, it would have to be lost for chords, which is contrary to experience.

Finally, my hypothesis seems to me to have a very striking analogy. Our eye is a dioptric apparatus built on the same principles as our artificial dioptric apparatuses, and in particular quite similar, only more perfectly than our *camera obscura*. So it may not seem inappropriate, though we keep our ears built up to one of our acoustic

apparatuses, that is, musical instruments, and it seems most like a piano, where there are so many strings with their keys, that all the tones, if not represented with absolute precision but sufficient for the practical need, and every special string is struck by a special hammer, except that, if the anatomical intimation is not deceptive, in our organs of hearing it is the hammer which is musically tuned, and transmits the sound to the string through its attack. In the eye, all art is used for the fact that rays of light coming from one visible point do not mix with those coming from other points, but can be separated separately. With all art this could not be achieved completely, but still very approximatively. So we also mean that a corresponding art is used in the ear to let the sounds that come from a sounding body be perceived separately from those that come from others; and again, this will not be complete, but with an appropriate approximation, we have achieved this.

Here are two objections which we have been able to oppose and have opposed to the hypothesis already suggested here and there.⁷⁵⁾

⁷⁵⁾ See also spark Physiol. 1st edition, p. 690. 3. ed. II, 141.

It can be noted, first, that the number of notes is infinite even within an octave, let alone within the whole scale of tones accessible to our ear, and that we are indeed able to hear all these infinitely different tones, but the number of nerve fibers of the acoustic can only be a finite one; secondly, that a decomposition of the sound waves arriving in composition by the labyrinthine water in such a way that each individual fiber picks out its own sound, could not be imagined by any physical principle.

But both objections can be met in the context.

The first objection would be engraving, if we really ascribe to every fiber merely the perception of a single absolutely definite tone, and at the same time no physical idea would be conceived, as each fiber is fed only an absolutely unique kind of vibration, or merely for its reception alone should be made receptive. But we have only to assume, as has happened from the beginning, that every fiber has a range of sounds small enough that it does not reach or exceed the threshold of difference. Not only will it be possible to obtain the continuity of the sound sensations through the whole gamut of tones with a finite number of fibers, but also physical ways of putting each fiber under conditions, that from a mixture of tones they only receive vibrations within a small margin, and in the mentioned discoveries on the structure of the auditory organ, they find hints that such conditions are really fulfilled. To be sure, this condition also requires, if not infinitely great, but still a tremendous number of nerve fibers; but since this condition is really fulfilled, this speaks for rather than against the presupposition. Kölliker found, as I have taken from a note in Funke's Physiol, 1st edition (p. 683), "an 18 "" long row of more than 3,000 nerve endings with mathematical laws next to each other in the snail of the ear." Corti's fibers for nerve endings, but this does not change the point of view, since they correspond to the same nerve fibers, it would be quite impossible

The objection that a physical device which can separate the individual components of a resulting sound mixture and pass them on to the various nerve elements is unthinkable by facts as well as by theory.

The experiment is well-known and doubtless that some glasses can be broken by shouts of a certain tone, but not of other tones. Such a glass therefore chooses between the notes, vibrates only with a certain tone sufficiently strong to be shattered. Thus, the window panes preferably tremble under the influence of certain notes; so a vibrating string in front of others brings only the same tuned to the swinging. It does not matter whether there are other sounds besides the ones in question.

In the meantime, just as certain as this selection is, so certain is that it is not absolutely limited to a single definite tone. On the one hand, neither the glass, nor the windowpane, nor the string can be absolutely tuned to the tone that makes it resonate. Moreover, that assumption would not be compatible with the laws of audio communication.

In the thorough essay of A. Seebeck's "On Vibrations Under the Action of Changeable Forces" ⁷⁶⁾, the case is generally treated that a plate-shaped body N , which (as we of the Corti fibers at least first row, and the bristles to the Presuppose end of the auditory nerve) is capable of independent vibration of the period n , or, in short, tuned to the tone n , in a resisting medium ⁷⁷⁾, vibrations of a self-tinting body M ⁷⁸⁾ are supplied from the period m through this medium. After that, mathematically, the following applies. ⁷⁹⁾

⁷⁶⁾ Pogg. Ann. LXII, 289.

⁷⁷⁾ Seebeck deals with the case for air; In principle, nothing prevents the transfer to water.

⁷⁸⁾ In the original, M is needed by the mass of the resonating body. Incidentally, our designations are identical to those of the original.

⁷⁹⁾ The second and fourth of the following sentences are to be inferred from the formula given on page 265.

1) Generally speaking, the oscillation period of the body to which the vibrations are communicated is composed of beginnings of its own period n and the period m of the self-toning body M ; But after some time in the latter period it passes over alone, the faster the greater the resistance of the medium in which the vibration takes place.

2) The less the period m is differentiated from the proper period n of the middle-toned body, the stronger the mid-tones after the period m ; and if the two periods are considerably different, a noticeable middening takes place only in areas which have relatively few masses of their area.

3) If the body N is stimulated by a composite vibration to a mid-tone instead of a simple vibratory motion, the same applies to the individual components of the vibration: "Namely, the body notices only noticeably those movements which are not too different from its own period. "

Afterwards one can hold the possibility of a selection of tones from a clay mixture by suitable physical meetings just as experimental as mathematically justified.

4) The greater the resistance of the body N in its oscillations through the surrounding medium, the greater the difference between n and m , at which it resonates appreciably in the period m , after which the environment of the auditory nerve ending apparatus with water takes place. With air in addition to a rapid damping of the Nachklingens could also have the success, the scope of the sounds, from which the Endplättchen can hint, something to expand.

In the meantime, there are two other difficulties of the hypothesis, which are not to be regarded as resounding, but just as little are already sufficiently lifted, and whose closer examination and, hopefully, elimination are therefore to be given attention.

The first is that the Corti fibers in the snail and bristles in the ampoules can only be tuned to a different pitch by virtue of a difference in their dimensions, substance, or manner of attachment. Now I am far from being well acquainted with the anatomical investigations on this subject, which have already gone too far (⁸⁰⁾, in order to be able to say what is more exact about determinations thereon. About the bristles in this regard, see the above remark. The Corti fibers, however, seem to be very similar in the whole length of the snail, and I also find nothing of a different kind of attachment. By name Kölliker noticed ⁸¹⁾ against the hypothesis expressed by Helmholtz expressly: "That the size differences of the parts of the organ of Corti are only minimal, the parts seem to become longer against the dome." Helmholtz declared "length measurements less important than thickness." It is only to be noted that the transverse number of oscillations of a parallelepipedal rod is independent of

the width, but proportional , if d is the thickness, l is the length of the rod,⁸²⁾ after which changes in length would have a greater influence on the pitch, as thickness changes.

⁸⁰⁾ The state of my eyes compels me to furnish myself to the most compendious in the use of literature.

⁸¹⁾ In the reports of the Karlsruhe Assembly, p. 279, p. 216.

⁸²⁾ see, my repertor. of experimental physics. Th. I, p. 274.

Another difficulty can be found in the fact that (to my knowledge, at least) no cases are known where the hearing for particular tones or a number of tones from the middle of the tone scale would have been lost, since one should think that pathological cases The destruction of this or that central part of the fiber mass of the

acoustic or the attached thereto accessory devices would occasionally occur. In the meantime it has to be taken into account, on the one hand, that a representation of the auditory nerves of both sides certainly takes place, a representation of snail nerve and labyrinth nerve possibly take place, secondly, that the middle part of the scale of the nerve key lesions not slightly different than by hitherto reaching damage to the extreme Parts should be accessible. But the fact that the audibility of sound can be shortened abnormally both from the lower and upper limit of audibility has been cited (Chapter 30). In any case, it would be useful to investigate more, than has hitherto been done, whether the ear on one or the other ear, in particular, has not been lost in particular for individual tones or parts of the tone scale.

The third hypothesis transmits some of the most general relations which exist between the external vibrations of light and sound to the inner vibrations which are aroused thereby, for internal reasons.

Our hearing is based, under normal conditions, on longitudinal air vibrations, which normally affect our eardrum, in that even of the obliquely directed vibrations only the normally normalized ones may be effective to effect the movements of the ossicles, which transmit the vibrations to the *fenestra ovalis*; on the other hand, seeing is based on transversal light vibrations. These are essentially linear, they can be rectilinear, but they also have and have all kinds of circular, elliptical and compound shapes.

The hypothesis which is used by us is that, in accordance with this normal form of external stimulation, hearing is also internally based on its psychophysical basis on simple rectilinear forms, and on seeing on vibrations of less definite changing forms. This is a hypothesis, because after the argument (see above), it is not to be expected that the external vibrations will be transmitted in their unaltered form to our nervous apparatus. Nor does our hypothesis consist in the fact that the inner form of the external power corresponds to a direct transference of the external, but because of the adaptation of the internal conditions to a generally corresponding form as the external one, so that z. B. in the auditory nerve, the vibrations are then simply straightforward,

The main reason for this hypothesis coincides substantially with one of the reasons for the previous hypothesis. The meaning of the octave interval, which has been shown by the elementary analysis of the relations of sensation at the end of the 30th chapter and in the 32nd chapter, essentially applies only to simple rectilinear vibrations. A theory which, by means of such analysis, wishes to give an account of this meaning of the octave interval for the notes, must presuppose that the vibrations in the nerves on which the sensation of the tones is based are straightforward and that they are not composed, of which the first of the present, the second corresponds to the previous hypothesis. It must, however, at the same time presuppose why the octave interval does not have the same meaning for the colors as tones,

In support of this, the occurrence of the key apparatuses at the ends of the auditory nerve can be drawn in again, which makes the development of an always identical simple mode of oscillation easily conceivable, while similar apparatuses are missing

at the ends of the optic nerve, and the point of view; that an arrangement of the sensory organs for a certain general correspondence between the form of external stimulating and inwardly stimulated vibrations per se seems natural.

Incidentally, it would not be necessary to assume a mathematically straightforward form for the vibrations in the auditory nerve, but it suffices that they deviate very little from the rectilinear; since everywhere very small deviations do not noticeably affect the sensation.

The fourth hypothesis I make contradicts the usual assumptions in a sense opposite to the second. After the second, each acoustic fiber reads out its particular vibrational number from a composite objective clay mixture; in our present view, each optical fiber undergoes a combination of oscillations under the influence of even the simplest color stimulus, and while there are no similarly composed subjective tones as objective, there is no simple subjective and objective colors in a similar sense, but the simplest objective color invokes only the comparatively simplest subjective mixing of colors, the composition of vibrations of different duration, and the quality of the sensation which depends on it;

The most binding reason for this view seems to me to be the deviation which the colors after the remark Th. I, p. 175 and the information Th. II, chap. 33b of Weber's Law. If the internal oscillation *numbers* corresponding to the external oscillation numbers $n, n', n'' \dots$ are just as simple again n, n', n'' for simple homogeneous colors as we have reason to suppose in simple tones, no explanation can be found for their deviation from Weber's law. If, however, the colors of every simple external vibration correspond to a composite internal vibration, it can be overlooked that the distinctness of two colors can no longer be made dependent only on the ratios of the external frequencies according to Weber's law, but a complex form of the conditions with which the composing rays enter into the awakened color mixture.

At the same time, under the assumption that the number of oscillations of the retina can not exceed a certain limit, it is possible to overlook the fact that, at the limits of the visible spectrum, the distinctness of the colors must be comparatively less than at the boundary the middle, as experience shows. For, as the exciting ray approaches one of the boundaries from the middle part of the spectrum, or even goes beyond the limit over which the vibrational numbers of the retina are not sufficient, the number of oscillations of the middle rays will remain predominantly, and will therefore be too so less easily in advancing beyond the boundaries may be possible a distinction from the rays lying to the middle.

If any question arises as to the relations in which the inner mixture of colors, which is presumably aroused by a simple homogeneous ray of color, is composed of components, then, if we formulate the hypothesis, it is undeniable that we have to consider two factors. From one side, it is expected that the number of oscillations of the excitatory color with the greatest intensity in the excited mixture will be weaker and the other numbers will be weaker as their numbers deviate further. But from the other side, if the excitability of the retina is limited only within certain limits of the

number of vibrations, it is to be expected that a vibrational number with comparatively greater magnitude will be produced the farther it is from this limit.

The limits of the inner frequencies of vibration must thereafter be narrower than those of the outer ones, by which they are excited, because an external number of vibrations, which is so high or low, that the retina is no longer able to correspond to them, yet to produce still weak vibrations It may thus be seen to be visible, which fall between the limits of the excitable, so that the outermost red and violet must be regarded internally as being formed by vibrations, which no longer suffice for the slowness and speed of the outer.

Apart from these subjective moments, the brightness with which each part of the spectrum appears still depends on the objective intensity with which the light beam strikes the retina, which, according to the discussions in section a), presupposes the identity of light and heat for the visible part of the spectrum can be considered as given by the thermal effects, provided that there is no non-uniform absorption by the ocular media in this part (according to chapter 33a).

Perhaps one might think that the deviation of colors from Weber's law is related to the brightness of the spectrum, which varies according to the location of the spectrum. But then, even with tones, the distinctness of the heights would have to depend on ratios of strength, which is not the case.

At the same time, the former explains why color in general seems analogous to the sound, the mixture of tones, rather than the simple tone, and something similar to the height of the tones, but rather the judgment of the same after their deviation from white or as fractions of white can assert itself, provided even the simplest objective color corresponds to a subjective mixture of colors, analogous to what would arise if all possible tones within a given interval were struck together. Yet the difference remains that the mixed tone is made up of tones that fall into different acoustic fibers, the mixed color of those falling into the same fiber, which helps to explain that sound is not color.

Furthermore, it becomes all the more easy to explain how a composition of two objectively simple colors can produce a corresponding impression as a simple color, since even the objectively simple represents a subjectively composed one.

Meanwhile, the question is whether the hypothesis is possible at all, and the conditions under which the colors arise in the eye are likely.

Now we know the mechanical conditions under which the light vibrations translate into nerve vibrations, not sufficient to *a priori* contradict or support the hypothesis . But the possibility of these can be proved by facts, and their probability supported by them. In that regard, I assert the following.

1) Even in the field of objective theory of light, a simple homogeneous colored vibration in one medium can, by communication, stimulate another to a composite color vibration. This is the case of fluorescence. As is known, the number of oscillations of the more refractive colors is actually lowered by fluorescent substances; but, according to Stokes' investigations, this is generally not the case in

that the homogeneous color is converted into another homogeneous one of lesser frequency; but the, caused by homogeneous color rays, dispersed light is generally more or less composed.

Whether the laws of fluorescence make a more specific application to our case, and the circumstance that the retina still shows some fluorescence even after death, as Helmholtz has determined (see Chapter 33a), to attach some importance to this , can be left completely open here first; the fluorescence is significantly thought only insofar as their fact proves that our hypothesis not the general laws of motion contradictory, but actually occurring requests ⁸³⁾ , like in all other respects the conditions and laws of the fluorescence, the reason is itself not yet fathomed all be others. Not an analogy with fluorescence, but facts of another nature seem to me to demand the present hypothesis.

83) With regard to the conceivability of the mechanical conditions, the discussion of Stokes with respect to the fluorescence in Pogg. Ann. 4th Supplement. Compare p. 823 ff.

2) To help in this regard, in fact, each optic fiber, in fact, even voluntarily, with no external color stimulus, develops all the color rays to some degree, provided that the eye-black representing a faint sensation of light is colorless. This facilitates; to think that everyone, even the most simple color stimulus, triggers all, possibly in a certain solidarity, activities, of which the optic fibers are capable, in connection, only with a relative overweight of that kind of oscillation which belongs to the stimulus itself; and which is the most distant from the limits of retinal vibrancy.

3) This reason is compounded by the fact that in abnormal cases no more colors are distinguished, while the light impression of the colors still persists. This seems to permit no interpretation other than that in such cases each outer ray of color triggers all color activities in inwardly equal proportions, and the well-known cases of erroneous appearance of color also seem to find their explanation easiest in that the normal relationship between the components of the color mixture is disturbed ,

"The achromatopsia," says Rüte, "embraces the condition, whereby the patient has no clear idea of the colors, and he can not distinguish yellow, red, nor blue, where everything appears gray (rarely) -example in Hudart's letter to Joseph Priestley (Philosophical transactions 1777. p.260) Four brothers could distinguish only white and gray, another example given by Rosier, see his Observations on the Physique et l'histoire naturelle vol., VIII, p.17, année 1779 . "

The different sensitivity to colors, which is abnormally exhibited between different individuals, is usually manifested in a certain sense between different parts of the retina, as the experiences of Helmholtz mentioned above teach.

(4) The peculiar circumstance that all simple and compound colors approach white more than the intensity of their intensification (see above) suggests, in our hypothesis, that the relative preponderance of the corresponding principal color

exceeds the excitatory color As-grown colors decrease more and more with increasing amplitude, and in general the relative strength of components of excited colors more and more approaches white. How this can be done according to mechanical laws may still be the subject of the question; but it seems to me that without the hypothesis, the fact in question would remain inexplicable.

However, the pitch also changes with the amplitude of the vibrations. The sound of a transverse vibrating tuning fork takes place known when Verhallen where the vibrations are small, something in the air⁸⁴⁾ smaller, and in general it is by W. Weber a property of all transversely vibrating body that her tone a little deeper at greater than Amplitude is, insofar as voltage changes do not take place, whereas for all longitudinally vibrating bodies, especially air columns, the opposite applies. Transversally vibrating strings sound somewhat higher on a larger or smaller excursion, but only because their tension increases with a larger excursion.⁸⁵⁾, By no means, however, does the sound become more like a sound due to its amplification. I have even heard a musician say that the richer composition of an orchestra or choir gives the sound, as he put it, something more ideal, in that the sounds that are strange to the sound would become comparatively less noticeable.

⁸⁴⁾ W. Weber, Pogg. XIV, 402.

⁸⁵⁾ See W. Weber, Pogg. XXVIII, 6.

Amplitude and maybe also shape will be summarized. In short, while the state of motion at which hearing hangs, grasping each contributing molecule as a whole, and all molecules repeating the same motion, when seen, the particles of the same molecule fall into individually distinct movements.

Every particle cooperating with the other in solidarity with the sensation of light corresponds, insofar as it can be associated with a movement of a simple period, with its peculiar number of oscillations of a certain simple objective color, which we never simply see, and after the nature of the sensation of light does not behold simply since the simplest sensation of light already presupposes the cohesion of different excitable and excited parts everywhere.

How much in the molecules in particular to count on the weighable and the unpredictable may remain undecided for now; since we have no sufficient knowledge to do so, though I think that the sensation of light rests essentially upon the vibrations of the unpredictable, which are therefore different for different ether particles, because not all are in the same proportions to the weighable particles. But even among the mathematical physicists there is still so much vacillation over the proportion that it attaches to the weighable particles in the formation of the objective light phenomena in the bodies, that I do not dare to express any definite presuppositions.

This hypothesis is a further determination of the former, according to which every simple external excitement of color, inwardly, corresponds to a majority of vibrational states with different periods and amplitudes. Now, according to the principles of interference, a single particle in different states of vibration may be regarded as being understood at the same time, and the above-mentioned facts permit the interpretation that all movements contributing to seeing are to be understood as composite oscillatory motions repeat on all individual particles contributing to vision, as is necessarily the case with the simple vibratory movements contributing to hearing. But other factual circumstances seem to call for the current hypothesis, which does not exclude

Before we go into the reasons for the hypothesis, it will be a little closer.

Further, according to this hypothesis, we shall have to think of a stimulable molecule as a system of several particles (atoms), each of which, when moved from its original position of equilibrium and left to itself, depends on its relative distance and mass others have a peculiar number of oscillations, such as tuning forks, rods, or strings, which are connected to a system by mounting on a common soundboard, except that the determination of a peculiar number of vibrations for each of these systems connected to the system by the relationship of its own parts against each other but for the particles linked to the molecule but by their ratio to the other particles of the same molecule⁸⁶⁾. Even without any external light stimulus, all excitable particles are in a certain oscillatory motion, upon which the colorless sensation of the black of the eye depends. If the amplitudes of these magnify absolutely with unchanged proportions of their size and unchanged number of vibrations, the sensation of the white light arises; on the other hand, the sensation of color, if the vibrational products *on, a 'n', a "n" ...*, which belong to the individual particles assume a different ratio than corresponds to the colorless black of the eye.

⁸⁶⁾ Since we see the planets connected to the system under the influence of a force immanent in the system, they can not be mechanically impossible in such an idea.

This happens generally under the influence of a color stimulus. Here the state of vibration of the whole system changes according to laws which we do not know *a priori*, for the simple laws of resonance for elastic bodies can no longer suffice here; - the formation of color by the color-stimulus merely compels, in general, to accept a change in the proportions of vibrational products, without allowing it to be decided, upon the modification of which factor, *a* or *n*, it preferably rests; probably on both.

The following are the reasons for this hypothesis.

1) The light, by its chemical activity, proves that it is indeed capable of interfering with the internal relationships of the molecules, and the view here set forth on its effectiveness as sensory stimulus requires nothing else. What we know about the

transmission of sound vibrations to the auditory nerves does not favor a corresponding view of the sound.

2) Every light stimulus, by its action, alters the way it is perceived, not only quantitatively but also qualitatively, the more, the stronger it is, from which manifold subjective phenomena emerge.

For all these phenomena, though they are not explained in detail and can still be explained so far, the following general point of explanation can be put forward in the sense of our hypothesis.

The light stimulus not only has the effect of stimulating the particles co-operating in solidarity to oscillate around the present equilibrium positions, or of increasing the vibrations present, but also of changing the equilibrium positions itself, so that the particles, during the action of the stimulus, have different equilibrium positions otherwise vibrate, which at the same time the conditions of their vibration products , a'n '...amend. This change occurs more or less gradually under the influence of the stimulus (cf the already existing facts), and gradually disappears again after the stimulus has disappeared, but so that the particles do not immediately appear after the return to the old equilibrium positions but to exceed them and return in the opposite direction to what oscillations can be repeated several more times. These slow oscillations of the equilibrium positions of the particles, on which the periodicity depends on the decay of the afterimages, are not to be confused with the faster oscillations of the particles around the equilibrium position (on which the color sensations themselves depend), and for brief distinction those may be considered as oscillations first order,

One can imagine that the slow oscillations essentially affect the weighable particles, but which follow changes in the dependent oscillations of the imponderable ones. But I leave that undecided.

I must now agree with Plateau, against my earlier view, that the oscillatory form in the course of the afterimages is the essential form of the latter, the first phase often being easily overlooked because of the too rapid rapidity with which it passes, the latter because of too great weakness without, incidentally, repealing my view that the phenomenon of the afterimages is a conflict of endurance and stultification, because this is basically merely a brief expression of actual circumstances and not a hypothesis. But a periodic form of this conflict, which I formerly believed to have to acknowledge only under exceptional conditions, is undoubtedly the normal form for the following reasons.

First and foremost, it can be fully observed under special experimental conditions,⁸⁷ and if it does not appear completely, it can be recognized from the following conditions. Every light impression sounds after the removal of the stimulus only in a positive phase⁸⁹⁾as evidenced by the rotated disc with white and black or colored sectors and the afterimages of dazzling impressions; This is followed by a negative phase, complementary to colored impressions, and in the cases of ordinary afterimages, gradually returns to the original state without exceeding it, while under

special experimental conditions several oscillations between primary and complementary color or appearance and disappearance of the afterimage follow. But also the return to the original state must be regarded as an oscillation in the opposite sense as the previous course, and it would be against all analogy to suppose that the declining oscillation would stand still at the original equilibrium position, and it does not show itself in the same way test conditions while it is easy to imagine that the crossing of them in the opposite sense is often too small to give phenomena which exceed the threshold of perceptibility; how, even in the case of a string that vibrates in a strongly resisting instrument, it may happen that, after returning to its original position, it passes unnoticed beyond it; but this return is the cause of an oscillation.

87) . Plateau in Pogg. Ann. XXXII, 550; Bridge in Pogg. Ann. LXXXIV; Aubert in Moleschott's Unters. IV, 230.

88) Positive and negative understood in Brücke's sense.

3) The main point of view, which seems to me to demand the present hypothesis, is that all other differences between the internal conditions of sensation of light and sound do not seem to me sufficient to explain the different basic quality of both sensations and the circumstance that the different optic fibers give the impression of spatial juxtaposition to perceived vibrations, whereas those perceived by different acoustic fibers do not give such an impression. Our current hypothesis, however, seems to me to explain both in context. For as far as the first is concerned, it must be of paramount importance to the quality of sensation, whether, as an element from which it depends physically, the movement of each particle is itself⁸⁹⁾. As for the second, it is easy to imagine that an element of extensive sensation also requires the state of motion of an extensively explicated system as the essential underlay.

89) In the sense of the views set forth in my Theory of the Atom, p. 181 ff., I would say that the movements to which the sensation of light depends depend on multiple forces of a higher order than those to which the sensation of sound is linked.

XXXIV. About extensive sensations in particular.¹⁾

From EH Weber's Investigations² it has become very probable that the distance between two touched or lightly struck points on the skin or retina is felt to be greater or less than the number of so-called sensory circles larger or smaller sensory points are understood, by sensory circle being understood as meaning any point of the skin

or retina which is supplied with branches of the same elementary nerve-fiber, or any union of such branches themselves; if there are sufficient physiological reasons to believe that all branches of the same nerve fiber are only capable of producing in solidarity a common impression on the brain.

1) In matters p. 174-177. Revision p. 423 ff.

2) The sense of touch and the common sense, in Wagner's Wort. P. 528; and a treatise in the reports of the Saxon Soc. 1853, p. 85; Excerpt from Fechner's Centralbl. 1858, p. 585.

This view has of course been disputed concerning the retina, especially Panum, 3), chiefly for the reason that "the lateral retinal parts do not see the objects smaller than the central ones, and yet they occupy a much greater number in the same space have sentimental points." It is undeniable that this counter-argument is noteworthy, but not decisive, because it proves too much. For if I hold one finger twice as far in front of the eye as the other, his half-size picture seems just as big to me, and indeed I can not raise this deception by applying any attention. Thus, according to Panum's conclusion, it would be inferred that the size of the image on the retina has absolutely no influence on the size phenomenon.

3) Gräfe's Arch. *F. Ophthalmol.* V, 1 ff.

Very instructive in this regard is the following experiment. Hold a compass, preferably a compass (not to include an angle estimate), with a measured distance of the points, normal distance, in front of the eyes, another very similar at about half or twice the distance, so that both projections on the Fall background next to each other, and search the peak distance of the second, wrong distance, according to the eye size of the normal distance equal. Regardless of the fact that the miscarriage distance of the same size with the normal distance in view of its other distance from the eye gives twice as large or half as large a picture as the normal distance, it is made the same except for a small variable and constant error ; and that is the constant mistake with me the way that if it is farther than the normal distance, I always make the miscarriage a little too small when it is nearer, a little too large, which only increases the difference between the size of the distance images, which depends on the different distance. On the other hand, another person made the wrong distance, both nearer and farther, always a little too big, a third closer to a little too small, the distant a little too big. It should be noted that even if you compare both distances from the same distance from the eye, a small constant error is committed, for me, both in the right and left position of the normal distance to the wrong distance, negative, positive for the other person, at the third positive in the legal position, negative in the left position of the normal distance if it is more distant than the normal distance, always a little too small, if it is closer, makes a little too large, which only increases the difference between the size of the distance images, which depends on the different distance. On the other hand, another person made the wrong distance, both nearer and farther,

the other person, at the third positive in the legal position, negative in the left position of the normal distance both the nearer and the finer, always a little too large, a third closer to a little too small, the distant a little too big. It should be noted that even if you compare both distances from the same distance from the eye, a small constant error is committed, for me, both in the right and left position of the normal distance to the wrong distance, negative, positive for the other person, at the third positive in the legal position, negative in the left position of the normal distance both the nearer and the finer, always a little too large, a third closer to a little too small, the distant a little too big. It should be noted that even if you compare both distances from the same distance from the eye, a small constant error is committed, for me, both in the right and left position of the normal distance to the wrong distance, negative, positive for the other person, at the third positive in the legal position, negative in the left position of the normal distance⁴⁾.

4) In the future, I will be sharing the details of this not yet completed series of experiments with other locations. The tips (blue tarnished steel tips) were parallel, movable along a pole, and were viewed with two eyes against a white door. In the case of the third of the above persons, when the third of the above persons were used, the equally estimated ratio of the two distances came a little closer to the actual ratio of the images in the eye, which is not the case for me, but there also remained far behind the actual conditions.

As it is easy to assume, the approximation that comes so close to the truth here can not be based on equality of images nor eye movement, but there must be other circumstances that correct the inequality of estimation that takes place in this respect, and they are experiments of the kind at all well suited to prove it sharply. It is undoubtedly an education through experience, which gives the moments co-determining the judgment. But if the judgment brought by experience on the distance from the eye acts involuntarily and compellingly in the estimation of size, why not also the judgment educated by experience on the position of the image on the retina?

Moreover, in my own experience, I would not dare even say that the picture on the lateral parts of the retina is as large as the central one. I find it difficult, because of the indistinctness of the lateral image, to make a definite judgment in this respect at all; but the extension of a bright object always seems to diminish somewhat in turning away the gaze from it in indirect vision, and to expand when directed in direct fixation. However, I do not want to emphasize this, as subjective deception would be possible and others would not seem to find the same thing.

It is not disputed that Weber's view can yet be settled with the evidence which has physiological views which are only the immediate expression of facts; yet it appears to me to be supported by weighty facts, especially in conjunction with what is valid for the skin and the eye, and has hitherto been regarded as the most luminous basis for the theory of extensive sensations, to which I shall henceforth adhere, which does not hinder Ancillary provisions of the same from their originator or even to put into question.

It is still disputed whether the sensory circles are purely juxtaposed or overlap (interfere) in how much minimo it is necessary to produce the sensation of appreciable extension or distance between two points, what role the eye's motion plays in estimating the Sizes, and distances plays. These questions are to be left undecided here with many other questions about distance, about which I can not admit to a new enlightenment.⁵ On the other hand, a few points will be discussed, their investigation of the position our doctrine has on the extensive sensations on acceptance Weber's view seems to be particularly important, or for which new points of view, or from experiments, arise from new facts.

5) Compare the literature to Th. I, p. 295.

For some of the points that could be discussed here, I do not go into detail, in particular, because investigations into which Volkmann is busy might be likely to shed more light on it in the future.

For the sake of brevity I shall now understand the number of sensory circles in proportion to the extent in which they lie, or in short their number, divided by this extension. It is not disputed that the relationships between the central ends of the sensory circles are more important than their relationship to the skin and retina itself; but those are unknown, and the observation can only hold to the latter.

Apart from the innate constitution of our organs of sensation, which, according to Weber's Principle, makes us appear an expansion the greater, the more sensory circles it covers, a judgment formed by experience is also determined by many circumstances in the estimation of size; and it is important not to mix, confuse or assert one to one.

As far as possible, the following will be abstracted from the causes co-determinate in the estimation of size according to experience, in order to consider only what depends on the innate device.

When I close my eyes, I have a black field of vision, which seems to me to be very small. When I open my eyes and look into a rich area, the field of vision seems tremendous; When I find myself on the sea, without seeing distant land or distant ships, or on a barren surface, where no objects in the distance give me any reason to judge the distance of the horizon, the horizon seems very near to me, the horizon closely.

In all these cases the innate device subject to the size estimation remains the same; but with closed eyes, the reasons which determine our judgment according to experience, especially all relations of determination, fall away. I therefore think that the size of the field of vision, as it appears to us when the eyes are closed, is the purest representation of the one who gives us the appearance of size, which depends only on the congenital device, and which corresponds to the extension and nerve-tightness of our retina.

There is something peculiar to the fact that, by opening our eyes during the day, the extensive size of the field of vision seems to increase approximately in the same proportion as its brightness.

Wundt in his essay on tactile experiments in Henle and Pfeuffer Zeitschr. In 1858, page 262 lists the following experiment:

"You take two equal circles with ground tips, with one of them you touch at a certain circular opening the selected area of the subject undergoing the experiment, and the one who has averted his face from the experimenter puts the second circle into his hand and leaves With the latter, it determines the distance of the tips of the first circle, as they appear to them according to the impressions of the emotions, since the uncertainty of the measure of proportion is infinitesimally small in comparison to the uncertainty of the feeling-estimation Sensation perception, the distance of the impressions from their actual distance is an immediate measure of the fineness of the skin in the space estimation "etc

I can not agree with the presupposition here given that the uncertainty of the measure of touch is incomparably greater than that of the measure of proportion, and consequently not with the measure principle built upon it; on the contrary, the fineness of the distance estimation by means of the measure of tact under the most favorable circumstances comes quite close to that of the eye.

An easy means to ascertain this is to try according to the method of mean error, which I have explained in chapter 8. Now I have made many experiments at different times and for different purposes by a measure of proportion, and even more by measure, according to this method, and in both respects very different conditions, depending on the mode of the experiments, the stage of the exercise, and on the tactile measurements also on the part of the skin but never and nowhere, according to which the accuracy of the estimation by the tactile measure could be regarded as negligibly small compared to that by the measure of the eye, although it has always been less for the tactile measure than the measure of the eye. I'm content here, the maximum values,

In a series of tactile tests according to the method of mean error, which is described in detail in the following chapter as series VI. Abth. γ described (where one can read the detail) was in the front joint of the left index finger, a normal distance = $10 d^6$) applied. 400 attempts (per 100 employed in a different time and spatial position) gave a simple pure variables means error of the estimate, the (after correction due to the finite m and because of the size of the intervals) only $1 / \sqrt{85}$ of the normal distance was (a constant error in means its absolute values at all 4 time-space locations determined) is equal to $1 / \sqrt{42}$ the normal distance. The pure variable error is more important here than the constant for the accuracy of the distance estimation, because the constant error depends only on the unequal situation in which the compared quantities enter the comparison according to time, space, and other circumstances, as has been sufficiently discussed. Incidentally, the constant error in tactile experiments may still be considerably less than previously, because in another

section of the same series of experiments, the series VI. Abth. α , which did not allow a similar accuracy of the distance estimation, therefore gave a considerably larger variable error, was also on average 400 tries for the same normal distance on the same phalanx a (corrected) pure variable error =¹ / ₅₅ of the normal distance, a constant error only =¹ / ₉₀ will receive the normal distance. Division α , where the pure variable error was greater, the constant error smaller, and Division γ , where the reverse occurred, differed in that in Division α , the two circles, by which the distances (normal distance and error distance) were determined, by a helper, at department γ but the finger was moved back and forth between the calipers and the calipers, which were clamped next to each other, as will be described in more detail in the following chapter, so that the series of tests becomes all the more comparable with the following over the measure of sight, as far as the eyes are in the measures of gaze wander from one compared distance to another. The latter application of the circle may, after a little practice, be much more uniform than that of an assistant; hence the much smaller variable estimation error.

⁶⁾ $d = 1/2$ par. Decimal line, = 0.72 duod.-line.

The experiments on the sense of proportion, in which I have been given the smallest estimation error ⁷⁾, are employed with distances, which through the vertical, blue annealed, purely tapered tapering steel tips (of 19.7 d length) of two very same bar compass ⁸⁾, are held against a white window opposite the window as a background next to each other, are determined. It gave me at the same normal distance = 10 d , 200 observations (100 at right, at left position 100 of the normal distance) a (corrected) of pure variables agents error = 1 / 126 of the normal distance and a constant error = 1 / 114 the normal distance, which was negative for both layers. It will be an opportunity to return to this series elsewhere, since it is only part of a series employed for other purposes (see above).

⁷⁾ They are considerably smaller than those obtained in Th. I, p. 214 ff., With less exercise and with imperfect measures.

⁸⁾ So by 4 parallel peaks, 2 each for a distance. Three parallel peaks, one middle between two lateral ones on the same pole, are indisputably more advantageous for the determination of the two distances to be compared, and also arranged thereon in a pole-circle, but I have not yet made any experiments in this way. For comparability with the Tastversuchen the above application was preferable.

The method of experimenting which Wundt bases on his assumption comes under the method of equivalents considered in Th. I, p. 131, and if it can not do what Wundt intended, it has some interest in so far as it has a comparable standard for the estimation of distances with skin and eye at hand.

To be sure, the comparison is far less certain than if one uses the method of equivalents in a sense-region for oneself, and transmits it only through experiences which we have previously made with the relative use of the two sense-organs. Also, I am not quite sure that one does not make a kind of comparative standard in the imagination arbitrary, and then the approximately made then holds; meanwhile, beyond certain limits, one measures a measure of eye size compared with a tactile size, and quite unconsciously either too large or too small; so that only the suspicion remains, whether the limit of the fluctuation is reduced by a co-determination on the part of the imagination, which I tried to avoid as far as possible during the experiments to be communicated, but I can not vouch for that as missing. At any rate, merely by many experiments on several persons and under very different circumstances, something definite should be deduced from such attempts, and the constant be distinguished from the accidental; but there is no important point of view which might require the effort of such extensive experiments. However, I want to cite the results of a separate series of experiments, which contain a variation according to some circumstances, without, of course, finally being able to draw a particularly meaningful conclusion from it. Perhaps it can be useful in combination with attempts to be made by others and draw attention to some points to be perceived. At any rate, merely by many experiments on several persons and under very different circumstances, something definite should be deduced from such attempts, and the constant be distinguished from the accidental; but there is no important point of view which might require the effort of such extensive experiments. However, I want to cite the results of a separate series of experiments, which contain a variation according to some circumstances, without, of course, finally being able to draw a particularly meaningful conclusion from it. Perhaps it can be useful in combination with attempts to be made by others and draw attention to some points to be perceived. At any rate, merely by many experiments on several persons and under very different circumstances, something definite should be deduced from such attempts, and the constant be distinguished from the accidental; but there is no important point of view which might require the effort of such extensive experiments. However, I want to cite the results of a separate series of experiments, which contain a variation according to some circumstances, without, of course, finally being able to draw a particularly meaningful conclusion from it. Perhaps it can be useful in combination with attempts to be made by others and draw attention to some points to be perceived. but there is no important point of view which might require the effort of such extensive experiments. However, I want to cite the results of a separate series of experiments, which contain a variation according to some circumstances, without, of course, finally being able to draw a particularly meaningful conclusion from it. Perhaps it can be useful in combination with attempts to be made by others and draw attention to some points to be perceived.

The distance, which is set as fixed in the comparison, is called the *A* distance, the equivalent to the *B* distance.

An *A* distance = 10 *d* was delineated on a horizontal black line drawn on white papers by two small streaks, viewed from ordinary viewing distance , and then with a pedunculated and stalked compass without the eyes being added the equivalent *B* distance to it on the left middle finger, so that always the rear tip in the articular joint between the front and middle link, the other was placed forward. On the average of 100 tests I found in a first section of the test series with 10 *d* of good measure 8,582 *d* of the tactile equivalent, which I write briefly:

$$\text{Augenm. } A \text{ 10} = \text{Tastm. } B \text{ 8,882.}$$

A second section of the series gave me an average of 100 attempts equivalent to 5 *d* of a good measure of 5,842 tactile measurements; so eyesm. *A* 5 = Tastm. *B* 5,842. While at the previous larger distance the Augenmaßgröße outweighed here, as you can see, the Tastgröße.

Conversely, in a third section, a distance = 10 *d* was delimited on the phalanx, and on a long horizontal line, the *B* distances, appearing equivalent to the eye, were delimited behind each other with dotted lines; then every 16 such distances measured together. I find this equation , where the *A*- distance falls on the tactile side, especially uncertain, more uncertain than the reverse, and not by long trial and error. The delineation of the 10 equivalently estimated distances therefore always took place quickly after each other after just as much skin contact with the compass without any effect on the previously defined distances. On average of 100 trials was with tactile measure *A*10 equivalent found good measure *B* 13,473.

In a fourth section *A* Tastm. 5 = ophthalmic *B* 3,202 found.

One might think it would be easier to compare by keeping eye size in mind while searching for the tactile equivalent. This is not the case. Having caught eye size in the eye, I have to close my eyes, otherwise I will not be able to find the tactile equivalent in the shared or dispersed attention; and so I close my eyes to the opposite direction of comparison as I place the circles on the skin.

The preceding 4 experimental divisions are not employed as a whole, but on each day *in continuo* only 10 of each division, that is, in the whole of 40; after days alternating in the sequence of the divisions I, II, III, IV, which will be designated by → , and IV, III, II, I, which will be designated by ← . In order to assess the degree of agreement of the series, the mean of the *B* equivalents to the above *A* distances follows from the individual successive fractions of 10 observations.

| Judgment <i>A</i> Tastmaß <i>A</i> | | | | |
|------------------------------------|----|---|----|---|
| | 10 | 5 | 10 | 5 |
| | | | | |

| | I | II | III | IV |
|------------|-------|-------|--------|-------|
| → | 8.56 | 6.28 | 12.15 | 3.28 |
| ← | 9.03 | 6.15 | 15.31 | 3.55 |
| → | 8.77 | 6.48 | 13.69 | 2.41 |
| ← | 8.73 | 5.35 | 13.35 | 3.50 |
| → | 8.61 | 6.08 | 12.52 | 2.38 |
| ← | 8.17 | 5.61 | 14.12 | 3.82 |
| → | 8.19 | 5.66 | 13.53 | 3.00 |
| ← | 8.56 | 5.66 | 13.26 | 3.13 |
| → | 9.12 | 6.02 | 13.14 | 3.35 |
| ← | 8.08 | 5.13 | 13.66 | 3.60 |
| Total cash | 8.582 | 5,842 | 13.473 | 3,202 |

We see that in II and IV, the result of the observations had a decided influence by ← are larger values at smaller II in IV when → .

After the previous 4 divisions 4 new departments throughout a corresponding manner were now only made so that the distances, which in the previous than B were found in Total Medium, now (by rounding down to $\frac{1}{2}$ unit) and A placed underneath the method were. Thus, the following results were obtained in the four divisions V, VI, VII, VIII together with the previous results.

Sense of proportion. Tastmaß. Relationship.

$$IA\ 10 = B\ 8,582\ 1 : 0,8582$$

$$II\ A\ 5 = B\ 6,842\ 1,1684$$

$$III\ B\ 13,473 = A\ 10\ 0,7422$$

$$IV\ B\ 3.202 = A\ 5\ 1.5615$$

$$V\ A\ 13.5 = B\ 11.088\ 0.8213$$

$$VI\ A\ 3,5 = B\ 4,172\ 1,1918$$

$$VII\ B\ 10,181 = A\ 8,5\ 0,8349$$

$$VIII\ B\ 3.915 = A\ 5.5\ 1.4040$$

The individual fractions from V to VIII gave:

| | Good judgment A | Tactile measurement B |
|--|-------------------|-------------------------|
| | = 13.5 | = 3.5 |

| | V | VI | VII | VIII |
|----------|--------|-------|--------|-------|
| → | 12.16 | 4.43 | 8.48 | 3.33 |
| ← | 10.57 | 4.19 | 10.00 | 4.25 |
| → | 11.17 | 4.64 | 9.24 | 3.75 |
| ← | 10.52 | 3.84 | 10.35 | 3.95 |
| → | 11.39 | 3.96 | 9.82 | 3.95 |
| ← | 10.54 | 3.81 | 11.42 | 4.25 |
| → | 11.26 | 4.20 | 11.99 | 3.74 |
| ← | 11.03 | 4.19 | 9.79 | 4.35 |
| → | 11.35 | 4.38 | 10.07 | 3.36 |
| ← | 10.89 | 4.08 | 10.68 | 4.22 |
| Middle I | 11.088 | 4,172 | 10.181 | 3,915 |

The sequence V, VI, VII, VIII applies here as → , the opposite as ← . As you can see, the influence of the sequence is noticeable here in all 4 sections.

If we look at the ratios of the table of results, we see that the divisions in which near- *A* values of the eye-size or tactile size are contained, such as II and VI, IV and VIII, also give close matching ratios, which may be appropriate To increase your confidence in these types of attempts. On the other hand, the ratio to the part is considerably different, depending on (noticeably) the same quantities as *A* or *B* in it. Although I and VII agree very well here, not so in III and V, in the sense that *B* 13,478 is equivalent to the measure *A* 10; Augenmaß *A* 13.5 with Tastmaß *B* 11.088 is; Neither do II and VIII agree. But even if one tries to make equivalence tests between different parts of the skin in the sense area, corresponding differences in the size of the equivalents can be found, depending on the direction of the comparison, according to which it is always necessary to measure the mean between *A* close to one another - and *B* take values. This is done in the following table.

$$\begin{aligned}
 &\text{Sense of proportion. Tastmaß.} \\
 &\text{III. V. } 13,487 = 10.544 \\
 &\text{I. VII. } 10,091 = 8,541 \\
 &\text{II. VIII. } 4,458 = 5,671 \\
 &\text{IV. VI. } 3.351 = 4.586
 \end{aligned}$$

The probes then rise much more slowly than their equivalent visual measures; those outweigh the small ones, those at great distances in the equivalent.

If we estimate on the skin in the sense of Weber's view the distance between two compass points as a function of the number of intermediate sensory circles, without these circles themselves being irritated, and consequently without their participation

in the sensation themselves, then is the reason been hit by Weber himself generally is⁹⁾ that we by past experiences where they have been tempted a later unconsciously asserted-making knowledge acquired them, and those hereafter insert a tacit reminder from the currently irritated points by we the distance the irritated one after the multitude of intermediate non-irritated, but by former experiences known to us according to their existence.

⁹⁾ Reports of the Saxon Soc. 1852. 111.

"If we set forth two impressions on two neighboring sensory circles, they would have to merge into one impression, for we would not perceive a gap between them." To perceive such a sensation, at least one circle of emancipation would have to lie between the sensed senses on which we touched There we missed the impression that we were otherwise used to receiving and feeling there, for the very fact that we perceive a lack of sensation in the sensory circles which lie between two touched parts of the skin and on which we have often felt impressions or that they receive sensations of a different kind awakens in us the idea of a space."

According to this, unexpressed sensory circles would be equivalent to missing sensory circles with respect to the sensation-power, insofar as the former irritation does not give us a knowledge of the existence of the latter, which comes to us in the present distance estimation.

As consistent as this view seems to be based on the basic assumption and the facts, it faces an important difficulty. The number of sensory circles in the section of the skin between the points of the compass, the former experiences may remain the same, and yet the extent which the route seems to us to vary greatly.

After Chloroformierung or taking narcotic substances (morphine, atropine, daturine) the compass points to be extremely much further off than otherwise to make them even to feel as distant as Lichtenfels and Cheerful demonstrated by detailed and repeatedly modified tests¹⁰⁾. Volkmann has informed me that, after earlier attempts by him, a cold on the skin had the same effect, and he had observed that in a person who was incompletely paralyzed on one side of his face, the compass points were considerably further away on this side had to be to give distance feeling, as on the healthy side. Wundt has recently published a more extensive account of this in the treatise cited on page 315.

¹⁰⁾ Meeting d. Vienna. Akad. VI, 1857, p. 338.

In addition, exercise has a very strong abändernd one as attempts by Czermak, Volkmann and myself¹¹⁾ have consistently shown, after Volkmann's and their own experiments in a way that not even the ratio of the sensitivity at various body panels for the same exercise remains unchanged.

¹¹⁾ Apart from those employed in connection with Volkmann, which he in the Sitzungsber. the Saxon Soc. 1858, p. 38, I have experience of the method of

equivalents.

In the sense of the senses, phenomena occur after etherization, in hashish, in some cerebral sensations, as in the sense of touch, the reason of which could certainly be sought in any changes in the shape and position of the refracting media or accommodation changes, if they are not so analogous to the senses of touch Those who would not fit that explanation, which is not likely to be

Panum, in his essay "The apparent size of the objects seen" in Gräfe's Arch. F. Ophthalm. 1859. V, 1, gives (p.16) the following facts by name; "About ten years ago, when I inhaled ether alone in my room because of an unbearably violent neuralgia, I made an observation that I did not remember, and which I often thought about in vain and questioned my colleagues, because I fixed myself on the bed lying down, a large picture hanging on the wall, and after having had in my arms and legs a tingling sensation similar to the so-called falling asleep of the limbs, and feeling almost numb with my fingers as strong as possible, the picture seemed to become ever smaller and seemed to be there into a great distance, when it was very small, it disappeared as everything blackened before my eyes and violent effervescence entered. I stopped breathing with ether and lay there for a while, motionless and numb with open eyes; then, as the sensation returned, the image was immediately perceived again, at first very small and distant, then coming nearer and growing, until, after sensation and voluntary movement had completely returned, it had reached its usual size A friendly colleague, to whom I gave the above-mentioned apparition, assured me that he had also felt the same in his boyhood years in the church, and with all his effort combating the feeling of drowsiness, and with unblinking eyes gazing upon the preacher, it was getting smaller and smaller and looking a long way off. Another claimed to have had in a typhus this phenomenon of becoming smaller and of the objects connected with it in the delirium; and finally I learn that this phenomenon is well known in psychiatry and is not infrequently given by persons suffering from brain affection with great certainty. Moreover, it should be constant in the hashish rash. "

Insofar as these facts can not be subordinated to Weber's conception, I am inclined to take them, with reference to the conditions of extensive facial perception, from the following point of view.

Even without external irritation with our eyes closed, our retina grants us the extensive sensation of the black field of vision, which is based on the fact that all sensory circles are always above the threshold by weak internal excitement, except that, just as in every case, by a weak one external sensory stimulation requires attention in a particular direction, in order to bring this sensation to consciousness. Thus here we do not estimate the distance between any two points of the retina by the number of intervening unexpected points known to them by previous experience; but, according to the number of inwardly excited and by virtue of it, a sensation of granting points, and if some of these points were paralyzed,

In my opinion, it behaves in accordance with the feelings of detachment of the skin, except that the nerve fibers of the skin are not always raised in such completeness by internal excitement above the threshold, as the facial nerve fibers, but by many circumstances can be lifted above and sink below.

In fact, certainly a part of the cutaneous nerves caught between two circular tips, in spite of being not also touched, is always excited in such a way that we are aware of the existence and the number of currently excited distension and distancing without regard for can make past experiences dependent. Thus, if we direct our attention to this or that part of the skin, we not only feel there mostly heat or cold, but apart from that we also have a feeling which gives us a certain direct customer of the existence and extent of the part that the feeling of this extension is by far not so definite as in the eye; we can not speak of any determinate and fixed appearance of a touchpad such as the visual field. But perhaps the easiest way to

Of no less interest to me in connection therewith is the feeling of bodiless, even of spaceless, existence, which is very generally cited as the success of etherization, insofar as the feeling of the skin, which informs us chiefly of the existence of our body, through the action of the ether can easily be suppressed below the threshold, although undoubtedly the loss of the muscular feeling, which the heaviness of our body allows us to feel, contributes to this, as both sensations generally interact in the first place. If, in the ordinary state, we have no sensation of the existence of our body through the sensation of the skin and the muscles, naturally none of them could be lost by etherification; but that it can be lost,

So Granier de Cassagnac writes¹²⁾ from the effect of Ätherisierens: "It was as if everything external to disappear; I no longer felt the flacon in my hand, hardly noticed that I had clothes on his body, and the ground on which I stood, seemed to have lost its original reality ... the outer and material world is no longer present If you sit, you no longer feel the chair, and if you lie, no longer the bed under you, you believe to float in the air. " - Another observer¹³⁾ states: "I did not feel anything of the external world at all, of my own body, for the soul was as it were isolated and separated from the body." - Dr. Bergson¹⁴⁾ states: "The intrinsic severity of the limbs disappears and one indeed believes to hover in the air In the sense of the touch, a feeling of drowsiness of the cutaneous nerves arises, and this, with tingling sensation, gradually increases to the degree, that strong pressure on the skin of the hand, pubes, stinging, burning is no longer felt. " - Similar is reported by action of other narcotics. Madden writes (Frer., Emergency XXVI, p.14) of the effect of an opium intoxication: "As I walked, I barely noticed that my feet were touching the earth, and it seemed to me that I was sliding along the street, driven by an invisible force along, and as if my blood were made of some ethereal fluid that made my body lighter than the air. "

¹²⁾ Hamb. lit. u. Crit. Bl. 1847. No. 13.

¹³⁾ Pfeufer, Zeitsch. 1847. Vol. VI, p. 79.

¹⁴⁾ Mag. For reference to the Ausl. 1847. March.

- Another observer says of the effect of hashish¹⁵⁾ : "The sensations evoked were such an extraordinary lightness, so to speak, airiness," and further: "the feeling of limitation (the feeling of limitation within the barriers of flesh and The walls of the organic body burst and tumbled into ruins, and without knowing what shape I wore, losing my face, indeed every idea of form, I only felt that I was an immense space has extended¹⁶⁾ , "etc.

¹⁵⁾ Mag. For Ref. Ed. 1854. No. 72.

¹⁶⁾ indisputable is the sensation of an expansion into the indeterminate without form and limitation less as an increase, than to grasp as a loss of the feeling of spatial determinateness.

Similar to the inhalation of effervescent substances, the natural approach of sleep seems to work. "The physical feeling - says Purkinje¹⁷⁾ - especially that of the skin, gradually loses (when falling asleep) the sensitivity to the middle degrees of warmth and cold, and the pressure of the environment is no longer felt. The body seems more on the surface Often it happens that when, by sudden awakening, the feeling shoots back into the depressed areas of the skin, it seems as if we had fallen from the state of hovering at once to hard ground, an experience; probably the most at first falling asleep will have done. "

¹⁷⁾ Guards, sleep and dream in Wagner's Wort. P. 420.

It is interesting to compare with the effect of the narcotics the very different kind of strychnine. While Lichtenfels of morphine, atropine, and daturin underwent the most striking diminution of extensive sensitivity, the diminution after use of strychnine, though definite and noticeable, was only slight in relation to those substances. It turned out, however, that the same pressure, which otherwise produced only a dull sensation, produces a very bright and definite after taking strychnine, that the quality of the sensation is changed, and the duration of the sensation is remarkably great. "If, in the normal state, the button of the caliper is pressed first against the skin of the arm and then against the tongue, the former sensation appears dull, the latter very sharp and limited,

It is easy to imagine that the influence of paralysis, of narcotic substances, of etherification and chloroformation, is to bring the sensation of a number of sensory circles below the threshold, and thereby produce the same result, as if a number of these sensory circles were altogether absent or dying ; this conception seems almost necessary, considering that dying is merely the greatest degree of paralysis, and the deepest sinking below the threshold.

This would also explain why we recognize the slightest misalignment of a compass point on parts, such as the upper arm, where two compass points, placed at the same time, require a considerable distance in order to appear at all remote. By passing a compass point through a given distance, we successively raise all intermediate

sensory circles through the incoming stimulus over the threshold, while at the same distance, when caught between two stationary compass points, a large part of the unattractive sensory circles below Threshold remains.

However well this statement suits the facts discussed so far, there is one fact which seems to contradict her directly, and of which I confess that she has long embarrassed me; How, then, I could base its explanation only on a hitherto hypothetical point of view, which, as we shall see, enters into a very natural connection with the previous one, from which, however, one can wish that he is still from another side as supported by the need of this explanation.

Volkmann made the remark, and I find it confirmed that an edge placed on a skin part of given length after direct evaluation, as in the method of equivalents, not only does not appear larger, but even slightly smaller than the distance of two compass points corresponding to this length notwithstanding, by the allure of the pressure of the full ridge, more sensory circles should be raised above the threshold, than find themselves in the empty circular distance above it. Also, the cold stimulus remarkably does not increase, but reduces the extensive sensation.

To accompany this information with some numbers, I just put a small series of experiments therefore. An 8 par. Lin. measuring edge, cut from a strong business card, placed on the forefinger of the index finger (on the volar side of the length of the limb, with the rear end in the joint), appeared in 5 experiments (without the use of the eye) equivalent to the following circular distances:

7.5; 7.3; 6.9; 7.0; 7.2 lines,

Mean 7.18.

Similar circumstances I have found on other fingers on the finger.

On the upper arm, too, I made the same experiments with edge lengths of 25 to 30 lines at different times, and always found smaller circular distances the same equivalent; but the ratio varied greatly with experiments on different days, as the comparison of the full and the empty distance by the feeling seems much more difficult here than on the finger. On the whole I would be inclined, partly by direct comparison, partly by the method of equivalents, to find the advantage of apparent size for the empty circle distance against the full edge length on the arm even greater than on the finger, at least not less. In order to obtain a sure and universal result in this regard, however, independent experiments on a large number of individuals would first be necessary.

The point of view that I put forward for explanation is this:

If we imagine that the tactile nerve fibers, which convey separate sensations, are just as confluent in the brain or in front of the brain as the branches of the same fiber forming a common sensory circle, their activities and the sensations dependent thereon would also be confluent, and so on common elevation of many such fibers over the threshold may carry only a great intensity, not extension, of tactile sensation, just as it holds true of the branches of one and the same sensory circle. It is therefore

indisputable that the activities of the discreetly felt fibers between them (through their links in the brain) do not extend in the same continuity as in them and their branches, but between them they are absent or sink below the threshold, and thereby establish a vagina of sensation; for otherwise there would be no reason why the different fibers should not give an equally simple result of sensation, as branches of one and the same sensory circle; they represent only one.

However, it is easy to imagine that if the pressure of an edge or the temperature stimulus acts on a tract of the skin, the increase in psychophysical activity is not limited to the tactile nerves and their central endings, but also to their connections with each other extends in the brain and raises a part of it above the threshold, so that the previously discrete nerve fibers now partially confluence with activities above the threshold, thereby becoming equivalent to branches of one and the same sensory circle.

It is already well-known that a sensory stimulus, as it is stronger, can induce reflex movements to a greater extent, which presupposes that the activity of the nerves can extend from a sensory nerve to a motor nerve through the connections existing between the two in the central organs; True, according to the strength of the stimulus and other circumstances, so that once a noticeable excitation of the motor nerves takes place, not otherwise. The corresponding thing which one finds necessary according to the facts of the reflex and the explanation of the same with regard to the sensory nerves and movement nerves, will now be necessary only for the explanation of the facts in question, and also for the nerve fibers which are in them Tastnerven are together, to assume,

Of course, the activity which can be elicited by the stimulus will everywhere change only in a certain solidarity in the nerves and their links in the brain, and therefore these and the previous explanation can not at all be strictly distinguished. Without wishing to enter into broad exposition here, it is conceivable that the activity, when the stimulus is changed, rises and falls more strongly in the nerves than in its links, and may even rise in the former at the expense of the latter, or for the advantage same can sink. And so the exercise in tactile tests could lead to the fact that more Tastnervenfasern with their central endings over the threshold occur, while at the same time more connections sink below the threshold; Just as the influence of exercise in mechanical motor skills is at the same time to strengthen the muscles, and to make the individual parts of them move more distinctly, certainly not without any influence on the nerves. In one way or another, however, the influence of the exercise will only increase the distance measure to a certain maximum; for when all sensory circles are raised above the threshold, or all are divorced in the brain, the maximum must be attained. In fact, such a maximum has been found to be consistent and decisive in the exercises attempted by Volkmann and myself mentioned above. Certainly not without some influence on the nerves. In one way or another, however, the influence of the exercise will only increase the distance measure to a certain maximum; for when all sensory circles are raised above the threshold, or all are divorced in the brain, the maximum must be attained. In fact, such a maximum has been found to be consistent and decisive in the exercises attempted by Volkmann

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There are still some facts which may be related to our views, and enter very well from one side, while from another they may be in a position to raise doubts, provided that they are, if not in definite contradiction with them, yet can not be subordinated to it informally.

As noted above, the movement of a compass point on the arm is felt to be a forgery, even if it is very little, while a much more substantial distance of resting resting compass points on the arm is not perceived as a distance. This was to be borne in mind by the fact that the charm of the compass tip lifts every sensory circle it encounters above the threshold, while in the distance between the resting points many sensory circles remain below the threshold. But if this is so, then the advantage of the moving tip before the stationary distance with respect to the extensive sensation produced by it must vanish on those parts where all sensory circles are above the threshold, and at any rate less on the parts of greater extensive sensitivity than on those of lesser magnitude his. This is definitely the case; only the result of the experiment exceeds the goal, so that not the majority, but not a few persons, among them myself, find the apparent size of a distance traveled by the tip of the compass much smaller than the same distance between resting ones Compass points for which it is difficult to find an explanation. Before I enter into the discussion of this strange result, I give the actual. as the same distance between resting compass points, for which it is difficult to find an explanation. Before I enter into the discussion of this strange result, I give the actual. as the same distance between resting compass points, for which it is difficult to find an explanation. Before I enter into the discussion of this strange result, I give the actual.

To make the experiment, I put on myself or on another person ¹⁸⁾ the one circle tip in the articular joint between the front member and middle member of the index finger (volar side) and the other about 9 to 10 par. Lines forward ¹⁹⁾, eighth on the sense of distance, then lifting the top, which is in the articulated joint, and drive with the other tip, always without the concurrence of the eyes, to the articulated joint down.

¹⁸⁾ In several experiments I have found that it does not make any difference whether one tries to do the experiment on oneself, or lets oneself do it by another.

¹⁹⁾ You can also use other fingers and larger lengths of the finger for experiments by z. B. the rear tip in the joint between the second and rearmost member, the other touches on the tip of the front member. Here too I find the length difference considerably depending on the above experiment.

This path of the moving peak, his name is *b* recently, seems to me incomprehensibly shorter than the distance between the dormant peaks called *r*.

I immediately repeated the experiment on another person, of course, as with all later tests on others, without indicating the expected direction of the result. She explained quite naturally after a few repetitions that you *b* about half as long as *r* appearing, making my own feeling very good match; Strangely enough, Hankel and Volkmann expressed themselves just as independently of each other; it'll be them *b* about half as long ago as *r*.

After this, and after rehearsals to several other persons, there can be no doubt that really *b* may appear much smaller than *r*. Only the result is by no means general. In total, I have examined 28 persons, including myself, of whom 17 could find no clear distinction between *b* and *r*; 10 found *b* shorter than *r*, and the majority were decidedly shorter; 1 initially found *b* significantly longer than *r*, but when the experiment was repeated, the feeling for both gradually faded. This is what Volkmann says to me, who himself (with rapid movement) very decidedly *b* shorter than *r* found that four other persons with whom he made the experiment could have found no difference, whereas Professor Dubois, who happened to be there, found the same as himself. In sum, 34 out of 34 found 12 *b* shorter than *r*, 21 no clear difference, 1 (initially) *b* longer than *r*.

As for myself, I have not been able to show any definite influence on the success of the experiment, as I guided the compass points with stronger or weaker pressure or with a faster or slower course. But in others the speed seems to make a

difference.²⁰⁾ The result has always been constant in the same direction with me at different times, and always clearly the same at the first attempt; but it has seemed to me several times, as if some repetition the apparent difference between *b* and *r* still increase; and it is probable that a certain influence of the repetition really takes place, since in some other persons, too, I obtained a decisive statement about a difference taking place only after some repetition, and even in the beginning (at the beginning) the opposite conclusion.

²⁰⁾ Volkmann writes to me: "I feel the circle distance really greater than the lacquered area of the skin of equal extent." The difference is not far from the Duplum. "I do not want to say with certainty, but it does seem, that the speed of the stroke has an influence. It seems to me that it seems to me that swift stroking makes the difference, or in other words, that at slower strokes the dimensions compared are pretty much the same size." Dubois found the influence of speed in the same sense as Volkmann.

I have also tried to describe whether the simple circular tip from the joint joint to the tip of the finger led upwards to describe a longer path than in the opposite direction down the same distance. The majority of persons found no clear distinction,

but those who found one, stated by exception (in independent experiments) that the way up from the fugue seemed longer to them than to the fugue downwards, among them several that made no marked difference between *b* and *r*. Of the 28 persons I submitted to the previous experiments, but several of whom did not make this second attempt, 10 have also found that difference, so that it does not seem to be mere coincidence.

At last I made experiments of the following kind: I gave a circle whose tips were dulled by wax or sealing-wax beads²¹⁾, a large span, let another person put the same one end on my index or middle finger, with the other on the forearm, and now to the longitudinal direction of the finger and arm back and forth so that one end up the finger that moved others in the arms at the same speed. Since the nerve-impermeability of the finger skin is greater than that of the arm skin, one would have thought that the space traversed on the finger, or the speed of the movement on the finger, should have been decidedly larger than on the arm. But I have not been able to decide anything in repeated attempts, both made by myself and by other people. Sometimes one seemed to me to move faster, the other tip sometimes or to go through the larger room, and from the other people I received partly fluctuating, sometimes even contradictory statements. The apparent success here seems mainly dependent on the imagination.²²⁾

²¹⁾ For previous experiments, they were used undimmed; in the present, however, is not a smooth leadership of the tips without the above measure to achieve.

²²⁾ This essay relates to questions which Czermak wrote in a small essay, "Ideas for a Doctrine of the Timing," in the Dean's Reports. Vienna. Akad. 1857. April, without, however, being able to contribute anything to the enlightenment of the same.

If one tries to give an account of the failure of previous experiments, one can first of all consider it possible that the combination of the points traversed by the compass tip in memory gives, in principle, a different result of apparent extension than the combination of the two at the same time. It is in fact not *a priori* to say that a coincidence of both cases takes place in the results. Only it would be difficult to reconcile the so different failure of these experiments with different individuals, and it does not appear that such a difference is asserted in the eye.

So I confess frankly that I do not have a secure explanation for these circumstances. In the meantime, perhaps an attempt could be made to explain the following point, which is still quite questionable.

Suppose you have a series of sensory circles in a given section of the skin *ah*

a b c d e f g h

Each belongs to an isolated Tastnervenfaser, which is found with their activity above the threshold. Now, if all go round after the row from the top of the circle, without interfering with their activities, then, as has been shown in many persons, *ah* will appear as great as between the dormant peaks, because the number is discreet. Feeding fibers neither multiply nor diminish. But supposing, by the charm of the circle tip, several of the previously isolated points confluence each time. B. three, the equivalent of a *sense circle* according to the principle discussed above, ie successively *abc*, *bcd*, *cde* . . , in the progress of the top from *a* to *b* and *c*. So, one wonders whether the whole distance *ah* can appear as great as if the points *a*, *b*, *c* . . care passed through as isolated or thus exist between the stationary compass points. This does not seem to me to be *a priori* decidable or decided by experience. If *ah* can appear smaller in this way, the success of the experiment with those who would *b* smaller than *r* find, thereby be explainable. But one should, of course, expect that the intensification of the pressure during the experiment would then manifest an influence which I can not confirm. It is undisputed that not all points *a*, *b*, *c* . . are above the threshold from the outset, but a part of them is raised above it only by the circumference of the compass, and thus the effect of greater pressure in this respect may be with that of increased confluence compensate in a way; but there is still a lot of doubt about the explanation. The influence of the opposite direction of the movement may, as it has shown itself, be due to some subsidiary circumstance, and to lay less weight upon it.

Of fundamental importance is the following earlier already touched, moved to this point, question:

Does the magnitude of extensive sensation depend on the function of the number of active sensory circuits used, rather than the magnitude of the intense sensation on the size of the stimulus?

In other words, does Weber's Law apply in this respect, and are our previous formulas based on this applicable to extensive sensation, insofar as we substitute the number of active sensory circles for the size of the stimulus therein?

The experiments cited in Chapter 9 have shown that Weber's Law is confirmed by the dimensions of the eye; but it has also been shown that this confirmation does not mean anything for the decision of our fundamental question, because the experiments are carried out under the influence of the eye's movement; yes their true meaning is not yet cleared up. It has just been stated that Weber's law in tactile measurements is not confirmed for the experiment; In the following chapter, I will cite the experiments, and these attempts seem to be more authoritative, because movement does not come into play here.

In fact, Weber's law-based dimensional formula does not apply to extensive sensation. Large lines would, according to this formula, appear shortened in a logarithmic relation to smaller ones; but a line twice as long is also regarded as twice as long by a good eye-size, and this is even the case with the eyes closed, where movements can not co-determine the judgment.

In the meantime, a more in-depth consideration teaches that if the number of sensory circles in extensive sensations were to represent the strength of the stimulus in intense, a smaller and greater stimulus would not be due to a smaller and larger part of the extension of the retina, but only to a smaller and larger one whole retina could be represented, but which we can not produce in our experiments, so that the observations to which we refer are altogether inappropriate to make a thorough decision on the question, since they always apply only to smaller and larger parts of the retina and skin go. The details, that is it:

The totality of the active sensory circles of our retina, assuming that their number has the same meaning for the extensive size of the sensation, will represent, as the strength of the stimulus for the intensity, a certain extension of the sensation, an apparent field of vision of a certain magnitude. If this totality, no matter what number of sensory circles, was increased by a given proportion, then according to Weber's law, if it were applicable, the apparent field of vision would grow by the same amount, and two retina of size n and na would be added have the same nerve density apparent fields of vision, which are like $\log a$ and $\log n$ behave when the number of sensory circles at which the expansion begins to become noticeable is set to 1. If, however, we only consider parts of the retina which have been given against each other, as is the case in all our experiments, provided that all the lengths and distances are defined only in the retina which has not been arbitrarily modified, then it is with respect to the extensive sensation the same, as regards the intense, when we consider a fraction of the intensity of one stimulus against the other. Everyone does the same with the other. The n th part of the retina is then the n must represent th part of the whole visual field, and an n - times as large a n -sometimes so much of the field of vision, according to the very simple principle, that the sum of the parts is equal to the whole.

In fact, let us assume that a small part of the retina is perceived relatively larger than the whole retina, as a weak light stimulus is relatively stronger felt by the measure-formula than a strong one, as would be the summation of these apparent expansions of the parts a larger apparent expansion, than for the whole retina, which contradicts itself. If, however, a weak light-stimulus is relatively stronger felt by the measure-formula than a strong one, it is due to this, and is only so in so far as the weak is not part of a strong one, but acts beside or after it. But insofar as a weak light stimulus is part of a strong light stimulus acting in the same space and time, it has no greater effect on the sensation, as the other weak parts, and so is this in proportion to the size that he forms of the whole light stimuli. Quite correspondingly at conception of an extensive size of a retina, than here at intensive size of irritation.

A similar consideration would apply to the extent of skin expansion.

I do not say that these considerations secure the applicability of Weber's Law and its dependent formulas to extensive sensations, but only that thereafter the possibility of this application still exists. I could not find a decisive proof of experience; In the meantime, there are many implications of this application, which in themselves are

not altogether inaccessible from a point of view and of interest, and which I therefore wish to discuss with some.

Insofar as the number of active sensory circles of the retina is proportional to the size of the retina under otherwise identical circumstances, I first replace the number of sensory circles by the size of the retina, pointing to the unevenness of the retinal nerve density in the same individual, and inequality of this density between different Individuals at first take no account of what will happen afterwards. The apparent field of vision will always be understood as the field of vision, as it appears in the closed eye, apart from the effects of experience.

After application of our measure formula, in order for an apparent field of vision to be produced at all, a certain extent of the retina (number of discretely perceived sensory circles) is required, which is to be regarded as a threshold, and provided that this threshold is expressed as a unit of In general, with the extension of the retina being denoted by a , and k being set in the measure formula = 1, $\log a$ will give the measure of the apparent extent of the visual field.

Should the apparent field comparable n -fold, it must $\log a$ in $n \log a$ = $\log a^n$ transition, that is, the retina which this n should give -fold field must obtain an extension which is not the n -fold size but the n -th power of those size has, which belongs to the retina by simple expansion.

If the size of the retina has already grown a great deal, a doubling of its size will no longer change the apparent field of vision, unless $\log 2$ disappears against $\log a$.

From this it is evident that very large eyes, when it was necessary to produce great services with the least possible expenditure of means, are not teleologically advantageous. Also, nature has preferred to look with many eyes in many creatures, as few in few, although of course other advantages come into consideration. Too small eyes, however, would just as little be beneficial, because below the expansion threshold nothing is seen.

If one then asks which retinal size A would give the greatest possible relative extensive power, ie the greatest possible apparent field of vision in relation to the retina size related to it, the maximum value of the expression will be obtained



to look for; which, by differentiation according to a known rule, allows us to find the maximum value that we have met several times,

$$A = e = 2.71828 \dots$$

where e is the fundamental number of natural logarithms. According to which the relatively most advantageous extension of the retina would be what the 2,718. . times their threshold.

Now let us examine what influence the size of the retina a has on the apparent size of the images falling on it. Let α be the part of the retina the picture covers. According to the principle established above, the size under which the picture

appears will be $\frac{1}{a}$ of the size under which the whole retina appears, but this appears below the size $\log a$. So the apparent size of the picture will be $-\frac{1}{a} \log a$. Insofar as a is in the divisor of this expression, the size of the retina is detrimental to the apparent size of the images falling on it. The image of given size a then covers a proportionate part of the retina a which is all the smaller, and on the basis of this proportion the proportion which the apparent size of the picture forms of the apparent extension of the retina is directed. But the apparent extension of the retina increases at the same time in the ratio of $\log a$, and herewith also the absolute size of the proportion part which comes to the picture. This justifies, on the other hand, an advantage of enlarging the retina for the apparent size of the image.

According to circumstances, the disadvantage or advantage may now prevail, and here too there is a point of greatest advantage, which coincides with the previous one. The maximum, ie, where a picture of a given size on the retina seems to be as large as possible, takes place again in a retina whose extent $A = e$, in the sense given above.

So far we have thought only of the extension of the retina, with uniform and equal nerve impermeability. If we imagine the nerve-impermeability of various retinas to be the same extent, the apparent field of vision will change in the same proportion, by changing the extent of the retina itself according to the number of sensory circles in it, so that a doubled dense retina has as large an apparent field of vision as a doubly extended one with unequal tightness.

In general, if D is the retinal density of nerves still assumed to be uniform, a their actual extent, α the extent of the part on which the picture falls, then the apparent size

of the visual field will be $\log D a$, the apparent size of the picture $\frac{1}{a} \log D a$, according to which, by concentrating the retina, more can be obtained for the apparent size of the image than by enlarging it, because D is not the same as a into the divisor of the expression for the apparent size of the picture. In fact, we see this point of view met by great nerve tightness with small size of the retina. However, of course, the nerve impermeability, ie, the number of retinal elements crowded together on a large area, if they touch each other, can only be increased at the expense of their extension, where then each can absorb only fewer rays of light, which must diminish the intensity of the sensation.

Incidentally, the increase of D can contribute proportionately only to the increase in the apparent size of the image, the farther it is driven beyond a certain point. For comparable m -fach to D in the formula for the apparent extent of the image, the

expression is growing at $\frac{1}{a} \log m$ what to $\frac{1}{a} \log D a$ disappearing more so the larger $D a$ has been.

So far, uniform nerve density was required. But such a thing does not really take place, and our theory includes the very peculiar conclusion, strangely coinciding with the institutions of nature, that a special advantage can be obtained in that the part of the retina on which the picture falls is very much like is made nerves tightly in proportion to the remaining by the fraction of the total number of circles of sensitivity, the cover image, characterized becomes larger without changing the divisor occurring in the total number of circles of sensitivity *thus* increased considerably.

In fact, if D is the average nerve density, a is the extent of the whole retina, d is the nerve density, and α the extent of the part on which the image falls, then the whole

apparent field of vision is $\log D a$, and the apparent extent of the Picture $\boxed{}$ $\log D a$; From this it follows that the apparent expansion of the image at given D grows in the direct relationship of d .

After this the device appears, according to which we have only a very small, very nerve-dense, clearly visible part, with a retina which is comparatively less nerve-sparing than the most advantageous possible to achieve the greatest proportion of vision. Except that this device made the second device necessary to set up the eyes movable, thereby obtaining the equivalent of a large clear field of view. Accordingly, our organ of touch is set up; and the most nerve-imperfect places are here especially on the most freely movable parts, the tongue and fingers, attached.

If more were known about the proportions of nerve density to the size of the retina and other conditions in different classes of animals than is the case now, perhaps more definite confirmations of this theory or even more specific objections would be made, without reference to the teleological principle because I am indeed far from spending it for a safe. In this respect, Bergmann (²³⁾, referring to the views based on the sense of touch by Weber's experiments, says:

"Thus, we come to the conclusion that the size of the image in the eye only makes accurate vision possible to the extent that it spreads the image over a larger number of nerve endings." But this leaves us with the question, To what extent the distribution of the nerve endings may be arranged in the eyes of various animals The extremely difficult anatomy of the retina has not yet been able to solve this question, but it is to be supposed that the former solution will shed some light on some peculiarities of seeing different Animals will have to spread. "

²³⁾ Anatom. Unters. P. 470.

The size which covers the image of a clearly visible object on the retina of a creature depends on the one hand on the clear sight of the creature, on the other hand on the distance of the point of intersection of the visual rays from the retina, and thirdly on the radius of the eye and consequently the retina. Now suppose we had creatures, destined to see clearly from a far greater distance than man, what would their eyes have to be like? It is undisputed that the smallness of the picture, which is

conditioned by the great distance of the objects, would be compensated by other circumstances. What will these relationships be according to our theory? The ratio of the nerve impermeability on the most clearly visible part to the rest, just as the radius, that is, the size of the eye, will have to grow, The size of the retina, however, must not be allowed to grow proportionally, because the most advantageous extent of the retina is determined independently of the size of the eye. In fact, the birds, which have a great deal to see in their flight, present on average very large eyes, but with a smaller retina, proportionate to the size of the eye, than mammals, as I take from the verbal utterance of a skilled person. About the conditions of nerve density, I know nothing. but with a smaller retina, relative to the size of the eye, than mammals, as I take from the verbal utterance of an expert. About the conditions of nerve density, I know nothing. but with a smaller retina, relative to the size of the eye, than mammals, as I take from the verbal utterance of an expert. About the conditions of nerve density, I know nothing.

In Müller, for example, Physiol. Der Gesichtss, p. 132, I find the following statement: "In the eagle and vulture, the retina should be folded like that of the fish in the genus Zeus and in the mullets in the meridians of a sphere and in the vultures the retina, after development, is supposed to be three times greater than in its naturally shaped extent. "

In these birds, then, the retina would have a considerable size; which would not fit our formula, inasmuch as this size, with its considerable fiber content, would not be calculated to make the obvious-looking part nerve-tight with nerve endings.

In any case, it can be seen that here many points of view for interesting investigations are presented on the anatomical side, to which only the purpose of the preceding remarks could be to stimulate.

It is not disputed when this theory is carried out that the following considerations apply: large (multibranched) sensory circles will give the advantage of producing intense sensations, in that the impressions add up to an intense sensation, but the disadvantage that there are various juxtaposed impressions on it It vanishes that, because of their reduced number in a given space, the apparent size of the images diminishes and the size estimate becomes uncertain, provided that according to the principle discussed with respect to Volkmann's constant (Th. I, p. 230), a length must be the same It may fall with its ends on the nearest or farthest parts of two sensory circles.

XXXV. Some tactile test series according to the method of the mean error with explanations of this method.

Of the following 6 series of tests, I to IV are particularly intended to prove that Weber's law is not confirmed for the measure of touch as well as for the measure of proportion, but that the mean error or sum of errors from which it is drawn is smaller enlarged than the normal distances on the skin at which it is obtained, and that it remains almost constant at longer distances; The series V, a very large one with 6400 observations, shows that the 5 fingers (forelim, volar side, longitudinal distance) do not differ much in the degree of difference sensitivity, but the index finger definitely has the greatest sensitivity, a result that to apply to general, admittedly still to be stated on other persons, and with different ways of using the hands to work and daily activities of life might possibly turn out differently. Series VI gives the maximum degree of difference sensitivity that I have so far acquired with the tactile organs on which (chapter 34) has been spoken.

Apart from this, the following series, especially V and VI, are intended to illustrate the method of mean errors according to various pages, more specifically by way of examples. A review of what is provided in Th. I, chap. 8, especially from p. 120, on the method of mean errors is mentioned, to which the remarks in Th. II, chap. 28 can be drawn into its components via the analysis of the constant error c , of which, however, the essentials are summarized below. The observations are made under the measures generally specified in Chapter 8, and the terms here and there are to be understood. However, for the general presentation of the method given there, it will be necessary to add a few supplementary discussions in the following.

The special measures in the following experiments were these:

In my own experiments always gestielte Schenkelzirkel were inserted with Nähnadelspitzen (length of the thighs 5 par. Duod.-inch), and this taken at the application to the stems. Where it is not particularly noted (as in series IV and partly in VI) that the application of the circle was made by an assistant, it was self-applied. The purpose of the series VI is to determine the different success of both modes of application. In the observations on the front of the fingers (series II, V, VI), one circular tip was always placed in the joint between the anterior and middle phalanges, and the other placed forward on the fore-limb. This was done, as in any experiment, without any involvement of the sense of sight, by practicing soon enough to hit the right place without it.

I have always made 10 observations in close succession under exactly the same circumstances (with the same normal distance, on the same skin, in the same time and space situation of the circles); except in row I in the observations on the forehead, whose skin is too sensitive to tolerate repeated application of the circular tips in the same place, and in row II on the finger, where the small distance involved is 5 d because of proximity. The circular tips on each other facilitated the development of a state of irritation.

If several normal distances were tested in the same row, they were always run through each other, and changed on different days with ascending and descending episode of the same, as well as in the time and space situation of Zirkelapplikation a very regular change to fractions à $m = 10$ or observed after days.

If the normal circle was held in the application with the left hand, the right hand wrinkles, this is denoted by **L**, and vice versa with **R**; ó if the normal circle was applied first, and the wrong circle was applied second, this is denoted by **I**, and conversely by **II**¹⁾; so that thereafter 4 time-space situations

I L , II L , I R , II R

are distinguishable, of which, however, in series **I** only **I L** and **I R** were used. When both circles have been grasped in the same hand to make experiments on the other hand, instead of the setting **R** and **L**, the socket with the upper and lower parts of the hand comes in the, Tb. II, Chap. 28 note the meaning given in consideration represented by **O** and **U** is discriminated.

¹⁾ Comp. on this special Th. II, p. 149.

The normal distance is always denoted by **D**, and the unit in which all the numbers in my experiments are expressed, 1 half paris decimal line = 0.72 paris. Duodecimal lines, with **d**. The reading of the errors happened on a scale with transversals, which gives 0.1 **d**. Smaller values than this size could not therefore be directly obtained, although a remedy from many observations can still give this with relative certainty.

The fractionation in the calculation of the rows I have made has always been done on ten observations, which, with the exception of series **I** and **II**, were always made immediately after each other, by determining the mean error distance for every ten observations, the pure errors Differences of the individual miscarriage distances were calculated from their mean, and the thus obtained fractionally pure error totals $\omega\epsilon\rho\epsilon$ combined to the total $\Sigma\Delta$. Now that m is the number of observations of each individual fraction, μ is the number of fractions from which each value $\Sigma\Delta$ $\sigma\delta\epsilon\rho\tau\omega\delta$ in the following test $\tau\alpha\beta\lambda\epsilon\sigma$, is μm the number of individual observations that have contributed; for the totals columns in the tables, however, still think *microns* multiplied by the number of summed items. The mean error ϵ is then obtained by dividing $\Sigma\Delta$ by the number of contributing errors.

The above essentially only concerned the own observation series (**I, II, V, VI**). The Volkmannians (**III, IV**) are employed with other circles, whose arrangement I can not specify, without distinguishing particular temporal and spatial situation, which was not essentially essential, and with a different summary of observations, also applied other units of measurement at the special message of a series the necessary.

In any case, to ensure the correct interpretation of the numbers in the tables, I explain the first number of the first test table.

Under $D = 15$ can be found here for **I L**, the number 32.7, however, above the table $m = 10$, $\mu = 5$ is, that is, at a normal distance $D = 15$ half pariser Dezimallinien, in the time-space location **I L** was by $m\mu = 50$ observations, ie by 50 pure single errors, a $\sigma\upsilon\mu\phi$ error $\Sigma\Delta = 32.7$ half paris decimal lines is obtained, which is derived by calculation from 5 fractions $\dot{a}m = 10$, giving as ϵ for 1 error 0.654 half

paris decimal lines. Similarly, all other numbers in the same table under the headings **I L**, **I R** interpret. The total number 66.5 for **I L** and **I R** at $D = 15$ is then, as valid for the double number of observations, of course, at 100, be divided instead of 50 to ε to give 1 for watching, and even with $^{31} / _{30}$ if one wants to correct because of the finite m and thus wants to get ε_1 . The constant error c is always given as the average for 1 observation. The number of observations from which one derives it, that is, the size of m , does not have the same $\pi\alpha\lambda\omega\varepsilon$ as in $\Sigma\Delta$ an influence on his size, but only on the certainty of his destiny.

Where observations are made at 4 times time-space attitude , the constant errors generally denoted by c are specifically named

$$\begin{array}{ccccccccc} c_1 & c_2 & c_3 & c_4 \\ \text{for} & \mathbf{I} & \mathbf{L} & \mathbf{I} & \mathbf{L} & \mathbf{I} & \mathbf{R} & \mathbf{I} & \mathbf{R} \\ \text{or} & \mathbf{I} & \mathbf{U} & \mathbf{I} & \mathbf{U} & \mathbf{I} & \mathbf{O} & \mathbf{I} & \mathbf{O} \end{array}$$

The same can then, as Th. II, Ch. 28 is explained in more detail, by analyzing a temporally dependent component p , a spatially dependent component q , and an independent component s , which probably has the origin given in Th. II, chapter 28, by setting

$$\begin{aligned} c_1 &= p + q + s \\ c_2 &= -p + q + s \quad c_3 = p - q + s \\ c_4 &= -p - q + s \end{aligned}$$

and from this p , q , s are determined by adding and subtracting these equations, which, depending on these or those two equations , gives a double determination of p , q , s , which is controlled. The two values thus obtained are distinguished by indices 1 and 2 appended below and their mean is given without index. Since the good or bad agreement of the double values of one component at the same time guarantees that of the other two (see Th. II, chapter 28), which states that the following series (II, V, VI) themselves provide sufficient opportunity, then in general merely the double values for the component s , as the usually largest, specified by the other components p , q only the funds indicated.

Where, as with series **I** , there are only observations in **I L** and **I R** , only the equations stand

$$\begin{aligned} c_1 &= p + q + s \\ c_3 &= p - q + s \end{aligned}$$

then one can separate the constant error only into a space-dependent component q and an independent $p + s$, without being able to separate $p + s$ itself.

In Th. I, p. 125. 127 I have spoken of several corrections, which can be applied to

the pure error $\sigma\nu\mu\Sigma\Delta$ or the derived $\mu\varepsilon\alpha\nu$ error $\boxed{}$, the most important of which is because of the finite m (Th. II, chapter 27). according to which $\Sigma\Delta$ or ε

σ still to $\boxed{}$ be multiplied by. Since I apply this important correction, which has not yet been deduced, in the following several times, I will attach the derivation of the same under the 1st addition to this chapter. The understanding of this derivation presupposes a somewhat closer acquaintance with mathematical error theory. Without correction, the mean error derived from the pure errors would be ε , after the correction because of the finite m denoted by ε_1 , so that

$$\boxed{},$$

In addition to this correction, I have mentioned Τητ I, p. 127 two corrections of $\sum \Delta$ and ε to $\beta\varepsilon \mu\delta\varepsilon$, the correction for the size of the intervals and the estimation of the classification, which are usually negligible, and of which the second not considered here at all, since no estimate of interim parts was made on the scale; the first, however, is not to be considered improperly in the experiments of Series VI ; because here the mean error (at Division V) is not much larger than 0.1 d , which is the smallest interval of the scale. Here I give this correction belatedly briefly and for practical purposes sufficient, and add the theoretic about it under the 2nd Supplement.

Be that because of the size of the intervals not yet corrected, thus wrong, error $\sigma\mu$ $\sum \Delta$ and the uncorrected center error ; If the smallest different intervals of the division are of the size i , then the corrected or true error $\sigma\mu S \Delta$ from the

wrong $\sum \Delta \sigma \phi\psi\nu\delta$ by the following equation $\boxed{}$

$$\boxed{}$$

as well as the corrected mid-level error ε_1 from the wrong one

$$\boxed{}$$

So is z. For example, if $i = \varepsilon$, then one has

$$S \Delta = 0.947 \sum \Delta$$

which is a non-negligible correction. If i only $= 1 / 4 \varepsilon$, as would be $\boxed{} = 1 / 16$, therefore, $S \Delta = 0.9967 A \Delta$.

According to this, one can measure for oneself to what extent the nature of observations and tasks makes it necessary to engage in this, by the way, very simple correction. I just went into it on Series VI .

With the very small constant errors, which occur in part in the following, one can repeatedly ask whether their existence does not rest only on unbalanced

contingencies. To assess this, one must look for the probable error of the constant error, and see if it is exceeded to a considerable proportions by the size of the constant error itself, which is very easy using the following rule by means of to the values c corresponding value $A\Delta$ can be done ,

Let $M = m\mu$ be the total number of observations from which c and therefore the corresponding $\sum\Delta$ is derived, where m is, as usual, the error number of a fraction, μ is the number of fractions that contributed to $\sum\Delta$, then the probable error w of c

$$\boxed{w = \frac{\sqrt{\sum\Delta}}{M}}$$

Thus, in the first series of observations (at $D = 15$, $I L$) the error error $\sum\Delta = 32.5$ is the constant error + 0.89. Since $\sum\Delta$ and c are derived from 50 observations, $M = 50$, and since fractions of 10 are used in the derivation, $m = 10$; hereafter

$$\boxed{w = \frac{\sqrt{32.5}}{50}}$$

The constant error c , therefore, if, as usual, we include the probable error with \pm so to write

$$c = + 0.8900 \pm 0.0804$$

what says, the probability is the same that the value +0.89 um more and that it differs by less than 0.0804 in plus or minus of the value c , which would have been obtained by an infinite number of comparable observations. Now, if the constant error is not much greater than this probable error, or, as we can express briefly, should it be absorbed by it, it is not unlikely that what was said to be a constant error could be absorbed merely to be dependent on unbalanced contingencies, and not to settle the constant error with any reality; but should z. For example, c is twice as large as w , so 82 would be to be betted against 18, and if he were to be 3 times larger then 96 would bet against 4 that he does not depend on chance; even more if he even greater proportions w überwöge. In our example, where $c = 0.8900$ is noticeably 11 times as large as $w = 0.0804$, the probability that it depends on chance is quite vanishing.

The previous general rule for determination w is as follows: the probable error of the constant error c coincides with the probable error of the mean error distance (= normal distance + c), since the probable error of a magnitude does not change, if one goes to this one fixed size (normal distance) added or subtracted from it. But the probable error of the mean error distance can be determined from the deviations which the individual misings have from the same, that is, from the pure error Δ ; either in the usual way from the sum of the squares of the squares and the resulting quadratic mean error ε_q according to the formula

$$\boxed{w = \sqrt{\frac{\sum \Delta^2}{M}}}$$

but also noticeably equivalent by means of the simple error sum and the simple mean error ε_1 derived from it according to the formula



so far as ε_q and ε_1 are concerned by the (theoretically justified and experimentally verified) normal relationship



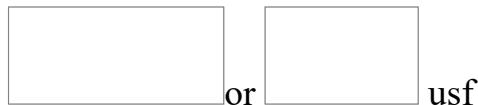
are linked. ε_1 , however, is obtained by dividing $\Sigma\Delta$ by the total number of observations M and correcting them by the finite m , which leads to the given formula.

The discussion of how the above special probability rules are found concerning the ratio of c to w would go too far here; this provision is also based on well-known principles.

Once one has determined the probable errors w for c_1, c_2, c_3, c_4 , and finds the corresponding values of $w = w_1, w_2, w_3, w_4$, one easily obtains from this the probable error the components p, q, s , which W hot. This is namely, if these components are calculated according to the equations (see above) from all 4 values c determined in solidarity, and equally valid for all three



If one has any of the components of the constant error merely two values of c , z. B. c_1, c_2 or c_1, c_3 is determined, so is the value of the probable error of this component only



Also, every component of the constant error will be considered as the same constant error as a matter of merely unbalanced contingencies if its size does not significantly exceed that of the probable error W .

If you have the values of the constant error c for μ specially designed fractions of a larger series of observations, which I in series VI give examples, one can also deviations which the μ fraction values of the constant error from the average c present, and which ϑ may be called, and use these deviations, according to the usual rule, by means of the sum of the squares $\Sigma (\vartheta^2)$ or by means of the simple sum $\Sigma \vartheta$ to calculate a probable error of c , the former by means of the formula



the latter by means of the formula



where μ is the number of fractions and thus individual values of c . In the meantime, the probable error thus calculated has not quite the same meaning with that, according to (αβωτε) from $\Sigma\Delta$, by being essentially dependent on the variations of the constant error which are never easily absent in longer series of experiments. While the latter is only decisive for the ρελιαβιλιτψ of the determination of the constant error, which depends on larger and smaller irregular random influences, this is at the same time decisive for the degree of fluctuation of the constant error, and therefore both μοδεσ of determination (from $\Sigma\Delta$ and $\Sigma\delta$). In some cases, where the fluctuation is small, there are results which are close to each other, but may also be exceptionally different, as the examples in row VI prove. Therefore, in order to decide if a sway has taken place, it is useful to compare both modes of determination.

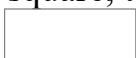
Where nothing is especially noted, w is always calculated from $\Sigma\Delta$ according to the formula (σεε αβωτε).

It is not disputed that an absolutely pure separation of the errors Δ from variations of the constant error is in fact possible by no fractionation and fractional treatment of the observation series, and suffers even from conceptual difficulties. But if all observations to be compared are always made into fractions of the same moderate number under comparable circumstances, and always summed up in the calculation to the same m , the resulting distinction between the variations of the constant error and the pure error Δ will always be useful, and these fractional treatment of unfractionated treatment, where the variations of the constant error mix indistinguishably with the error Δ , remain preferable.

It will not be without benefit, if I here also the probable error of the pure error $\sigma\upsilon\mu$ $\Sigma\Delta$ and the derived middle error ε indicate. It is obtained by relative $A\Delta$ or ε with



multiplied²⁾. If we take $m = 10$ as usual, then $\lambda = 0.16115$; after which each pure error sum so as each pure means error from a fraction A to a mean probability of $m = 10$ is approximately about $1 / 6$ of their size determined incorrect. Not that this really happens in every single fraction; but if one has many fractions with $m = 10$, the error is just as often over than under the given one. In order to determine the probable error of a total error sum from μ fraction sums of the same m , one has the μ To make group sums one by one square, to draw the root from the sum of these squares, and to draw



them with λ , di [] ; so in case of $m = 10$ multiply by 0.16115.

²⁾ astronomer. Year f. 1834, p. 293.

There would still be many useful provisions about the probability ratios of the errors, but this would go too far.

I. Fechner. Oct. 1857 - July 1858.)

Forehead: Nine transverse distances. Unit 1 d . Total number of observations 900, divided into 100 days of 9 observations.

The distances are given in duplicate as follows, as D , as they correspond directly to the span of the circle placed on the skin, as D' , as they correspond to the actual length of the skin stretch conceived in this Hautstrecke. Because the forehead is somewhat curved, both do not coincide. To determine the related values of D and D' , a strip of paper was placed over the forehead and marked by the compass at the span D points in the same, the distance of which was then measured after the strip had just been spread. From several such provisions the funds were taken. The values were:

| | | | | | | | | | |
|--------|----|----|------|------|----|------|------|------|------|
| $D =$ | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 60 |
| $D' =$ | 15 | 20 | 25.3 | 30.5 | 36 | 41.5 | 46.9 | 52.9 | 65.7 |

The values of the following tables obtained at the last distance $D = 60$ or $D' = 65.7$ can be disregarded, since the great deviation of them from the others can be very well based on the fact that the compass points become very considerable Curvature of the forehead is very wrong to hit the skin, so that the observations here with the others are as good as incomparable. Therefore, the values obtained at this distance are bracketed in the table and are not included in the drawing of the total sum, which therefore deals only with the values at distances up to $D = 50$ inclusive. Every day, the series of 9 distances could only be traversed once for the reason stated above.

$$\sum \Delta (m = 10, \mu = 5)^3.$$

| | | | | | | | | | |
|-------|------|------|------|-------|------|------|------|------|---------|
| D | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | (60) |
| IL | 32.3 | 43.4 | 46.6 | 62.0 | 42.7 | 47.1 | 49.2 | 50.3 | (77.6) |
| IR | 31.9 | 40.2 | 50.9 | 40.8 | 44.6 | 41.5 | 48.3 | 48.1 | (73.2) |
| total | 64.2 | 83.6 | 97.5 | 102.8 | 87.3 | 88.6 | 97.5 | 98.4 | (150.8) |

c.

| | | | | | | | | | |
|------|-------|-------|-------|-------|-------|-------|-------|-------|---------|
| D | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | (60) |
| IL | +0.90 | +1.20 | +0.92 | +0.85 | +1.12 | +1.14 | +0.61 | +0.43 | (+0.49) |
| IR | +0.11 | +0.36 | +0.24 | +0.42 | +0.27 | -0.10 | +0.10 | +0.20 | (+0.17) |

³⁾ The following is the corrected table: In terms of p. 217 f. communicated.

From $D = 15$ to $D = 25$ one sees a clear increase of the error $\sigma v \mu \sum \Delta$ with D , which even for **I L** alone until $D = 30$ is very exactly proportional to D , but beyond that no significant growth any more, but only irregularities could have compensated for further continuation of the observations in part. Determine the mean error as the average for the observations at the 6 distances $D = 25$ to $D = 50$, within their appreciable constancy (for **I L** and **I R** taken together), one finds

$$\varepsilon = 0.921 d; \varepsilon_1 = 0.952 d$$

this value ε_1 is = $\square D$ at $D = 15$ and \square at $D = 50$ 4).

⁴⁾ See p. 218.

The constant error is positive for all distances in both layers with a single exception; but, as you can see, the position **I R** (version of the normal circle in the right) is smaller everywhere than the position **I L** (version in the left), which is an example of the not insignificant influence of the way the circles are held; however, no legal dependency of the constant errors on the size of the distance is noticeable. For the components q and $p + s$ of the constant error we obtain on the average for all distances excluding $D = 60$

$$q = +0.372; p + s = +0.527$$
⁵⁾.

Earlier (1856 and 1857) I made similar series of tests on the forehead with similar results, which I pass over because they were employed with undisturbed circles and with less careful prevention of the irritation of the frontal skin.

⁵⁾ See p. 218.

II. Fechner (January to March 1859).

Left index finger. Forelim, volar side, two longitudinal distances $D = 5 d$ and $D = 10 d$. In total 400 observations on 20 observation days.

$$m = 10, \mu = 5.$$

| | $A\Delta$ | | c | |
|-------------|-----------|--------|---------|---------|
| D | $5 d$ | $10 d$ | $5 d$ | $10 d$ |
| I U | 7.28 | 6.14 | 0,000 | - 0.240 |
| II U | 8.52 | 9.02 | - 0.230 | - 0,296 |
| I O | 7.18 | 8.50 | + 0.054 | - 0,272 |
| II O | 8.18 | 8.30 | - 0,292 | - 0,444 |
| total | 31.16 | 31,96 | O | O |

Here the error $\sigma v \mu \sum \Delta$ almost unchanged at doubled distance, ε_1 on average from all observations $0,163 d$.

The calculation of the components of the constant error gives the following result:

| D | 5 | 10 |
|-------|---------|---------|
| p | + 0.146 | + 0.057 |
| q | + 0,002 | - 0.045 |
| s | - 0,117 | - 0.313 |
| s_1 | - 0.146 | - 0.342 |
| s_2 | - 0.088 | - 0.284 |
| W | 0.00963 | 0.00994 |

We see here the component s of remarkable size and, at $D = 10 d$, in the double values as close as one might expect in the relatively small number of observations, whereas at $D = 5d$ no particular agreement of s_1 and s_2 in the while the still significant size and correspondence of the sign of s_1 and s_2 , as well as the small size of the probable error 0.00994 calculated by the rule, prove that the error s really exists. Only the error q at $D = 5$ can be explained by chance at all.

III. Volkmann (April 1857).

Middle finger. Anterior, volar side, four longitudinal distances. Unit 1 mm. Without regard to special time and space situation. 264 observations.

$$m = 33, \mu = 2.$$

| D | 2 | 4 | 6 | 8th |
|-----------------|---------|--------|---------|---------|
| $A\Delta$ | 6.68 | 9.13 | 12.70 | 12.13 |
| c | + 0.045 | +0.131 | + 0.012 | - 0.018 |
| ε_1 | 0,102 | 0.140 | 0.194 | 0,216 |

The growth of $\sum \Delta$ or ε_1 with the distances was so much more important than mine in Series II, but also by far not proportional to D .

IV. Volkmann (January and February 1858).

Left back of the hand, four transverse distances. Unit 1 Paris line. Application of the compass by an assistant without regard to special time and space. 480 observations.

$$m = 20, \mu = 6.$$

| D | 6 | 12 | 18 | 24 |
|-----------------|--------|--------|--------|-------|
| $A\Delta$ | 67.2 | 60.8 | 86.8 | 83.1 |
| c | + 0.45 | + 0.47 | + 0.37 | +0.31 |
| ε_1 | 0.569 | 0.515 | 0.735 | 0.704 |

V. Fechner (Nov. 1857 to April 1858).

Five fingers of the left hand. Forelim, volar side, on each finger 1 longitudinal distance = 10 d . In total 6400 observations, distributed over 64 observation days of 100 observations.

Every day pass through all 5 fingers in two time-space situations with 20 observations (10 for one position).

It means the following **D** thumb, **Z** index finger, **M** middle finger, **G** gold finger , **K** small finger.

This series is connected in a row by the method of equivalents on the same five fingers, so that the method of mean errors and equivalents change every two days. Here only the results according to the method of mean errors are given; because it would go too far for now, even those of the other method to consider.

$$m = 10, \mu = 32.$$

| $D = 10 d$ | | D | Z | M | G | K |
|-----------------|----------------------|----------|----------|----------|----------|----------|
| AΔ | I U | 77.92 | 67.54 | 67.36 | 78.80 | 74.94 |
| | II U | 80.70 | 65.34 | 73.54 | 69.14 | 75.00 |
| | I O | 68.56 | 54.68 | 68.03 | 68.40 | 71.40 |
| | II O | 76.00 | 64.54 | 63.34 | 70.26 | 71.92 |
| total | | 303.18 | 252.10 | 272.27 | 286.60 | 293.26 |
| c | I U | - 0.057 | - 0.0882 | - 0.0075 | + 0.0625 | - 0.0438 |
| | II U | - 0.1700 | - 0.0953 | - 0.2066 | - 0.2766 | - 0.2582 |
| | I O | - 0.2691 | - 0.3950 | - 0.2222 | - 0.1641 | - 0.2432 |
| | II O | - 0.3700 | - 0.3310 | - 0.3779 | - 0.3816 | - 0.4303 |
| ε_1 | | .2448 | .2035 | .2198 | .2313 | .2367 |
| | p | + 0.0538 | - 0.0142 | + 0.0887 | + 0.1392 | + 0.1002 |
| | q | + 0.1034 | + 0.1356 | + 0.0965 | + 0.0829 | + 0.0929 |
| | s | - 0.2162 | - 0.2274 | - 0.2036 | - 0.1899 | - 0.2439 |
| | s₁ | - 0.2128 | - 0.2096 | - 0.1927 | - 0.2204 | - 0.2508 |
| | s₂ | - 0.2196 | - 0.2452 | - 0.2144 | - 0.1596 | - 0.2370 |
| W | | 0.00579 | 0.00514 | 0.00520 | 0.00548 | 0.00560 |

After that, the largest error sum 303.18 in the thumb, the smallest 252.10 takes place at the index finger, which shows so the greatest difference sensitivity among the 5 fingers.

For the sake of the finite m corrected agents error ε_1 is the average of all 5 = fingers at all positions $0.2272 d = 1 / 44 D$. The constant error c is negative, with one exception in all fingers in all positions, which large from the negative component s depends, whereas p, q , there are positive, with the exception of p in **Z**, an exception, which is all the more striking since they in series **II** and **VI** does not take place under similar experimental circumstances on the index finger. At **Z** and **G** donot agree with the double values of s , but very well with the other three fingers. The probable error W_{ofp}, q, s is everywhere too small to be considered as coincidental.

On average for all five fingers you have

$$\begin{aligned} p &= +0.0735 \\ q &= +0.1023 \\ s &= -0.2160 \end{aligned}$$

according to which the result of constant errors on average for all observations on all 5 fingers is this.

If I applied the normal circle with the span $10 d$ first, the squared circle too secondly, by virtue of this influence of the time position the wrong distance was too large by $+0.0735 d$, or instead of the normal distance 10 the miscalculated distance 10.0735 was found. If the normal circle was applied secondarily, then the misreading was just as much too low, or was obtained instead of 10.99265, which is in solidarity with the previous results.

If the normal circle was grasped with the lower part, the bad circle with the upper part of the hand (see chapter 28), then the error distance was too large by 0.1023, in the opposite case too low.

Apart from this influence of the time and space situation the wrong distance fell from the cape. 27 reason given by 0.2160 too low.

These three influences combine in an additive or subtractive way, as they are in the same sense or in the opposite sense. All three are in the same sense at **II O**, hence the corresponding values c on average the largest, whereas in **I U** the large error s is most compensated by the joint opposition of p and q , hence here the smallest values c .

From the above calculation of pure error sums, the fractionation usually used by me is below $m = 10$. But in order to show the influence which according to Th. I, p. 124 has the more or less driven fractionation on the size of the pure error sum, the previous series of observations is also using $m = 160$, and finally unfractioniert for each Fingers and every position, ie $m = 320$. The result contracted for all 4 layers is as follows with the one obtained above.

$$\Sigma \Delta .$$

| | | | | | | |
|--|----------|----------|----------|----------|----------|-------|
| | D | Z | M | G | K | total |
|--|----------|----------|----------|----------|----------|-------|

| | | | | | | |
|---------------------|--------|--------|--------|--------|--------|----------|
| $m = 10, \mu = 128$ | 303.18 | 252.10 | 272.27 | 286.60 | 293.26 | 1,407.41 |
| $m = 160, \mu = 8$ | 350.64 | 285.91 | 315.51 | 337.34 | 336.88 | 1,626.29 |
| $m = 320, \mu = 4$ | 354.76 | 291.19 | 320.24 | 345.34 | 349.25 | 1,660.78 |

Ωιτηνωτ exception, the size of $\sum \Delta$ γροωσ with the size of the applied m grow.



The correction of finite m by multiplication of values, which I have applied , merely emphasizes the weaker part of this growth, since it is demonstrably based chiefly on the variation of the constant errors in the course of the long series of experiments, which at the collapse of many observations made at different times Fraction increases the sum of errors deduced therefrom, hence the preference that I give to smaller fractions from observations obtained in the context of the correction by reason of the finite m must be more adequately compliant, as this of the pure error sum in itself foreign increase falls away. That really a variation of the constant error took place in the course of the series of observations, it follows from the below following statement for the two main periods of the observation series distinguished by the time.

In Th. 1, p. 213, I have occasionally noticed that, if one divides the sum of the error squares

$\sum (\Delta^2)$ by the square of the error $\sigma v \mu$ ($\sum \Delta$)² multiplied by twice the number of errors , the Ludolfian number π is approximately obtained. which approximate number **P** **is** called, so that one has



if m is the total number of errors (at $\mu = 1$). Our series can serve as an example. For thumbs using $m = 160, \mu = 1$ (by dividing the 320 total number of observations for each layer into two fractions by time, and γιταινγ each particular $\sum \Delta$ and $\sum (\Delta^2)$ the value of $\sum \Delta$ and $\sum (\Delta^2)$ with the **P** calculated from the above formula in the following table.

$$m = 160, \mu = 1.$$

| | AΔ | $\sum (\Delta^2)$ | P |
|------------------------|-------|-------------------|----------|
| I U. 1st fract. | 43.97 | 18.75 | 3,103 |
| 2. - | 42.16 | 16,52 | 2,974 |
| II U . 1. - | 42.91 | 17.56 | 3,052 |
| 2. - | 46.23 | 21.87 | 3,275 |
| I O . 1. - | 49.24 | 25.48 | 3,363 |
| 2. - | 40.86 | 17.62 | 3,377 |
| II O . 1. - | 48.28 | 21.14 | 2,902 |

| | | | |
|-------|--------|--------|--------|
| 2. - | 36,99 | 15.11 | 3,534 |
| total | 350.64 | 154.05 | 25.580 |

The mean of the 8 \mathbf{P} value is 3.198. The calculated mean values for all 5 fingers were:

$D \ Z \ M \ G \ K$

3,198; 3.183; 3.072; 3.144; 3,145

The total average of these 5 average values, that is why the whole 40 values \mathbf{P} determined, each of 160 observations have contributed is

3,148

which completely agrees with the normal value $\pi = 3.142$ except for the last decimal, which is unsure due to rounding off.

This makes it easy to keep the constant ratio



to deduce, of which Th. I, p. 123 the speech was.

Furthermore, I occasionally note that one approximatively obtains the fundamental number of natural logarithms e by $\delta\varpi\delta\varpi\gamma$ the sum total of the errors $\sum\Delta$ by the sum



of the errors that \square exceed the square $\mu\varepsilon\alpha\nu$ error in magnitude, and by raising the quotient to the squares. The, according to which, as above, the total means of \mathbf{P} calculated from 40 partial values ($am = 160$), the total mean was found to be 2.707 instead of the normal value $e = 2.718$.

Although I do not think that these strange circumstances have already been explicitly stated, they can easily be deduced from mathematical error theory by means of the well-known expression for the probability of error, into which π and e enter for whom, in this theory, those who are versed in this theory will require no special execution, by the way otherwise by myself with further test documents to be set forth. The stated ratios π , strictly apply to an infinite number of errors obtained under similar circumstances, and if repeatedly determined, will vary from a finite number, as can be seen from the above example with 8 determinations of \mathbf{P} , to the normal ratio, a fluctuation which takes place within such wider limits, the smaller m is. Only in the case of a very small value m , on the average of many determinations, is there a noticeable deviation from the normal value, which grows with the smallness of m , and is vanishingly small at a somewhat large m . This deviation is due to the correction of the least square error and the square of the error sum due to the finite m determine by a general expression; according to which a \mathbf{P} derived from a finite number m is normally



instead of $= \pi$

is what z. For example, for $m = 10$, $\mathbf{P} = 3.0166$.⁶⁾

⁶⁾ Corrections to p. 218. See also Poggendorffs. Ann. Cheers band. P. 66 ff.

In the course of the long multi-monthly series of observations, both the variable and the constant error gradually decreased. If you divide the whole series into two main fractions according to time (each at 32 observation days), you get in summa for all 4 layers:

$$\sum \Delta (m = 160, \mu = 4).$$

| | D | Z | M | G | K | total |
|--------------|----------|----------|----------|----------|----------|--------|
| 1st fract. | 154.94 | 134.56 | 150.12 | 159.26 | 161.28 | 760.16 |
| 2. - | 148.24 | 117.54 | 122.15 | 127.34 | 131.98 | 647.25 |
| relationship | 1,015 | 1,119 | 1,229 | 1,253 | 1,194 | 1,175 |

On the whole so had the pure error sum of the 1 . for the 2nd fraction reduced from 760.16 to 647.25; which numbers have the ratio 1,175.

Furthermore, the average error constant components for all 5 fingers were as follows:

| | 1st fract. | 2nd fract. |
|----------|------------|------------|
| <i>p</i> | + 0.1006 | + 0.0465 |
| <i>q</i> | + 0.1260 | + 0.0785 |
| <i>s</i> | + .2281 | + 0.1942 |

The time error *p* and the space error *q* were therefore very considerable from the first to the second fraction, but the error *s* was noticeably reduced. Such a change, however, had taken place not only from the first to the second main fraction, but within each main fraction, and when the observations of the latter were added to $m = 160$ it increased the variable error.

At about 1 hour supervision of each day alternating with days fingers in the order **D became . Z . M . G . K .** and in the reverse order, of which the former is designated by \rightarrow , the latter by \leftarrow . In \rightarrow , attention was the freshest at the thumb, the most tired at the little finger; at \leftarrow it was the other way around. It seemed to me of interest to examine the influence which results from this, which, as we see from the following, is not great, but is visible. Summing up, I got for all 4 layers:

$$\sum \Delta (m = 10, \mu = 64)$$

| | D | Z | M | G | K |
|---|----------|----------|----------|----------|----------|
| → | 148.56 | 128.20 | 136.22 | 152.24 | 151.32 |
| ← | 154.62 | 123.90 | 136.05 | 134.36 | 141.94 |

With the growing exercise, gradually, to a certain limit, the observation time required for the 100 trials of each day was shortened; by gradually coming to make the decision faster in each experiment than at first. The fact that this greater rapidity carried no greater inaccuracy into the estimation is proved by the fact that, conversely, in the progress of the series of observations, the error totals were reduced. But even if I compare the error totals of the days with the largest and smallest test duration from the same experimental period, I find no relevant difference between the two. Some days you can not finish with repeated applications of the circle before you decide On the other hand, on average, one is much faster in the judgment; but the slowest decisions are not always the best. Here are some more data about these conditions.

I did not enter the duration of the experiment from the beginning of the series of observations, which lasted from Nov. 21, 1857 to April 6, 1858, and later also not on all days, but on thirty-two different days from the third of January onwards; and found on average 63.6 min. But if I divide the series of observations from the 3rd of January to the end into 4 equal divisions of 24 days, the following average observation times were found in them:

1st compartment. 71.8 min. (Mean of 4 determinations)

2. - 67.3 - - - 8 -)

3. - 60.4 - - - 10 -)

4. - 60.5 - - - 10 -)

according to which the progress of the shortening from the beginning was considerable, later came to a standstill.

The observation time varied from 53 to 76 minutes. Now, excluding the earlier period, when all observation times are relatively large,⁷⁾ from the last time, from the 17th of February to the 6th of April, when larger and smaller times change irregularly, the error totals for the days with the 5 smallest test durations (53, 84, 55, 56, 58 min.) And with the 5 largest test durations (64, 64, 65, 66, 68 min.) Together; and obtained from the former in summa for all fingers and all positions (with $m = 10, \mu = 50$) $\sum \Delta = 1009.4$, from the latter 995.6, which deviates only insignificantly.

⁷⁾ To compare these observations with the later ones would not have been permissible because the later ones give smaller numbers because of advanced practice.

VI. Fechner (Oct. 1858 to Jan. 1859).

Left index finger. Forelim, volar side, 1 longitudinal distance = 10 d . In total 1200 experiments in 40 test days, à 30 observations.

These experiments are divided into three main sections, each containing 400 observations, according to the mode of application of the circles.

α) Application of the compass on my finger by an assistant. Observer and assistant sit opposite each other, the assistant supports the arm, which applies the compass, for a firmer hold, to the table.

β) Self-application of the circle with the right hand on the left index finger.

γ) The circles in a vertical position next to each other clamped in a screw clamp, and the finger moves from one to the other. Both circular distances are close to each other, parallel to each other, perpendicular to the front surface of the body AB as follows:

$$b. .d$$

$$a. , c$$

$$A\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}\ddot{o}B$$

where a , b are the tips of the one, c , d those of the other circle, and indeed the normal distance was (once a day) taken to the right (R), the other to the left (L), to which the spatial position refers, however in α) and β) the spatial position (O and U) goes to upper and lower version of the compass. Every day 3 experimental sets of 10 observations consecutively for α , β , γ employed, α for external reasons always first, while β , γ $\chi\eta\alpha\nu\gamma\varepsilon\delta$ with the second and third place.

The layers are labeled with bracketed numbers as follows:

| | | | | | |
|-------------------------|-----|------|-----|------|--|
| | (1) | (2) | (3) | (4) | |
| at α and β | I U | II U | I O | II O | |
| at γ | I L | II L | I R | II R | |

$$m = 10, \mu = 10.$$

| | | (1) | (2) | (3) | (4) | Summa |
|-------|----------|---------|---------|---------|---------|--------|
| AΔ | α | 19.18 | 16.64 | 15.68 | 19.12 | 70.62 |
| | β | 12.66 | 14.00 | 13.08 | 12.74 | 52.48 |
| | Γ | 10.70 | 12.54 | 11.50 | 12.65 | 47.39 |
| Summa | | 42.54 | 43.18 | 40.26 | 44.51 | 170.49 |
| c | α | - 0,107 | +0.096 | - 0.086 | +0.154 | |
| | β | - 0.178 | - 0.366 | - 0.266 | - 0.422 | |
| | Γ | - 0.330 | - .306 | - 0,102 | - 0.216 | |

| | p | q | s | s_1 | s_2 | W |
|----------|---------|---------|---------|---------|---------|---------|
| α | - 0,111 | - 0.020 | +0.014 | +0.023 | +0.005 | 0.00771 |
| β | +0.086 | +0.036 | - .308 | - 0.300 | - 0.316 | 0.00574 |
| Γ | +0.023 | - 0.077 | - 0,239 | - 0,273 | - 0,204 | 0.00519 |

$$\begin{array}{ccc}
 \varepsilon & & \varepsilon_1 \\
 \alpha & 0.1766 & 0.1794 \\
 \beta & 0.1312 & 0.1311 \\
 \gamma & 0.1185 & 0.1178
 \end{array}$$

The value of ε_1 is here from the value ε by correcting not only because of the finite m , but also because of the size of the intervals by

multiplying ε with $\boxed{\quad}$ derived, while in the earlier series I to VI, the correction is not appropriate because of the intervals.

It can be seen that the μετηδοφ application of the circles α , di by an assistant, has by far supplied the largest error σνμ $\Sigma\Delta$ and accordingly the largest values ε_1 ; which depends on the fact that a foreign hand is not able to apply the circles as uniformly as one can, and how much to compare the values depends on the comparability of the manipulation in the experiments. β and γ are not very different, but γ is a little more advantageous than β . The mean error ε_1 at γ is only 0.1178 d, Di \boxed{D} .

While the variable error at α) is greatest, the constant errors c are the smallest at α) and q , s are so small that s could be shifted to coincidence, since W reaches more than half of s . The double values s_1 , s_2 are in β) very good, in α) and γ) bad. This is at α not strange) because s here almost disappears. If one takes instead the double values of the largest component, which here p is, we find $p = -0.0995$ and $p_2 = -0.1150$, which is quite tolerable.

If you divide the whole series into two fractions according to time, you will find in summa for the 4 positions:

$$\Sigma\Delta (m = 10, \mu = 20).$$

| | α | β | Γ |
|------------|----------|---------|----------|
| 1st fract. | 33.10 | 25.56 | 23.18 |
| 2. - | 37.50 | 26.92 | 24.21 |

It may be noted that the values of both $\Sigma\Delta$ and c for the index finger in row **II** and row **V**, albeit in the same way, only at a different time and in different contexts than the values in this row according to β), are very different which is an example that one can not compare attempts made under the same circumstances at different times, where exercise and other circumstances may have altered the sensitivity, and another play of contingencies may take place.

In itself, it may be of some interest if I here add the complete list of the c - values obtained in the individual experimental fractions of $m = 10$ in series α , insofar as one sees from it, as even under circumstances which reduce the constant error as much as possible, but the character of constancy is still asserted in the sign. As a basis for the following calculations, I also add the directory for the other two rows.

Values of c in row α for the individual fractions

à $m = 10$.

c_1

c_2

c_3

c

4

-

0,22

- 0,0

4 -

0,02

+0,1

0 -

0,16

+0,0

8 -

0,10

+0,0

7

-

0,14

+0,1

2 - 0

, 03

+0,2

5

-
0.06
+0.2
1 -
0.16
+
0.10
-
0.11
+0.1
6 -
0.20
+0.1
1
-
0.07
+0.0
7
+0.0
4
+0.1
1
-
0.20
+0.1
1 -
0.13
+
0.16
-
0.07
+0.0
9 -
0.18
+
0.25
-
0.04
+0.0
8-
0.06
+0 ,
18
0.00

$$\begin{array}{r}
 + \\
 \underline{0.08} \\
 - \\
 \underline{0.02} \\
 + \\
 \underline{0.21}
 \end{array}$$

$$\text{Mean} - 0.107 + 0.096 - \\
 0.086 + 0.154$$

Corresponding values of c in series β .

| c_1 | c_2 | c_3 | c_4 |
|----------------------------------|--------|----------|------------------------|
| - 0.40 | - 0.43 | - 0.25 | - 0.49 |
| - 0.17 | - 0.39 | - 0.26 | - 0.33 |
| - 0.27 | - 0.55 | - 0 , 40 | - 0.54 |
| - 0.21 | - 0.48 | - 0.30 | - 0.41 |
| - 0.12 | - 0.13 | - 0.30 | - 0.56 |
| - 0.09 | - 0.37 | - 0.27 | - 0.57 |
| - 0.08 | - 0.36 | - 0.37 | - 0.46 |
| - 0 , 26 | - 0.21 | - 0.33 | - 0.46 |
| +0.04 | - 0.25 | - 0.13 | - 0.14 <u>- 0.22 -</u> |
| <u>average</u> - 0.178 - 0.366 - | | | |
| <u>0.49 - 0.05 - 0.26</u> | | | |
| 0.266 - 0.422 | | | |

Corresponding values of c in series γ .

| c_1 | c_2 | c_3 | c_4 |
|-----------------------------|--------|----------|------------------------|
| - 0.55 | - 0.24 | - 0.11 | - 0.19 |
| - 0.50 | - 0.27 | - 0.26 | - 0.30 |
| - 0.56 | - 0.38 | - 0 , 24 | + 0.01 |
| - 0.37 | - 0.22 | - 0.25 | - 0.36 |
| - 0.35 | - 0.34 | - 0.07 | - 0.22 |
| - 0.15 | - 0.47 | - 0.08 | - 0.14 |
| - 0.17 | - 0.18 | - 0.03 | - , 009 |
| - 0 , 39 | - 0.42 | - 0.12 | - 0.28 |
| - 0.04 | - 0.32 | +0.09 | - 0.26 <u>- 0.22 -</u> |
| <u>average</u> -0.330-0.306 | | | |
| <u>0.22 +0.05 - 0.33</u> | | | |
| -0.102 -0.216 | | | |

- From the row α may also be given the list of error sums in the individual fractions
à $m = 10$.

Fraction ωαλυεσ ΣΔ ($m = 10, \mu = 1$) in row α .

I U

I

I U

I

O

II

O

1.64

0.56

0.88

1.60

2.12

2.12

1.00

1.10

1.48

1.88

2.22

2.60

1.60

1.90

1.96

1.60

2.12

1.20

1.00

2.52

1.70

1.50

1.80

2.32

2.00

2.34

1.70

1.72

1.84

1.50

1, 40

1.90

2.08

2.44

1.88

1.84

2.60
1.20
1.84
1.92

Total amount 19.18 16.64
 15.68 19.12

Let us now calculate the probable error w of the constant error from both $\sum \Delta$ and $\sum (\vartheta^2)$ by means of the given formulas, by setting $\mu = 10$, and for $\sum \Delta$ to $\beta \varepsilon$ based on the values given in the table, $\sum (\vartheta^2)$ but from the values of the previous tables determine ⁸⁾. so we find ⁹⁾:

Values w .

| | α | | β | | Γ | |
|-------|-----------|----------------------|-----------|----------------------|-----------|----------------------|
| | to | To | to | to | to | to |
| | $A\Delta$ | $\sum (\vartheta^2)$ | $A\Delta$ | $\sum (\vartheta^2)$ | $A\Delta$ | $\sum (\vartheta^2)$ |
| w_1 | 0.0164 | 0.0160 | 0.0111 | 0.0270 | 0.0093 | 0.0383 |
| w_2 | 0.0145 | 0.0138 | 0.0122 | 0.0285 | 0.0110 | 0.0205 |
| w_3 | 0.0137 | 0.0171 | 0.0114 | 0.0226 | 0.0100 | 0.0259 |
| w_4 | 0.0167 | 0.0144 | 0.0111 | 0.0299 | 0.0111 | 0.0201 |

Here we see that at α , both modes are close, but at β and γ , the mode of $\sum (\vartheta^2)$ gives more than twice as large a value as after $\sum \Delta$, which proves a considerable fluctuation of the constant error. The values W in table (σε ε αβωτε) are calculated according to $\sum \Delta$.

⁸⁾ For example, for row α , the 4 values $\sum (\vartheta^2) = 0.050619; 0.037840; 0.048040; 0.041440$.

⁹⁾ The calculation according to $\sum \Delta$ comes back shortly after αδδινγ the logarithm 0,94128 - 4 to the logarithm of $\sum \Delta$, the calculation after $\sum (\vartheta^2)$ on it, the logarithm 0,85186 - 2 to the half logarithm of $\sum (\vartheta^2)$, and in both cases to add the number.

Occasionally one can convince oneself that the calculation according to $\sum \vartheta$ means of the formula (σε ε αβωτε) does not ψιελδ a significantly different

result from the calculation according to $\sum (\vartheta^2)$. To take the series β with the strongest values c as an example, one has

| | w_1 | w_2 | w_3 | w_4 |
|-------------------------|--------|--------|--------|--------|
| to $\sum (\vartheta^2)$ | 0.0270 | 0.0285 | 0.0226 | 0.0299 |
| after $\sum \vartheta$ | 0.0260 | 0.0284 | 0.0207 | 0.0303 |

A similar agreement can always be found, according to which, since deviations of this order are not significant for the purpose of these provisions, it would not be necessary to go back to the more complicated determination of $\sum (\vartheta^2)$, but be content to go back to $\sum \vartheta$ ¹⁰⁾, if in principle the determination after $\sum (\vartheta^2)$ is a little safer.

¹⁰⁾ For this we have to add the logarithm 0.44128 - 2 to the logarithm of $\sum \vartheta$ and to take the number.

The table of fraction ω_{Δ} of $\sum \Delta$ on (σ_{Δ} αβωτε) gives an opportunity to prove the rule for calculating the probable error of $\sum \Delta$ (σ_{Δ} αβωτε). Of the 40 fractional values in this table, 20 show a lesser deviation from their (4-position) four means than the probable error when calculated according to the rule given. For I U, 1,918 is the mean sum that is multiplied by 0.161, 0.309 as the probable error. If one takes the deviations of the 10 individual sums of 1.918, one finds 7 smaller, 3 larger than 0.309; at II U correspondingly, 6 deviations are on average smaller, 4 larger than the probable error, which is 0.267 here; in I O 3 are smaller, 7 larger, in II O 4 smaller, 6 larger than the probable error; in total so 20 smaller, 20 larger. For the individual departments, one can not expect equality between the number of smaller and larger values because of too few cases.

1. Addition.

Derivation of the correction because of the finite m ¹¹⁾

The problem is as follows: a series of errors Δ , whose total number m , is calculated from the arithmetic mean A of the observation quantities (in the palpation and eye measurements from the mean error distance), ie determined as differences of the individual observed quantities of A , and has given the error σ_{Δ} $\sum \Delta$, in which all errors, positive and negative, are calculated according to absolute values (like positive ones). But the mean size A derived from m observations is not the true mean size V which would yield observations from an infinite number of observations, and hence the errors calculated by the average size, are not the true errors. The sum of the true error $S \Delta$ to by a correction of the sum of false $A \Delta$ are

derived. The correction factor, which results for $\sum \Delta$, is then applicable to the wrong mid- $\rho \alpha v \gamma \varepsilon \epsilon \rho \rho \rho \rho$.

¹¹⁾ In the matter of p. 216 f. See Ber. d. Saxon Soc. 1861, p. 57 ff.

Suppose first, the size $V - A$, about which the true mean size V of the found A different, is known. Her name was α , and they were looking hereafter the relationship between $S \Delta$ and $A\Delta$.

α can be positive or negative. Now these false faults are to be called those which have the same sign with α , and otherworldly ones which have unequal sign with them. Then, you have to $A\Delta$ in $S \Delta$ to turn¹²⁾:

1) All false errors of this world, which are absolutely greater than α , whose number s and whose sum is \mathbf{S} , in order to reduce the absolute value of α ; gives $\mathbf{S} - s \alpha$.

2) all otherworldly false errors whose number is n and whose sum is \mathbf{N} to increase the absolute value α ; gives $\mathbf{N} + n \alpha$.

3) For all false errors of this kind, lying between 0 and α , whose number z and whose sum is \mathbf{Z} , substitute the difference of these from α for absolute value; are such $\alpha - \mathbf{Z}$.

So you have:

$$S \Delta = \mathbf{S} + \mathbf{N} - \mathbf{Z} + (-s + n + z) \alpha.$$

But if $\mathbf{S} + \mathbf{N} + \mathbf{Z} = \sum \Delta$ and $s + n + z = m$, this expression goes over into

$$S \Delta = \sum \Delta + (m - 2s) \alpha - 2 \mathbf{Z}$$

where α is to be taken to absolute values.

¹²⁾ If necessary, the following rules 1) 2) 3) and the inferred equation between $\sum \Delta$ and $S \Delta$, on which everything depends, can be explained and proved by an arbitrarily fabricated example, by arbitrarily appraising a series of errors, only with Consideration to take the sum of the positive equal to the sum of the negative, and just so the value α arbitrarily takes, since these rules apply to any kind of error distribution.

The required correction will be found if we are able to substitute certain values for α , s , and \mathbf{Z} . But this can be done insofar as we presuppose the normal distribution of error, which in fact gives certain values for it¹³⁾.

¹³⁾ Of course, the arbitrary example can no longer serve that purpose.

Now what α concerned, we can according to the same approach, which is also used to correct the error sum of squares $A\delta$ 2 because of the finite m led¹⁴⁾ set,



For the mean size of the observation is determined on the average by 1 observation
by false, consequently by m observations according to known probability rule
by false.

¹⁴⁾ Comp. Encke in the astronomer. Year for 1834. p . 282 f.

As far as s and **Z** **are** concerned, s can be considered the number of errors lying on one side above α , ie positive or negative



given if the probability determined by the known integral table means that the errors lie on both sides (as positive and negative) above the absolute value α . From other side is



when the fraction of the total sum to be calculated as below is the error $S \Delta$ which is between 0 and the absolute value α on both sides.

Substituting these expressions for α , s , and **Z**, we get that



consequently, under substitution of



Now it still applies, and to determine in numbers. This can be done exactly for each value of m , the first according to the integral table 15) for the probability or relative number of errors between the size limits 0 and α ; The latter, after the expression for the relative error sum between the size limits of the errors 0 and α , which gives:



if e is the basic number of the natural logarithms, π the Ludolf number ¹⁶⁾.

15) astronomer. Year f. 1834, p. 305 ff.

16) First, one has for any value of α

$$\boxed{\quad}$$

where h is the measure of precision. But according to a known

equation, $\boxed{\quad}$ if ε is the simple mean error. If one substitutes this

value for h , and sets $\boxed{\quad}$, one finds by integration the above equation.

After that, a table can be calculated in which the correction factor is given sharply for each value of m . The fragment of such a table follows below, according to which, at $m = 10$ instead of $\boxed{\quad} = 1.033333$, strictly speaking, it would be 1.0326699, which difference, as we can see, is negligible. But in order to obtain a general correction

factor applicable to every m , one has to develop the values $\boxed{\quad}$ and, $\boxed{\quad}$ according to their general expression, into infinite series, and to keep only the first member,

which, as shown below, is completely sufficient. Now, if set short $\boxed{\quad}$, and $\boxed{\quad}$, generally, for every value α

$$\boxed{\quad}$$

$$\boxed{\quad}$$

$$\boxed{\quad}, \quad \boxed{\quad}$$

But since here $\alpha = \boxed{\quad}$, then $u = \boxed{\quad}$.

If one considers only the first term of both expressions, one obtains hereafter

$$\boxed{\quad}$$

what can be set with sufficient approximation

$$\boxed{\quad} \text{ or } \boxed{\quad}$$

of which the latter, as seen from the following table, adds something more than the first to the very sharp correction.

Finally, here follows a small table which gives the correction $\phi\alpha\chi\tau\sigma\pi$ of $\Sigma\Delta$ for some values of m both after the very sharp calculation with decrease on the attached values

of \square and \square , as from the various approximations, from which it can be seen that even if one up to smallest values m descends, the correction \square differs quite considerably from the very sharp, to, or even to \square go back, would be entirely superfluous CIRCUMSTANCES. At the same time, the correction \square factor for the quadratic mean error is added according to the already known correction method, from which one can see that this factor is larger everywhere than \square for $\Sigma\Delta$ and therefore for \square is.

| Correction $\phi\alpha\chi\tau\sigma\rho$ for $\Sigma\Delta$ and ε . | | | | | | | | for ε_q |
|--|-----------|-----------|-----------|-----------|----------------|-----------|-----------|---------------------|
| M | \square | \square | \square | \square | sharp Corr. | \square | \square | \square |
| 2 | 1.20000 | 1.16667 | 1.189318 | 1.183515 | 0.4273712 | 0.1471351 | 1.4142 | |
| 3 | 1.12500 | 1.11111 | 1.118697 | 1.116404 | 0.3549580 | 0.1006682 | 1.2248 | |
| . | | | | | | | | |
| . | | | | | | | | |
| 10 | 1.03448 | 1.03333 | 1.032889 | 1.032699 | 0.1992010 | 0.0313296 | 1.0541 | |
| 20 | 1.01695 | 1.01667 | 1.016173 | 1.016139 | 0.416010 | 0.0157896 | 1.0260 | |
| 30 | 1.01123 | 1.01111 | 1.010724 | 1.010702 | 0.1158224 | 0.0105573 | 1.0171 | |
| . | | | | | | | | |
| 50 | 1.00671 | 1.00667 | 1.006407 | 1.006400 | 0.0898408 | 0.0063460 | 1.0101 | |
| . | | | | | | | | |
| . | | | | | | | | |
| 100 | 1.00334 | 1.00333 | 1.003193 | 1.003192 | 0.0635945 | 0.0031780 | 1.0050 | |

The values of \square and \square , which have served to compute the sharp correction, are the former by interpolation of the table, which Encke in the astronomer. Jahrb. 1834

gives, with Zuzug the second differences, \square but directly after the (so) given formula one computes.

Derivation of the correction due to the size of the intervals.

In a mathematical sense, any observation error of a definite size has only an infinitesimal probability, and would only be able to recur indefinitely. But in the actual observations one can not distinguish errors down to the smallest detail, but only go down to a certain limit with it, and thus one remains, according to circumstances, at ten parts, hundred parts, thousand parts of lines, degrees, and the like. Like. Stand in the record. What falls in between is moved to the nearest limits of the differentiated intervals. Insofar as one now by this. On average, if the error is too large, it is too often undersized, but it seems that this would have to be compensated for by a large number of attempts. This is also close but not exactly the case; rather, the circumstance that the number of errors of a given magnitude diminishes relatively faster than their magnitude, with the result that the error sum is greater than if each error were recorded according to its correct value, and the greater the intervals, the greater one still distinguishes at the record, in proportion to the average error. Because set, one goes at the recording by the intervals 0.00; 0.10; 0.20; 0.30 etc., then every error z. B. over 0.15 and less than 2.5 to 0.20 beaten; hence the first mistakes too big, the last ones too small; but the number of errors in the interval from 0.15 to 0.20 is so much greater than that of the errors in the interval from 0.20 to 0.25, that the increase in the sum of errors which arises from the first circumstance,

¹⁷⁾ See reports d. Saxon Soc. 1861, p. 93ff. In the matter of p. 217.

As far as I know, it has not yet been investigated how much of the error that depends on it and which laws it obeys.

I now find the above correction in the following way.

If we first assert that every error is noted with its true value as often as it occurs, we obtain the true error sum $S \Delta$ by summing these errors, whose number is m . and by deduction from this the true mean error, which is called ε_1 . On the other hand, if i is the interval of the division where no errors are assumed, and for example $i = 0.25 \varepsilon_1$ or $\frac{1}{4} \varepsilon_1$, then all the errors are shifted to the limits of the intervals of this size and an incorrect sum $\sum \Delta i \sigma$ obtained, their ratio to the true $S \Delta$ it has to be determined.

According to the known table of the probability integral (by consultation of interpolation) is in the interval of error quantities bis 0 of $\frac{1}{4} \varepsilon_1$ normally contain 0.1581058 of the total number of errors ¹⁸⁾. By this error semi- $\frac{1}{4} \varepsilon_1$ be beaten half to 0, as false sum for this interval get the one with 0.1581058 m multiplied, means 0 to $0.25 \sigma_1$. For the interval from $0.25 \varepsilon_1$ to $0.50 \varepsilon_1$, the normal number of errors according to the table of the integral is 0.1519585 m , So hereby multiplied means are between $0.25 \varepsilon_1$ and $0.50 \varepsilon_1$ di $\frac{3}{8}$ 0.1519585 $m \varepsilon_1$ the incorrect sum for that interval, and so on through the whole range of defect sizes. The totality of these sums is $1.003321 m \varepsilon_1$, instead of the true sum of $m \varepsilon_1 = S \Delta$.

¹⁸⁾ This is to be considered with regard to the fact that the

precision h coming into the integral is equal if π is the Ludolfian number.

However, the summation is only continued up to $\Delta = 7.00 \varepsilon 1$; but the neglected higher errors, because of their vanishingly rare occurrence, have only an influence on higher decimals than are considered here.

For an interval $i = \varepsilon_1$, the procedure was followed accordingly, and thus the value

$$\sum \Delta = 1.053643 S \Delta$$

receive.

These determinations are found by interpolation of a probability integral of the errors up to $h \Delta$ ¹⁹⁾ = 3, taking into account the second differences and own calculation for higher values after transformation of the integral into an infinite series²⁰⁾ with careful revision of the obtained values.

19) $h = .$

20) I obtained the following values for the probability of the errors from 0

to Δ with the following values of $h \Delta$, if h is the measure of precision which I use to facilitate the above derivation:

| $h \Delta$ | <input type="text"/> |
|------------|----------------------|
| 3.0 | 0.9999779093 |
| 3.1 | 88,351th |
| 3.2 | 939740 |
| 3.3 | 969422 |
| 3.4 | 984780 |
| 3.5 | 992569 |
| 3.6 | 996441 |
| 3.7 | 998329 |
| 3.8 | 999230 |
| 3.9 | 999652 |
| 4.0 | 999846 |
| 4.1 | 999933 |
| 4.2 | 999971 |

Without interpolation I obtained directly for the following interval \square ratios the following ratio of the wrong to the true sum, where $\square = 1,7724539$

| | |
|----------------|-------------|
| \square | \square |
| 0.10 \square | 1 , 0016673 |
| 0.20 \square | 1.0066757 |
| 0.40 \square | 1.026713 |
| 0.80 \square | 1.109193 |

It can be seen from these as well as from the preceding determinations, that the value, by which \square the value exceeds 1, and which is called u , stands noticeably in the ratio of the square of \square . But the value grows slightly stronger, because while it is equal to 0.0016673 at $\square = 0.10 \square$, it is equal to 0.109193 at $\square = 0.80 \square$, instead of being 0.1067072 after the quadratic ratio. The same can be seen in the intermediate values. However, the deviation from quadrature progress is so small that it can be properly neglected.

Now let u be the value u for $\square = 1$, then according to the quadratic relations

$$\square$$

And, if σ the wrong, ε_1 is the true agent errors, even

$$\square$$

This leads to the quadratic equation

$$\varepsilon_1^2 - \varepsilon \varepsilon_1 + \gamma i^2 = 0$$

whence

$$\square$$

Since $4 \gamma i^2$ is always small compared to ε^2 , because γ is a small fraction, we can put resolution according to the binomial theorem and keep the first two terms



what gives



But $\psi m \varepsilon_1 = S \Delta$, $m \varepsilon = \sum \Delta$, $\tau \eta \varepsilon v$ it follows from this also by multiplication on both sides with m



Since one is less likely to deal with series of observations where > 1 is less, but



for < 1 but u is a little less than the value of $\gamma = 0.053643$ according to the quadratic progress, then for 0.053643 I have only 0.053 assumed as γ in the correction formula (see above).

Internal psychophysics.

XXXVI. Transition from external to internal psychophysics.

Our previous investigations, results, formulas were essentially in the field of external psychophysics, and only casually and occasionally did we resort to that of psychophysics in advance and beyond. But, as I have argued earlier, external psychophysics is only the basis and preparation for the deeper leading inner psychophysics.

Let us call ourselves back: not the stimulus arouses immediate sensation, but between it and the sensation an inner bodily activity pushes, we briefly call it the psycho-physical one, which is awakened by the stimulus, and which now immediately brings along or follows sensation according to a different view, which we will discuss in the next chapter; and the legal relation between the outer and inner end-link of this chain, stimulus and sensation, necessarily translates into such between the stimulus and this middle-limb on the one hand, and between this middle-limb and the sensation on the other.

In external psychophysics we have skipped this middle link, saying that, following direct experience, the legal relation is merely between the end-links of this chain, the stimulus, that of the external, and the sensation, that of the inner experience. directly to state. Beginning with the inner psychophysics, we have to be guided from the outer end-member to the middle-limb, and henceforth consider its relation, instead of that of the outer end-member, to the inner end-member. The stimulus is then dropped after it has fulfilled its purpose to guide us to the middle limb. You can not look into a

watch, but keep the gear of the wheel that carries it along, as long as the watch is in the right gear.

Of course, the passage of the pointer can not give us any information about the inner movement alone; it also requires a knowledge of the internal gear; and what anatomy and physiology teaches us of the inner bodily transmission that underlies our mental activity is so far too incomplete as to permit definite conclusions even on the most general of the nature of the psychophysical movement. Are they electrical, chemical, mechanical, or other shaped movements of a ponderable or imponderable medium? Let's just say we do not know; yet the sequence itself will show that we are able to penetrate into internal psychophysics to a certain extent, without knowing it, without letting any knowledge or special presuppositions about nature, that is to say, of nature

In fact, one has to distinguish the two questions and to distinguish them in treatment: what nature is the psychophysical movement, and what are the conditions of this movement in which these and those relations of the mental movement depend? The first question remains to be seen, because it can not yet be decided, in order to give a general opinion in one of the final chapters, whereas for now it will be only questions of the second kind, and thus only of the psychophysical movement which remain valid, no matter what will ultimately prove to be the basic nature of this movement. And certainly in no doctrine it is so important, as in ours, indeed it is to be considered as one of the first formal principles of the same, to presage that which remains valid for all conditions, and to draw, which can remain undecided, as long as doubts remain over the decision. Incidentally, we have long enough in physics to the doctrine of the light and stand still as the doctrine of electricity. Because what is electricity? Let's just say we do not know; and how developed is the doctrine of electricity!

Even external psychophysics has been able to prove to us that it is not the nature of the motions, what the most important questions in this doctrine are, but that they are relations of these movements. Little did we need to care about the nature of the stimulus, whether it was light, or sound, or weights; it was by no means necessary to delve into the nature of these stimuli and the movements they awaken to establish the fundamental laws of external psychophysics and so we will be able to connect internal psychophysics with the external, and ascertain its essential points, without the need to know the nature of the psychophysical movement.

The first, the main question to be dealt with here, and to which we turn first after discussing some general preliminary questions in the next chapter, will be which translation, the foundations of external psychophysics, Weber's Law, and the fact The threshold, which finds its expression in the fundamental formula and the dimensional formula, has to be experienced in the transition into internal psychophysics. This translation allows a choice from the outset, with the decision of which the entrance into the inner psychophysics will be decided and the first reason of which will be laid. The 38th chapter is destined to lead to this decision. Now it might seem that, after we have stepped completely inside, we are moreover completely abandoned by

experience. But it is not like that. Rather, we are able to what external psychophysics had suggested, to meet and meet experiences from the inside, in order to partly lead the chain of inference that was attached to the outside, to draw it more firmly. Secondly, we have immediate knowledge of the inner experience of our whole psychic life; secondly, we know the organ of psychophysical activity and its accomplishments, albeit incomplete, but to a certain extent, and every day this knowledge is completed by new facts of anatomy and physiology and pathology; according to which not only the outer end-member, the stimulus, but also the inner end-member, the sensation, and something of the intermediate, the organ of the psychophysical activity, together with the legal nexus between the outer and inner end-member, are objects of experience;

As good as the relations of the external end-member, the stimulus, make certain demands on the relations of the inner intermediary of the psychophysical movement, which enable us from one side to do so, it is with the relations of the inner end-member, the sensation, on the other side here's the case. To be sure, we can in no way infer the nature of the underlying physical movements from the nature of the mental movements, that is to say, which substratum and form these movements have, but conclude that the psychic connection has a psychophysical connection, the psychic upheaval Succession a psychophysical, the psychic similarity and dissimilarity a psychophysical, the psychic strength and weakness correspond to a psychophysical, as far as the psychical has its basis in the physical. For not only would a functional relationship between the two be unattainable without such conditions of reference, but also the experiences which we can make in the field of external psychophysics, if the relations between the effects of the stimulus and the sensation into such between psychophysical movement and sensation are translatable.

Insofar as in the future we will make use of this principle several times, it may be designated by the short name of the principle of operation in the absence of a more apt expression for it, and in view of the fact that it is essentially essential with a functional relationship between body and soul and explained by an example.

Memories evolve from intuitions, assuming a general consciousness in which both are included. Without knowing the psychophysical processes underlying one and the other, we can infer from the functional premise that the psychophysical conditions of the memories evolve from those of the intuitions, on the condition of more general psychophysical conditions, which require the existence of the general consciousness. Memories still carry the form of intuitions; Even the processes subject to the memories will still bear the form of the processes which are subject to intuitions; Memories are generally weaker than intuitions; it will also be the underlying processes. Memories come from within the mind, intuitions come him from the outside; even the underlying processes will develop purely from the existing psychophysical structure or require the addition of new stimuli from the outside; Memories are subject to association; even the underlying processes will be subject to a principle of association.

Now it would be very idle to carry out this kind of translation of the psychic into the psychophysical broad, as long as it does not lead us further than mere translation. But it signifies the way of accommodating what we can infer from external psychophysics and anatomical, physiological, and pathological facts, and only where such accommodation shows itself will we have to go into it and promote it. This is so far relative to what internal psychophysics will have to do, but little; but already many things seem to me, in proportion to what could be afforded without the cooperation of these principles.

In fact, a cautious and prudent combination of these various ways may be apt to make internal psychophysics something more than the object of mere speculation, and to carry on gradually, but surely, on a step further. Not all of the steps that are done in the following are already firm and sure; but I consider the plant of the whole firm and secure.

XXXVII. About the seat of the soul.

The need for general preliminary discussions on the relationship of body and soul, which we have pushed back as far as possible when we enter into external psychophysics, makes itself felt anew when entering into the inner, and I want to try to give it a single, but certainly one rather, it will attempt to trace everything that will happen to it to certain questions of fact, which will only be of a more general nature than these we will treat later. Accordingly, here as before, the soul is spoken of its fundamental nature, regardless of special metaphysical presuppositions, its existence simply by its unified consciousness, and what appears to be a feeling, Feeling, thinking, wanting to summarize it, to keep it given, all the same, with which one wants to keep everything grounded, which may seem philosophically very insufficient, but which will suffice for the following. Does the soul have an independent existence or not? Keep everyone's opinion or seek discussion in philosophical writings. In the following there will be nothing dependent on opinions, even if the actual circumstances which will be discussed here are better suited to one opinion than the other, and are therefore not indifferent to opinion. Does the soul have an independent existence or not? Keep everyone's opinion or seek discussion in philosophical writings. In the following there will be nothing dependent on opinions, even if the actual circumstances which will be discussed here are better suited to one opinion than the other, and are therefore not indifferent to opinion. Does the soul have an independent existence or not? Keep everyone's opinion or seek discussion in philosophical writings. In the following there will be nothing dependent on opinions, even if the actual circumstances which will be discussed here are better suited to one opinion than the other, and are therefore not indifferent to opinion.

a)
Seat
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The expression, the seat of the soul in the body, proves that one has found occasion to associate the soul with a spatial relationship to its body. It is common to think of the soul as a peculiar fine being of a peculiar nature circulating throughout the body, or thinking as a simple being sitting in this or that more or less definite or indeterminate place, at least its relation to the body itself, as that of a bodily one Essence of other physical beings; and some metaphysical ideas about the nature of the soul lead back to this. As a subject and an object of inner experience, the soul, of course, can be palpated, visibly, in no given space, by what it proves its existence, feeling, feeling, thinking, etc.

In the meantime everyone finds himself - and to this fact there must be actual reasons - urged to reckon his soul to his own body rather than to the body of another. Everyone can not help believing that his soul is more in the place of the Earth, where his body finds himself, as found in any other place, and that walks with the body through the world; Thus the soul, if not the body, but by the agency of the body with which it is related, to which it is bound, as it is said, must be capable of a localization in space.

But if this must be acknowledged, then the question must not be rejected whether the same point of view, from which we hold each given soul bound to one given body rather than the other, rather than to the other part To think bound to this body, and thus to restrict the seat of it even more. But first of all, it asks itself only about the very point of view from which a soul can ever be thought of as bound to a body, in that the term boundness at first only points to another picture borrowed from the body-world, as the term seat, for which it has been substituted is.

If, on the philosophical side, we now receive very different and very contentious answers, we fortunately do not have to worry about it according to the course we have taken. From the experience side, the following unequivocal answer is offered:

Our soul, like every soul of which we know, can be alive in this world, with which we have to deal alone, that is, with the possibility and reality of phenomena of consciousness only insofar as a given bodily system keeps it alive, that is, with a peculiar one there is a periodic alternation and a periodic succession of movements not arising in the periodicity of the outside world, and this physical system can only exist and hold alive if a given soul lives on in this world. This is the most general, the basic fact by which we sum up a given body and a given soul. Then comes the second fact, which, however, presupposes the first, that the conscious activities of the soul on

this side are connected with those of the body to which this life on earth is bound in general by a relation of conditionedness in particular. In both respects, each soul has a relation to its own body which it has neither to the body of another, nor to any body or bodily systems of the external world, and this is what makes both experienceively account for each other.

The spatial relation of the soul to the body, which the expressions of sitting in the body seem to imply to the body, translates so far as we are based on the factual and do not want to begin with metaphysical presuppositions, at first only in the relation of a conditionality between the two Existence and the activities of the soul and the body, which we can experientially pursue only in this world, and of which we can ask whether it reaches beyond this world.

Insofar as all parts of the body unite in solidarity with one another in the achievement of preserving the soul in this worldly life, and holding together only in living activity, as long as the associated soul remains in this worldly life, one can call the whole body animated, the same as Explain the seat or bearer of the soul in a broader sense. The general performance of the body for the soul then arranges and subordinates the particular parts, organs, limbs, systems of the body with benefits for special purposes; which later becomes a point of view, nor to speak of a seat of the soul in a narrower sense.

These expressions, soul seat in a broader, narrower sense, do not prejudge anything, as long as they are always understood as they are defined here. Even if the soul were really to be a substantially simple being, one would still be able to name the whole body in the wider sense described here, as one calls a palace or an entire capital the seat of a king, without meaning that He sits in every place in the capital.

In the meantime, it may seem closer that the whole body does not contribute much to the preservation of this worldly psychic life, as we can cut off feet, nose, ears, and many other parts of the body without significant discrimination of the psychic life, by providing the soul with the loss feels as if its external means of relating to the outside world, of acting on it, are lost, but without their vitality suffers and without their interior being disturbed. According to this, all these parts of the seat of the soul in a broader sense seem to exclude the point of view laid down for it, and to seek that part which can not be destroyed on its own or be taken away from or slackened in its activity, without the earthly soul-life falling away or becoming essential be disturbed.

However, such a body part of exclusive importance for the preservation and undisturbed existence of this world's soul life is not found. Rather, what applies to the hands, feet, noses, ears, every part of the body, even the brain, unless the destruction reaches at once, is a fundamental fact, which is more clearly stated in section c) of this chapter should be discussed where it occurs with particular importance. Conversely, this worldly psychic life can be suspended by interventions from every point, every side, every system of the body, if the intervention happens only far enough or in the appropriate form and strength. However, certain parts are far more important than others, in so far as a destruction or disturbance of them carries on to the same extent or degree more easily a stagnation or disturbance of the

activity of the rest of the organic machine than another; but the difference is only relative, not absolute.

Even those parts of the body whose integrity is most important for life are able to survive themselves only in the context of the whole; therefore, instead of being able to communicate the life principle inherent in them to the rest, their lives owe their connection to the rest other; so that the relationship of solidarity is always what matters most.

Summing up these relationships, they subordinate themselves to the following general point of view: the co-operation of all parts of the body with the achievement of preserving the soul in its worldly life and serving the soul is such a solidarity that every smallest one and to a certain extent even larger parts can be represented by others or by the rest of the rest. Therefore, if the destruction does not go beyond certain limits, so that there are still sufficient means of representing the destroyed, then the soul does not feel the disadvantage. But from the other side, even the slightest destruction, whether or not it affects the nervous system, will weaken the power of the solidary representation of the parts in their performance for the preservation and service of the soul in this world, and if the destruction goes too far, impossible, so that even seemingly indifferent interventions are not indifferent insofar as from now on only a lesser new intervention is needed to make the survival of life impossible, or the services for the soul in life to see shortened substantially. Certain parts have greater importance than others both for the survival of life and services in life; nobody has an exclusive one. Certain parts have greater importance than others both for the survival of life and services in life; nobody has an exclusive one. Certain parts have greater importance than others both for the survival of life and services in life; nobody has an exclusive one.

On the condition that the parts of the organism, by virtue of their similarity, similarity, and similar position, are more apt to represent themselves in the performance of the soul, they at the same time support it, so that the two hands, feet, eyes, ears, lungs, kidneys, Brain halves, on each hand the individual fingers, in each lung the individual alveoli. As long as all the parts that can be represented are fully present, the function divides between them or alternates between them; If one disappears, the others must be able to perform the required service on their own, which according to circumstances can still be done sufficiently or not sufficiently. On the other hand, inasmuch as the parts, by virtue of their heterogeneity and unequal position, are less apt to represent themselves, they are complementary to accomplishments, which could not be done by any of them alone. Inasmuch as most of the parts have something similar and unequal, the effect of both principles combines, sometimes with the predominance of one, then the other.

One might think that the same point of view, which allows our whole body to count as the body of our soul in a broader sense, would consequently have to allow the whole world to reckon with it, just as little does our whole body without its connection, change of substance and action with the rest of the world is able to maintain the life of the soul in this world, and to serve purposes of life on earth, as

our brain and nervous system without its connection, change of substance and action with the rest of the body; even the principle of representation and supplementation of the parts at the service of our soul is proved to be valid only on a larger scale in the world than in our own body, in connection with that which is at work in our body,

But with all this there remains a point of view which makes our body, in a privileged relation to the rest of the world, appear to our soul. Of course, the soul can not exist without the other world context on this side; but when the soul dwindles from this world, only that part of the world which we therefore call our body, not the rest of the world, decomposes, and so there is only one aspect for it, but not at the same time the other point of view, which is why we take our body count on our soul.

To the important fact discussed so far, that the existence of our soul-life on this earth is essentially not bound up with the existence of a single particular part of the body but with the solidarity of the body, the second important fact is that it does not concern the preservation of a special substance in the body but that he is bound to the metabolism in the body. The same soul is successively planted on a collection of ever new substances, or new substances are always added to the composition to which the soul is attached, with the excretion of the old, so that the body of the old man is composed of quite different materials. as that of the child. In addition, the psychic life itself increases in liveliness in accordance with the rapidity of the metabolism.

It can then be up to each one to unite the factual relations between the body and soul which have hitherto been dealt with under a formula which briefly summarizes the facts, only that they are always understood and interpreted in the sense of the facts , And so, when it comes to following the relationship of dependence in the direction from the soul to the body, I like to use the formula that the soul is the linking principle of the physical composition, the physical change and the sequence of activities of the body, and I do not want to have said anything else here than what the previous facts state.

Another may find it more convenient, and we may find it elsewhere, when it is a question of pursuing the relationship of dependence between soul and body in the reverse direction, finding ourselves more comfortable, the soul or soul-life rather as a result, than as a linking principle of the soul It must be no less permitted to do so inasmuch as nothing else is said with this expression than what the facts imply. It is true that the difference between the two modes of expression may seem philosophically very important insofar as they are placed at the head of one-sided philosophical systems, or that metaphysical notions about the nature of the soul are linked with them, but in their application they dwindle to the facts.

With the formula (Th. I, chap. 1) that the spiritual is the inner manifestation of what externally appears to be corporeal, these formulas are linked by the factual viewpoint that in the internal manifestation that is uniform or simplified, What separates the external appearance into a multiplicity? how what appears outwardly as a compound process of nerves may inwardly appear as a simple sensation.

For both dualistic and monadological conceptions, both expressions are not at all comfortable, and then they are free to express the same facts in their sense by

attaching appropriate forces and relations to the body to the presupposed particular soul substance or monad. All this is, we can not repeat it enough, indifferent to the course of investigation undertaken here, as long as one does not want to infer from the printout but only from the facts.

There is no doubt that the question arises as to whether the organic system of our body does not carry the same spirit as a linking principle or result, or entelechy, or preferred monad, or peculiar substance, as one might conceive of it from the whole world applies, and, if already now our soul exchanges their body slowly with the outside world and alternates, whether the death is not only a quicker change of seat, in which it exchanges the old narrow body at once with another one. In fact, such analogies can be asserted in natural-philosophical and religious considerations, and in my opinion with real fugue; but this is not our task here; we are staying here with what is the subject of more direct experience.

b) Seat of the soul in the narrower sense.

Of the relation of the conditionality between this living substance of our soul and our body in general and on which we have founded the concept of soul-being and soul-seat in the broader sense, is a relation of special conditionality between the conscious processes of our soul and the corresponding processes of ours Body to distinguish well. We call a soul alive as long as it has the capacity to produce the phenomena of consciousness without being conscious because it alternately sleeps and watches. Now, to those physical conditions and processes, which, as general conditions for the preservation of this life of the soul, are common to waking and sleeping, and are founded on the solid connection of the living activity of the whole body, there are still special conditions to support the wakefulness, which must be regarded as special conditions of consciousness, provided that Consciousness is there and dwindles, but which themselves can arise and exist only on the basis of these general conditions of life, and demand them for their presupposition and support. By the way, that sleep and waking are in fact connected to physical conditions can not be doubted; because pressure on the brain causes sleep, a physical impulse to the sleeping one can wake it up. to entertain the wakefulness, which have to be regarded as special conditions of consciousness, insofar as the consciousness is there and disappears, but which itself can arise and exist only on the basis of these general conditions of life, and demand it for its presupposition and support. By the way, that sleep and waking are in fact connected to physical conditions can not be doubted; because pressure on the brain causes sleep, a physical impulse to the sleeping one can wake it up. to entertain the wakefulness, which have to be regarded as special conditions of consciousness, insofar as the consciousness is there and disappears, but which itself can arise and exist only on the basis of these general conditions of life, and demand it for its presupposition and support. By the way, that sleep and waking are in fact connected to physical conditions can not be doubted; because pressure on the brain causes sleep, a physical impulse to the sleeping one can wake it up. By the way, that sleep and waking are in fact connected to physical conditions can not be doubted; because pressure on the brain causes sleep, a physical impulse to the sleeping one can wake it up. By the way, that sleep and

waking are in fact connected to physical conditions can not be doubted; because pressure on the brain causes sleep, a physical impulse to the sleeping one can wake it up.

Just as the special conditions of consciousness exist only through one part of life, while the general ones extend through the whole lifetime, so that only through a part of the body, but these through the whole body, and indeed we are induced in man and creatures in general, which have a nervous system and brain to seek the particular conditions of consciousness, preferably in front of the rest of the body, in the nervous system, especially the brain, which we may hereby regard as a seat of the soul or of consciousness in the narrower sense, and those in the following sections In this chapter of special question to be discussed remains whether the narrower seat of the soul nor a more specific localization within the nervous system, or brain, is capable of and how it behaves with creatures other than man and creatures close to him.

The necessity of distinguishing a narrower seat of the soul within the other as just stated, and of holding the nervous system, and consequently the brain, or a special part of it in man and in the higher animals, is founded on the following facts. Only those parts of the body which are provided with nerves are sensitive, and only in proportion as stimuli affect our nervous system and the affected nerves are constantly connected with the brains, do they produce a sensation. Arbitrarily movable parts are subject to the influence of the will only so long as they are connected with the brain by nerves. Conversely, however, the brain does not require a continuous connection with particular parts of the body or nerves in order to produce activities accompanied by the phenomena of consciousness. as long as life, and thus the possibility of such phenomena, remains intact. By destroying special nerves or the parts of the brain with which they are connected, one can abolish the power of particular sensations, not by destroying other parts of the body. Less decisive, though on the whole speaking in the same sense, are the observations on the disturbances of the general mental life, depending on the injury or disturbance of the brain and other organs, on the one hand, the incompatibility of different parts of the brain with one another in the achievements for the general spiritual life but it can often not be caused by local injuries or disturbances of the brain, but, on the other hand, by disturbances of other organs as well, by virtue of secondary influence on the brain.

The narrower seat of the soul is not external to the other, but is itself only part of the other. Only through its connection with the rest of the rest can he accomplish his achievements for the conscious, while he himself essentially belongs to the solidary connection of the rest. Changes in the narrower seat of the soul, which are accompanied by consciousness, can draw consequences into the remaining parts of the other, which, however, as they reach beyond the narrower, become unconsciously conscious; conversely, stimuli that pass through the other soul seat can not arouse sensation, consciousness, until they have reached the inner seat of the soul.

Insofar as we call the physical activities with which the mental beings are in a direct functional relationship psychophysical; and insofar as they can only carry consciousness, as far as they exceed a certain degree of strength, a threshold, as will

be discussed in more detail on the basis of facts, as in the chapter on sleep and waking, we can, by the way, be completely ignorant of the nature of the psychophysical. In view of the discussion that follows, it is generally the time of waking as time, and the narrower seat of the soul, to designate the body part in which the psychophysical activities are able to exceed the threshold.

It may still be questionable whether they are absent during sleep and in the remaining parts of the body at all or are only below the threshold, and whether what exceeds the threshold of them can not change the place itself. These more specific questions call for special inquiries, which are not the case now.

c) Question about simple or extended (closer) soul seats.

The above referred to very general conditions which were less likely to cause a dispute about the factual than its expression, interpretation and use in the philosophical interest, a dispute that does not affect us here. Now, however, we come to a question of fact of the most important interest in psychophysics, about which, however, the dispute affects us, so much so that no decision could be made about it.

It is unanimous that the whole body is not in equal relation to the soul, that a closer soul-seat is somehow still to be assumed in it. But by what point of view and how far is it to be restricted? To a point or not? Of course, no movement can take place in one point, and as long as the movements of the soul are functionally related to bodily movements, and the place of these movements is to signify the narrower seat of the soul, a punctuated soul-seat seems excluded from the outset. But if such movements can not proceed in one point, they can nevertheless begin and end in it; and this raises the following important question:

In the wake of psychic activity, all movements, which arise through psychic impulses in the body, start from a certain point of the body, respectively the brain, and all movements to arouse sensations (and what else is physically conditioned by mental processes) must first have come to a certain point of the body, in order to wake up such; or are movements, linked to psychic impulses, sensations, ideas, thoughts, in essential functional relation to them, in a certain extent of the body, in particular brain, directly with them, according to their nature, as far as a specialization reaches at all¹⁾, I will briefly describe the former as the view of a simple, the latter of an extended soul-seat, without wanting to think of anything other than the factual relation just discussed.

¹⁾ Although I set no limit in this regard; but since no investigation is conducted here, everyone's view is left here too.

So also Lotze, the weightiest representative of the view of the simple soul-seat, grasps the notion of simple soul-seat, by saying²⁾: "One will ask for the soul's seat: the meaning of this question is simple: let us leave it open whether it is possible to ascribe to the indivisible nature of a truly being something spatial expansion in the sense in which we attach it to the material substances we may believe that all

opinions will unite in the same way that a place in space may be given to the inexhaustible being, and it will be there until all the impressions of the stranger to him have to reproduce in order to reach their effectiveness. and from whence all the suggestions come, through which it immediately sets its surroundings, indirectly through them the further world in motion. this point of space is the place where we must descend into the non-spatial world of true being. In order to find the active and creative being, and in this sense, every view may seek a seat of the soul, even if, apart from the place, it can not at the same time concede to it the extension of a spatial form. "

2) microcosm I, 316; and similar medic-psychol. 117th

According to the view of simple soul fits, there is a mere follow-on dependence, after which extended or simultaneous interdependence takes place between bodily and mental movements. According to the first view, they are merely impulses at a certain point or from a certain point, whereby the changes of the soul from the body and vice versa are functionally related; after the latter, there are changes in a variable system of movements, which are linked with the changes of the soul as essentially simultaneous, functionally.

As one pays homage to one or the other view, the whole conception, and even to a certain extent, the very possibility, of an inner psychophysics must be different, and the discussion of the question can therefore in no way be circumvented here.

The decision, however, must turn out for us from a double point of view in favor of the view of the extended soul seats, of formal, because only on its ground a development of inner psychophysics is possible at all; but it is necessary for psychophysics to prefer the aspect which gives it more, and certainly psychophysics will be preferred one day, which will do more; - out of factual, because the nexus of facts forcing it. The formal advantage of a greater efficiency of the view of the extended seat of the soul, of course, is related to the merit of its factual thoroughness.

However, this preference does not lie from the outset during the day, and is not to be assumed as granted. On the contrary, the view of a simple seat of the soul is old, is widespread, may appear after its relation to the view of the simple central nature of the soul as the most natural, is itself an essential moment in some philosophical systems. And if it was not otherwise easily grasped and presented with clarity and clear consciousness of its conditions and consequences, it has recently become so much eloquence, astuteness, knowledge of the striking facts and conciseness of the implications of a philosopher, as representatives of the exact natural sciences ³⁾, to which scientific medicine has a great deal to thank for clarifying some of the main questions, that for that very reason it would be inappropriate to ignore the contradiction of this view, or to deny it lightly. The philosophical side of the matter can not be discussed here; but what must be decisive here from the point of view of experience, will be put into the light of something. Unfortunately, I find myself in

conflict with that highly respected researcher, with whom I would have preferred to go hand in hand with this question.

³⁾ Lotze, medicin. Psychol. 115 and Microcosm I, 316.

The view from the simple soul fits poses certain anatomical, physiological and pathological demands; the view from the broad soul seats represents others; and, if one finds one or the other fulfilled, one, if one wants to be guided by experience differently, one or the other have to join.

The first view requires a certain center of impulses, the second an extensive field of motions; the first simple and direct paths between the external world and the soul-seats, which supply and remove the impulses, since the processing of the sensory impressions takes place in the soul, the second a great complication of ways to the complicated course of soul-movements and the Processing the sensory impressions in it to give an appropriate basis. For the first, with the destruction of a certain small part of the brain, the soul surely falls out of life; for the second, in the destruction of any small part of the brain, the solidarity of the whole affords the means of representation. The first one has to explain how impulses, who arrive at the seats of the soul as aggregates, or assume that they are still different, or can divide themselves according to the will of the soul into differentiated effects; the second has differentiated paths and motions for everything to distinguish.

Who would deny that all these demands are met in the sense of the view of the extended rather than the simple seat of the soul?

The brain is known to be an extensive web of intertwined nerve-tracts with so-called ganglion bodies, well suited to give room to an extensive game of intricate motions, for which the sutures form pathways and ganglionic bodies beginning and endpoints or intermediate stations, without any anatomical Hunch, let alone fact, lets discover a center of this innumerable centra. Instead of all the sensory nerves radiating to one center and radiating all the movement nerves from one, many who arrive compactly at the brains, when passing into the same, break themselves into several nerve roots. In general, it is the large brain hemispheres that reveal the greatest, if you will, central meaning for the soul life, as even the followers of the simple soul seat can not deny; but they are double. Does the soul now sit in the left or right hemisphere? she will sit between the two, in the stone, the beam, the bridge, or any other unpaired parts of the brain. So naturally all the followers of the simple seat of the soul: Descartes, Herbart, Lotze. Well, the task is so relieved; Thus, in the whole brains, only the unpaired part will be found, which can not be destroyed without destroying life on earth. The anatomical knife and the pathological coincidences have been busy to do us this service. And the more the trials and cases have accumulated, the more firmly has the result been found that what is sought can not be found. the bridge, or else an unpaired brain parts. So naturally all the followers of the simple seat of the soul: Descartes, Herbart, Lotze. Well, the task is so relieved; Thus, in the whole brains, only the unpaired part will be found, which can not be destroyed without destroying life on earth. The anatomical knife and the pathological coincidences have been busy to do us this service. And the more the trials and cases

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The insignificance of the Zirbel, where Descartes sought the simple seat of the soul, for the life and integrity of the soul, has long since been proved by pathological and physiological experiments, that the newer representatives of the simple seat of the soul have abstracted from it.

With regard to the bar, let the following passage from Longet⁴⁾ be here.

Le corps calleux peut manquer dans l'espèce humaine, ou presenter of the vices de conformation très-prononcés sans qu'il résulte un préjudice notable pour l'entretien de la vie, pour la receptivité sensations ou l'exercice of the mouvement volontaires. Plusiees fourssissent la preuve incontestable: tels sont ceux que rapportent Reil, Solley, Foerg, Chatto et Paget. "

⁴⁾ Longet, *traité de physiol. II*, p. 234th

Lotze, with Herbart, is more inclined to seek the seat of the soul in the bridge than in the beam (med. Ps 119); and, according to the anatomical dispositions of the bridge, the view of the extended soul-seat must also be one of the most important foci of mental life, but not the sole or last in it, and expect important disturbances from its injuries. Longet says in this regard (Anat. Et physiol., Du syst., Nerv., I, 348): "Since it is well known that the sensory and motor strands of the spinal cord, before they radiate into the cerebral lobes, pass through the bridge, it is easy to foresee that their injuries must disturb the activities of movement and sensation. " But he also says after compiling it on facts and opinions: "For the smell, face,

With facts of a very general significance, Rud. Wagner⁵⁾ against the centralization of the soul seat.

⁵⁾ *Götting. gel. 1860. News No. 6. p. 55 ff.*

"With pigeons (but also rabbits) with naked or undiscovered brains, if one uses a larger number of individuals, it is possible to destroy all individual parts of the brain with a simple or a Staar needle, without any if any deadly hemorrhage takes place, which, of course, often occurs, stops the sensory perceptions and the higher psychic functions (conceptions) of documented reactions

"The possible objection that it is very difficult in animals to distinguish reactions of the sphere of consciousness from reflex movements is, I believe, refuted by observations in man, which are, however, the most important for such questions.

"I have found in a close comparison of the clinical experience and sectional reports, that in all parts of the base of the brain, even of the unpaired, such as the hypophysis and the stone, morbid degeneration, and indeed, it seems, can be devastated without the activity of the soul always being disturbed, indeed often completely preserved.

"These two sets of experiences, though not considered to be unequivocal proofs, must make it extremely unlikely that there is a common place of sensation in the brain, a pointless sensorium commune." Yes, I confess, by limiting my previous views that a certain amount of souls appear to be preserved if, as is the case with pigeons, one has removed large, small and part of the mid-brain and keeps the animals alive.
"

In addition, there are animals in which there is no unpaired part of the nervous system where one could lay the seat of the soul. Every rational version of the simple seat of the soul must, in a symmetrically constructed animal moving in the sense of this symmetry, think that the body is arranged symmetrically to this seat. In humans, this would still be possible; in the echinoderms it is no longer possible, should be otherwise the soul seat in the nervous system.

"The nervous system of the echinodermas encapsulates as the central organ the entrance to the pharyngeal cavity in the form of a mostly pentagonal ring of nerves, from the corners of which the main nerves run down the middle line of the rays or the corresponding parts of the skin up to the opposite end of the body Ganglion nodules have so far can not perceive the gullet rings. " (Stannius' and Siebold's Lehrb., See Anat. I. Ed. I, p.

If anything can prove that anatomically a central point or narrow central space can not be found which could be regarded as the seat of the soul, then it is the circumstance that one has to look at almost every part of the brain bit by bit ⁶⁾, So Descartes placed the seat of the soul in the Zirbel, Bontekoe, Lancisi, Louis, Chopart, Saucerote and la Peyronie in the beams; Digby in the septum, Vieussens in the largest circle of the marrow; Others in the optic nerve mounds; Others in the brain nodes; Arantius in the third cerebral cavity; Willis in the striped hill; Drelincourt in the little brain; Wharton and Schelhammer in the beginning of the spinal cord; Fabri

in the folded wire net; Mieg in the spinal cord. These views may have been very uncritical in part, but the most prudent criticism will only go beyond all these beliefs in that it rejects all equally.

6) Summering, 407th

If one goes further into the pathological experiences, they seem at first to present only contradictions. While a myriad of pathological experiences prove the great importance of the brain's integrity to the integrity of psychic life, it seems almost indifferent to it after a great deal of other experiences. Among the most respected observers are examples of wounds, softening, indurations, hydatides, and other brain disorders, which, despite a very wide spread, were not associated with any mental disorder. U. a. Haller (Elem Physiol IV, p.338), Arnemann (verse on the brain and spinal cord p.136), Longet, anatomy, and Physiol. of the nervous system, such cases collected. Yes, Sömmerring (v. Brain and Nerves p. 400) says: it is almost no part of the brain mass that one would not have hardened, wounded, suppurated, or destroyed at any time without any sign of a disadvantage to life and reason. Similarly, Burdach, who in his work on the brain compiled the known cases of injuries and abnormalities of the brain according to the categories of their consequences with meticulous diligence, notes in general (III, p. 267): experience has taught that there is no part in the brains, whose abnormality would not sometimes have resulted in a disturbance of the activity of the soul, but just as neither in whose abnormality the activity of the soul would not have remained undisturbed. (See also Wagner's references in this regard, p. Similarly, Burdach, who in his work on the brain compiled the known cases of injuries and abnormalities of the brain according to the categories of their consequences with meticulous diligence, notes in general (III, p. 267): experience has taught that there is no part in the brains, whose abnormality would not sometimes have resulted in a disturbance of the activity of the soul, but just as neither in whose abnormality the activity of the soul would not have remained undisturbed. (See also Wagner's references in this regard, p. Similarly, Burdach, who in his work on the brain compiled the known cases of injuries and abnormalities of the brain according to the categories of their consequences with meticulous diligence, notes in general (III, p. 267): experience has taught that there is no part in the brains, whose abnormality would not sometimes have resulted in a disturbance of the activity of the soul, but just as neither in whose abnormality the activity of the soul would not have remained undisturbed. (See also Wagner's references in this regard, p. whose abnormality would not sometimes have resulted in a disturbance of the activity of the soul, but neither would any of whose abnormalities the activity of the soul have remained undisturbed. (See also Wagner's references in this regard, p. whose abnormality would not sometimes have resulted in a disturbance of the activity of the soul, but neither would any of whose abnormalities the activity of the soul have remained undisturbed. (See also Wagner's references in this regard, p.

Now it is necessary to formulate a view which solves the apparent contradictions in this respect, not one which it allows to exist. But the view of the punctual soul-seat can not resolve those contradictions, but lets them persist in full force. A point, a small part of the organ, whose destruction or disturbance would certainly destroy or disturb the psychic life of this world, would have to be demanded after that, and it has not yet been found. On the other hand, the seeming contradictions, according to the view of the expanded soul-seat, are resolved quite consistently and simply in the sense of the institutions that otherwise exist in the organism. What applies to the whole other soul seat, applies only just for its most important part, the narrower. When the right lung is destroyed, you can still breathe with your left, and when one piece is destroyed, you still breathe with the other. Thus, the two eyes, ears, hands, the collateral vessels of the great vascular tribes, etc., can complement and represent each other in their performance at the same time. Thus, in the sense of the extended soul seat, the two halves of the brain, and even to a certain extent, parts of the same half of the brain, as long as they are there to represent and perform. If not, then the possibility of representation ceases, and in this regard all cases which happen are possible on variable constitution, state of health, earlier damages of a brain. The Flourens'chen experiments with cutting away now one,

The only thing that may seem to speak for the first sight of simple soul-sitting, for the first sight, is the circumstance discussed above, that we can lose so many parts, arms, legs, and much more of our body without that Spiritual life and life in general seems to lose nothing but external tools of help, that certainly the nervous system, and especially the brain, forms the hearth of an activity which is in some preferential relation to the activity of the soul, and even of the brain can fall away without the integrity of life and soul suffers; for this can be interpreted in such a way that in the end it is only the preservation of an innermost and last core as the essential bearer of psychic life, and the last, where one can go at this conclusion is a simple being with simple seats. I have not found anything that would speak otherwise only with a note for the simple soul seat of the experience. But after having so far reached the conclusion, the keystone of this conclusion, upon which everything ultimately depends, is denied by experience; If at last every part of the brain can be destroyed, it is just not too much at once, without the soul's life being destroyed or disturbed. But if this keystone is missing, then the whole conclusion falls, and even those facts which seemed to point to it must receive a different interpretation. On the other hand, the interpretation in the sense of the view of the expanded soul seat can not be based on a principle that is valid throughout the whole organism,

There is a fact, however, which opposes the former for the first sight. The intersection of the elongated medulla, that of the part still in the skull, through which the brain continues into the spinal cord, safely and suddenly produces death in man and in the higher animals. Should not the seat of the soul, as the center, the entertainer, the engine of this life, finally be located here with the seat or the main condition of physical life? Flouren's ⁷⁾ has sought to determine more closely the point in the extended mark, by which injury or extirpation occurs safely and suddenly death, and has found that it is only about a pinhead sized lot of gray matter, the tip of

the V-shaped gray mass in the Beak of the so-called *Calamus scriptorius*, with which the fourth cerebral cavity passes into the spinal cleft, which small mass ⁸⁾ he calls in view of this exclusively attributed property *point vital* or *noeud vital*. Cut them or stab a small troika /emporte-pièce/ Thus, in the extended medulla, that the knot of life is separated from the remainder of the extended medulla by a circular incision surrounding it, the animal falls to the ground as if struck by lightning; the breath, sometimes the movement of the heart, suddenly stops, and the animal is dead with almost no convulsions and agony, while incisions in front of and behind this node allow life-events such as breathing and heartbeat to persist. According to Flourens, the distance between the two boundaries, where the incision can still be made, without canceling the respiratory, circulatory and life processes, hereby the diameter of the vital node, is scarcely 1 line. Yes, the integrity of this little part as a condition of life is more important than that of the whole brain, for in the same animals the entire great brain with its basal ganglia can be ablated without immediately altering or even stopping respiration and heart activity. Moreover, with the existence of this knot in the extended mark, Flourens sets the fact he has noted⁹⁾ that, in dogs breathed in by inhalation, when pugs of the posterior spinal nerve roots cause no signs of sensation, pens of the anterior no movement, yet signs of pain and muscular contraction in the cervical region are sensed when the extended pith is pinched or touched ¹⁰⁾, and sudden cessation of all respiratory movements, hereby suddenly full of death, if one later cuts through the knot of life, which he interprets so that the life-knot is still alive, if otherwise the life in the whole spinal cord is suppressed by the etherization.

After all, Flourens considers this point, or rather this little mass, really as the actual seat of life, saying among other things:

"On voit que ce point, premier moteur du mécanisme respiratoire, et noeud vital du système nerveux (car tout ce qui, you système nerveux, reste attaché à ce point, vit, et tout ce qu'on en sépare, meurt) n'est ainsi que je l'ai répété bien des fois, pas plus grande que la tête d'une épingle."

"C'est donc d'un point, qui n'est pas plus great qu'une tête d'épingle, que dépend la vie du système nerveuse, la vie de l'animal par conséquent, en un seul mot, la vie."

"Les physiologistes m'ont souvent demandé de leur indiquer par un terme anatomique la place précise du point, que je nomme le point vital."

"Je leur réponds: la place du point vital est la place marquée par la pointe du V de substance grise."

Sur le cerveau du chien, l'origine du nerf pneumo-gastrique est 5 millim au-dessus du point vital, Sur le cerveau du lapin, l'origine du nerf pneumo-gastrique est 3 millim au-dessus du point vital ."

⁷⁾ Compt. rend. 1881. XXXIII, 437, XLVII, 803, earlier investigation in p. Right expér. 1842. p. 204, later note in Compt. rend. 1859. XLVIII p. 136th

- 8) R. Wagner thinks of it in the essay cited in p. 397 under the name of the gray wedge.
- 9) Compt. rend. 1847. XXIV, 253.
- 10) That this is especially the case with *noeud vital* is not mentioned.

It is undeniable that these facts are very striking, and accordingly, contrary to what we have said above, there would be a tiny little part whose destruction or removal would certainly save life, and one might be all the more inclined to suppose that here Sitting or the last condition of the physical life at the same time the seat of the soul in the above (so) indicated sense should be sought, as the roots not of all, but many important nerves and under it sensory nerves, up to the extended mark, in which this *noeud vital* lies, let track.

After a closer examination, however, both the fact and the interpretation of the fact are very different, so that instead of confirming the view of the simple seat of the soul, it almost cuts off its last resort.

It is *undeniable* that in the *noeud vital*, after Flourens and other experiences , we are allowed to see the relatively smallest part whose destruction is the safest, most often sudden, death, and the followers of the simple seat of the soul should have little hope of finding another, equally small, brain area. which here *denied* the *noeud vital* primacy. Can now even this



so-called life-nodes, under appropriate measures, are extirpated completely, without body and soul life ceasing, so one must accept the same from any other pinhead-sized parts of the brain (as well as the above-mentioned experiments R. Wagner's speak for this directly), and Life and soul do not depend on a particular point at all, but on a connection in which every smallest part can be represented by other smallest parts of the same context. That's the way it is.

Indeed, Brown Séquard (¹¹⁾) has shown by numerous, often repeated and modified experiments on guinea pigs, rabbits, and dogs that the *noeud vital* may not be done suddenly with a troika or with a very quick circular cut, but with a slow cut, thus avoiding a sudden strong irritation of this part of the extended marrow; then breath, even with acceleration and heartbeat, with the most unequivocal signs of sensation and caprice, may persist for even more days, under favorable circumstances, even for a long time. The sudden death that occurs in Flourens's mode of operation (and even rapid intersections of the elongated medulla), according to Séquard's discussion of the various circumstances, does not depend entirely and essentially on the removal of this part, but on¹²⁾ , after EH Weber u. A. Regarding the movement of the heart by electroplating the respiratory nerves opening into the elongated medulla.

¹¹⁾ whose journ. de Physiologist. 1857. I, p. 217th

¹²⁾ Bernard in *Lecons de physiol. exp.* 1853. p. 326; Budge in *Compt. rend.* XXXIX. 1854. p. 749; Séguard in d. *Compt. rend. de la Soc. de Biol.* déc. 1,853th

If this explanation of divergent success is valid or not, which I can not decide, then the very fact that the success of the operation is by no means necessary, as would be the case if the so-called *noeud vital* of the to seek the essential seat of life and soul.

Among other things, Brown Séguard quotes an attempt (*Exp., IV*, p.228), where he extirpated an adult rabbit with the knot of life at the same time the whole V-shaped gray mass, the top of which is the life node, and some of the surrounding white mass. The respiration, instead of ceasing, was exaggerated, the beat of the heart continuing; the other appearances are as follows: "L'animal est à peine troublé et il marche presque sans tituber (il titubait davantage avant l'ablation du point vital, apres la muscular du cou). effort qu'à l'état normal, Moins d'une heure après l'opération, il a mangé." The following day: "Il se promène et il court lorsqn'on veut le prendre." Il ne semble y avoir aucune diminution de la vue et de audition. Les mou-veroents volontaires s'exécutent librement et l'animal ensemble être très-vigoureux. Il a mangé avec assez d'appétit. "On the seventh day after the operation, the animal tries to swallow, if in vain, and dies under gradual increase in respiratory distress until the eighth.

In another trap, not detailed, (p.232) Brown Séguard saw a rabbit survive the operation for 9 days and a few hours. Several other cases are reported as examples of many, where life with signs of sensation and caprice persisted for only a short time, but always for a time, after the operation.

Also, after earlier attempts by Brown Séguard ¹³⁾ by no means in all other animals quick death is the consequence of the removal of the entire extended marrow, yes, in some animals, this operation is survived for some time. According to him, the maximum lifespan after it is 4 months for frogs and salamanders, 4 to 5 weeks for toads, 9 to 10 days for turtles, 4 to 7 days for snakes and lizards, 1 to 6 days for fish, 2 for birds to 21 minutes, 1 day for hibernating mammals, 34 to 46 minutes for newborn dogs, cats and rabbits, 3 to 3 minutes for adults. The higher the external temperature, the faster death occurs; even frogs die at 30 to 40° C. after just a few minutes.

¹³⁾ *Exper. research. New York 1883. Compt. rend. de la Soc. de Biol. pour 1851. Vol. III, p. 73; Compt. rend. de l'Acad. of the sc. 1847 XXIV, p. 363; here after Funke Lehrb. d. Physiol. 1st edition, p. 1026.*

The long life of the frogs after removal of the elongated medulla can be attributed to the fact that these animals have a limited respiratory process through the outer skin, which is why they remain in oxygen gas longer after the operation than in

atmospheric air, and easier to maintain of life in cold, warm air, the fact that the respiratory process through the skin at first suffices more easily than at last.

Finally, Brown Séquard points to future pathological cases in humans which he has to communicate, which seem to prove that the slow destruction of this small mass of gray marrow does not bring about death here.

In addition to all the above, Flouren's¹⁴⁾, according to his new investigations within the life-node itself, recognizes a representation of one half by the other, so that if only one half is cut, death does not take place, but only occurs when both intersect so that the knot of life in this respect completely under the same principle, which we find in the rest of the organism. He adds one more proof to the others, and perhaps the most striking proof that any not too great part can find his representation by others.

¹⁴⁾ *L'Instit. 1858. p. 381. Compt. rend. XLVII, 803.*

If the fact that neither in the *noeud vital*, yet elsewhere a point has been found, the destruction of which undermines life on earth, speaks directly against the view of the simple seat of the soul, but on the other hand there is the great and preferential importance, which nevertheless the integrity of Flourens' life - node for the integrity of the Life has, in its destruction, in no way at variance with the view of one, beyond the knot of life, extended seats of souls, the easy and certainly destructive destruction of life. Hereinafter, the death of the soul can rather be made dependent on the prolonged suspension of important bodily vital functions, which according to the organic connection with the destruction of the life-node, can be made dependent on the destruction of this small part itself.

But supposing that death was really inevitable, with the destruction of the vital node, or of some other place, it would satisfy only one of the demands that the view of the simple seat of the soul would have to make, but it would never have been proved. The question is whether by destroying a point the soul falls out of this life, and whether this point is at the same time a central point in the sense to which we have attached the concept of the seat of the soul. In fact, we have no experiential reason to attach to the so-called life-point a particularly important central or functional significance for the higher soul functions.

Against the difficulty raised here, that no *no vital* can be found in a strict sense, only the following evasion seems to me possible. It can be said that it is not the Flourens'sche, it will be another, who rest in some hiding, and the pathological and physiological experiences just not enough to let him find, especially since it is not necessary that the on it The simple seat of the soul, which is always related to exactly the same place, is rather possible to change place in case of threatening or real destruction of the seat. Could this not happen without the soul losing its most favorable position to the body? Thus, the disadvantage of such destruction is shown.

Actually, Herbart has established a mobility of simple soul seat.

Now the assumptions that the anatomical knife has hitherto been unable to strike the simple seat of the soul, and that the soul is able to escape from it, are undoubtedly equally unlikely; but they would have to be permitted if the view of the simple soul-seat were otherwise secured by a connexion of actual points, since then they would be kept by the durability of the view; But if this view can be based everywhere else only on reasons which are only preserved by the presumed durability of the view, it is difficult to say what it is actually based on. By trying to show that this is the real state of affairs, I can only turn against the sole representative of the view of the simple soul-seat. where I find a serious attempt to eliminate their difficulties; because usually you have not made the difficulties clear. In my opinion, however, it can only help to secure the decision for the view of the extended seats of the soul, when it becomes clear which ways the astuteness of one of the most ingenious representatives of the contrary opinion must hold.

In order to eliminate the anatomical difficulty that the nerve fibers do not meet in a single point, as one would expect in the case of the simple seat of the soul, Lotze notes that the sensory excitations may nevertheless strike the soul as the nerve fibers either enter into a nervous parenchyma In which the seat of the soul is, and thus at least partially reach this seat (Psychol., 118), or unite in a few, even a single path of nerves, which leads to the soul's seat, unite (Micr , 323. 328). To be sure, the first premise seemed so unsatisfactory teleologically that this was probably the main reason why Lotze substituted the second in his later work. But because both are very much in the way of difficulty, In the parenchyma or in the simple pathway, the sensory excitations must be mixed into a middle one, that is to say, the discriminating ability of the same can not take place, which experientially exists, and Lotze (Med., Psych., 121, Micr., 323) refutes this by saying that It is also possible that the parenchyma or "the structure of one and the same fiber could be passed through many excitations at the same time, without these interfering with each other until their essential characters became unknowable." "The waves of sound and light, intersecting the same airspace at the same time, crossing each other in infinite variety, offer us also a rich example of movements which, in the same substance, disturb only a limited extent,

But in fact we are not able to decompose composite light vibrations into their color components when they enter through the same optic fiber; and should not be a special *qualitas occulta* the feeding nerve path to the simple soul *seats*If we are ahead of the optic fiber, we will not be able to dissect it any more if we arrive at it in composition; or would they have to be able to disassemble just as they passed through the optic fiber. In a nutshell, the potentiality Lotze invokes does not materialize in our nervous system. Of course, light vibrations can intersect outside and yet be distinguished from us, but only if they meet separately from our intersection, either side by side or next to each other, like waves on the pond can also pass through each other, and assert their effects separately; according to Lotze, however, all the vibrations of light which send the innumerable points of a region into our eye, at the same time passed through the same path of the nerves, and at the same

time, in their composition, arriving at the simple seats of the soul, still retain their ability to discriminate; This can not be the experience.

It might be objected that the soul, through a mixture of sounds, which reaches through the same auditory nerve, is able to hear through attention the individual sounds. But we must not call on the face an analogy with the ear, if direct facts contradict the face; Much is true for the one sense, which does not apply to the other. Moreover, in the 33rd chapter good reasons have been put forward, according to which even the sounding out of single tones from a clay mixture is only possible insofar as they are precipitated by different acoustic fibers.

The ingeniously introduced and executed concept of so-called local signs, whereby Lotze seeks to explain the emergence of composite spatial intuitions and tactile images, not only does not raise the difficulty, but does not even know it.

Here I give some particularly characteristic passages from Lotze's famous and influential doctrine of the local signs,¹⁵ without being able to reproduce them here in all their fine execution, which one must read for oneself, but which can only be preserved by a solid foundation :

p. 328. "Just as a variable variable may decrease to a zero and beyond, the regularity of geometrical influences is infallible in a point of perfect spatiality, and is reproduced beyond that, and as a variable magnitude unfolds anew It is not because it hauls its former real values secretly into the zero value, but because the law of change preserves itself through this instantaneous disappearance of real values, so also the impressions which occur in the soul become again in the soul a world of space spread, not by blackening a hidden spatiality into the consciousness, but because they were able, between the intense excitement of the soul, which they produced,

¹⁵⁾ *Lotze, medicin. Psychol. 325 ff.*

p. 330. "When we find events taking place in order to have a multiplicity of external stimuli in orderly geometrical relations on the nervous system, such arrangements are, however, important to us as indications that nature intends to make something of these spatial relations something for the consciousness. In themselves, however, they do not explain anything, and it is necessary to seek out, at the same time, in the sensory organs those other means by which the position of the excited points may influence the soul, in addition to their qualitative excitement spatial perception is independent of its qualitative content, so that at different moments very different sensations can fill the same places of our spatial image, every excitement, by virtue of the point in the nervous system on which it takes place, must have a peculiar coloring, which we wish to prove by the name of its local sign. We will soon have further comments on the nearer nature of this local sign; We can only designate it here as a physical process of the nerves, which constantly associates with each variable nervous process for every part of the nervous system, which at the

same place underlies the qualitative content of the changing sensations. Either process disturbs each other either not at all, or to a very negligible extent, and while the soul continues to form its usual qualitative sensations under the influence of the latter, each of them is accompanied at the same time by another excitement,

p. 334. "These considerations determine us not to seek those local signs of nervous excitations in general in passive secondary circumstances, which only suffer every part of the nervous system according to their structure beside the sentimental stimuli, but in the movements which they suffer through their connection with the rest of the nervous system to produce in the manner of the reflex strives¹⁶⁾ . "

16) Also p. 340 it is said that "the local signs consist in the awakening of motor tendencies."

p. 335. "For all our physiological considerations, the notion that spatial perception is an inherent and a priori possession of the nature of the soul, which is not generated by external impressions, but only provoked to particular applications, is sufficient."

It is undeniable that it is difficult to get a clear idea of local signs as motor tendencies, for which Lotze essentially explains them. What is a tendency - exact physics does not know the word - if one does not think of any real movements or spiritual strivings that first awake in the soul; is it a propagation of pressure or tension, or a quiet movement? and something should be able to think of it, so as not to impose a mere word on the performance imposed on the local sign, and to make the performance itself a *qualitas occulta*. I did not succeed in getting clarity about it.

In any case, the various local signs which adhere to the excitations of the individual optic nerves and palpation nerve fibers in the parenchyma or the simple connecting fiber, whereby ultimately everything arrives at the soul, can only merge into a compound local sign. Now the soul is given the task, and one may well say, the ability to explicate the quality of this fusion as a spatial extension and arrangement. But no matter which form one would like to think of the local signs, it is not a mystical one, nor does any want to yield to such a capacity. Lotze himself makes comparatively use of the expression for the characteristic of the local signs, "that every excitement, by virtue of the point in the nervous system, where it takes place, acquires a peculiar coloring." Nobody else is happier to express a view aptly, than Lotze; but the most complex colors do not carry the trace of an ability to be spatially explicated by the soul.

According to Lotze (p.339), "the isolation of the nerve fibers and the position of their central ends are important only insofar as they are both a means of providing each individual nerve process with a qualitatively determined local character, by which its later classification into space is conditioned in which the soul unfolds its intense perceptions. " But what can this isolation in the primitive nerve fibers be fruitful for, given that they must be reversed in the general connecting fiber in which they flow and leading to the seats of the soul, as if the branches of the same tactile

sensation branch into a common tactile nerve fiber, in spite of this their different situation, which might well imprint on them a different local character, are by no means able to convey discreet spatial sensations,

Lotze himself raises the second objection (Micr., I, 323), "that, above all, the ability of the soul to impart precisely measured impulses to movements in terms of movements precludes such an arrangement (as presupposed by it)." Thus this definite diffraction or extension It would be necessary for this and no other motor nerve to be given this and no other measure of contention, unthinkable, if not each of these individual threads extends uninterruptedly to the place of the soul, so that it can immediately find and excite it . " But, he replies (Micr. 1, 325), the quality of the state of the soul is "of which not only the size and nature, but also the place of action which the course of nature attaches to it depend ..." "From the countless sound waves, which cross the air will undoubtedly bring about any vibrations in a strained plate, a window-glass, which hits them, but only one of them will bring the plate to a mid-sound, only that of repeating its oscillations regularly its own structure and tension is capable "" If the soul were in fact ordered the whole range of motor nerve endings, then the mode of their influence could be none other. It would not in every case carry out a similar collision, to which it would give only one definite direction, and which only because of this direction, and not on that end of the nerve, would it only have to produce this, not another motion .

But, if I understand this view correctly, which may not be quite the case, then I can only find half a drop in the view of the extended soul seat in it. For, since the origin of the nerve is concomitantly connected with the soul-seat not directly, but only by means of an interposed parenchyma or a simple pathway, only a compound impulse or a composite wave-movement from the seat of the soul can propagate to the nerve-origin; and since he is here to divide between them according to the quality of the psychic impulses, the quality of the activity of the soul must, beyond the common path of communication, bring about the imparting of these impulses, that is, determine the mode of physical activity at once in a majority of points; and the difference from what the view of the extended soul-seat is, is only that, according to him, the quality of mental activities is not merely the imparting of impulses to a majority of points, but equal to the course of movements in a certain contiguous extension of Body determines. However, by half admitting the view of the extended soul seat, one gives the view of the simple half lost.

Since Lotze establishes a decomposability of the impulses connected with the soul seat through the action of the soul, the assumption of a parallel decomposability of the composite impulses emanating from the soul can not be alienated, and this assumption is fundamental for the whole view of the simple soul seats. For not only does it have the possibility of having different sensations at the same time and giving ordered impulses to the muscles, but also the possibility of attaching a rational meaning to the entanglement of the brain, which grows with the growth of the mental faculty. For what does the appendix of the enormously entangled great brain hemispheres at the simple soul seat in humans want, if of all entangled motions in the

latter only a composite resultant arrives through the parenchyma or the connecting fiber at the seat of the soul; unless this disintegration is again used to help.

The most important difficulties are raised by a simple assumption like a magic stroke; but the connecting fiber also gains quite the character of a magic wand, which misses all difficulties with the same simple blow, without requiring or respecting a natural law.

As regards the fact that an animal, feeling in one, can be divided into two by the like, it certainly does not seem to offer either Herbart's or Lotze's view any particular difficulty, as long as the whole body consists of slumbering souls, and the separation gives cause to the awakening of a new soul. But if a symmetrically constructed animal is divided symmetrically, in which of the two parts shall the old soul remain, and in which the new will awaken? Of course, it will be said that the old soul remains in the part where it is, in the other a new one awakens; Or, the old soul dies, and two new ones awaken. But both can not be done, because I can take the animal from one side and I can bring it down from the other side by gradually cutting away to half, and the continuity of old life always persists, at least I think that the phenomena are so special, for of course I have not made any experiments on it. But how can one reconcile this with a view according to which the soul can only sit on one side at a time? After the view of the extended soul seats, that's easy. The equal parts of the expanded soul seat support each other in the same psychic performance as long as they are connected, and give the same benefit separately, if they are no longer related, only weaker at first, until each half has replaced the missing one, as more fully described in a future chapter is discussed. For this we need no hypothesis of a wonderful influence of the mechanical separation of an animal, but merely the principle of solidarity and solidary representation which is de facto valid for the whole organism, and whose applicability to the narrower seat of the soul is directly proved by Flouren's experiments on the brains, so that there really is nothing left of hypothesis here. It certainly would not have to be that way, but it is so, and because it is so, the soul seat must be a broader one.

Let's look back: the view from the simple soul seat wants to be supported by experiences. She seeks the place in the brain from which all the nerves run, in which all converge; such a place can not be found. It seeks the point that destroys the soul from its life, such a point does not exist. It assumes there will be a connecting fiber to the soul seats and an ability of the soul to separate what is fused into a fiber; neither the connecting fiber nor such a fortune can be found. By splitting an animal, she wants to separate the part with the soul seat from the part without soul, and both parts remain animated.

Such a view can not be made the basis of exact investigations of the relation of body and soul, in that it can base itself only on the presupposition of an impossibility of exact research in this field; for everything that could be used to justify a view is here set aside, and a view based on contrary assumptions that are partly inaccessible to research and partly contradictory to its results.

It is undisputed that a view which is so factual rests not at all on contemplation of the facts themselves, but on more general grounds, and it could generally be said that there is something binding here which we miss in the realm of facts. To discuss this in detail is not appropriate to this document, since it can only be based on facts, and to address the controversy of philosophical systems, neither intention nor success. However, having met with the foregoing discussion of the more urgent and here essential task of basing factual considerations on the preference we shall give to the viewpoint of the extended seats of the soul, I may wish to take some casual supplementary discussion on the more general questions one might ask of our question could make dependent

It is chiefly the view of the simple nature of the soul, which again has its roots, which can not be traced here, in which the view of simple sitting is rooted. Now, one can first of all question whether unity is the more appropriate expression for the nature of the soul than simplicity, and this question seems to me to be affirmative, since the soul includes and unfolds so great a variety of moments as to give the soul Concepts of simplicity, but not unity, contradict. For the difference between unity and simplicity lies precisely in the fact that it is comprehensible as a link or a link, just as even the numerical unit can still be divided into innumerable fractions. But why should the soul be regarded as a unitary one, a manifold in itself, It is not rather a being that is bound to a physical system, which in turn is the connection of a manifold, as a point in this system. That is more than that; and there is no metaphysical difficulty here except that one makes oneself.

Now, of course, and in the monadological systems, one can make the unity of the soul dependent on the metaphysical simplicity of a fundamental being behind the multiplicity of the phenomena of the soul. But let it be that a metaphysics will one day be found which justifies the concept of this unity and the dependence of unity on simplicity more clearly and without contradiction than ever since-I myself have never been able to find fruit in the explanations of the real through the real-that would be so nothing less than the simple soul seat justified. For in itself nothing could hinder the ability to trust in a metaphysically simple soul the capacity to convey a system of movements of different parts of the body at the same time through its action. without transposing the movement from one to the other, successively, according to the principle of the thrust, as the sun actually possesses such a function by virtue of its gravitational action; and it is not foreseeable how a metaphysical simplicity could force the soul to take the attack on the rest of the corporeal world from a certain physical point rather than a physical connection.

This is generally spoken; but special views may, of course, necessitate this. The Herbartian system might still stand, in spite of the fact that the view falls from the simple seat of the soul, should it otherwise be able to survive; because it may not be strictly bound to this view, even if its originator is bound to it; but otherwise it seems with the Lotze'schen systems. Lotze¹⁷⁾identifies the simple soul-beings with the simplest elements of the corporeal world, as those who are able to give inwardly the phenomena of the soul, while they convey only physical phenomena externally; and

our soul itself is merely a by its very nature the same kind, his position and inner development of atomic preferred midst of the system of se him evenly matched equally emotional body atoms¹⁸⁾, Here the view of the simple soul-seat is a necessary one, since a simple atom alone can not have the power to maintain on appreciable stretches a connection of extensive noticeable movements, according to which (excluding mystical mediations) only the principle of molecular action traceable impulse to the neighboring atoms and left by the neighboring atoms, to mediate the connection between the soul and her body.

¹⁷⁾ Microscope. I, 371 ff.

¹⁸⁾ As I have been told, in the writings "the harmony of the results of natural science with the demands of the human mind" and "the genesis of consciousness on atomistic principles" Drosbach has set a similar view independently of Lotze; but I do not know these writings from my own view.

Lotze's view of the nature of souls and their relation to the corporeal world is undoubtedly philosophically possible; but there are so many other philosophical views that the decision between them must be sought before a decision can be made. I myself believe that, in order not to be left with a half-heartedness or a one-sidedness, nor to go back to an incomprehensible reality in the orientation towards reality, one has only to choose between the two fundamentally opposite views, either the whole world of the soul Splitting up the body-world attached to it, according to the last in Lotze's sense, and again to be cemented by something that is spirit-like, but not spirit, or to connect and divide the whole world in our sense from the outset uniformly by a spirit. The one and the other of these views can be consistently developed in relation to our most general interests¹⁹⁾; One can live in one and the other in such a way that it seems completely natural and the contrary quite unnatural. Where should the decision come from?

¹⁹⁾ It has been tried by Lotze in his microcosm, by me in my script Zend-Avesta.

I believe it will be here, as it has been in physics with the theory of undulations and emissions: each has consistently developed into a complete theory; Every one of them had their representatives, and most recently Biot stood for one, while Fresnel stood for the other; Where did the decision finally come from? Hence that the demands which both theories put on experience diverge on certain points, in a few but fundamental ones; and experience has given one right. Such points, however, seem to me to be present in relation to the quarrel at issue here, which relate to the question of the simplicity or extension of the seat of souls, and I consider it a favorable circumstance that here once so rare Possibility shows

The chief advantage of the monadological systems, to which Lotze's belongs, would lie in the fact that it is easiest for them to assert the indestructibility of the soul, in that the simplicity of the monad does not allow disintegration. Now simple centers, emphases can not decay, but they can vanish if what they belong to decays; and to that extent this assurance seems only apparent, but by postulating the systems of autonomy of the monads or simple beings, or of hypostatising them by the simple atom, the immortality of the soul appears to be secured in the simplest possible way. In experience, the soul, despite its presupposed self-preservation, can only be active and awake under special conditions of corporeality. and with this, in principle, for the monadological view, the whole difficulty of every other view returns, as it is now possible after death to do without a body, which in life they could only accomplish with one body, or where they find a new body could. However, the next difficulty is easily overcome.

But the simplest ways are not always the most valid, and the first and simplest gratification is not always the most appropriate. As indestructible as a point is, so indestructible is the context of the whole and the causal sequence in the whole, of which our system is part. And if our soul in this world is not supported by one point, but by a constantly changing and changing part of the whole context, which grows to a certain extent, then in the hereafter it can also be carried by another and wider circle of this indestructible connection , But I have said enough about it elsewhere ²⁰⁾ and this is not the place to say more about it.

²⁰⁾ Zend-Avesta, Part 3.

While the monadologic view may retain the advantage of a simpler, though less than adequate, answer to a difficult question, it is all the more difficult to answer the other difficult question. When every mind sits in one point, does the divine sit in one point? and if all spirit is in points, what binds the world, the connection of points? The view of the extended soul-seats of the finite spirits need only remain consistent in order to become the view of an ubiquitous conscious God, and to see in it the bond of all things. The monadologic view can not dare to gain a fabulous reputation, to put God at a point among other points, and so you only return to the increased task of ingenuity,

I do not want to reproduce here the monadological conceptions of Leibniz and Herbart; the former has his bond of things and beings in preestablished harmony; the latter has no real tie of things.

Lotze seeks to fulfill the need of a general volume of things (Micr. I, 413 ff. II, 45 ff.) By the view of an "infinite substance" or a "substantial infinite," in whose essence all laws, all causal connection of things are comprehended with these themselves, and which in the individual phenomena and things are fully present everywhere by their very nature; but in no way does this being fully manifest. "What each individual element accomplishes, it can not, if it is this individual, but only if it is this individual as the manifestation of this universal." One may be tempted to consider this infinite

substance to be God, and, if I am not mistaken, it or the idea of goodness, which for Lotze is the ultimate principle of its working and weaving, must Represent God's place; although there remains a fragile gap that may well be filled in the last remaining parts of his work, that he will never say so clearly. If, in many places (I, p. 424, 432, 435), it seems to attach intentions to the infinite substance of will, such laws can be given to oneself, then elsewhere (Micr., 418) one finds expressly only the essence of infinite substance compared to the essence of the soul, yet not identified; even this could not be done without interrupting the consequence. Now, when I am so often obliged to compare the essence of the infinite substance as a band of all points with the conscious soul being, to demand the consequence, conversely, that the nature of the soul-being is represented according to that comparison with the infinite substance, that is, that it does not bind to one point, but grasps as a band of points, and then, of course, the bond of things is not exposed as unconscious substance with the essence of the conscious mind but really to present it. So here, too, the view inevitably seems to me half on the way, which she only had to go completely in order to remain consistent, but hereby of course to abolish it.

Acts of all, the ingenuity celebrated the triumph of overcoming all difficulties which oppose the view of the simple soul-seat of experience, the art of representation capable of appeasing or concealing the whole difficulty which consciously possessed a satisfying or possibly possible version of divine omnipresent Opposed to this view, but what would be gained for psychophysics? only the overcoming of a mountain of difficulties, to reach a dark cul-de-sac for them and to hit the wall the next step; while the view of the extended seat of the finite spirits, with the view of the widest seats of the infinite Spirit in support, enters into an open and fruitful field of experiential inquiry,

In fact, the whole corridor, which we will go in the following, can not at all be taken into consideration from the point of view of the simple seat of the soul; Rather, just be said: here is not to go. But if we can really go by the hand of our view, with success and the prospect of further success, why should not we go?

Accordingly, the following will be based on the expanded soul seat view.

One may perhaps find it strange that in the previous discussion I referred to Lotze rather than Herbart. Herbart's view is not so alien to me that it could not have been more intimate ²¹⁾; but I did not think it right. For Herbart's simple beings are hyperphysical or behind-physical; his intelligible space is no less; he has not been able to raise his relation to real space, even for his most avowed adherents, to a self-consistent clarity, according to which the whole question depends on the place of Soul retains an unclear background; He does not enter into the anatomical and physiological difficulties of the question, and of course a quarrel with his metaphysics is not a matter of this writing. In contrast to this, Lotze's view and presentation of his view from the outset offers clear and definite opposing points of view against the points of view of this work, which directly intervene in the sphere of experience, and without reference to a metaphysics to be studied. as directed by Herbart to the physiologists (Works V, 114), allow a dispute with him. Incidentally,

apart from the specific physical hypostasis of the souls and the bond through the essentially infinite, which is of course important and on the other side, Lotze's view has all the essential features of Herbart's relation to the soul's relation to the body. The whole of what is said against Lotze's opinion would no less be asserted against Herbart's.

²¹⁾ The most essential here belongs in s. Lehrb. d. Psychol. Works. T. V, 114 and T. VI, 390 f.

d) Question about the extent of the extended seat of the soul.

After finding that the seat of the soul in the narrower sense can not be regarded as an easy one, the second main question arises, how far its extension extends, whether only to the brain and how far in the brain?

There is a great material of facts which can be related to this question, especially in the experiments on beheaded animals. However, I consider it questionable to go into a more detailed compilation and discussion of this material here, and conclude with the confession that so far scarcely anything more can be derived with certainty than that simplified in accordance with the organization and soul level of the animals, the relative expansion of the narrower seat of the soul grows, and that not the whole nervous system, and hence the brain, is of equal importance for the functions of the soul, without any sharp boundary determinations being able to be drawn. After sufficiently known experiences ²²⁾ Few are likely to deny decapitated insects sensation; and in animals where there is no brain, of course, the sensation can not be linked to it. But the main question, which is still the subject of the dispute, revolves around the vertebrates, and in this respect I think it most advisable to leave the discussion of the facts and the dispute about their interpretation for the time being to those who bring about these facts, ie the physiologists until they are either more apt to provide psychophysics with information or psychophysics will be more apt to do so. Only a few general, if not new, critical points of view may fit here.

²²⁾ Treviranus Biol. V, 439. The same appearances and laws of org. Life II, 192. Froriep's Tagesber. 1852. Febr. No. 467.

The interpretation of all signs, which seem to speak for the existence of sensation and arbitrariness in beheaded animals, requires great caution, and always retains some uncertainty, considering the possibility of regarding them also as consequences of an organic device or mechanism which, as long as the brain is present, with which its sensation and arbitrariness come into relation, but after the cessation of the brain, its play as a result of external or internal stimuli even without sensation and arbitrariness in a similar manner.

Neither an apparent voluntary nature of the movements, nor the expediency and purposeful modification of the same, in accordance with the difference of the stimuli

acting on which one has principally directed his attention, can afford certain signs of sensation and arbitrariness; for when seemingly voluntary movements arise in beheaded animals without external stimuli, then, apart from the fact that often the stimulus of the air to the wounded part can produce such, the possibility is not excluded that the still continuing as a result of an organic remainder of life and internal unpredictable changes, caused by the wound itself, as internal stimuli trigger the relevant movements, which may then be very similar to the movements of the whole animal, because the whole former musculoskeletal system persists without necessarily being related to sensation and sensation. But the expediency and purposeful alteration of the motions according to circumstances may, to the extent that they still exist, be grounded in the proper organization of the organism itself, in that some of our assembled machines themselves naturally alter their play according to circumstances, the convenient arrangement of the much more complicated Organisms but in this respect indisputably goes much further.

According to this, the one is regarded as a sign of arbitrariness or sensation, and is regarded by others as a play of a mechanism, be it a simple reflex mechanism or an even more complicated mechanism, which in intact animals is related to the conscious brains, influences them, and influences them manifests. If the brain falls away, the game can go on for some time according to the facilities that once exist, or it can be renewed under the influence of stimuli that replace the influence of the brain, but without any further connection with consciousness. The signs of arbitrariness are then only apparent. The eventual appearance of freedom depends on the unpredictability of how accidental external and internal stimuli intervene in the complicated mechanism, the semblance of intention, to expose oneself to stimuli and to behave, to eliminate and avoid harmfulness, to the expediency with which the mechanism for the attack of ordinary stimuli and the defense of ordinary injuriousness is set up in advance. Habituation and practice in life can themselves do much to set up the mechanism and increase the subsequent appearance of its deliberate use.

In the meantime, the legality with which movements take place in beheaded animals, and the traceability of them to reflex phenomena (the concept of which is taken by different persons in very different latitudes), can not be proved to be secure against associated sensations, insofar as a demonstrable legality and traceability to reflex mechanism there is no obstacle everywhere, that sensation and psychic instinct are just as legally linked to reflex action after decapitation as to decapitation. However, after interruption of the conduction from the spinal cord to the brain by means of cuts or pathological destruction, movements in the parts supplied with nerves by the spinal cord follow the laws of reflex action, without the main consciousness, what is related to the brains, feels something of it; but one supposes this to be proved, if one assumes that sensation can not arise for itself in the part whose continuity with the brain is interrupted, and that it can attach itself just as well to the reflex actions as it does in the case of the existence of the brain Especially since the phenomena of divisible animals teach that a psychic unity, by separating the organism to which it is attached, can give two separate units, none of which feels

what the other feels. Hereby the experiences and points of view, upon which the opponents of sensation in chiefly beheaded animals are chiefly based, lose their evidential value. whose continuity with the brains is interrupted, nor which can develop sensation for itself, and can just as well attach itself to reflex actions, as is the case with the existence of the brain, especially since the phenomena of divisible animals teach that a psychic unity is achieved by separation of the organism to which it is attached may give two separate units, none of which feels what the other feels. Hereby the experiences and points of view, upon which the opponents of sensation in chiefly beheaded animals are chiefly based, lose their evidential value. whose continuity with the brains is interrupted, nor which can develop sensation for itself, and can just as well attach itself to reflex actions, as is the case with the existence of the brain, especially since the phenomena of divisible animals teach that a psychic unity is achieved by separation of the organism to which it is attached may give two separate units, none of which feels what the other feels. Hereby the experiences and points of view, upon which the opponents of sensation in chiefly beheaded animals are chiefly based, lose their evidential value. can give two separate units, none of which feels what the other feels. Hereby the experiences and points of view, upon which the opponents of sensation in chiefly beheaded animals are chiefly based, lose their evidential value. can give two separate units, none of which feels what the other feels. Hereby the experiences and points of view, upon which the opponents of sensation in chiefly beheaded animals are chiefly based, lose their evidential value.

Finally, there are two main points to emphasize as of great importance. First. If it should be possible to show that no sensation and no psychic instinct can be made with a spinal cord detached from the brain, this would not in the least prove that it is not so long as it is connected with the brains The share in its psychic function, ie, in the movements which are in direct relation to the change of condition due to the psychic functions, may be sufficient, since its connection with the brain is necessary, but also sufficient to lend it its share. Since we must acknowledge that the narrower seat of the soul is a broader one, there is at any rate the possibility of its extension to the spinal cord,

Even every part of the brain, when separated from the rest, can no longer do anything for the psychic function, while contributing to it in connection with the others, and consequently one would just as well share in each part of the brain as the spinal cord To deny the psychic functions, if one wanted to hold experiments on pieces which are separated from the rest, as determining for what they contribute in the connection to the functions of the whole. On the contrary, in the principle of the organic connection lies the fact that, like every part in the connection of the whole contributes to its functions, so also in its functions is it supported and held or even enabled to do so. According to this, it can be said that experiments on decapitated animals, should they also have hints about the

Secondly. Nor can the fact that the psychic functions of the brain be regarded as undisturbed, when there has been an interruption between the brain and the spinal cord, of which there are multiple pathological experiences in humans and

physiologically in animals, prove that the spinal cord is involved in the psychic functions of the brain. Brain should not take part in it as long as it is in connection with it, because the same reason should justly be asserted against the participation of every part of the brain itself in the psychic functions, since even an entire brain hemisphere can be removed according to earlier experiments without the mental functions of the remaining brain appearing disturbed. Rather, it lies in the principle of solidarity representation,

According to this, the well-known fact that after amputation of the limbs the feeling of possession of the limbs still exists, and even pain is apparently felt in them, by no means strictly proves that, as long as these limbs are present, the psychophysical activities are not on which these feelings rest, extend into the nerve and contribute to those feelings in solidarity.

The question of whether the narrower seat of the soul, instead of extending to the whole brain in vertebrates, can not be limited to a particular part of it suffers from the same difficulties as the question whether it extends at least in some animals beyond; so that just as little has taken place so far a certain decision. Only, as already noted at the beginning, have physiological experiments decided that not all parts of the brain are of equal importance for the functions of the soul; As with removing the large, but not the cerebellum, the activities of the soul ever suffer²³⁾ while the capacity of certain sensations is linked to the integrity of the central parts into which the sensory nerves enter. The way in which Gall has shown the connection of the activities of the soul to certain parts of the brain can not be regarded as adequately justified either by experience or aprioristic considerations.

²³⁾ Comp. on the lack of reference of the little brain to the conscious activities of the soul, especially the new investigations of Wagner into the goding. gel. 1860. Nachr. No. 4.

e) Resume and conclusion.

Summing up the above, one may regard as well-founded by empirical facts and points of view:

1) That the preservation of the soul in this life is based not on the preservation of a particular point or smallest part of the body, but on the solidarity of all parts and activities of the body in mutual complementation and with the possibility of mutual representation reaching to a certain extent the related further seat of the soul in the whole body should be sought.

2) That the bodily activities, on which sensation and conscious psychic activities in general depend, do not arouse such by impulse to a certain point of the body, but carry them in a certain extent during their process, that accordingly the closer soul-seat referred to in one to seek a certain extent in the body.

3) That, in proportion as the level of organization and soul is simpler, the proportionate expansion of the narrower seat of souls grows.

4) That not all parts of the brain have the same meaning for the soul functions.

On the other hand, the question of whether in creatures that have a brain, the vertebrates by name alone, is to be found in whether and how far it extends beyond the brain and in the brain itself, nothing is decided by taking each one from it Reason and any difficulty after one side counter-reasons and rejections of the difficulty can be opposed by the opposite side. Still less is there a philosophical decision in this regard, so that finally the view on the matter of faith remains of each, which is to be placed after the connection of his other views.

Following the interplay of our own views, and in the light of the discussion of the following chapters, even the most probable seems to us to be the following.

The place of bodily activities with which conscious soul activities are linked in functional dependence, or in short the narrower seat of the soul, is not strictly circumscribed, not only by the series of different creatures, but also in the same creature, according to this or that sphere of sensory activity or higher mental activity, the main focus of the movements which are subject to consciousness, briefly psychophysical activity above the threshold, changes its place and extent. At any time, there will be a place in the nervous system where there is one, or brain, where this activity is strongest, and here one can search the respective headquarters of the soul or soul seat in the narrowest sense. From this point onward, the movements of decreasing strength will pass through the whole tract of nervous fibers in the brains, spinal cord, nerves associated with it, and in so far as they reach above a certain degree of strength, the threshold also contribute to the consciousness to raise above the threshold; which may be up to different width according to circumstances. Whether the spinal cord and the nerve are able to mediate psychic functions even after separation from the brains will depend on whether they can subsequently produce psychophysical movements of sufficient strength to exceed the threshold, which may also be different according to circumstances previous attempts not sure is decidable. and in so far as they extend beyond a certain degree of strength, the threshold, also to raise consciousness above the threshold; which may be up to different width according to circumstances. Whether the spinal cord and the nerve are able to mediate psychic functions even after separation from the brains will depend on whether they can subsequently produce psychophysical movements of sufficient strength to exceed the threshold, which may also be different according to circumstances previous attempts not sure is decidable. and in so far as they extend beyond a certain degree of strength, the threshold, also to raise consciousness above the threshold; which may be up to different width according to circumstances. Whether the spinal cord and the nerve are able to mediate psychic functions even after separation from the brains will depend on whether they can subsequently produce psychophysical movements of sufficient strength to exceed the threshold, which may also be different according to circumstances previous attempts not sure is decidable.

XXXVIII. Transmission of Weber's law and the fact of the threshold into internal psychophysics. ¹⁾

By believing that I have done enough in the preceding chapter of the discussion of general preliminary questions, I turn to what I regard as the actual entrance into the inner psychophysics of the point described in Chapter 36, according to the course chosen here.

¹⁾ With regard to p. 82 revision p. 221.

The legal relation between stimulus and sensation presupposes, as we have said, between stimulus and psychophysical activity on the one hand, and psychophysical activity and sensation on the other.

Insofar as the statement is to speak of size relations of psychophysical activity, in order to preserve internal psychophysics in connection with external and exact kinematics, we will have to consider psychophysical activity to be the same measure we use the physical activity, from which it is stimulated from outside, or the stimulus, insofar as it is comprehensible as activity, measure, that is, by the living force, which is not even included, that it is proportional to the living force of the stimulus. and what needs to be examined first of all, if and how far it is the case. In fact, generally speaking, nothing hinders the fact that two sizes are measured with the same yardstick and yet are not the same size, still proportionally growing and decreasing, if they are already a function of each other. The application of the same rule has only the formal advantage of being able to understand more easily and without reduction the factual relations of the two.

The main question that needs to be dealt with is:

Is Weber's law, according to which the increases in perceptions are constant, when the relative increases in stimulus are constant, and the fact of the threshold, according to which sensation acquires a marked value only with a certain finite stimulus value, into a relation between internal psychophysics To translate sensation to psychophysical activity, to think that the stimulus and its growth are represented by proportional values of psychophysical activity, or rather, in a relation between the psychophysical activity and the stimulus of the kind that psychophysical sensation and its growth are multiplied by proportional values Activity represents think. In other words:

Even a very general point of view is sufficient to make the decision in favor of the first assumption. According to the essential difference between the physical and psychical realms, a dependence between psychic and physical activity in the sense of the fundamental formula and measure-formula is very conceivable, whereas such a dependence is between two bodily activities, as represented on the one hand by the stimulus effect and on the other hand by the psychophysical activity , in the sense of physical and physiological laws is unthinkable.

On the other hand, the simplest and most natural presupposition we can make in the sense of these laws is that the increases in activity stimulated by the stimulus of light and sound in the visual and auditory nerves are proportionate to the adulterations of the stimulus, as long as the organ is not suffers. Furthermore, proportionality can not be claimed because Weber's law no longer applies.

To be sure, this presupposition is not entirely necessary, for the stimulus does not give rise to organic activity according to the principle of the collision, and we do not yet sufficiently know the manner in which it causes it, the proportional course of it with the external excitations in the normal limits Sense activity without further assert. But if only the choice is between this simplest and most natural and an otherwise unlikely premise, and if this presupposition can be further supported by other reasons, then the decision can not be doubtful.

The deviations from the proportionality between the adulterations of the stimulus and the psychophysical activity, which the experiment shows when certain limits are exceeded, are nothing surprising; for even in the case of simple impact effects, corresponding deviations occur when certain limits are exceeded, the easier it can be expected in the intervention of the stimulus into the complicated organic machinery. The living force of a string or plate, and thus the physical sound intensity, will be proportional to the height of fall of a falling body (T, p. 179 f.), When the elastic limit is not exceeded; if this is the case, the string or plate undergoes a continual stretching, squeezing or tearing by the body falling thereon, so this proportionality suffers a demolition. Increases in physical tone still depend on the growth of the living force of the vibrating string or plate for the same function, but no longer on those of the falling height of the falling body. Thus, even after exceeding the limits of the validity of Weber's law by the strength of a stimulus, the sensation will undoubtedly still depend in the same way on the psychophysical living force of the nerves, but no longer on the stimulus.

Even the parallel law (PI, Chapter 12) is compatible only with the first assumption and can itself be regarded as an inference of the same. According to this law, the magnitude of the perceived difference between two stimuli does not change when the sensitivity blunts evenly for both. But it would have to diminish if the perceived difference were rather proportional to the absolute difference of the psychophysical activity from the relative one; for if each of these stimuli, by virtue of blunted sensibility, produces only half as much psychophysical activity, the difference of the same is reduced to half.

If, by the way, even a logarithmic dependence of the strength of the movements stimulated by light and sound stimulation on the strength of the stimulus be considered possible in the sense of the second presupposition, this would not suffice, but because the sensation of the height of the sounds is according to the corresponding law In addition to that of strength, the vibrational number of the psychophysical movement in this ratio would have to be dependent on the oscillation number of the stimulus, which is in fact unthinkable.

According to the connection in which the fact of the threshold with Weber's law stands by the measure-formula, the question as to how this law is to be transferred into internal psychophysics decides at the same time the question for that fact. Yet, especially with regard to the latter, we examine the question: whether, just as the stimulus, the psychophysical movement which it induces must attain a certain strength, before sensation can be linked to the fact that the threshold value of the stimulus would be that of psychophysics Movement can reach its threshold, or rather the stimulus must first reach a certain strength before the psychophysical movement even begins, and at the beginning of the psychophysical movement the sensation begins immediately.

It is undeniable that the last assumption seems quite possible from a general point of view. If a horse attracts a heavy wagon in a bad way, it will not succeed in setting it in motion until the exertion of force exceeds a certain magnitude, from which time it starts working. As he gets under way, he also carries his load with him, and the smallest speed of the car also carries a corresponding load of its own. It may be said, of course, that a certain strength of the stimulus is necessary in order to set in motion the psychophysical movement, but not first of all a certain strength of the psychophysical movement to carry sensation; but the smallest such movement will carry even a smallest sensation.

But this interpretation becomes untenable by the fact that it is not transferable to the threshold of difference, and it is common ground that the same principle of explanation must suffice for both thresholds. If I can see absolutely nothing of the stars in the daylight and discover absolutely no irregularity on a rapidly turned disc with white and black sectors, I can neither say that it was not a psychophysical impression, nor that it did not make a different impression greater noticeable differences can only come about by summation of such small imperceptible. So there is nothing left to suppose that a real difference of psychophysical impressions can not be understood as a difference, remains unconscious unless it exceeds a certain magnitude; but if this is to be admitted of differences, then, according to the connection of the facts, the threshold of irritation and of difference will also be conceded for absolute quantities. Besides, I want to remind you of some very simple facts which show that the carriage of psychophysical activity, however, can be put on without already having sensation; or rather, that the example with the car does not apply to our case. To be more precise, these facts will not be explained until we turn later to the more specific consideration of attention. that the carriage may, however, be attracted to the psychophysical activity, without already having sensation; or rather, that the example with the car does not apply to our case. To be more precise,

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Early in bed, I tend to think about all sorts of things. Opposite the bed is a black stovepipe on a bright wall. As the head is still, the impression of the black tube is strong in the eye when I lie with broken eyes after broken morning light, but I think of something completely different, and I am completely unconscious of this impression. But very often, when I closed my eyes, I was struck by a very intense white afterimage of the stovepipe. The physical impression was thus made in such a way that the sensation of the face could arise, but as long as the attention was diverted it remained unconscious, and yet it could still enter consciousness.

Similar reports Scoresby²⁾. He often perceived parts of an object in the picture, which he had not realized when looking at it with his eyes open. If a passage of a printed edition in larger letters was fixed exclusively, Scoresby states that he had succeeded in reading the adjacent characters in the picture as well.

²⁾ Instit. 1854. 154; here after Liebig's u. Kopp's Jahresber. 1854. 185.

Corresponding experiences can be made in the sphere of hearing.

For example, someone speaks to us; but we are scattered and do not hear (unconsciously) what he has said. But the next moment we gather, and what he has said comes into our consciousness. It is not disputed that the movements to which the hearing is linked had to have arisen beforehand, and the collection of attention had only the success of lifting it above the threshold.

In this way, even an earlier impression may come to consciousness later than a later one, when attention was directed more to the later than the former. This explains a very paradoxical experience that Dr. Ing. Hadekamp in the Prussian Club Newspaper³⁾ The time difference between the two acts was, of course, an impossibly small one, but it was always large enough that I can assert the correctness of my observation as undoubted Some time ago, Hr. Dr. Schmeisser, that the same phenomenon had once occurred to him. He first saw the blood flow out of the vein, then saw the Schnepper go off, and then he heard his blow. "The author further remarks: "I would like to believe that in all cases when the deception occurred to me Blood flow was very tense. " that the same phenomenon also occurred to him once. He first saw the blood flow out of the vein, then saw the Schnepper go off, and then he heard his blow. "The author further remarks: "I would like to believe that in all cases when the deception occurred to me Blood flow was very tense. " that the same phenomenon also occurred to him once. He first saw the blood flow out of the vein, then saw the Schnepper go off, and then he heard his blow. "The author further

remarks: "I would like to believe that in all cases when the deception occurred to me Blood flow was very tense."

³⁾ Here to Fechner's Centralbl. 1854, p. 422.

Probably of a similar nature to previous experience is the following, which Hartmann ⁴⁾ on occasion made of experiments which he employed to discuss the relations of the so-called personal difference by means of a specially constructed apparatus.

⁴⁾ Grunert's Arch. F. Mathem. XXXI, p. 17.

An artificial star passed uniformly along a scale in front of a thread; the path he takes in 1 sec. was just divided into 10 parts. If now the graduated part was read, where the star was before the thread with the last blow, then it had to be by the next blow by 10 scale parts further.

He then flew through the right point during the stroke and the information became correct. This usually happened at the end of the observation series, when I was already tired, or when I made the observations somewhat nonchalant. The same phenomenon I had even with slower and faster movement, z. Eg at a black dot on the paper disc, which par. 8 sec. Inch went through. The anticipated space was also the same here, circa with a black dot on the paper disk, which par. 8 in sec. Inch went through. The anticipated space was also the same here, circa with a black dot on the paper disk, which par. 8 in sec. Inch went through. The anticipated space was also the same here, circa¹ / ₂₀ of 1 sec traversed. Pathway. "

"I do not want to dare to explain this phenomenon, it's as if you pay close attention to the regular second-hand beats, and you might anticipate it yourself, as you would expect an expected bump earlier than it really is while you are the wandering star, which one pays less attention to, must always be brought to consciousness in a new place, whereby the soul, which finds it difficult to hear and see two heterogeneous businesses at the same time, performs, as it were, the idea of the one seen After that, until another time, less attentive to the blows, one follows the wandering star with greater interest, and thus fly it through the sound without stopping in the open, and even see it running ahead."

"Something similar should be suspected here, as it were ahead of the second beats as expected phenomena, but to perceive the lightning as a surprising phenomenon, but this is what I have, the greater uncertainty of these observations because of, can not directly ascertain, also indirectly turned out in the observations of a consequent delay - too large information of the publication times - not determined.

For the sake of previous direct reasons, I still set forth the following general point of view. Since the relations of the psychophysical movements are beyond our

immediate experience, we have to choose between different possible assumptions of the one which allows the facts to be most easily and completely represented in the context.

Now it will be shown how the relations between conscious and unconscious mental life, sleep and waking, general and special phenomena of consciousness, in short the most general relations of mental life, are a very simple and satisfying psychophysical representation on the presupposition that the threshold concept is transferable to the psychophysical movement let, which is not possible, if one obeys the opposite assumption.

After all, I do not consider it an uncertain hypothesis, but rather a requirement of the whole actual situation on which we have to base ourselves, that rather the sensation of the psychophysical activity, as it depends on the stimulus in the sense of the fundamental formula and Maßformel, according to which it will only be necessary to introduce the psychophysical activity instead of the stimulus β into these formulas to an appropriate degree.

With this translation of the dependence of the sensation from the external stimuli into a dependence on the conditions of the psychophysical movement, our doctrine is freed, in principle, from all the precarious conditions and restrictions which it still experiences in the field of external psychophysics. We must have recognized from the outset that our formulas based on Weber's law are only within a certain experimental limit in relation to the external stimulus, only with a more or less close approximation, only for the same external mode of applying the stimulus and the same prove the internal state of the sensitivity; that the constants b , your formulas are not truly constant, but change after changing these conditions. But not only does it not prevent us from accepting anything, but, if there is any essential functional relationship between body and mind, we are obliged to assume that the validity of the laws linking the magnitude and nature of the sensation to the magnitude and nature of the psychophysical movement "Absolute and unlimited" is as good as the validity of the gravitational law essentially grounded in nature, so that wherever and wherever the same size and type of psychophysical motion is present, there is always the same magnitude and type of sensation, and all deviations which we find of the validity of Weber's Law and the formulas based on it in relation to the external stimulus,

It is only with this that the dependence relationship between β and γ in our formulas becomes truly reciprocal and binding. Then we will really be able to say so well: the psychophysical movement β can not be present according to how the conscious or unconscious sensation γ exists, as we can say, the sensation γ can not exist, as in motion with the value β whereas, as long as we stand by the external stimulus, the external stimulus and the requisite irritability are present, and yet no sensation can arise, unless the stimulus also operates under appropriate external conditions, and conversely, internal sensations may be present that external stimuli are there.

Against this, however, may raise an objection.

It is not doubted that a given sensual sensation can not come about without a given bodily change; but does the formation of this bodily change also presuppose the given sensation? Can not the same motions which a sensation needs to come to fruition proceed in other circumstances, unless they carry a sensation or, in other circumstances, carry other sensations? in particular, according as they proceed in organisms or in the external world, or as they proceed in different organisms?

It is undisputed, except that one then has to reckon with the other circumstances to that on which the sensation is conditioned, or, according to our expression, function. Since it does not depend on a point at all, and yet nothing is decided as to which connection it depends on, the possibility remains still open that given movements in a given connection carry a sensation, by adding the connection to the full condition of the sensation, while they do not carry in another, by not adding to the context.

The matter may also be considered from the following point of view: if a string, without being attached to the violin, could be put into the same kind of vibration as is attached to the violin, it would give the same tone; but it can vibrate only on the violin case and produce such a resonance as it does. And so any strands, if they could accept such movements outside of the organism and find such co-movements, as the nerves in the organism, would give just such sensations (which one could lay in the spirit of the world, so as not to embarrass them) yes, the vibrations would still take place in the world), but they just can not do it; every organism is a special kind of instrument,

XXXIX. General significance of the threshold in internal psychophysics.

The contrast between a rise above the threshold and a sinking below the threshold with the threshold point in between is not peculiar to the realm of sensations. The whole spiritual life of man alternates between sleep and waking, that is, an unconscious and conscious state; in waking, individual regions and individual phenomena in each area can exceed the threshold or sink below it. The psychophysical representation of all this must necessarily be connected and grounded on the same principle. If we are somewhere certain of the psychophysical representation of consciousness and unconsciousness, then the connection between the facts and the consequence of contemplation automatically compels us to generalize and deduce. And without knowing the psychophysical activities,^β) is to be substituted in our measure-formula, the generalization of the fact that the same psychophysical movements or changes, which carry consciousness above a certain degree of strength, become to a certain extent unconscious, suffices in itself to provide very general points of view and important consequences to let go. Let us

recall for a moment the foundation of this all-important generalization and anticipate the course of the same.

The mode of action of the stimuli has first served to establish in the field of external psychophysics the fact that what stimulates the sensation from outside must exceed a certain degree of the strength to make it conscious. In this connection, by translating the stimulus into psychophysical activity, the first conclusion is that the psychophysical activity triggered by the stimulus must also exceed a certain degree of strength in order to become conscious. The discussion of the following chapters on sleep and waking and attention will be added to show that what holds for sensory and special phenomena can be transferred to general consciousness and general phenomena of consciousness. This will create a need to educate ourselves about the relationship, in which the threshold of the general consciousness stands at the threshold of particular phenomena of consciousness. The discussion of the experiential relations between the effect of attention and the stimulus in the 42nd chapter will serve to prove that which can be assumed from a general point of view in this respect, by the co-ordination of all experiential relations, and the step-relationship which is in us will finally be in the 45th Ch. even beyond us. through the co-ordination of all experiential conditions to prove it, and the stage-relationship which presents itself in us, will finally be found in the 45th chap. even beyond us. through the co-ordination of all experiential conditions to prove it, and the stage-relationship which presents itself in us, will finally be found in the 45th chap. even beyond us.

This proves a fundamental significance of the fact of the threshold for the whole development of inner psychophysics; this would be, irrespective of it, what an organism without sections, incisions, herewith without organs and limbs.

The concept of the psychophysical threshold has the most important significance in all of this because it gives a firm foundation to the concept of the unconscious. Psychology can not abstract from unconscious sensations, ideas, even from the effects of unconscious sensations, ideas. But how can work what is not; or what is the difference between an unconscious sensation and the idea of something we do not have? The difference has to be made, but how is it to be made clear? And where has there been clarity since then?

In fact, I regard it as one of the most beautiful results of our theory that it gives this clarity, by the sensation, or what it is for a state of consciousness, with something to which it depends not on contestable speculations but on indisputable experiences in such a functional relationship that something can persist while being silent. Of course, in the state of the unconscious, sensations and ideas have ceased to exist as real, as long as they are grasped abstractly from their substratum, but something is progressing within us, the psychophysical activity of which they function, and the possibility of the recurrence of sensation depends, as the oscillation of life or special internal or external causes, the movement to raise again above the threshold;

XL. Sleep and wake¹⁾.

Whereas the psychophysical relations of sensation afford the easiest point of attack for external psychophysics from the experiential side, on the other hand, the phenomenon of sleep and waking seems to me the most suitable point of attack from this side for the inner, once, as far as the experience is so far accessible, secondly, insofar as it concerns the whole consciousness of man, higher and lower in one, while sensations are merely a special phenomenon and that of the lowest order within the general consciousness, whereby on the one hand we gain the most important generalization, on the other hand an approach to progress, in that it introduces the psychophysical view of the relation between the general consciousness and its special phenomena.

¹⁾ Revision p. 284-290.

Let us first follow the phenomenon from its psychic side.

During sleep consciousness is silent; it is suddenly there with the moment of awakening, but not immediately in full strength; only gradually does man encourage himself²⁾; but the brightness of consciousness rises rapidly to a summit where, in the manner of the maxima, it remains near unchanged for a time. Gradually it sinks again and man falls asleep when he awoke.

²⁾ "In the beginning everything appears dark and confused, then more distinctly, but not yet of its real meaning: one does not immediately remember the past and yet can not quite grasp what is being said." (Burdach's Physiol. III, p. 455.)

From falling asleep, sleep deepens after a similar reverse course only, when consciousness first ascended the threshold, more and more, that is - and here lies the real thing for the expression deepening of sleep - it requires stronger and ever stronger stimuli to awaken the sleeper³⁾ until, after reaching the greatest depth, the consciousness rises again to the threshold, in order to pass on from then on to further increasing values.

³⁾ A listener of mine (Kohlschütter) pronounced the idea of using the sound pendulum described in Th. I, p. 179 to make experiments on the depth of sleep in the various epochs from falling asleep and under different circumstances, by the strength of the sound, which is necessary to wake the sleeper, can serve to measure the depth of sleep. Whether this idea will come to fruition and the attempt will not fail because of the great difficulties of establishing comparable circumstances, I leave it to one side; At any rate, one sees a principle here of dealing with the very negative nature of the depth of sleep with moderation.

It is, in order to explain the oscillation of the psychical by a physical picture, a similar oscillation as that of the sun, which rises rapidly from the horizon, the

threshold of the day, keeps for a time near the same height at noon, then descends again, sinking down to the horizon, descending deeper and deeper below it, to ascend once again to the horizons and above, after the greatest depth reached.

It may be that the ascension of the psychic sun is relatively quicker than that of the physical one, and perhaps (the time considered abscissa) the ascent is steeper than the descent, for it seems that man is the most active soon after awakening, and from there the cheerfulness only gradually, not noticeably sinks; just as the sleep seems to be deepest soon after falling asleep, and from this maximum the fall to awakening very slowly⁴⁾; However, these particularities do not concern us here, but merely the ascending and descending of the brightness of consciousness in the whole, for which the picture always keeps something interesting. By the way, the picture should prove nothing to us, but only serve to explain.

⁴⁾ Burdach almost says (Physiol. III, p. 454) "sleep is at its deepest in its beginning, gentle and calm in its progress, and least at its end." It is now easier to wake a sleeper immediately after falling asleep than after some time.

and a generalization and reinforcement of the earlier conception grows at the same time. The following discussions can help secure this fundamental view in our present case.

The state of sleep is causally related to the state of waking. The soul itself needs sleep in order to be able to wake up afterwards, and must have been sufficiently awake to sleep; yes usually the depth of sleep corresponds to the subsequent degree of merriment. Sleep can be denied for a while, or it can flee on its own when the mind is unusually tense or agitated; but then usually follows a longer and deeper sleep. It's just like a wave; the depth of sinking and the height of the rise of a wave with respect to the level correspond and condition; one can not abstract from sinking below the level as nothing; but for reasonable representation has the proportions of sinking below the level and rising above the level, to consider that as transition into negative, this as transition into positive values with respect to the zero value of the height in the level. And so sleep can not be abstracted from nothingness for the soul, and the life-oscillation of the soul can not be related to waking; but the wakefulness of the soul is the height of oscillation above, sleep the depth of oscillation below the threshold of consciousness, and if we denote the height of consciousness with positive values, then we will just as necessarily have to designate the depth of sleep with negative values.

If one were to conclude the oscillation of the psychic intensities with the waking state, and denote the intensity in the state of sleep everywhere as zero, then the life of the soul would be represented by oscillations separated in time from each other and separated by zero states of consciousness. instead of the representation of the state of sleep by negative intensities, the oscillation of the soul's life proceeds in a continuous coherent manner and in continuous relation to the bodily life to which it is tied during waking. It is undeniable that only the latter, not the former, can be found appropriate.

Let us now turn to the physical side of sleep.

The living power of our whole body appears diminished in sleep⁵⁾, Pulse and breath slow down, the temperature of the body is lowered, the excretion of urine, of carbon dioxide, of exhalation diminishes, and as regards the activities of the brain, in particular, which we have as carriers of conscious phenomena, the psychophysical activities, so it speaks The cessation of these phenomena and of all voluntary movements, even for the diminution of those activities, is further characterized by the fact that the brain sinks in sleep, which is observed in craniofacial injuries and in the cranial falcons of small children Brains flow, and the slower pulse also suggests a slower blood flow in the brain. Everywhere we see, at least to a certain extent,

⁵⁾ See u. A. on this Purkinje in Wagner's Wort. Art. Guards, Sleep, p. 426.

In short, the reduction of the physical activities which are subject to the conscious phenomena can certainly apply; but it might be wondering if this reduction does not really stop. It is true that not all brain activity stops; but those activities which by their very nature are capable of serving consciousness may possibly cease altogether the psychophysical, dreamless sleep; yes, this view may seem more natural than the time.

In the meantime, the most urgent need here is to maintain the psychophysical connection with the increase of consciousness in waking for the increasing deepening of sleep. If the psychophysical activity ceases altogether with the moment of falling asleep, the psychophysical connection with the onset of sleep is interrupted, whereas if the psychophysical activity falls asleep only to a certain limit of a threshold, the deepening of sleep increases its appearance Consciousness finds corresponding expression in the decline of psychophysical activity below this threshold. These formal needs are assisted by experiences related to waking up and falling asleep. And if they are not binding on their own,

A sleeping person can be aroused by a local stimulus of whatever kind he is and through which sensory nerves he also finds access. Shaking, stinging, poking, tickling, a drop of hot sealing wax somewhere on the skin, cold while revealing, a bang, sudden flash light, which shines through the eyelids, even unfamiliar smells⁶⁾can wake the sleeper. Equally successful is the stimulus afforded by the gradual accumulation of faeces and urine during sleep. What is the general success of such stimulants? This, that an excitement of the nervous system arises, which propagates to the brains. In the place and the manner nothing matters, as far as can be deduced from experience, but only on the strength, with consideration that a strong difference of stimuli itself represents a strong stimulus, and thus a strong reduction of a usual stimulus act no less waking can, as a strong stimulus, and even a weak stimulus⁷⁾can be easily aroused if it is suitable in waking to associate a strong arousal with itself. Otherwise every stimulus is ineffective until it exceeds a certain degree of strength, and undoubtedly causes awakening when it exceeds such as long

as man is still able to awaken at all. But a subtle stimulus will produce a less powerful effect of the same kind than that to which the awakening is linked. So it does not matter that an excitement of a special kind and a special place, but of sufficient strength, takes place somewhere and somehow in the field of psychophysical activity, so that the awakening may take place; just as it takes a certain strength of the stimulus to awaken a special sensation during awakening. But before the required strength is achieved,

6) "As it happens not infrequently that people are awakened by the burning smell of a conflagration." (Burdach, Physiol. III, p. 460.)

7) For example, the quiet stirring of a child next to the sleeping mother.

Burdach says in a sense meaningful (Physiol. III, p. 460): "If one did not hear and feel in sleep itself, but only after waking up, one could not be awakened at all." But if one heard and felt in sleep as well as in waking, there would be no difference between the time before waking up and after waking up. Now the difference can only lie in the fact that until awakening the psychophysical activity remains below the threshold at which awakening crosses the threshold. The same, however, which takes place through the successive growth of a stimulus until the appearance of awakening, must also take place in the voluntary approach to awakening, so that, at most at the moment of the greatest depth of sleep, a complete cessation of psychophysical activity is possible, if only through no circumstance is made probable.

Burdach further remarks (p. 461): "If one has fallen asleep listening to a conversation or a speech or lecture, and one is awakened, one knows the last words that were spoken before waking up, for example the last one Sentence, when it was short, but without connection with the former It is even more general that one knows what makes one awake, even though the awakening can no longer be perceived after waking up. " These are evidently facts proving a psychophysical affection during sleep, which may be analogous to that which takes place when we forget a speech in the dispersion, and afterwards remember it; which was already mentioned.

The phenomenon of falling asleep leads to the same result, only in the opposite direction. It is the easier the more all local external stimuli are held, and the less, whether by local pain or especially directed and strained attention, the conscious, nervous activity of the nervous system, or brain, locally increases the more it is and the more uniformly distributed at the same time. This can not be successful in the sense that it will become zero somewhere, but it does understand how the summit of psychophysical activity, which at the approach to falling asleep becomes more and more constricting, at last only very weakly raised above the threshold the adjustment with what is already below the threshold, even sink below the threshold and thus can fall asleep. Of course, if the wakefulness depends only on such a local increase, the distribution must of course suffice to cause it to fall asleep. In fact, in drowsiness we just do not need to focus our attention on anything special, so we really fall asleep. In

full awake, where the psychophysical activity goes up, this does not succeed if the man already distributes his attention completely in the same way, because the adjustment of the raised summit with the remainder can not bring the activity under the threshold, conversely at very deep Sleep even strong local stimuli can become insufficient to raise a point above the threshold and thus cause awakening. Of course, if the wakefulness depends only on such a local increase, the distribution must of course suffice to cause it to fall asleep. In fact, in drowsiness we just do not need to focus our attention on anything special, so we really fall asleep. In full awake, where the psychophysical activity goes up, this does not succeed if the man already distributes his attention completely in the same way, because the adjustment of the raised summit with the remainder can not bring the activity under the threshold, conversely at very deep Sleep even strong local stimuli can become insufficient to raise a point above the threshold and thus cause awakening. Of course, if the wakefulness depends only on such a local increase, the distribution must of course suffice to cause it to fall asleep. In fact, in drowsiness we just do not need to focus our attention on anything special, so we really fall asleep. In full awake, where the psychophysical activity goes up, this does not succeed if the man already distributes his attention completely in the same way, because the adjustment of the raised summit with the remainder can not bring the activity under the threshold, conversely at very deep Sleep even strong local stimuli can become insufficient to raise a point above the threshold and thus cause awakening. In fact, in drowsiness we just do not need to focus our attention on anything special, so we really fall asleep. In full awake, where the psychophysical activity goes up, this does not succeed if the man already distributes his attention completely in the same way, because the adjustment of the raised summit with the remainder can not bring the activity under the threshold, conversely at very deep Sleep even strong local stimuli can become insufficient to raise a point above the threshold and thus cause awakening. In fact, in drowsiness we just do not need to focus our attention on anything special, so we really fall asleep. In full awake, where the psychophysical activity goes up, this does not succeed if the man already distributes his attention completely in the same way, because the adjustment of the raised summit with the remainder can not bring the activity under the threshold, conversely at very deep Sleep even strong local stimuli can become insufficient to raise a point above the threshold and thus cause awakening. In fact, in drowsiness we just do not need to focus our attention on anything special, so we really fall asleep. In full awake, where the psychophysical activity goes up, this does not succeed if the man already distributes his attention completely in the same way, because the adjustment of the raised summit with the remainder can not bring the activity under the threshold, conversely at very deep Sleep even strong local stimuli can become insufficient to raise a point above the threshold and thus cause awakening.

This is then also the awakening effect of the withdrawal of usual stimuli in relation. A strong noise awakens us; but the miller awakens as well when the corridor of the mill falters, the sleeper in the church, when the preacher speaks, the child sneezed by the nurse, when the nurse ceases to sing, Who sleeps by night light Used to when the night light goes out, the driver in the car, when the car is stationary. During tiring marches, the soldiers probably even sleep while walking and wake up when they stop. Now the influence of accustomed stimuli also during waking belongs to maintaining such a uniform height and distribution of the psychophysical activity, that we do not become conscious of any sensation before the other. Something is removed from this stimulus somewhere,

All this is connected with the idea, and may be represented in connection with it only by the idea that the psychophysical activity, which is subject to our general consciousness, sinks below a threshold in sleep, without ceasing to do so. If, on the other hand, one were to maintain the view that the awakening is linked to a peculiar process in the brain, which arises at the moment of awakening, then one would have to assume that the weak stimuli which do not yet bring about the awakening are not capable of overpowering a certain obstacle, which in some way opposes the emergence of these activities, a view which we have previously explained in relation to sensations in the image of a car to be dressed and denied with facts. But maybe you take another picture to help here. Could not be, like a steam engine, where a certain amount of power is needed to turn a valve to put it into operation; until this force is reached, the machine stands still. Could the stimulus that causes the awakening not represent this turning of the valve? In fact, such a conception in itself has nothing impossible; but there are two real points in opposition to it: first, that the revival by a stimulus is not bound to any particular form and place of irritation; how it is the awakening of the activity of a steam engine by turning a valve; in which respect, in particular, the awakening by deprivation of some familiar stimulus, and the awakening even by very weak stimuli, but which are capable of associating with a strong stimulus of attention in waking would be quite incomprehensible; secondly, that as the stimulus increases beyond the point at which it causes awakening, the psychophysical activity increases further, which directly proves a functional relationship between the two, which is therefore also occasion to go below the point of awakening, whereas the force which turns the valve of a steam engine and thereby sets it in action, by its reinforcement then nothing further contributes to the strengthening of the power of the machine, so would expect no functional relationship between stimulus and psychophysical activity beyond the point of awakening, which actually exists.

If we consider what has been discussed so far, we can thereby justify the dimensional formula with a certain probability in the domain of internal psychophysics for the totality of consciousness; and if we add the more rigorous justification which it has found in the field of the external for the special phenomenon of sensation, this at the same time results in a reciprocal reinforcement and generalization of the two justifications.

In fact, sleep and waking are to be introduced after previous discussions with negative and positive values in the mental field; the boundary between the two does not occur at zero values but at finite levels of underlying physical activity. Insofar as there exists at all a function between mental activity γ and the measure of the underlying physical activity β , the function must be such that these relationships are thereby represented. It is undeniable that countless numbers of such functions can be set up; But if we allow ourselves to gain a fundamental relation of the greatest possible simplicity, as it is in the sense of the other fundamental laws of existence,

one can only by the formula $\gamma = k \log \frac{P}{P_0}$ stop. In fact, before the experience of Weber's Law was available to me, I sought in the so-called phenomena of sleep and

waking a main document of the formula, which, as I tell in the historical chapter, I am the first to look at internal psychophysics has justified. But the stricter justification will be possible only through Weber's law, with the addition of the fact of a finite threshold of stimulus.

One may ask what we do with dreams in our conception of sleep. It is undeniable that one has a kind of wakefulness in them and yet no actual wakefulness. In a sense, consciousness appears below the threshold, and in a sense, it is above it. Can a psychophysical representation be found for this?

In my opinion, however, but in order to give it, the relation of the general consciousness to its special phenomena, to which the dream-conceptions as well as the waking ideas belong, must be discussed from a general point of view, and so will be discussed only in a later chapter (42).

Not to mention, when looking at sleep, the fact remains that adequately placed pressure on the brain safely induces sleep, and the abatement of this pressure rescinds it. It is not disputed that the pressure on the brain can do nothing other than to block paths and to remove conditions on which the vital course of psychophysical activities depends, and it would be premature to conclude that natural falling asleep is also due to pressure, rather than subsidence of the brain in natural sleep speaks against it, and can arise not less by the brain's shaking than by pressure unconsciousness. After all, this artificial way of suppressing psychophysical activity is remarkable enough, and perhaps not unrelated, that sufficiently strong pressure on a nerve also interrupts the supply of a stimulus of sensation to the brain, and thus the sensation of sensation. It may indicate that the sensory and sensory processes are not substantially different. Perhaps, however, the compression of the vessels is the effective one, as far as indisputably the blood flow and the blood flow are essential for the maintenance of the psychophysical processes.

If one presses on, by means of the trephine or some injury of the skull, the place of the brain with the hand, the observed success of falling asleep occurs. According to Haller, this attempt is also successful in animals, if one presses only strongly and persistently enough. He brought dogs to snore ⁸⁾. So did Foderé ⁹⁾ in animals by a gradual and uniform pressure on the middle part of the brain anesthetic. The same success, as easily understood, has any unintentional pressure on the brain as produced by accumulated or leaked blood or blood water or pus or depressed areas of the skull. The reason of unconsciousness in the impact is usually in such circumstances. A man could be seen, whose skull was not completely ossified, so that one could squeeze his brain and bring him into a state of impact, which, however, did no harm to him (Philip in Philipp Transact, 1833) in *spina bifida* Sleep should be created by applying pressure to the spinal cord by applying pressure to the brains through the accumulated water. (Darwin's Zoon, L 410.)

⁸⁾ Haller, *elem. Physiol.* IV. 301.

⁹⁾ Magendie, Journ. III. p. 195th

XLI. Partial sleep; Attention.

Sleep is in the ordinary sense in which it has hitherto been contemplated, a phenomenon which affects the consciousness of the whole man, or otherwise the whole consciousness of man, and presupposes that nowhere is psychophysical activity raised above the threshold. But if the view of the extended seat of the soul is valid, it must be possible that the psychophysical activity, instead of suddenly sinking below the threshold, now here, now sinking below it, and thus man may partially fall asleep and watch.

This simple consequence of the view of extended soul seats finds its just as simple as direct confirmation in the experience.

Every turn of attention to a sense is to be understood as an awakening of that sense, and every turning away from it as a sinking into sleep, from which an awakening by arbitrariness or stimuli can take place, and seldom or never is all that is awake of man at all can be awake at the same time. When a person is so absorbed in reflection that he does not see and hear what is going on around him, the sphere of all outer senses sleeps as well as in real sleep. A sensory stimulus must then, just as in the case of the latter, exceed a certain strength before it awakens the sense in question, but it also awakens it as surely as the whole human being when he transcends them. Also, this sleep of the external senses, as well as the general sleep, more or less deepen,

On the other hand, in a person who is, as we say, completely an eye or an ear, not only does every other sense sleep, but also the whole sphere of the inner performance, whose psychophysical setting, according to reasons to be asserted later, is connected with that of sensuous images but it does not coincide, and the circumstances mentioned here are among the reasons for accepting it.

Not only does this change occur between the outer and inner sphere of the activity of consciousness as a whole, but also between individual parts of it.

When the man of the morning awakens, at first only one point of the whole man awakens, as at first only one point of the rising sun exceeds the horizon, the threshold of the day. And if a person falls asleep, he has for the most part already fallen asleep before he falls asleep completely. If a person, before falling asleep, still wants to focus his attention on something, then the last point oscillates alternately over and under the threshold for some time; by momentarily being raised above it by the attention, and diminishing in the case of its decline.

"Le sommeil ne s'empare pas brusquement de tout notre être, nos organes s'endorment successivement à des degrés variables: plusieurs veillent encore que

d'autres sont déjà endormis, qui s'éveilleront peut-être à leur tour quand les premiers s'endormiront.' ... 'Presque toujours la vue, c'est le sent, qui s'endort le premier Plus tard que la vue, l'ouïe s'endort De l'étude précédente sur l'état des sens dans le sommeil, il résulte, que s'ils ne s'endorment pas en même temps ni au même degré, leur réveil ne se fait pas non plus instantanément pour tous. " (Longet, traité de physiol, T. I, p.409 suiv.)

During the full awakening itself, as we have already discussed (chapter 40), man is unable to fall asleep at will, as long as he can not by arbitrary means press down too high a peak of psychophysical activity below the threshold; as which only the distribution, but not the generation obeys it; but soon to lay this summit there, now to lay it forth, to spread it out, to concentrate, and to put so soon this, now that sphere into waking, another into sleep, and the entrance of the general sleep itself by as uniform a distribution of the psychophysical Indirectly to promote activity in the previously mentioned sense. So in the wake the peak of psychophysical activity changes place, and as it rises in one place higher,

If attention is divided, the psychophysical activity which it is subject to is divided, it becomes more conscious, but the individual is apprehended and considered only with a weaker consciousness. It seems, however, that man is unable to divide this division between different sensory spheres in such a way that their sensations, at the same time, enter into consciousness as distinct, but succeed only by virtue of the alternating attention from one to the other.

After all, partial sleep differs from the general only in that it is a partial one, of which, however, some important differences depend, which make it explainable that the common name of sleep is not indifferent to both.

In general awakening, as well as falling asleep, there is a temporal change between the state of the psychophysical system below and above the threshold; in the case of the partial the threshold always remains exceeded; only a spatial change occurs between the crossing of the threshold at one place and the sinking below it at another place. It goes without saying that the awakening from the general sleep takes place without the influence of arbitrariness; as she herself sleeps, she can not effect her own awakening; whereas partial sleep arises merely from a transference of the conscious state to another place, which therefore can take place under the influence of consciousness.

The awakening from the general sleep can, of course, be effected by a sensory stimulus of every kind, the awakening of a single sensory sphere only by the stimulus adequate to it, of course, since that awakening consists only in the awakening of any of the spheres, which are awake in particular and awake through the adequate sensory stimulus.

XLII. Relationship between the general consciousness and its special phenomena.

The wave scheme. 1)

Having considered the relation between consciousness and unconsciousness in the realm of sensation as well as in the realm of general consciousness, it will now be necessary to consider both in relation to each other.

1) Revision p. 218, 243, 264, 269 ff. Psychic measurement principles p. 195, 207 ff.

Let's tie this consideration to some actual relationships.

We see an object brighter when the light-stimulus that comes from it is stronger, but we do not see it brighter as we look at it more attentively. We hear a sound as a stronger one when the sound-stimulus is stronger; but the increased attention does not give us any greater sensual strength. May we look more attentively, listen, the brightness, the sound does not seem sensually amplified. However, we feel the heightened attention as an intensified activity of our soul, but we are also well able to distinguish what is the matter of increased attention and matter of intensified sensation, and by no means at the same time as what we feel to be amplification of the first a reinforcement of the last one.

On the other hand, it is certain that in the absence of attention weak stimuli are not felt, that some attention is needed to make them noticeable at all. How, then, should not aggravating attention make anything more perceptible?

In a sense, we have the counterpart of a previously noticed paradox. When a stimulus is below the threshold, it does not produce a conscious sensation; we only need to strengthen it, so it works such; so apparently by amplifying something that does not work, an effect arises. Now we see that by amplifying something that produces an effect, there is no enhancement of the effect.

With the above, we have the following to say: we can, without content, have weak ideas with great intensity, think. The most intense reflection operates on the fadedest schemes; yes, we can strive hard to think of something we can not think of. Thus, the strength of the idea and the strength with which we think it must be differentiated in a certain sense; but the idea exists for us only in accordance with what we think, understand.

Further, while the attention directed to a sensory sphere can be intensified so much that no sense sensation awakens, if there is no sensory stimulus, a sensory stimulus can not be there and can not be amplified without stimulating attention, and either closer to the threshold bring or raise it with sufficient strength.

It is undeniable that these conditions are very difficult from the outset, and that it is difficult to find a suitable psychophysical representation for them, even if it is difficult to establish clarity in a purely psychological field where direct observation is at our disposal ; On the other hand, perhaps clarity in the psychological field is possible only with reference to a suitable psychophysical representation. In any case,

a psychophysical theory is just as likely to obtain it if it offers the possibility of a cohesive solution of these difficulties for simple basic requirements, as we see ourselves forced from the other side to these presuppositions.

The following is a first attempt at such a theory.

Essentially it is only the same principle that the psychophysical activity of man as a whole must exceed a certain strength, so that consciousness, guards take place at all, and that during awakening every special determination, whether by stimulus or spontaneously arising, determination of this activity which is capable of giving a special destiny of consciousness, must exceed a certain strength in order to become really conscious, and both, like the connection between the two, are proved by the facts already asserted.

We can at the same time explain this purely factual relationship, which in itself requires no image, by means of a picture or a schema, and at the same time shorten the presentation of the factual relations which are connected with it. Let us imagine the entire psychophysical activity of man as a wave, and the magnitude of this activity is represented by the height of this wave above a horizontal baseline or surface, to which each psychophysical point contributes an ordinate. Insofar as it is a spatially extended system, which expresses the activity, and this activity extends through time, we can apply the schema to the spatial as well as the temporal in itself, the first, by placing all in space next to each other ordinates at the same time, the latter, by placing ordinates for the successive moments in one and the same place in space, and so we can represent the connection of activities in space for many points, and their temporal succession for a point by such a scheme. But in order to connect the representation for space and time, we only have to grasp the simultaneity at once in the scheme, but to think the shape and height of the wave-train changing in time. Thus, the whole configuration and the whole course of the consciousness activity will depend on the present and following evolving form, the rise and fall, of this wave, the intensity of the consciousness at all times on their respective heights, and the height of this wave somewhere and somehow a certain limit, which we call the threshold,

This wave is called the total wave, main wave, total wave, and the associated Schwell-le the main threshold.

From experience, in so far as we can infer the sensation of sight and hearing, the activities in which our particular phenomena of consciousness hang can be represented by movements of short periods (vibrations), which intervene in a movement of long period, in which the state and The course of our consciousness in general hangs, a period that usually coincides with the day-period, as long as sleep and waking, save for contingencies, depend on it, and both periodic movements are capable, to a certain extent, of separate consideration.

Let us now represent for ourselves the movement of a long period through a wave that swings up and down gradually, depending on the general state of our cheerfulness and the direction of our attention, and changes the place of its summit, we call it the lower wave from short periods to which our particular phenomena of

consciousness hang, represented by smaller waves on the lower wave, let us call them harmonics, which intervene in the surface of the lower wave; so that the, modified by the harmonic lower shaft is the total shaft or main shaft.

The greater the magnitude of the movements of a short period (the amplitude of the oscillations), the higher the mountains will lift the waves that represent them over the lower wave, and the deeper the valleys will press into them (as the direction of their motion is equal or opposite with which the sub-wave is), elevations and subsidence, which in turn must exceed a certain limit of greatness, we call it the upper threshold, so that the special phenomenon, which is connected to it, enters into consciousness.

Nothing else is done with this scheme except graphically, as stated above in words, that the particular phenomena of consciousness depend on particular periodic forms of motion, which are to be regarded as modifications of a more general periodic form of motion, to which the general state and course of consciousness depends. and that the special activities, such as the overall activity, have their threshold.

Here we must remember that not only is our general consciousness sustained at every moment by a system of movements, but also that all phenomena which stand out as peculiar to the ground of the general consciousness, even if they appear simple to consciousness, are not to the simple moment of movement of individual parts, but to the interaction of a majority of particles and moments. (See chapter 32g)

The mathematics has a sharp expression for the composition of two waves to a resulting main wave, as we here represented by the composition of the sub-wave and its harmonic to a total wave, in the composition of corresponding periodic members with particular amplitude and period. Our scheme can be considered as the graphic representation of such a composition, thereby relieving the vagueness that would otherwise remain after multiple relationships.

More specifically, any point in the psychophysical system can be thought of as being in the movement of long and short periods at the moment when we look at the system. By pursuing this movement in a particular direction (which would not be sufficient for a complete consideration), let us imagine the resulting velocity in that direction for each point represented by an ordinate contributing to the total wave, but combining the ordinate into two one of which represents the speed of the one, the other the speed of the other movement, herewith one representing the ordinate of the lower wave, the other the ordinate of the harmonic. Depending on whether both speeds go in the same or opposite direction, the ordinate of the harmonic is to be applied to or subtracted from that of the lower harmonic, or the ordinate of the total wave must be taken as the sum or difference of the composing ordinates. If this happens for all points of the psychophysical system in a given moment, we obtain the whole shape of the main wave for this moment through the summit series of the resulting ordinates. In any case, the harmonic increases the sub-wave at certain points, even if it is thereby degraded by others, so that if we judge the height of the total-wave after the elevation of its highest points, then in the question whether and how much she ever exceeds the threshold

If one wanted to introduce the living force into this construction instead of the velocity, then the harmonics would only form wave crests without valleys on the lower wave; but the correct ratio of the components to the main shaft would be lost. With each wave, it is immaterial in terms of the representation of the general conditions, whether one introduces the speed or the living force.

If the amplitudes and periods of the composing movements, whose composition in the schema we consider, are to be regarded as constant for given conditions, then nothing prevents them from thinking variably about circumstances. Thus, assuming normal conditions, the long period of our psychophysical activity coincides with the daytime period; as guards and sleep conform to it, and the intensity of our general consciousness rises and sinks after a certain normal course; but by many circumstances the period may be lengthened and shortened, the intensity increased or diminished abnormally. There may also be circumstances which influence both movements together or only one. These relationships are not to be deduced from the schema or mathematical expression that it represents; but from the experience and the general laws of motion, and to define and interpret the schema itself afterwards. The same can prove nothing at all, but only in general want to show how, by combining reference to the fact of the two thresholds, to what is psychically related, can also find a psychophysical context, which is much easier by a coherent scheme , as is possible with abstract words, notwithstanding that everything the schema says must also be expressed in words.

The better our schema will fulfill the purpose of this explanation, if we ourselves explain it by some references to reality.

Not only the system of psychophysical movements in man, but the system of all earthly movements is subject to the day-time, in which the whole earth revolves around its axis in 24 hours. But countless parts of the earth have their special periodic movements, so the sea in its ebb and flow, the atmosphere in periodic rains and winds, the organisms in their inner cycles. But it does not prevent anything, though these parts also participate in the rotation of the earth, in particular, and to a certain extent, and to treat up to a certain extent the general periodic motion of the earth and the special periodic movements of its parts.

The rotation of the earth here represents the lower wave, the special periodic movements on earth the harmonics, what emerges from the composition of both as reality, the main wave or total wave. If we represent the velocity of each point of the earth by an ordinate, then for a given parallel circle of the earth's surface, the sub-wave represents a horizontal straight line, provided that all parts of the earth's surface have the same rotational speed apart from their special movements; but because the special movements on the earth's surface can go with or against the general rotation speed, they produce wave crests and troughs in that line.

The sea, to a certain extent, represents to us the reality of our scheme. There are waves produced by a general cause, such as wind, but on which special causes cause ripples, harmonics, which are disturbances of one independent of the perturbation

existing form, which gives the lower wave can be viewed; while the whole wave, as it is, represents the main wave or total wave.

Although such examples, taken from non-psychophysical systems, can not prove anything in themselves for psychophysical systems, they nevertheless prove possibilities grounded in the general laws of motion, from which we can no longer alienate them, to find them also realized in the psychophysical systems. and it will therefore be permissible to apply our scheme in this sense, insofar as reality shows the proper conditions.

Now our schema first and foremost represents in the most general sense the two main facts on which it was founded: 1) that the form and magnitude of particular phenomena of consciousness within consciousness depend upon the form and magnitude of particular activities which intervene in a general activity; in a sense capable of a separate view of the same.

2) That just as the awakening of the particular phenomenon requires the exceeding of a certain greatness on the part of the underlying particular activity, it is necessary for the awakening of consciousness on the part of the whole activity.

However, the representation of many of the most peculiar circumstances is connected with the representation of many special ones, which occupy us partly in earlier chapters and partly in the reception of the present one.

If the main wave is everywhere under its threshold, then we have sleep, if it is somewhere above it, then we have guards; but in waking it is never above the threshold in all parts capable of elevating above the threshold, and the degree of its elevation above the chief threshold in any particular field determines the degree of attention which is engaged in it. All the circumstances of the change of attention, which was mentioned in Chapter 41, can be summed up as a wave of the main wave.

The height of the main wave, judged by its highest points, and hence the amount of attention paid in any particular field, depends not only on the level of the harmonics nor on the sub-wave therein, but on both of them, but soon more of this, and soon more of that Be determined. When a bang suddenly gets our attention, it is the sudden rise of a harmonic, which drives up the main wave; the attention is here involuntarily determined from the sensory side; If we straighten our ears without sound, it is driven up without the existence of a harmonic in the region of hearing, only by the rising of the lower wave; irrespective of sensory determination, it is arbitrarily directed and elevated for internal reasons.

Attention is all the more involuntarily determined by the strength of the particular phenomena of consciousness, or independent of them, that is, arbitrarily, according as the elevation of the total wave depends more on a great elevation of the harmonics or the lower wave in the region concerned.

When an intense reflection with faded schemes operates, playing on a high sub-wave very weak harmonics. If, without tension on the arbitrary side of our attention, we enter into a receptive sensible sensation, then a strong harmonic wave is carried

by a comparatively lower sub-wave. But both may also be raised or sunk at the same time.

The attention in a sensory area may increase without increasing the sensation of strength, inasmuch as the main wave rises by the arbitrary elevation of the lower wave alone, whereas the sensation can not rise without raising the already alert attention, or not waking closer to awakening bring, because by increasing the harmonic, the main wave grows so well, as by increasing the lower shaft.

Just as harmonics that are low enough not to reach their own threshold, but raised high above the main threshold by the high level of the lower wave, that is, to belong to a main wave raised above, without giving their peculiar phenomena of consciousness, so can harmonic waves are high enough to exceed their own threshold, to be pressed down by the low level of the lower wave below the main threshold, ie to belong to a lower principal wave or lower part of the main wave underneath, and then for that opposite reason will not enter the conscious consciousness, but only the elevation of the main wave by sufficient increase of the lower wave need to enter.

If they belong to only one part of the main wave which is lowered below the main threshold, whereas it is above the threshold elsewhere, that is to say in the case of general waking, we have the case of the word not heard for distraction or distracted attention, merely the arbitrary increase attention needs to be listened to later, or a pain that we do not feel as long as we are able to distract attention violently, regardless of its internal cause; or the black in the closed eye or habitual eardrum, in which some persons suffer, of whom we are unaware in ordinary circumstances, but can be immediately aware of it when we arbitrarily focus attention on it.

Yet it is not the same thing whether something sensible is not grasped only because of a lack of attention, or whether it affects the sense too weakly, or not at all. That it is above its threshold (the upper threshold) always gives it a positive value in consciousness; but, while the main consciousness is not awake for it, but awake for others, it occurs as the unconscious co-determination of what the main consciousness is awake, a co-determination which, according to circumstances, can be disturbing or harmonious. Thus the sunshine, the green, the birdsong express an unconscious co-determination when the stroller goes into his thoughts; he sees and hears nothing of all this and yet feels differently, and his thought-flow will be different than when he thought in the dark room; - so on the listeners in the opera the glamor of the scene, on the spectator in the opera the music. Every intuition of things which we know through life, of a house, of a person, draws by association a multitude of other ideas which remain in the unconscious, and yet so unconsciously constitute the meaning of the house, of the person for us, which in any case merely would count as a color spot for the eye. They are attached to harmonics which are connected with the external cause raised at the summit of the main wave, but remain below the main threshold as they pass over the main threshold. which anyway would just count as a color patch for the eye. They are attached to harmonics which are connected with the external cause raised at the summit of the main wave, but remain below the main threshold as they

pass over the main threshold, which anyway would just count as a color patch for the eye. They are attached to harmonics which are connected with the external cause raised at the summit of the main wave, but remain below the main threshold as they pass over the main threshold.

From the trap we are now considering, we have to distinguish the case where the whole main-wave sinks below the threshold, but below that threshold, but harmonics on the low sub-wave play, which exceed their own threshold. This is undoubtedly the case of dreams, which, by virtue of the state of total wave below the threshold, are naturally characterized by the lack of arbitrary direction of attention, and are chiefly based on an associative evocation by one another and accidental external stimuli.¹⁾

¹⁾ See in p. 218 f.

The dream has a significant similarity with our waking life in the external world, which helps to explain that the dream does not appear to us as the play of imagining what it is, but as external reality. In the life of the imagination as opposed to the external during waking, the main wave is relatively more lifted by the lower wave than the harmonic, while living in the outer world under the influence of its stimulating, stimulating ideas, it is the other way around, and the reality is all the more so. The more it increases the harmonics in relation to the lower wave. The same thing, however, which occurs during waking by predominant rising of the harmonics, occurs in sleep by predominantly sinking the lower wave.

On the same circumstance it may be based on the fact that hallucinations, phantasms, even when fully awake, can assume the full character of reality; it will be when the harmonics to which they are attached, in abnormal circumstances, overgrow the subshaft.

In doing so, one can still cherish a double view of the nature of dreams. It may be imagined that dreams, while we have them at night, are unconscious in the same sense as a word overheard in distraction, and only later, upon awakening, like this, are consciously reproduced in memory. But one can also think, and I think it more likely, that we have already known the dreams in a similar sense during the night, as we believe to have had them in memory, and that the difference that they have in this regard of To the unconscious co-determination of consciousness during waking, only depends on the fact that there is nothing conscious, what they could have a say in, provided that everything lies under the main threshold of consciousness. But this may still be an object of doubt. To another, the dreams concerned point, which is also so far only a matter of conjecture, I come in the 44th Chapter.

In the past there has been no particular occasion to refer to a mutual or mutual dependence of the sub-wave and the harmonic, and in fact, to some extent, they are independent of each other; but only up to certain limits, and it is also necessary to consider those conditions which can only be explained by their common or mutual dependence.

When a stimulus is applied to a sensory area, the harmonic increases in it, and as the main wave increases with the rise of the harmonic, it seems sufficient to explain the attention that has been drawn to this area. But even when the stimulus ceases, attention tends to remain more or less in this area; the sleeper, awakened by a bang, seldom falls asleep immediately, and it does not appear that this can be explained solely by a persistence of the harmonics evoked by the stimulus and associated with it; but every elevation of a harmonic by a stimulus is, it seems, at the same time to be regarded as a stimulus for an elevation of the lower wave.

On the other hand, while we generally do not see the liveliness of sensations growing through increased attention, there are cases where, through a very prolonged, intense, and, so to speak, pointless, arbitrary direction of the imagination, mental images become more intense to the point of intensity sensible intuitions could be increased, and vice versa, the strong lifting of the lower shaft must be associated with an elevation of the harmonic; in the interesting experiments of H. Meyer, of which the 44th chapter will be discussed.

These are not contradictions to the previous presentation and the validity of the scheme; it will always be able to represent the conditions of independence and dependence, as far as they exist.

Much else could be explained in the scheme, which I will not go into here in detail, since such explanations are in principle nothing to promote, if they do not open new points of view or rest only on conjecture. So it makes sense to represent the formation of concepts of individual ideas or intuitions by interference of the underlying harmonics; So one could imagine that pleasure or pain arises as the lower wave is raised or depressed by the access of the harmonics as a whole and in this respect a certain limit (threshold of pleasure and displeasure) is exceeded, bearing in mind that the harmonics are indeed necessary certain points increase the lower wave, but at the same time they push the same in other parts, which may compensate, among others may not be able to compensate. But this for now only vague and perhaps incorrect guess remains open for now.

XLIII. Relationship between the sensory and mental phenomena.¹⁾

The relations between sleep and waking, and those of attention, are relations which concern consciousness in general and in general. On the other hand, sensations caused by external stimuli, their after-images and the common feelings of pain, hunger, etc., which we briefly unite under the name of sensory phenomena, appear with our memories, phantasy pictures and schemata accompanying abstract thinking, which we briefly call conceptions unite, finally, the middle links between the two classes existing in the phenomena of the sensory memory, the hallucinations and illusions, under the general concept of modifications, special determinations of total

consciousness, according to which the position of these phenomena automatically results in the schematic presentation of the preceding chapter.

¹⁾ Revision, p. 290 ff.

This depiction refers to the psychophysical basis of the phenomena of consciousness. Now, however, one may ask: are the special phenomena of the second class in general still psychophysically grounded, ie to be regarded as functionally linked to physical changes in us? Certainly some philosophers and psychologists who admit it of phenomena of the first class, the sensible phenomena, where a contradiction can not be raised, are reluctant to admit it just as much from the phenomena of the second class, the phenomenal phenomena inclined to detach the memories and phantasy pictures from the psychophysical underlay and to regard them as acts going on in the soul which, although they were inspired from the sensory side, but as they proceed in the soul, to require no bodily activity that is specifically related to it more than the function of which they function, even if they retroactively produce changes in the body and thus can not proceed without them; and by name this inclination consists in the view of the simple soul fits. For if the sensory stimuli have given their impression to this, it is only natural to give their preservation and processing essentially to the soul, whereas the view of the extended soul-seat only increases and develops the brain itself with the growing intellectual capacity It can be explained that it has to carry out special psychic achievements beyond mere sensory functions, in which the animal does not give preference to man.

Since we have no direct experience whatsoever of the inner processes, the consequence of what is established by experience must guide us, and finally the following general point of view must be decisive in this and all questions connected with it. If the connection and the consequence of the psychophysical system are not to be broken off at all, then differences in the psychical sphere, as long as they can still be translated into psychophysical differences according to the functional principle, can also be translated into it, but not interpreted as meaning. that some of them are psycho-physico-based, others are not so well-founded anymore. And so it will only be wondering whether in the proportions of the phenomena of the first and second class,

But the relationship of memories and sensory intuitions offered us from the very beginning (Chapter 36) a preferably suitable example for explaining the applicability of the principle of operation in this respect, and I think it unnecessary to discuss new or further explanations here ,

The difficulty of such a separation between the sensory and imaginative phenomena, that they have a psycho-physical justification, that they no longer have, is all the more striking when we pay attention to the transition, which manifests itself in the facts of the following chapter, that of the sensory intuitions through the persistence of the impressions, the phenomena of the so-called sensory memory, the arbitrarily generated sensory phantasms, the illusions (where external objects are only

misinterpreted), the hallucinations with or without the reproduction of earlier sense impressions (to which the delusions of madness belong) pay attention to the real memory and fantasy pictures.

What seems to be the most difficult aspect of the view that the memory images are as psychophysically grounded as the visual images is the possibility of keeping countless things in the memory and reproducing them in memory. But it is no more wonderful than the physically existing possibility of combining the skills of the most diverse handling in the same hand and changing them. Also, one must not forget that the memory, so unlimited in a certain sense, is so limited from other side. It is subject to laws of association governing the connection and sequence of the memories, and just as related skills of the hand can support and disturb disparate ones, it is the case with the memories.

To formulate the psychophysical mechanism or the organic device, by means of which the achievements required by the memory, are, of course, very premature, so long as we have barely any idea of the principle of the effect of the nerves in general, and thus of the way in which it would have to be charged. So much can only be said quite generally that the mechanism must be, if not in principle, but in the means spent, enormously more complicated and not solid, but changeable, capable of development. We see these conditions met; and much more is not required for now. But there are still some things that can be explained.

The echoes of our views in the afterimages have, according to the discussion in T. II, chap. 33c per se, a periodically regular process, the phenomena of the sensory memory, which will be discussed in the following chapter, periodically, even in irregular periods, even after a long time, figures and movements quite involuntarily back into the appearance, and would it be undeniable that they do much more, if not partly new impressions, partly the composition with the old ones limited the distinct emergence of individual periodical phenomena in this rolling sea only to the consequences of very intense, often repeated impressions. But after that, in fact, the principle of a voluntary periodic inner repetition of not only individual movements, but even sequences of movements, actually exists in us. which have been aroused in us by sensible influences, no matter what it is based on, one does not want to detach the sensory phenomena from the physical substratum; and so there is no obstacle to believe that this principle also plays a major role as one of the psychophysical foundations of our memory. In addition, it can be assumed that the principle of undisturbed coexistence and superposition of small oscillations and the related principles of interference and undisturbed intersection of waves is not out of play at the intersecting, interwoven, temporarily submerged and unconscious memories will be. When we see how all physical resources are mobilized, To enable the eye and ear to perceive separate sensory impressions, one may find it more convenient to regard the preservation and repetition of the same as a faculty of the soul without all external aids, but only to find it consistent with it if one adjusts it to one even more profound use of physical principles and remedies, whereby one does not both minimize the spiritual and elevate nature, and nothing hinders that which now develops with immanent consciousness through the conscious activity itself in every single creature

to think of the first creation of the entire organic world with such ordered. Certainly, we find the comfort of contemplation by the institutions of nature not met.

If the memory images, fantasy images, and the thought-accompanying schemata are all still psychophysically grounded, so is thinking itself, since every other material and course of thought presupposes a different material and a different way of linking the schemata, without which no thought at all can take place how a different melody and harmony can not be without other sounds and a different way of connecting the sounds. Now a piano, in its comparatively small number of fixed keys, nevertheless offers the possibility of carrying out the most varied melodies and harmonies, and so many and so high a thoughts man can grasp, 28 letters suffice to express them; in both cases, it depends only on the connection and the sequence in which the keys or letters are traversed.

XLIV. Observations and remarks on the relationship between afterimages and memory images in particular. Memory replicas, sensory memory phenomena, hallucinations, illusions, dreams.

In the following, I will put together some observation material, some of it own, some of which are foreign, about the phenomena mentioned in the title, which may provide a useful basis for theoretical views, without, however, exhausting the very broad and branching subject Chapter, but a book would belong, and without even going into more than a few very general theoretical explanations, since no longer seems to be giving for now.

a) memories and afterimages in relation to each other.

The sensory impressions, once made from the outside, persist for some time after the external stimulus ceases, as afterimages, after-sounds, generally as repercussions, which are less easy to perceive in a healthy, strong state of the senses, less intense and lasting than weak irritable; and leave behind the ability to be recollected or more or less transformed into phantasy images. All after-effects are to be considered here chiefly, if not exclusively, in the field of facial perceptions, where they are most studied; but here the validity applies more or less to other areas of sensation.

The main differences between the afterimages on the one hand, memory and fantasy images on the other hand consist in the fact that the first ones arise and exist only with a feeling of receptivity, only in continuity with the sensory impressions made, of arbitrariness and association of ideas Immediate preceding sensory impressions also of arbitrariness independently, legally, expire, while the memory and fantasy images with the feelings of lesser or greater spontaneity for some time after previous sensory influences partly involuntarily arise by imaginary association, sometimes arbitrarily elicited, again banished and modified.

These differences of distinction are related to other, but generally less decided, differences in different persons, more or less variable and transient, in which the following prevail.

In order to gain a starting point, I first present the phenomena as they are with me, which, so to speak, stand at the lower extremity of the scale through which memories of sensible phenomena, such as the afterimages, can approach. There is, however, what I have found in myself, and in which I must stop after careful and often repeated observation, by no means restoring everything to others, as will be seen from the cases given below.

In general, images of memory and fantasy always seem to me like something lacking in corporeality, something airy, breathy, the more material impression of the after-images.

Thus the drawing of the images of memory and fantasy without comparison is more indefinite, more washed-out than that of the afterimages. Clear sharp outlines I can not at all, even at the most common memory images of the objects that are in my daily eye, to get, while the afterimages occur with appropriate sharpness as directly seen objects.

Afterimages in the closed eye are either deeper black or lighter than the surrounding ground of the eye and the uniform black of the field of vision, depending on the brightness ratios of the objects being viewed to the ground on which they appeared. In contrast, souvenir pictures generally give me a weaker impression than the black itself. From white to black there is a scale of continuously graded brightness and the deepest black is the pure black of the eye. If I now wonder where this scale would lead, if I still thought it continued under the black, then I think that one is led to the indistinct impression of memory and fantasy pictures.

Colors I can not or only in a volatile, questionable bills in memory of very striking impressions reproduce the memory images of colored objects with all the effort¹⁾; while I get lively colored afterimages in the open and closed eye. Also, I never dream in colors, but all my experiences in the dream appear to me as going on in a kind of twilight or night.

¹⁾ When I think of sliced eggs on spinach, where the white, yellow and green very sharply against each other.

I am unable even for a short time to steadfastly hold even the most common memory picture, but, to look at it for a longer time, I must, so to speak, constantly regenerate it; it does not change both by itself, as it always disappears on its own. But if I want to reproduce it with consistent intention often behind each other, it soon does not succeed at all, by dulling the attention or production activity quickly. But this is not a dulling of memory activity at all; for I am - and this seems to me to be worthy of attention - not hindered, but instead immediately present another common memory picture, as clearly as it is even possible for me to imagine, and, although for

this the attention or production activity has been exhausted, to return to the first picture where I can produce it again with the initial clarity. This is true even of quite related pictures; like me For example, I often employed the experiment with two portrait figures in the same photograph or hanging portraits in my living room, none of which I can often reconstruct in memory, but both in multiple alternations. However, if I continue this change a little bit quickly in quick succession, I finally find myself dull for both pictures, but can pass to a third picture with success. I have often made the attempt with two portrait figures in the same photograph or hanging portraits in my living-room, none of which I can often reconstruct in memory, but both in multiple alternations. However, if I continue this change a little bit quickly in quick succession, I finally find myself dull for both pictures, but can pass to a third picture with success. I have often made the attempt with two portrait figures in the same photograph or hanging portraits in my living-room, none of which I can often reconstruct in memory, but both in multiple alternations. However, if I continue this change a little bit quickly in quick succession, I finally find myself dull for both pictures, but can pass to a third picture with success.

I can not transform afterimages at will. I can easily exchange memory pictures with others at will, much more gradually transforming them into others or changing them fantastically.

In no case do objects in the field of remembrance present themselves to me in other relations to one another than correspond to the forms of intuition with open eyes, and my imagination with its creations can not escape these limits. So I can not imagine a person at once *en face* and from his back, although with the idea as it were walking around him.

What was very unexpected to me, and yet I can not find any other way from repeated observations, is that it is easier for me to produce souvenir pictures with an always very slight but comparatively greater clarity with open eyes than with closed eyes; only I have to completely abstract the attention from the exterior; so that it disappears from me, something which is not difficult for me, and which is all the more easily achieved, when I cast my eyes down and direct it as if dreaming against the ground. It seems to me as if, at the very end of the eyes, the light matter lacked to weave the pictures out of it, as if the black of the eye did not give anything, and interfered more with their perception than the softness of the day.

Afterimages seem to move in the same direction when you move your head or eyes; Whether the same thing is the case with memory pictures is difficult to judge on account of its great weakness and the difficulty of keeping anything of it present at all, when at the same time making something else conscious. But it always seemed to me that z. For example, a tower, a tree, the moon in the sky, if I imagine it only (with open or closed eyes) stationary, also keep their position unchanged in the imagination while I move my head or eyes back and forth. I can not say how it deals with images of memory not intentionally fixed by imagination; they disappear with every

movement of the head or the eyes, if at the same time I want to heed whether they are moving or not moving; by not tolerating this division of attention.

The field of vision in which the afterimages are inscribed and the apparent visual field of the memory images present the following differences for the appearance. The field of afterimages with closed eyes, the black field of vision, seems to me of a very limited size, without any depth, immediately before my eyes or coinciding with the vertical plane of the same. Even if I have the afterimages of very different distant objects at the same time in the closed eye, they nevertheless appear to me as if they were on a surface next to each other and their size determined only by the angle of vision under which the objects appeared, which gave the afterimage, so that the illusion which, with open eyes, has become another nature to us, so that equally large, differently distant objects appear equally large.²⁾.

²⁾ Pogg. XLIV, 524.

In all these respects, the appearance of the field of memory and fantasy pictures behaves quite differently with me. Since we always see the objects in front of us, I am, of course, inclined to imagine the objects which I remember, rather than in front of me; but I can not only imagine her as far as I can, but also behind me, sideways, above, beneath me. At the same time or in quick succession, I can imagine a tower in front of me and a tower behind me, as well as the objects in front of me imagine each other as next to each other.

When, early in the morning, I am still in bed after dawn, and the still-open eyes close once more, the black afterimage of the white bed usually appears in front of me, and the white afterimage of the black stovepipe on the opposite, rather distant wall of the Both of them appear to me as if they were on a surface next to each other, and while I mean to see the whole length of the white bed with my eyes open, I can only imagine with my eyes closed rather narrow black stripe instead, considering the great foreshortening in which I saw the bed. Instead, the memory image reproduces the whole delusion of appearance with the eyes open.

In short, while the black field of view, with its contents of afterimages, seems to me to have only two dimensions without depth, the visual field of the memory images seems to me to have three dimensions with depth like the field of vision with open eyes. At least this is so far as I imagine a whole area, a district, a room or the like at once.

To the afterimage of a limited object, z. As a light flame, to perceive in the closed eye, I must direct attention to the black field of view of the closed eye. The afterimage occupies a definite place of this field of vision, which can not be changed arbitrarily by me, and is surrounded by it in such a way that the relations of its brightness and position to it can be immediately grasped and judged. On the other hand, in order to perceive a memory or fantasy image, I must deduct the attention from the black field in the same sense as I have to subtract it from the sphere of auditory sensations, etc., and the more I withdraw it, the more clearly it can to me a memory or fantasy picture to appear.

Sometimes, though, I seem to succeed in projecting a memory or fantasy image onto the black field of view, or, in this way, painting pictures with the imagination. But this seems to be based only on the fact that I am most inclined to search for or postpone the memory image; I am not succeeding in such a way that I could calmly become aware of the relations of the picture to the field; but in the process I feel a peculiar effort, which seems to rest on the attempt to bring into coincidence the rapid change between the field of vision of the afterimages and mental images, and I never realize a perfect outcome.

I am quite well able to conceive a greater picture of memory, which includes a plurality of distinguishable parts, or at the same time consciously conceive a plurality of coherent memory-pictures, or, in so far as a real simultaneity, a very rapid passage should give the appearance of simultaneity That which is not quite possible to differentiate strictly, to survey rapidly successively with a feeling of perfect continuity of activity, as if I remain in the same field to do. Just as with images of the past, it deals with afterimages for itself. I am also able to change very quickly between a conscious conception of afterimages and memories, but I am not in a position to

On the occasion of the (above) mentioned experience in my bedroom, I have tried to make the memory picture in which I see the bed and stovepipe behind each other, from the picture in which everything appears as if on a surface, passing it through the To try to transform the idea of it into something; and one might think that it would be even easier to create the memory image from the image than to produce it fresh. But the attempt did not succeed, but the attention had to be withdrawn entirely from the image to make the memory image with the bills of the front and back.

If we turn our attention from one sensory area to the other, then we have at the same time a definite sense of the changed direction, which can not be described, but which is easy to reproduce in every experience, which we can call the feeling of a differently located tension. We feel a forward tension in the eyes, a sideways in the ears, which grows with the degree of attention, as we fix something attentively, listen for something attentively, which is why we speak of a tension of attention itself. The clearest way to feel the difference is to change quickly with the direction of attention between eye and ear. Correspondingly different in relation to the various sense organs, the feeling,

But now I have a very analogous feeling of tension, as if I wanted to grasp something quite sharply with face or ear, if I want to visualize a memory or fantasy picture as clearly as possible; and this very analogous feeling is located very differently. While the sharpest possible conception of objective, visible objects, as well as of afterimages, the tension goes clearly forward, and when attention turns to other sensory spheres, only the direction between the outer sense organs changes, while the rest of the head is de-energized, then it withdraws in the occupation of the memory or fantasy activity, the tension, according to the feeling, quite differs from the outer sense organs, and seems rather to occupy the part of the head which the brain fills; and I want to z. B. It will become all the more vivid in front of me to

present an area or person vividly to me, not the more I draw the attention to the fore, but the more I withdraw it from the background. More about this below.

Hallucinations before falling asleep, as they have so many persons, do not occur to me; and the lively flickering of light, which I always have in my closed eye because of the morbid state of my eyes, never turns into definite figures, nor can I shape it through imaginative activity.

After all, the memory and fantasy images in my mind appear in a, as it seems in other rare, weakness, even if I still so much strain the memory and fantasy, while afterimage with great ease and intensity, often annoying, adjust with me; and I have no reason to regard my sense of color with open eyes as less developed than that of other persons.

Where possible even more difficult than in the field of the sense of sight I produce memories in the field of other senses. Thus I am even less able to reproduce in my memory the sound of the voice of my wife or of other persons with whom I deal daily, with any distinctness, than her face, even if I recognize the same persons when they really hear their voices Darkness among thousands would recognize. I can not manage the reproduction with smell and taste sensations. However, I can often remember simple melodies after listening to them and relieve the memory of them by singing softly or by gently moving the larynx as if I were singing. The local feeling of reflection on sensations in sensory areas other than that of the face seems to me to correspond to the local feelings in it; However, I think some rushing music in the memory more like listening with my ears.

So far first your own observations. With these I found the perceptions of others, which led me to introspection, generally the more consistent the more they agreed with me in the weakness of the memory and fantasy pictures, but I easily noted the two facts that the vivacity of these pictures The more these phenomena approach sensuous phenomena than the after-images in strength, the more the other differences in them appear, so that finally only the essential difference between spontaneous and non-spontaneous generation is lost and change between the two seems to be left over.

It would be of interest to work on this subject statistically, and I regret to have neglected the formerly really intended such persecution of the object over other objects, so that at present there is no such extensive material for comparison as I desired , Perhaps, however, there would not be much more to learn from a greater number of cases than from the relatively few to be communicated, which I have collected lately. Incidentally, it is obvious that it is difficult at all to obtain accurate, reliable information in this area, since it is difficult to give such information and to find only the right expressions. A careful and repeated self-observation with self-deception, and a certain question, if one requires information from others, with caution, not to put them in the mouth answers, it is assumed. In addition, an objective guarantee that one has been correctly understood and correctly understood when interrogated by others, and that quite comparable circumstances of internal observation have taken place, will scarcely be given in regard to many points.

It is undeniable that in the last analysis it is necessary to refer to comparable objects of memory in order to be able to expect comparable answers without my being able to hold on to certain objects. Only one has to distinguish whether they are familiar or not familiar memories, limited memory pictures, such as a rose, a face, a tower, which I usually use as examples, or unrestricted, as from a whole area, and whether the memories are won by using this or that association means. In order not to start with complications, it seems expedient for me, for the time being, to exclude memories of intuitions that have been obtained with the help of one's own activity, whose memory then associates with that of the viewed object, as if the painter is painting, a walker by the area he imagines, walking thinking. Incidentally, a further continuation of these observations would probably still lead to many considerations and distinctions that must be made, and in this first attempt to subject this field to closer scrutiny have not yet presented themselves.

I will now first tell the specific details of some more or less extensively questioned by me people, then notice some general about the subject. Hopefully one will not regret too much the space these communications occupy; since details about the behavior of the phenomena in different people are the only way that can lead to anything at all, and so far was almost completely lacking in this experience document. For almost only the cases in which the memory images approach or pass into hallucinations have attracted attention so far; but it is indisputable that, first of all, it is first necessary to see how the phenomena behave in normal cases.

The following cases are arranged according to the ascending degree of the approach to sensible phenomena which they seem to me to have according to the description.

1) Ch. H. Weisse, Professor of Philosophy, with me at the same age (59 years), seems to be on a very similar level with regard to the memory pictures as I am, because he can produce as little clear color or drawing on it, When he closes his eyes, just as I do not have a purely black field of vision, he has all kinds of colorless light in them, but from this, the longer he keeps his eyes closed, weaving the more shaped phantoms, which is not the case with me is. In order to observe it, he must direct his attention quite as though he wants to look at external objects with his eyes open; in this regard, they (like the flickering of light in my case) completely represent his position; whereas he, in order to get memories, just like me,

2) AW Volkmann, professor of anatomy and physiology, also 59 years old, can also produce only "extremely weak and indistinct memory images", both in form and color, but the degree of distinctness seems to vary noticeably without him to indicate the circumstances in which this depends. Before falling asleep, he has frequently, but in very different distinctness, the well-known hallucinations, "under circumstances so clear that the phantasy pictures are hardly inferior to the objective pictures in clearness of the contours and intensities of the colors", no less in the dream areas and others Objects with colors³⁾, On the other hand, he does not easily see afterimage and usually has a completely black (if completely light dust-free?) Field of vision at the end of his eyes. In the attempt to capture images of the memory, they disappear

periodically, or, as he would rather express themselves, "periodically become a mere thought-thing." The location of the memory image in absolute space varies with the position of the eyes, so that he the memory picture imagines also up while raising the eyes⁴⁾. He can only imagine the memory pictures in front of him. He finds no significant difference in the ease of generating the memory images in the open and closed eye. If it is intended to produce souvenir images with the eye closed, it must concentrate the attention in the memory image so that it "loses its clarity about the sensation of the black field of vision", and it does not succeed in painting a single memory image into the black field of vision. that it seems to be surrounded by it, as is the case with an image. However, the simultaneous conception of a memory image and an afterimage seems to him to be possible if the sensations of the afterimage and memory image do not alternate so rapidly that they are thought to exist at the same time. in the same way, "remembering what he has heard seems to exert an effort on his head, and the local feeling of the memories of the visible and the audible about the same." The feeling in the head with strained meditation "resembles an inner pressure." in the same way, "remembering what he has heard seems to exert an effort on his head, and the local feeling of the memories of the visible and the audible about the same." The feeling in the head with strained meditation "resembles an inner pressure."

³⁾ To this the following remark: "In my dreams, I think, the auditory perceptions are constantly more vivid than the colors I can not remember odor dreams I certainly never have taste dreams I eat in the dream not infrequently, but always without taste sensation. "

⁴⁾ It has been neglected to ask whether this is still the case when he purposely imagines the object of memory as stationary during the movements of the eyes or the head.

3) W. Hankel, professor of physics, 46 years old, remembers that as a boy he was able to produce memory images arbitrarily with sensual liveliness, as if he saw them with eyes, and could modify these images; but this is not the case anymore. But still he is able to clearly imagine objects with their colors (for example the color spectrum) and their shape; but no longer with the character of sensual phenomena, no more than if he saw them with eyes. He can not speak of a definite place where he has appeared to him, or state a certain relation of the same to the black field of vision with his eyes closed, from which he must, in producing a memory picture, abstract his attention as well as from external objects. He also can not paint memory pictures in the black field of vision so that they seem to be surrounded by them like afterimages. He does not see any afterimages as difficult, has no hallucinations before falling asleep, but in dreams he has many dreams. His field of vision, with his eyes closed in the dark, is pure black, only with the dome of light, which is probably normal everywhere, but with no particular attention paid to it. On the whole he produces easier memories with open eyes than closed eyes. He can hold on to them

without involuntary changes, with the attention, as if naturally, becoming dull. He can imagine a tower just as easily behind him as in front of him, a color spectrum easier in front of him than behind him. Whether the memory images move with the movement of the head and the eyes, seemed to him difficult to decide. The generation of memory images seems to him accompanied by a sense of intention located behind the forehead; this feeling, however, when lying on melodies, lies farther backwards than when thinking of the visible. The exertion of feeling in reflection seems to him more expansive, than contrasting.

4) MW Drobisch, Professor of Mathematics and Philosophy, several years younger than me, creates slightly colored memory images of colored objects, while he does not easily succeed in obtaining a firm definite drawing of them or steadily capturing the images, since rather the imagination does so to say soon. In dreams, he sometimes sees areas of oriental splendor. Even after-images appear to him very light, so that at the end of his eyes (of which the left one is paralyzed in the eyesight) they tend to fulfill his field of vision for a while; but finally leave the same thing empty. Before going to sleep, he often has the familiar facial hallucinations. He does not want to decide whether he will make the memory pictures easier with his eyes open or closed. In order to produce souvenir pictures at the end of the eyes, he must turn his attention away from the black field of vision, can not project the pictures onto it, nor can he take pictures with afterimages at the same time. The visual fields of the memory and afterimages seem to him different and the black of the eye disappears from his consciousness while he deals with visible objects. Yet, as if he needed his eyes when looking at common memory pictures, he does not seem to be thinking about the head behind them; just as he remembers common impressions of hearing, as he does from the use of his ears, when he remembers the taste and the taste of the tongue. However, in order to make an unfamiliar memory picture clear, he feels the effort behind his eyes rather than in his eyes. In the sensation of pondering, as if he were about to break his head over something, he has not both (like me) a sense of contraction of the scalp, but as if the head were to be shattered from within, and the skull to the pressure of the inside Resisted. He creates memories in areas other than the face just as easily as in the self.

Regarding the specific question of whether the memory images seem to move with his head and eyes, he explained to me after my request for closer written record as follows:

Precisely because the image in relation to my body, or at least the head and the eyes in particular, does not change its position, I can not say that I observed a movement of the picture, but I come to accept such a movement only by reflection I realize that the position of my eyes and my body has become different. Imagine - walking down the window -: "" the church is behind you, while the Thomasturm is in front of you "", so I can "" behind me "" when I realize that the position of my eyes and my body has become different. Imagine - walking down the window -: "" the church is behind you, while the Thomasturm is in front of you "", so I can "" behind me "" when I realize that the position of my eyes and my body has become different. Imagine - walking down the window -: "" the church is behind you, while the Thomasturm is in

front of you "", so I can "" behind me "" indeed, but not at once with the "" in front of me "", but it is as if I have to look around for this purpose.

5) My own, many times asked by me, wife, Clara Maria, sister of Prof. Volkmann, 51 years old, with in every respect very sharp and sound senses, and of very lively memory, can reproduce in the clearest color and shape of the objects in memory, even in dream sometimes sees regions in colors and sunshine, other times only nights, like gray in gray, and has Not infrequently, the familiar hallucinations fall asleep, whereas they know nothing of occasional afterimages, and these are very difficult to obtain even in deliberate attempts. The field of vision with eyes closed is pure black, only with the sparingly sparse light dust normally scattered. It can hold pictures of memories with constant attention, without them disappearing, fluctuating, changing. With movements of the head, her memory pictures, when she thinks of them as fixed, seem not to move at all, but to be the case if it does not fix it with the imagination. She sees the souvenir pictures more vividly with closed eyes than with open ones. She can draw individual memory images, such as that of a rose, into the black of the closed eye, so that they seem to be surrounded by it, but this takes much more effort than producing the memory image independently of it, but rather the inner head when the eyes seem to be working. Although the images generally seem to hover before her eyes, she can present them backwards and sideways, but with a certain difficulty, but she feels as if she must turn around, or rather turns her eyes away, an utterance, which she did independently of Drobisch and without being led to. If she imagines a whole area with her eyes closed, she thinks she sees them in colors with background and foreground, as in reality, with the black of the eye completely disappearing, but it is as if she were the same more by means of an action of the whole interior of the head as the eyes see. The feeling of exertion, when she wants to reflect on something, seems to her to be a feeling of contraction, it seems, very similar to mine, without my statement having preceded it. Even impressions of the ear, such as the sound of a known person's voice, floral odors, taste sensations, can easily and clearly be remembered. A violet smell, a clove smell eg

6) dr. M. Busch, 39 years old, known as a traveler, author of various travel books, which are characterized by vividness of the descriptions, and editor of the border messenger, sees light and vivid memory images with clear outlines and in their full colors, but knew nothing of afterimages, dreams Although rare, but lively, it also sees colors in dreams, never has hallucinations before falling asleep, and at the end of the eyes a dark, uniform, somewhat bluish field of vision. He can also capture clear memories with consistency. In repeated experiments he finds that the memory pictures follow the movements of the eye and head; asked, however, whether this still takes place when he purposely presents the objects of memory as fixed, he thinks, that they then stay firm. He directs the attention in common memory images of visible objects with his eyes closed, almost on the black field of view, painted with ease limited memory pictures in color and in solid contours, so that they seem to surround it or imagine a whole area in front of the eyes, feel the activity, with whom he sees them, as in the eyes, not in the brains; It is the same with memories of what he has heard, which he is no less able to reproduce than what he has seen, than when

he needed his ear to do so. However, as with Drobisch, this feeling, as if he needed the outer sense organs in memories, takes place only insofar as he imagines familiar memory images, whereas in the process of pondering, In order to bring together an unaccustomed memory picture, the brain seems to operate rather than the eyes, until the picture is in full clarity where it behaves like the others. The exertion of feeling in contemplation is a contractive one, like contraction of the scalp.

Busch is also able, from his fourth year of life, to visualize with utmost clarity the domestic furnishings and persons of his surroundings ; however, during the school years and university years he has not been left with such clear memories. Strange that a double dose of hashish, which he ate on his oriental journey, did not strike him, did not make him fantasize. Nor did etherification succeed despite a relatively long inhalation of tooth surgery. Consciousness and pain remained.

In the last of the cases reported here, the memory images of both their liveliness and other circumstances are already very close to the sensory phenomena. But the rapprochement can go even further; and to complete the climax. I share some examples of the type with other authors ⁵⁾.

⁵⁾ The following small compilation, with the exception of the one communicated by Brierre de B., is from J. Miiller, on phant. Ges. (P. 27. 82) borrowed.

Goethe says in s. Contributions to morphology and science:

"I have the gift, when I close my eyes and, with my head down, think of a flower in the middle of the organ of vision, it does not remain for a moment in its first form, but it unfolds and new flowers unfold from within They are not natural flowers, but fantastic, but regular, like the rosettes of the sculptors. It is impossible to fix the emerging creation, however, it lasts as long as I like, does not tire and It does not increase, and I can do the same when I think of the ornament of a brightly colored disc, which then also constantly changes from the middle to the periphery, just like the kaleidoscopes. "

Cardanus (*de varietate rer libii VIII*, pp. 160 seq., *De subtilitate XVIII*, p. 519 seq.) Tells of himself that he has brilliantly imagined what he wanted. - Gruithuisen (Anthropol., § 449) tells the story of a man who, in his youth, was able to picture his father brilliantly, which he later succeeded less well. J. Miiller (Phant, Ges., § 117, p. 149) commemorates a painter H., who often succeeded in seeing what he imagined in the dark field of vision as luminous and colorful. The arbitrary phantasms developed and immediately changed without any determination of will.

Brierre de Boismont (*Des halluc*, p. 39) states the following fait:

"On peintre, qui avait hérité en grande partie de la clientèle du célèbre sir José Reynolds, et se croyait d'un talent supérieur au sien, était si occupé qu'il m'avoua, dit Wigan, avoir peint dans une année 300 portraits grands et petits. Ca fait paraît

physiquement impossible; mais le secret de sa rapidité et de son étonnant succès était celui-ci; il n'avait besoin que d'une séance pour représenter le modèle. Je le vis exécuter sous mes yeux en moins de huit heures le portrait en miniature d'un Monsieur que je connaissais beaucoup; il fut fait avec le plus grand soin et d'une ressemblance parfaite.

Depending on the thunder quelques détails of the son procédé, voici ce qu'il me répondit: "Lorsqu'un modèle se présentait, je le regardais attentivement pendant une demi-heure, esquissant de temps en temps sur la toile. J'avais pas besoin d'une plus longue séance, J'enlevais la toile et je passais à une autre personne, Lorsque je voulais continuer le premier portrait, *je prenais l'homme dans mon esprit, je le mettais sur la chaise, où je l'apercevais aussi distinctement que si il y eût été en réalité*: et je puis même ajouter avec of the form et des couleurs plus arrêtées et plus vives travail pour examiner la pose, absolument comme si l'original eût été devant moi; *toutes les fois que je jetais les yeux sur la chaise, je voyais l'homme.*"

Gradually, this painter came to confuse his fantasy with reality, fell into a thirty-year mental illness, of which he was finally made, after which his memory and painting talent was still almost unimpaired. But he died soon afterwards.

Some other related examples are reported by Brierre de B. p. 58 f. and 479 of his work.

Especially carefully has H. Meyer in s. He describes the description of the sensory phantasms which he himself observed, and I share his description here in particular, because it derives from an exact observer and takes more careful consideration of the special conditions of their production rather than she does not seem very well known.

but without thinking of a particular person, I saw the borderline of a profile shining in the black ground of darkness; Thus, when I tried to imitate Darwin's experiment (Zoonomy, I, p. 378), only the edges of the cube appeared as luminous lines in the dark ground, but several times I saw the cube really white and its edges black, it was then in a lighter ground; I could even see at random a white cube with black edges in a lighter field and a black cube with white edges in a darker field and can do this any moment. After a long exercise, the experiments are more complete and better. I can now see almost every object I want as a subjective phenomenon, in its natural color and lighting. So I have already called objects of various kinds before my eyes. I always see them on a more or less light or dark, mostly dusky, reason. Even familiar faces I have seen in all liveliness with the color of the cheeks and hair very sharp. From the results of these experiments I have to note the following:

1) Some time after the creation, the figures disappear or change into others, without my being able to prevent it.

2) If the color does not belong to an object, then I do not always have it completely in my power. A face seems to me z. For example, never blue, but always in its natural color; on the contrary, instead of the imaginary red cloth, a few times may appear blue; in fact, the production of a particular color is more difficult than a certain shape, and the first I did not succeed in my initial attempts, since I was the last succeeded.

3) I have succeeded in seeing pure colors without objects, and then they filled out the entire visual field.

4) I often do not see objects which are not known to me, that is, mere phantasy pictures, and instead of them appear familiar objects of the same kind; so I wanted z. For example, once we saw a sword handle of brass with a brass basket, but instead saw the picture of a rapper basket that is more familiar to me.

5) Most of these subjective appearances, especially when they were light, leave behind afterimages when the eyes are quickly opened during the appearance of the apparition; so I thought z. A silver stirrup, and after looking at it for a while I opened my eyes and saw for a long time the dark afterimage of it.

The best way to do this is to try the exercises in a supine position with my eyes closed; Noise may not be around me, because it would prevent the view to the necessary intensity from being increased. The experiments are now so easy for me, that I must be surprised that they did not succeed me at the beginning, and that I think that everyone must be able to do so as well. The main thing is to make the intuition intense enough by paying attention to the same and removing all disturbance. "

The previously mentioned concerned facial perceptions. Meyer also made experiments to produce, by the power of attention, auditory, olfactory, taste sensations, which would be equal to the sensuous in strength and character. This did not succeed here, but with sensations on the skin, about which he communicates the following:

"On the skin I easily succeed in producing subjective feelings at which point I want to, but because prolonged conversation of intuition is necessary, I can only arouse sensations that last for a long time, such as warmth, coolness, pressure; On the other hand, I am unable to elicit rapid passing, as from a sting, cuts, blows, etc., because I fail to awaken the corresponding intuitions so abruptly in the proper intensity. "The first-mentioned sensations, however, can be quite well on any part of the skin excite them, and they can become so vivid that I, whether I like it or not, have to stroke over the skin with my hand, as is customary in cases of local skin irritation. "

That, incidentally, under favorable circumstances even severe pain can be produced by a very lively idea, the following case, also reported by Meyer, speaks in favor of this:

"An educated man of the merchant class once told me (Meyer) that one day, on his way home, he was frightened by one of his little children, who, just as he entered, squeezed a finger between the door, and in the moment of terror he had felt a sharp pain at the corresponding spot on the same finger of his own body and that pain did not leave him for 3 days. "

After that I turn to some general remarks. Lotze⁶⁾ Quite simply calls the color conceptions produced by memory absolutely colorless, and to me, like Weisse and Volkmann, they appear to be pretty much the same; but not only the other persons, whose information I have specifically communicated before, but by far the largest majority of the many persons whom I have occasionally asked about this particular

circumstance, most assuredly assured to clearly reproduce the colors of the objects in memory can. Some described the vibrancy of the colors of their memory pictures. For example, from the rainbow, the flowers, a sunlit area, even with vivacious colors and did not want to believe that one can not reproduce such in memory. Yes, I was repeatedly vividly regretted

6) In his article Soul in Wagner's Wortb. P. 169.

Most likely, the greater or lesser ability to create distinct memory images is related from one side to the habit of conditioning, occupation, and living, to focus more on the outside world or to abstract it from the outside world, and at least that is strikingly striking for Lotze⁷⁾, Whites and myself too. I must confess that I usually need to be especially stimulated or excited to see and hear what is going on around me, and sometimes, after walks, I did not know for certain which of two very different paths I went. Hankel, on the other hand, who has so much more vivid memories than I am used to keenly eyeing the external things, and even if he is completely preoccupied with his subject during his lectures, nothing escapes him in his audience. Busch, in whom among the persons whom I have asked, the memory pictures betray the strongest approximation to sensible phenomena, says for himself that the tendency, on his travels, to faithfully grasp the objects and clearly for a reproduction, may, it seems, be As early as in his youth, he was able to refresh his memory of external objects, which he had learned by studying but had not been used to. It is also a good thing that women, whose attention to the outside world as a whole is much more attuned than men, as many as I have asked them, can easily produce clear and colorful memories. However, Volkmann writes to me, which seems to me not without interest, that in his wife the deliberately produced memory pictures are very indistinct and pale, while sometimes they come to the soul with an almost frightening vivacity, so the image of a distant daughter during the performance of female works in highest clarity on form and color. Memory of external objects could have been refreshed. It is also a good thing that women, whose attention to the outside world as a whole is much more attuned than men, as many as I have asked them, can easily produce clear and colorful memories. However, Volkmann writes to me, which seems to me not without interest, that in his wife the deliberately produced memory pictures are very indistinct and pale, while sometimes they come to the soul with an almost frightening vivacity, so the image of a distant daughter during the performance of female works in highest clarity on form and color. Memory of external objects could have been refreshed. It is also a good thing that women, whose attention to the outside world as a whole is much more attuned than men, as many as I have asked them, can easily produce clear and colorful memories. However, Volkmann writes to me, which seems to me not without interest, that in his wife the deliberately produced memory pictures are very indistinct and pale, while sometimes they come to the soul with an almost frightening vivacity, so the image of a distant daughter during the performance of female works in highest clarity on form and color. easily create clear and colorful memories. However, Volkmann writes to me, which seems to me not without interest, that in his wife the deliberately produced memory pictures are very indistinct and pale, while sometimes they come to the soul with an almost frightening vivacity, so

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7) According to the brief information in s. Article Soul in Wagner's Wortb.

In the meantime, the tendency to reflect on external things may possibly be reversed by the ease with which they are internally reproduced; and it is common ground that not everything can get used to habituation, but that there must also be innate differences in productivity in this field. The weakness of the images of memory in Volkmann, which almost corresponds to mine, is not connected with any correspondingly one-sided abstraction of the outer world, even if I believe that the turning inward outweighs it; and Drobisch's profession, which is similar to mine, would not be expected to produce so much livelier memories, even though he undoubtedly abstracts less from the outside world than I do.

The example of Hankel's and Busch's, as well as the examples which J. Muller (g., GS 45. 82) cites from himself and after Gruithuisen from another, invariably require to be investigated, if not in children who, like women are preferably turned to the outside world, the memory and fantasy images are on average more lively than in adults; but it will usually be difficult to make reliable comparisons after remembering yourself and gaining certain information from children.

The difference between remembering images more easily with open or closed eyes is also likely to depend substantially on the ability to abstract attention from the outside world. Where this is difficult, the external things will always be disturbing; Where it is easy to succeed-and this may be different even in the same individual-the general excitement of light, or perhaps the habit of seeing things only with our eyes open, may be more favorable than detrimental. Women generally seem to be more comfortable at producing closed-mouth memories than closed eyes; at least three others, whom I asked about except my wife, at least explained themselves by very casual observation, in the same sense. Prof. Ed.

The different behavior of different persons in this respect reminds us that in some people, too, hallucinations are more likely to occur in open than closed eyes, while in others it is reversed (see below).

To the greater or lesser ease of the emergence of afterimages, the ease of producing memory images seems quite unrelated. Drobisch and me z. For example, both see very easily afterimage, but while in him the memory images are lively, they are quite weak for me, Incidentally, it is well known in afterimages to distinguish the duration of predominantly dependent first duration positive phase, and of blunting predominantly dependent second negative phase and It would require further investigation, whether perhaps different individuals differ with regard to the

relationship between the two phases, according to which the relationship of the memory images to the afterimages with respect to both phases would then have to be specially examined.

The question of how memory images behave in movements of the head and the eyes seems to be answered only with regard to the particular circumstances of their generation and consideration. If one imagines them stationary in the movement, they also appear according to Busch's and my wife's statements, and as it seems to me, to stand firm; on the other hand, if one does not imagine them intentionally, they seem, because of their natural inclination, to think them before them, and not to change their position in space with the position of the head and the eyes, as they most certainly do from Drobisch's data emerges.

It is important to remember the behavior of the involuntary hallucinations. J. Müller ⁸⁾ *says of the involuntary hallucinations before falling asleep and otherwise at the end of the eyes, which are described in more detail below: "Even with my eyes closed, I have never been able to move them with my eyes like the dazzling pictures." He emphasizes (p.38) their difference in this respect from the dazzling images (ie afterimages after intensive light imprints) by saying: "The dazzling images change their relative positional relation to our own physicality with the movement of the eyes, the fantastic pictures With all the movement of the closed eyes, they maintain a stable place in relation to our own space, if they do not move for internal reasons of their spatiality. "*

⁸⁾ On Fantastic Ges. ES 35.

As a rule, when it is weak or strong in the area of the sense of sight, memory also seems to behave accordingly in the other senses; at least I have yet to find any exception in this respect; but there will probably be such; and, in particular, artists in the various subjects, and in general, those who deal with a certain one-sidedness with objects whose conception belongs to a particular sense-sphere, must be questioned; for which I have missed the opportunity so far. In general, I took other sensory areas into account only casually and above; and it would be z. B. in relation to auditory sensations first be examined whether a good memory z. B.

The distension of attention in the use of the various sensory organs seems to me to be but a muscular feeling, involuntarily, by the use of the senses, involuntarily putting into action, by means of a kind of reflex, the muscles related to the various sensory organs in the use of the senses. One may then ask, to the contraction of which muscles the feeling of tension of attention should be linked with the strained contemplation? My feeling about this gives me very definite information; I do not seem to regard it as a feeling of tension inside the skull, but as a tension of the scalp with a contraction of the scalp and an outward-inward pressure on the whole skull, indisputably produced by a contraction of the muscles of the scalp, which harmonizes very well with the printout, breaking his head, taking his head together. In an earlier morbid state, in which I could not bear the slightest lasting reflection, and no theory

could even determine me, the muscular sensations felt clearly in the scalp, especially the back of the head, assumed a morbid character in every attempt at reflection.

Like me, Busch, my wife, as well as Rüte and a few others whom I have interviewed, found the feeling of contemplation contractive; however, Drobisch and Hankel are expansive. This difference is remarkable and may well be further explored.

I will discuss some of the more general considerations in section e), and now turn to various phenomena that are, in a sense, transitional elements between after-images and memory-pictures, approaching one or the other from one side or circumstances.

b) memory replicas.

In depicting the phenomena of memory, I have hitherto diligently abstracted them from a mode of production according to which they also present themselves to those which, as Volkmann and I, otherwise can only extremely weakly produce, with comparatively distinct forms and colors; a mode of production which simply consists of producing the memory image immediately after momentarily looking at an object. Persons, of course, who very easily produce souvenirs, find no particular advantage from this fresh production of them; for Drobisch, like my wife, declared that they could produce the familiar memory images of objects that had not been seen shortly before, at least as easily and clearly as after a fresh short view; on the other hand, as with Volkmann, the advantage of fresh intuition is very noticeable and probably just the same with anyone who is difficult to produce clear memories. Hankel, too, recognized the advantage of fresh production, and it seems to me not without interest to communicate something more about the sometimes peculiar circumstances of these memory images, which for the sake of brevity I will call memory mementoes. I give them this name because, like the afterimages, they are immediately grasped according to the intuition of the objects, and approach them in clearness; indeed, they seem to coincide with such persons in some persons, but they do so as they do to me, Volkmann, and Hankel 'n represent, carry all the essential characters of the souvenir pictures.

I get a souvenir replica when I look at any object, light or dark, colored or not colored, momentarily sharp, then immediately close or turn away the eyes, which latter I find even more advantageous than the first, and immediately, preferably even during the closing of the eye or the turning away, the memory activity in the otherwise ordinary way in force. I then see the picture quite clearly for a moment with the drawing and even the color of the object being viewed, as I have never been able to obtain from objects that I have seen a long time ago; it only quickly extinguishes its definiteness and color and makes room for the usual indistinctness.

It is indisputable that from the outset one will be inclined to see nothing but an ordinary after-duration afterimage, and I myself had this opinion after the first superficial attempts. But there are four circumstances in which such a reminiscence of memory differs in an equally striking manner from ordinary after-images, and equates to the only weaker, actual images of memory, as I otherwise receive from previously seen objects.

1) Afterimages are formed, even if one has focused the attention on the object or not (see chapter 38). In order to receive a souvenir replica, however, just as in order to obtain a common memory image, I must first have focused my attention on the object in question. The more sharply I draw attention to the object as I look at it, the more clearly the memory image can appear afterward; Therefore, I am not able to obtain a clear memory copy of a whole region at once, but only of limited objects, such as a human, a flower, whereby I can reproduce nothing of the surroundings of the object in the memory image, if I do not pay attention to the next environment with extended;

2) If, after looking at an object in ordinary daylight, I focus my attention on the black field of vision with my eyes closed, or on open objective reason, and what I see is merely receptive to what the conditions are I do not see anything under which an afterimage can appear to me; rather, in order for the memory-replica to appear, I must turn my attention away from the external senses and actively call forth the image inwardly, as if I wanted to evoke a common memory. Also, I see it all the more clearly, the more I strain the memory activity in the usual way. Involuntarily, I stretch the scalp, as I usually do in strained meditation (see above).

Further, when the memory-image has become extinct or indistinct, which remarkably happens quickly, I can revive it repeatedly, if with diminishing clarity, by letting the memory of memory, which is always self-defeating, make a new effort.

3) While an actual afterimage seems to me to be more distinct and intense to a certain extent, the longer and more steadily I have fixed the object, strangely, I find just the opposite in the memory imitation. They seem most obvious to me when I have only glanced at the subject matter in a quick but attentive manner, and it seems to me as if, for a long time, the stimulus for the attention necessary for the creation of the memory image is dulled , on the other hand, the freshest on the shortest.

This may be related to the fact that, if I have a souvenir replica z. For example, from a man who chops wood or advances quickly, waking it up to me in the attitude of a moving (as the sculptor would portray the human being), yet not truly moving, focusing on the moment of the keenest attention for the appearance of the picture seems. But this experience is not entirely unambiguous, because the look at the object may be only briefly with me, I should get clearly the memory Nachbild, in which short time no large movement can be accomplished, a full clearness of the picture also does not take place.

Occasionally it may be remembered that even if the disc of the thaumatrop, on one side of it, for example, has a thaumatop. For example, a bird on which a cage is painted, quickly rotated about its diameter by means of the ax-thread twisted between the fingers, and cage and bird successively presented to the eye in all possible foreshortenings, but the bird seems to be sitting in the cage, as if of the infinite many phenomena only one (which seems to me to be somewhat shortened on the whole) comes into its own. However, this probably depends on the fact that when moving through the position where the facial ray is perpendicular to the disk, the phenomenon changes the slowest.

4) The afterimages that I receive from non-self-luminous objects in ordinary daylight, for example, If, for example, a colored object fixates for a certain time, then turns the view to a white ground or pushes it forward, the object presents itself not in its own color, but in the complementary color, since the duration of the primary impression is too short to be noticed while the memory replicas always render the object in its own color without complementary echo.

After past differences, however, I have to remember a point in which the memory replica conspicuously follows the actual image. If the memory emblem seen with open eyes is extinguished for me, and I maintain the intention to see it, always in the same direction (which is essential to success), but without reinforcing it anew, it is enough to have it momentarily momentarilly revive weakly, as if I strengthened the intention; an attempt that I can often repeat behind each other. I have in Pogg that even with after-images this means of revival works. XLIV, cited 528; in the case of souvenirs of previously seen objects, however, the ophthalmic supplement does not help me to revive it. Incidentally, it is not the darkening of the field of vision caused by the eye which causes revival in the memory replicas; for the sudden opening of the eyes, or violent sideways turning of the eyes, does the same, but indisputably only an inward propagating excitation, given by the motion.

Volkmann, to whom I have communicated these experiences about the memory replicas⁹, writes to me that he finds them thoroughly confirmed; only he notices that, contrary to the statement made under 4) concerning the ordinary afterimages (obtained by prolonged fixation), these initials, before the transition to the complementary color, also appeared to him in the primary color, and indeed this may vary according to the Individuality be different.

9) With the exception of what I added after some later observations about the success of the supplement surcharge.

Under ordinary circumstances, a momentarily looking at an object does not grant me an after-image at all, that is, a picture perceptible without any particular tension of the memory activity. In the following way, however, I succeed in catching up on the momentary glimpses of a color in such a way that there is no such tension, which is not the same as the primary, but complementary to it.

I put an inwardly black tube in front of one eye and point it at a colored ground, next to which there is a white ground. I first close both eyes for a while, then open the eye in front of which the tube is located, so that the color background falls to my eye and immediately turn the tube to the white ground. In spite of the great sensitivity that I have for subjective phenomena, in spite of the fact that I had only momentarily seen the objective ground of color, I see now, on the white ground, the after-color of this ground; but it is always complementary to it.

In the meantime I can not help noticing that I perceive very well the appearance of the thaumatropes in the colors of the pictures painted on them, which can only be the

result of a simple endurance of the impression. But the circumstances are different here than in the creation of the memory replica. The two images on the front and back of the disc frequently appear repeatedly in the thaumatrope before the eye, so that the impressions can add up; whereas the memory image is obtained by means of a single glance.

For all this, I believe, in view of the general discussions to be added under (e), that my memory-image succeeds only by an immediate continuation of the activity subject to ordinary imitation into the field of mental images, where it is still influenced by memory activity I can be taken after it has already died out in the field of intuition, while in the experiment with the thaumatrope the picture, which preceded by a moment, is composed with the following still in the field of intuition itself.

If this is the case, it can not be unexpected if the same phenomenon, which in my case is a memory image after its main moments, behaves as an afterimage in another. So it seems to be the case with Prof. Rüte, who receives at all very easily distinct afterimage, but also produces ordinary ordinary clear memory pictures, and from the information given to me, I take the following: if he has even momentarily considered an object, At the same time, the same appears to him most clearly in its original color and form and extinguishes quickly; but he needs no arbitrary effort of attention; but as he closes his eyes or averts his gaze, the afterimage appears to him, he may or may not, and when extinguished, it changes from the positive to the negative, thus carrying all the characters of the common after-images. He thinks this just as determined, as I think I think it necessary to take the memory activity especially in the usual way to help, to see the memory image. Also the Helmholtz production of lively positive afterimages¹⁰⁾ by momentarily looking at an object, after previously the eyes have been closed for a long time, over which I have no sufficient own experience to command, according to Helmholtz's presentation gives the phenomenon without any special tension of memory activity. Precisely because of these differences, however, the reminiscence of memory seems to me to be of special interest, since it shows with particular clarity how the same phenomenon can vary according to individuality and circumstances between the character of the memory image and the afterimage.

¹⁰⁾ Official. Report on the 34th Assembly the German naturalist in Karlsruhe. P. 225.

After the above was already completely written down, I first became attentive to a passage in Purkinje's Contribution to Subjective Vision, p. 166, which proves that he has already observed the memory replicas with similar characters as I did before; but by contrasting it with the mere name of afterimage, the dazzling pictures (which I have understood among the afterimages), which are dependent on the duration of the impression of the senses. Since his statements confirm and partly complement each other with the above statements, I let them follow literally: "I have often wondered why the blinking of the eyes does not disturb seeing, by imagining that a total darkness would have to occur during it On closer inspection, however, I found that the field of vision of the open eye, with all its lights and images, remains

for a short time before the senses, after the eyelids have been closed. The more attentively I perceive a simple, not too extensive picture, the longer I can hold it with my eyes closed before the senses. This afterimage is to be distinguished exactly from the dazzling image. The afterimage is held for some time only by free activity, and disappears as soon as the will subsides, but can be called forth again by it; the dazzling image involuntarily floats before the senses, disappears and reappears for objective reasons. " the longer I can hold it with my eyes closed before the senses. This afterimage is to be distinguished exactly from the dazzling image. The afterimage is held for some time only by free activity, and disappears as soon as the will subsides, but can be called forth again by it; the dazzling image involuntarily floats before the senses, disappears and reappears for objective reasons. " the longer I can hold it with my eyes closed before the senses. This afterimage is to be distinguished exactly from the dazzling image. The afterimage is held for some time only by free activity, and disappears as soon as the will subsides, but can be called forth again by it; the dazzling image involuntarily floats before the senses, disappears and reappears for objective reasons. "

The dazzling picture, on the other hand, tends to be sustained in a nervous mood, in the asthenic state, and disappears the quicker the energetic the body through which life flows. Moreover, the nearer it is to the moment of the conception of the archetypal image, the more imitative and objective, and in every succeeding moment it becomes more and more difficult to obtain the same in the same clarity from the senses. In contrast, the dazzling image of mildly luminous objects is confused in the first moments after viewing and only gradually develops completely before the senses, which only gives a passive audience. " Moreover, the nearer it is to the moment of the conception of the archetypal image, the more imitative and objective, and in every succeeding moment it becomes more and more difficult to obtain the same in the same clarity from the senses. In contrast, the dazzling image of mildly luminous objects is confused in the first moments after viewing and only gradually develops completely before the senses, which only gives a passive audience.

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c) Phenomena of the sensory memory and reaction phenomena according to intuition of movements.

If the memory replicas in their form, as they present themselves to me, represent a transitional link between memory pictures and afterimages, which rather follow the first one than the last, the phantoms of the so-called sense memory provide another transitional element, which is the other way around rather connects the Nachbil-dern as memorial images. For they demand the direction of attention on the black field of vision in order to be understood, and are not a matter of voluntary generation and modification, like the images of memory and fantasy; However, they do not appear

merely as echoes of previously transient sensory impressions in their immediate wake, like the afterimages, but return voluntarily in the dark,

Naturalists often have the opportunity to make experiences that belong here, although such are not often described¹¹⁾. The earliest description known to me about it comes from Henle¹²⁾ ago. He relates that when he had worked on an arterial and nerve preparation for hours in the morning, suddenly in the evening, in the dark and rubbing of the eye, or at congestion after it, during the coughing, blowing his nose, and so on, suddenly the glowing image of that preparation in all its details may have shown where else perhaps a flash of lightning would have quickly illuminated the field of vision. The apparition was momentary and involuntary, and deliberately could not be evoked again. Likewise, at another time, when he had spent several days examining the flickering hoses of Branchiobdella, he appeared in the evening, amid the jumble of threads that float before the calm eye, again the shimmering streaks, shining,

¹¹⁾ Ruth tells me, for example, that the phantoms of the sensory memory, according to present observations, have often occurred to him in the evening, especially to the annoyance, in the evening in bed.

¹²⁾ Casper's Wochenschr. 1838. no. XVIII.

I have repeated similar (though modified in some points) experiences, especially strikingly at a time when my eyes and my whole nervous system were suffering from a pathological irritability that later turned into photophobia.

I take my notes about this:

When I was still in charge of the physical professorship in Leipzig, magnetic intensity observations with the Gaussian apparatus were made in the physical cabinet, with a black thread in the telescope moving across a white scale with black graduations and degrees, and at the same time as the secondary counter Eight gives. If I had done these observations for two hours afterwards, I only needed to close my eyes or open my eyes to the dark, so I saw the black thread and the white scale with the black graduations and numbers appear in the field of view and, indeed, the thread in the same quietly moving movement over the scale he had in observation. I have experienced this very often repeated times after all the observation dates that fall in that time. Columns and threads were well distinguishable (though by far not as clear as in reality), but the numbers were never so clear to see their value. I have never seen the trains shining. Even 24 hours after such a series of observations, I repeated the phenomenon at each conclusion of the eyes, without any attention being drawn to it. It was not just momentary, but not continuous, but was alternately swallowed up by the darkness to reappear without me somehow having it in my power. Columns and threads were well distinguishable (though by far not as clear as in reality), but the numbers were never so clear to see their value. I have never seen the trains shining. Even 24 hours after such a series of

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I experienced a similar phenomenon in connection with the previous one in the hearing. When I lay in bed at night after such a series of observations, and even the next morning, when everything was quite still, I heard the clearest (continuous) beat of the seconds counter with its peculiar rhythm, as if a pendulum clock in the next room so that I had to convince myself that no such external cause really existed.

At the same time, I often made continuous observations on the multiplier, paying attention to the needle playing over a circling; I also saw this picture with the movement of the needle reproduced in similar circumstances as before.

Even after the restoration of my aversion to light, similar phenomena have often repeated themselves to me, and still today, though less frequently than before, sometimes after long-lasting occupations, when it is necessary to return often to the same objects,¹³ again . However, the following observation seems to me of particular interest, as long as it shows that for the sensory memory as well as for ordinary memory, the conditions of quite different images can coexist without substantial disturbance.

¹³⁾ Still a few examples in this regard s. in my Zentralbl. f. Natural sciences. 1853, p. 777. 780.

On the 21st of February, 1847, I saw for a long time the table with a number of big souvenirs. Firle (Borle, Tirltanze, di discs with a peg through the middle, which, in the manner of a gyroscope in rapid rotation on the tip of the pin are added), which was driven to the entertainment of others, and took part occasionally itself. The greater part of the rest of the afternoon, and even till 11 o'clock in the evening, I occupied myself with drawing from several series of numbers expressed in numbers. When at last I went to bed, rows of numbers, of the form of those with whom I had to deal, appeared black in the dim ground of the field of vision, both closed and open eyes in the dark chamber, so that I was right well read, even though they never had great sharpness and clarity. The phenomenon was also not fixed, but

was always devoured by the dark, and then make room for another number series. Attention had no influence here; and although the bills were still in my head, the numbers that appeared did not have any relation to it, had the character of something seen, not thought. The strange thing, however, was that sometimes, instead of the phantasm of numbers, the phantasm of a spinning Firl entered, notwithstanding, busy with the bills, no longer thinking of that indifferent pastime during the afternoon or evening, or thinking now, except me now involuntarily reminded the apparition of it. Soon it was this soon that Firl (they had different size and shape), which appeared in the field of vision, turned and fell over; as it has been in reality. The appearance was unambiguous, though weaker than the number-phantasm. This alternation of phantasms, of which, however, the number phantasms appeared much more often, lasted over an hour until I fell asleep.

In view of Henle's experience, I have often tried, by rapid shaking of the head or rapid patting of the eyelids, or otherwise deliberate concussion of the head or body, to indiscriminately cause these involuntary appearances to disappear in the field of vision in times when they repeatedly persisted after prolonged occupation with fine objects; I never succeeded. Just as little did deliberate quiet vibrations. Nevertheless, I do not want to completely deny an influence of the shock, but without being able to fix it. It seemed to me, however, that the phenomena in question occurred preferably with occasional slapping of the eyelids, often with a slight involuntary wink of them, without, however, being able to reach it again through arbitrary nighting. Also one remembers oneself (so) with the memories Nachbildern mentioned experiences.

It would be desirable if the phenomena of sensory memory were to be attempted, especially with regard to the reproduction of movements from accidental observation. From what has occasionally been observed, it may not seem improbable that, if properly practiced, one would also see that the afterimage of moving objects obtained immediately after observation is lawfully moved; yes, for a certain form of movement, the question is already decided. Where, of course, the movement happens so rapidly that the lasting effect of the impression makes the path described appear to be continuously filled with the impression of the face, as in the case of the electric spark, the rapidly curved glowing coal, the after-image naturally takes on this form; if, on the other hand, the eye follows a slowly moving object with its own motion in such a way that it keeps it constantly fixed, as it is natural to us, it is just as natural that the appearance of the after-image coincides with that of a dormant body. But there is a third case to investigate, namely, that the objective image is slowly allowed to travel over the retina. Only, because every part of the retina receives only a brief impression, one often repeats the movement, or with very strong light impressions, or has to combine both. In this case the following two are to be distinguished as the simplest cases: 1) that the objective movement always goes in the same direction, 2) that it reciprocates back and forth. For the first case, teach the following facts that the objective movement reproduces itself subjectively in the opposite direction; for the second case, the quoted facts of the sensory memory suggest that the pendulatory movement would be subjectively repeated.

Examples of the first case, which are easily found in ordinary life, are that the objects on the path, which seem to move alongside the carriage during driving, seem to assume an opposite motion at the moment of stopping, and that, if one of one Continuously considered rapids looking at the sand and the stones on the way turns, they seem to move in the opposite direction of the water movement. More specific observations on this phenomenon are on the one hand by Plateau¹⁴⁾, on the other hand by Oppel¹⁵⁾ and the strange fact that the direction of the movement in the subjective after-effect is opposed to the objectively looked at, has been compared with the formation of complementary after-images. Oppel, who has studied the apparition with particular care and has himself designated a device for the safe production, makes the following 6 conditions indispensable for the safe success of the experiment.

¹⁴⁾ Pogg. LXXX, 287.

¹⁵⁾ Pogg. XCIX, 540.

"1) The movement in question must be continuous and uniform.

2) It must as a whole be a fairly fast, but not so rapid, that it makes it impossible for the eye to distinguish between the individual moving points; Which, of course, does not depend on the absolute velocity, but only on the angular velocity with respect to the position of the eye, and thus especially on the distance of the latter from the moving object.

3) It must be considered for a good while, that is, for an average of probably a minute, generally almost to the fatigue of the eye (which duration will of course be quite different for different eyes).

4) The eye must, as in the subsequent fixation of a still picture, even in (relative) rest, and may not be irregularly shaken, especially by accidental movements of the body or head.

5) The calm object to be fixed must present a surface which has been modified in many ways by changing the colors or the shading of its parts.

6) Both in the observation of the moving and the stationary picture, the eye must fix one point unerringly, and therefore, by no means, should not be tempted to follow more or less in the former case, or back and forth along the outlines of the moving picture to wander. "

There is still a lack of attempts at the second case to be considered. Quite in passing, I repeatedly shuffled a spot of white paper on a black ground in front of the fixed eye; but, though I have very easily after-images and phenomena of the sensory memory, yet I did not receive any result; nothing appeared. Nor could I obtain a result by means of stroboscopic disks. The condition of my eyes, since these attempts can not be otherwise very strenuous, prohibits the experiments for a long time with strong

pendulum light impressions and with necessary modifications, where a result would probably be obtainable.

d) involuntary hallucinations and illusions¹⁶⁾.

By hallucinations we understand in general deceptions that assume wholly or almost the character of externally awakened sensory perceptions for the deceived, without there being anything in their external reality to stimulate them. A sharp demarcation of them from the images of memory and fantasy enhanced on the one hand to the highest vivacity on the other hand, the phenomena of the memory of the senses on the other hand, can not be drawn; yet many hallucinations are not a matter of arbitrary creation, such as phantasy images and arbitrarily recalled memory images, and many do not reproduce slavishly former sensory phenomena, such as the phenomena of the sensory memory. Of these not yet discussed forms will therefore preferably be discussed below¹⁷⁾. Illusions are understood by some to be hallucinations of any kind, while others, as it may be here, distinguish illusions and hallucinations insofar as they understand delusions under illusions, for which, however, causal objects are present, but which are misunderstood; Hallucinations of external causative objects of appearance are missing at all. So it is an example of an illusion to see an object that is really there with wrong color or distorted features, but a hallucination when you see an object that is not there at all.

¹⁶⁾ The literature on hallucinations and illusions is very large, and not exhaustible here. I am content to cite the new writings which have come to my knowledge, and which are to refer to them, of which I know only 4, 6, and 7 only according to the titles. By the way, not only all works on mental illness, among other things, also deal with hallucinations, but also innumerable treatises and reports of individual cases:

1) Hibbert, Allusions to the Theory of Ghost Phenomena, ad Engl. Weimar 1825. - 2) J. Müller, on the Fantastic Facial Phenomena. Koblenz 1826. - 3) Hagen, about hallucinations. 1837. - 4) Griesinger, the pathology and therapy of mental illnesses. Manch. 1845. - 5) Moreau, du Hachish et de l'aliénation mental. Paris 1845. - 6) Michéa, you délire des sensations. Paris 1846. - 7) Szafkowski, Recherches sur les Hallucinations. Montpellier 1849. - 8) Brierre de Boismont, of Hallucinations. Paris 1852. - 9) Leubuscher, on the genesis of hallucinations. Berlin 1842.

¹⁷⁾ It would be desirable to have the fantasies, which, apart from the mode of origin, are so similar to each other, arbitrarily produced, of which the memory pictures were mentioned in section a) and the involuntarily arising phantasms, of which the following will be discussed to be able to distinguish by significant names, but did not want to applaud me quite right.

Simple cases of hallucinations are sparks before the eyes, ear-blades, as they so often occur in congestive states after the sensory organs in question; but also shaped

phenomena, such as human figures, speeches can appear through hallucinations in the appearance. Here belong the fantasies of many fevers and insane persons, the phenomena of alpinism, the hallucinations of the enjoyment of narcotic substances, the phantasms which many people are about to fall asleep. But also in mentally healthy persons, when fully awake, with open eyes, under certain circumstances very developed hallucinations may occur; indeed the number of strange cases of the kind which have been reported is very great. At the same time the most credible, most interesting, The most instructive and extensively described cases of this kind, the physiognomy of which is in line with many other cases, include the case of the formerly famous bookseller and author Nicolai, himself in the Berlin Monatsschr. 1799. May and in the first volume of his philos. Abhandl. P. 58 ff., Also reproduced in Hibbert's treatise, whose special rendering, however, would exceed the limits to be found here too much.

Also seems to me that for Connections to the processes described under a) phenomena from such conspicuous Halluzinationsformen as it presents the Nicolai'sche case and which always relate indisputably with physical disease states by so many to be observed in good health conditions hallucinations before falling asleep¹⁸⁾ deserve special attention, in respect of which I believe I can do no better than reproduce the description of J. Miiller from his work on facial phantasms, which is based on self-observation, in the most essential way.

¹⁸⁾ They are closer to, inter alia, Nasse in s. Zeitschrift. f. Anthropol. 1825. 3. p . 166 ff., And essentially in agreement with it by J. Miiller in s. Writing "On the Fantastic Facial Phenomena" 1826, p. 20 ff. as far as I can remember, some of Maury's and Baillarger's absences into Ann. méd. psychol., whose position I can no longer specify, and indisputably several times otherwise.

§. 34. "It is rare that I do not see many shining images in the darkness of the field of vision before I fall asleep with my eyes closed." From early youth I remember these apparitions, I always knew how to differentiate them from the actual dream images, for me could often reflect on them for a long time before falling asleep, and multiple introspection has enabled me to promote their appearance, to hold on to it When I want to observe these luminous images, I see with my eyes closed, completely restive into the darkness of the visual field, with a feeling of relaxation and the greatest peace in the eye muscles, I immerse myself completely in the sensual calm of the eye or in the darkness of the field of vision.

§. 35. "If, at the beginning, the dark field of vision is still rich with individual patches of light, mists, changing and changing colors, then instead of these soon appear limited pictures of manifold objects, at first in a dim glow, more clearly Sometimes they are also colored, there is no doubt about it: they move, they transform, sometimes they emerge completely to the sides of the field of vision with a vibrancy and clearness of the picture, as we never see so clearly something to the side of the field of vision with the slightest movement The eyes are usually gone, even the

reflection scares them away, they are rarely known figures, usually weird figures, people, animals that I have never seen, enlightened spaces in which I have not yet been. There is not the slightest connection between these phenomena and what I experience during the day. I often follow these apparitions for half an hour, until at last they pass into the dreams of sleep.

§. 36. "Not at night alone, at any time of the day am I capable of these apparitions, and I have spent many hours of rest, far from sleep, with their eyes closed, to observe them To close my eyes, to abstract from everything, these pictures, which have been kind to me since early youth, seem involuntary. If only the place is quite dark, I am only mentally very calm, without a passionate mood, but I just did not eat or drink spirits So, though it is impossible to think of sleep at the moment, I must be sure of the appearance.

§. 37. "Often the light image appears in the dark field of vision, and often, before the appearance of the individual images, the darkness of the visual field gradually brightens to a kind of inner dull light of dawn.

§. 39. "I can distinctly distinguish the moments in which the phantasm shines forth, I sit there for a long time with my eyes closed: everything that I want to imagine is mere imagination, imagined limit in the dark field of vision, it does not shine, it does not move organically in the field of vision, suddenly enters the moment of sympathy between the fantastic and the light nerves, all of a sudden figures stand there luminous, without any stimulation by the imagination. The appearance is sudden, it is never imagined, imagined and then brilliant I do not see what I want to see, I can only put up with what I must see without any excitement.

§. 40 "I can imagine and imagine for hours, when the disposition to the luminous appearance is not there, never will this first thing presented receive the semblance of aliveness." And suddenly a light, not first presented against my will, appears without all recognizable association

§. 41. "These phenomena most easily occur when I am quite well, when no particular excitement mentally or physically prevails in any part of the organism, and especially when I have fasted." By fasting I can bring these phenomena to a wonderful liveliness. I never noticed her when I drank wine before

§. 66. "I have never been able, with my eyes closed, to move the fantastic pictures with my eyes like the dazzling pictures.

§. 147. "As readily as the phantasy images involuntarily occur to me, yet in the greatest effort I have almost never been able to produce arbitrarily a certain phantasm of definite illumination and coloring." I have spent half a day in this volitional exercise in the dark What I could not evoke, could not hold on to the will that defied the will, as easily as I see subjective colors, never could I redeem a blue in the field of vision with the will to fix it. "

§. 87. "The dream images are nothing but the luminous phantasms that appear in the visual matter with their eyes closed, usually with the recognition of their objectivity, often with the awareness that only dream images are seen, in the latter

case the dream images In the self-observations before falling asleep, I have often surprised myself over the beginning of the real dream. The real dream, with euthanasians of the reflection and recognition of the objectivity of the phantasy pictures, then enters the easiest and most immediate when, in the place of darkness, the inner subjective illumination of the visual field has gradually taken over. " (This is followed by a more elaborate account of this in the original).

As for the hallucinations related to disease states, these generally carry the character of excitements of the nervous system and vascular system, and perhaps they are always congested in the brain. This is expressed partly in their causal moments, partly accompanying symptoms and partly remedies. With the exception of Nicolai's case, which provides proof of causal origin as a cure, I recall her habitual presence in fevers, in some kinds of insanity, such as the drunkenness (in which one often over-replicates the brain with venous blood death), after the enjoyment of Narcotizis, by which the pulse can be greatly increased, etc. Leuret et Metivié¹⁹⁾ After numerous observations in the Salpêtrière, it was found that among all the madmen who appeared there, those with hallucinations had, on average, the most frequent pulse; he himself was more common than mania-afflicted. But I also find a case reported where after the strongest blood loss hallucinations persisted²⁰⁾.

¹⁹⁾ Fror. Not. XXXVII, 137.

²⁰⁾ Brierre de Boismont p. 613th

According to Baillarger and Moreau, the horizontal situation favors the hallucinations, indisputably because the blood flows more towards the head; and Pinel also reports of a melancholy woman, where the hallucinations of hearing cease immediately when it is seated.

The images which appear in delusion and in extatic states in hallucination are, by their very nature, in clear dependence on former external circumstances and occupations, but also on the earlier mental life of persons, which of course is itself so connected that a pure separation Assessment of the causative moments of hallucinations is not well possible. (Evidence in Hagen p. 16 ff.)

On the other hand, the hallucinations, as already noted above, often consist of formless light phenomena; and also the formed phenomena often begin with or are accompanied by, a proof that, apart from all the influence of the imagination, a disposition must be present in the sphere of the senses. (See Hagen, p.

Frequently, the hallucinations of several senses and then not infrequently combine as it corresponds to laws of association.

une femme qui reçut un pot de fleurs sur la tête et entendit immédiatement le bruit que faisait ce pot en s brisant en éclats sur le pavé. Pins tard; All sentimental vip fois par jour le même coup et entendait le même bruit. "(Brierre de Boismont p. 557.)

Often the hallucinations are lacking in all reasonable connections, and Nicolai says, for example, For example: "If my nervous system were so tense, so weak, so briefly

annoyed that such figures could appear, then these delusions did not follow a known law of reason, imagination, and the otherwise usual association of ideas. "

The illusion of hallucinations, as if external objects of perception were present, may, according to circumstances, be more or less complete, and in any case is in many cases perfect. In fact, all possible gradations seem to take place here. Some hallucinators are fully aware of their condition and deception; the phantasms really recognize as phantasms, whether in some way they do not have the full character of reality, or that they are found to be incompatible with the connection of the real relations that assert themselves from another side, as soon as only otherwise the full condition is there.

"I could, Nicolai assured me, as I was at all in the greatest peace and prudence, at any time to distinguish phantasms of phenomena exactly, whereby I never once mistaken myself I knew exactly, if it seemed to me, that the door itself open and if the door was really opened and someone really came to me. " He also saw the colors a little paler than in reality. Similarly in a case reported by Bonnet²¹⁾.

²¹⁾ Bonnet, essay analytique sur l'âme. Chap. 23 p. 426; Hagen's sensory noise. P. 47.

In other cases, however, it behaves differently. "I saw, said a healed patient of this kind to Esquirol, I heard exactly how I see and hear you." - "If my perceptions are erroneous," said a delusional priest to Foville, I must also doubt all that you tell me, I must doubt that I see you, that I hear you. "

A patient said to Leuret²²⁾ : "Vous dites, que je me trompe, parceque vous ne comprenez pas comment ces voix que j'entends arrivent jusqu'à moi, mais je ne comprends pas plus que vous comment cela se fait; ce que je sais bien, c'est qu'elles arrivent, puisque je les entends: elles sont pour moi aussi distinctes que votre voix, et si vous voulez que j'admette la réalité de par paroles, laissez-moi admettre aussi la réalité des paroles ; qui me viennent, je sais d'où, car la réalité des unes et des autres est également sensible pour moi. "

²²⁾ Leuret, fragments of the film. p. 203rd

It is also very often the case that insane and fever-ill people see actions which prove that they confuse the hallucinations with reality.

Some people claim that their visions disappeared when they closed their eyes, and others that it was sufficient to let the eyelids settle down in order to induce hallucinations. With others, it did not matter if they opened or closed their eyes. Nicolai says: "Incidentally, at any time and in all kinds of circumstances, the figures seemed to me equally clear and definite, when I was alone and in company, by day and by night, in my house and in strange houses, when I closed my eyes. Sometimes the figures were gone, and sometimes they were there even with their eyes closed, but when they were gone then, after the eyes were opened, the figures

before appeared again. " Dr. Crichton asked ²³⁾"that patients, when they first begin to fantasize in fevers, do so only when the room is darkened, or when they close their eyes; but if they open them, or if the room is sufficiently lighted, the fantasizing stops, and they often say themselves when they remember the things they saw, that they were convinced they had fantasized. " Various cases where hallucinations disappeared at the end of eyes, s. in Rüte's Ophthalmol. I, p.193 u. Griesinger's writing p. 72.

²³⁾ Hibbert p. 285.

In conflict with external sensory perceptions, the hallucinations behave in such a way that, according to circumstances, they can be displaced by them, or, conversely, they are able to displace them or to assemble with them.

According to Baillarger ²⁴, some hallucinators may interrupt their hallucinations if they turn their attention to external impressions; while others are unable to do so. Therefore, hallucinations often lose their hallucinations during the presence of the doctor, which recur immediately after removal of the physician.

²⁴⁾ Schmidt's Jahrb. 1849. p. 77.

Often, when phantasms cover an indifferent background, they vanish as an object that stuns attention moves to its apparent location, or an obstruction of seeing intervenes between the visions and the apparent location of the vision.

In general, J. Miiller (Phantom, GS 35) remarks: "Those who see fantastic images in the waking state with their eyes open testify that one can not turn their eyes away from them, that is, when they are in the middle of the field of vision are coincident with all objects which fall into the axis of vision when the eyes move away, and observations of this kind have been collected by Gruithuisen (contribution to Physiognosia, pp. 238, 259) from his own and others' experience. "

In a case that Scott in s. Demonology reports that, by the way, an otherwise quite reasonable man, after many other previous hallucinations, had the appearance of a skeleton, which he was unable to banish at all, regardless of the fact that he kept reminding himself that it was only a schematic. "Is this skeleton, the doctor asked, always in your mind?" The patient affirmed it. "So now?" However, the patient replied. "And where do you see it?" Immediately at the foot of my bed, and when the curtains are left a little open, the skeleton, as it seems to me, fills this empty space The doctor stood between the two half-drawn curtains at the foot of the bed, the he was designated as the place which the apparition occupied. He asked, if the ghost is still visible? Not quite, replied the patient, because your person is between him and me; but I see the skull of the ghost over your shoulder. "

In a Dr. med. Trapped by a trapped trap, a 12-year-old girl, frightened by a strangely outfitted man with a red cap, gnawing at a bone, contracted a convulsive evil and a recurrent vision in which that person reappeared as a phantasm. When she approached the phantom for the first time or reached for him, she took a few steps away from her. Dr. Brach set about 14 days after the first seizure the following experiments: He let the patient go to the apparition a few times against a wall and now asked if they could even see the human through the wall? This was not the case; for if they were allowed to step outside the wall, the apparition faded. On the other hand, if you let them come close to a window, So the apparition fled out of the window and looked at her through the window. If you let her see in a mirror, she did not see the apparition, but her own image. If someone between them and the place where, according to their information, the man was, she saw him partially, as far as he was not covered by the intervening person. If someone stood straight to the spot where the dummy image stood, it disappeared one time, but another time it turned sideways. Using appropriate drops of the nerve, convulsive coincidences gradually diminished, and the phantom began to blanch and soften. At first the red cap became yellow and gradually paler, then the outlines of the whole figure became more indistinct, and then the man disappeared, and only the face, cap, and hand in which he held his bones, He stayed behind, then his face and hand were gone, and Patient saw only the bone and the cap over it, which also became whiter and paler. After 5 weeks, however, Mirage and St. Vitus' dance disappeared. (Med. Zeit v. Associations for Healing in Pr. 1837. No. 5.)

As a conflict with objective views, it is also indisputable that the phantasms appear several times transparent or translucent, where they seem to behave in a similar way, as when one takes a double picture, for example, a double picture. As a wafer, produced on a sheet with pressure or writing, which then shines through the double image. Such information I find several.

The Cardanus seemed to have different shapes of little rings how to pass the limbs of mail shirts. "Everything was transparent, but not as if it did not seem to be anything" (Hagen p. 47). One who saw the corpse of a dissected man saw through the shape of a copper engraving. Another man observes that the more the soul was in a state of inactivity or suffering, the more so were the hallucinations in him, so that real objects in the room were not seen. "But when attention was awakened and put into action by a kind of effort, the phantasms began to become, as it were, transparent, and the objects of sensation (objects) looked as if they were seen beyond the phantasms. It was not in the least difficult

As a kind of combination of hallucinations with external sensory impressions, the illusions, as understood in the sense given, may hold, of which innumerable examples could be cited, which, however, would be partly superfluous, partly too far-reaching.

In spite of the fact that images produced by hallucinations generally bear all the colors of the real world, the fact that the inner production of colors is heavier than that of forms is already evident in Meyer's experience (²⁵) can also be seen in some experiences of hallucinations , Nicolai saw that as his phantasms began to fade, the

color of them first paled, and the figures already whitened, when their outlines were still very definite, and also in the case of that girl who repeatedly saw the strangely outfitted human as a phantasm Gradually recovering, the red cap first yellow, gradually paler.

²⁵⁾ However, the statement of Drobisch (see above) is not entirely correct here, but concerns less decided phenomena.

Brewster, as a probe to distinguish a phantasm from a real object, has stated that one should press one eyeball to see if a double image arises, which can arise only on condition of a real object. Paterson 26 reports, however, of a trap in which a decided phantasm should have doubled in the displacement of the eyeball with the finger. This would not be impossible in so far as the idea of doubling itself indisputably gives a twofold picture in the phantasy, which in the case of a person inclined to hallucination can fashion himself as such; but with this the whole sample seems unreliable.

²⁶⁾ London med. gaz. 1843rd March.

Of importance is the remark that not a few cases are known where vivid hallucinations occurred, whereas the patients suffered from the black cataract, and indeed at the dissection the optic nerves were both completely atrophic. A distortion of such cases gives J. Mueller, over phant. Ges. P. 31 ff. And Rüte in s. Ophthalmol. I, p. 194.

e) General considerations.

From the totality of the facts which are communicated about the relation of the memory images and afterimages and the transitional elements intervening between them, one receives the impression that the processes which are subject to the memory images and afterimages are not essentially different in themselves, but rather It is the same psychophysical process which, depending on whether it is directly stimulated from the inside or from the outside, gives a memory image or an after-image, the first as a later rejoicing, the latter as the immediate echo of an objective image. With this different mode of production, then, the difference in strength, the contrast in the feeling of spontaneity and receptivity, and the different local feeling for both phenomena can be related as follows.

By whatever internal mediation the reminiscences of the externally produced pictures come into existence, about which we know as much as nothing, it seems quite natural that they, insofar as they are only late after-effects of these pictures, are comparable in their intensity It remains more difficult to explain why they remain as upper limit in the permanent state of the organism, and it seems more difficult to explain how they can approach, or even seemingly reach, those cases of this upper limit that are still exceptional, but remain behind as much as they do Rule is. However, if in some extatic states they even seem to excel the outer images, this is only so far as the excited state,

The difference in the feeling of spontaneity, what we have in generating the memory images, and the receptivity with which we understand the afterimages, can easily be found in those who are inclined to divorce the soul phenomena into those which essentially depend on physical processes, and such which are not essentially dependent on it, give rise to at least the act of producing the memory pictures, if not the first page itself, and the objective pictures and their echoes on the second page. But it seems to me unclear, and therefore untenable, whether to divorce the activity of production or the conception of images from the images themselves in such a way that they can proceed abstractly in the soul, whereas they can not proceed abstractly in it. Without the dispute with opinions, which are in conflict with a system based on the view of the extended soul seat, we must remember that the memory image, like the afterimage and the objective image, do not float in the mind either psychically or physically, but special determinations of the general consciousness activity on the one hand this underlying general psychophysical process on the other hand. In the sense of the schema and with regard to what has already been said, I present this as follows: we have the feeling of spontaneity in the memory pictures, because in the generation from the inside the total wave is raised more strongly by the elevation of the lower wave than the harmonic; vice versa when generating from outside; but the design of the harmonic is the same in both cases. There is basically nothing in the meantime which excludes cases where the total wave increases more from the inside by elevation of the harmonic wave as a lower wave; then one has the involuntary hallucinations, which are only to be regarded as an exception; and in general many transitions are possible here, as we have looked at in the memory imagery, phenomena of the sensory memory, and so forth.

Attending to the local relations between memory pictures and afterimages, it turns out generally from the observations reported that with the awakening of not familiar memory pictures the attention with open eyes from the outside world and with closed eyes averted from the black field of vision and behind the feelings behind it and, where the memory images remain weak, they can be perceived and recorded from the external senses only in such an abstraction, in a manner similar to that which one must abstract from one sensory domain in order to become aware of the perceptions in another to be able to. This suggests that the field of memory *images in statu nascenti* and as long as they remain weak, and the field of the after-images, which coincides with the black field of vision, are similarly differently located in the brain, than the various sensory-regions themselves.

On the other hand, if one looks attentively at an afterimage in the closed eye or the black field of vision itself, one finds the tension of the attention turning just as much towards the outside world as when one looks at external objects with open eyes. This suggests that the field of afterimages and outward views must be considered as coinciding.

Further, one finds that in order to recall something audible and fragile, whose memory we are not familiar with, we must turn our attention away from the external senses, in order to reflect on something visible, without the feeling of one different localization according to the difference of the sensed, to which one reflects; to

assume, then, that the whole mental images assume in their origin a common field different from that of the sense-picture, so that the attention between these two fields can change as well as between different sensory fields.

This consideration is not invalidated by the fact that the distension of attention on which we are based is probably a reflex muscle sensation (see above); for a difference due to the reflex of excited motor fibers indicates a difference of primarily excited sensory fibers.

However, the spatial diversity of the field of memory images and afterimages is to be considered as no separation; Rather, both domains are naturally organically related, are collectively included in the general nexus of the brain, transplant effects into each other, and associate activities with each other.

The external light-stimulus produces mighty activities in the field of external intuitions; their effects extend into the field of mental images, leaving behind them the conditions unknown to us in which the possibility of the voluntary and associative excitement of the weaker memory and fantasy images is bound up. Conversely, according to the phenomena which the images of memory and fantasy present with greater liveliness, we must believe that the production of images in one field exerts effects in the other field which extends the sense-picture, such that real sense-pictures cross over the threshold insofar as they acquire the essential characters of objective intuitions and afterimages and demand the same direction of attention.

The difference that images of memory, as they are livelier, can also be more easily painted into the black of the eye, which has been presented as a kind of contrast between Me and Busch, like Meyer, is perhaps only due to the fact that it is all the more likely to give the impression of blackness, which is itself equivalent to a light imprint, outweigh. At least I myself find the difficulty or impossibility of painting pictures of memory in the black of the eye, in a very natural connexion with the fact that the black of the eye makes a much more intense impression on me than the memory images produced by the black of the eye. If I try to put it in the same way, their pale lineaments are completely extinguished, but in their peculiar weakness, when I am, drawing attention away from the black of the eye, as it were, entering it into the void. Where, as with Busch, the memory-pictures of nature are very lively, or, as with Meyer, enhanced by exercise to great liveliness, this obstacle, of course, disappears, and it may become quite natural to take them preferentially in the field where the objective pictures and afterimages are conceived.

Also, the apparent contradiction that I and many others, in looking at the pictures of the memory, mean that they use the part of the head which the brain occupies, while others seem more than if they needed eyes and ears for it, indisputably depends on the different strength the souvenir pictures together. I myself can never make the memory images so strong that they influenced the sensory area noticeably from their original seat: but I have difficulty keeping them in their first development; just as I let up with the activity of contemplation, they go out, and therefore I always have the tension of attention, which is tied to reflection. Where, on the other hand, the memory images gain strength and duration, they spread to the sensory area,

It is not improbable that the activity, which is first excited in the optic nerve by the external light and then propagates from there to the brain, is also echoed in the optic nerve itself in the afterimages, and in the phenomena of the imagination, if it is more sensuous Liveliness can flourish, extending backwards until then, while this is not the case with weaker mental images. But it is not possible to decide on the validity of this special version of the localization view.

f) Some remarks about dreams.

About the dream, the manifold turns and forms that it can accept, its causal moments, its transitions into somnambulistic states, etc., there is much scattered material of experience²⁷⁾. But I must renounce any further communication concerning the extension of the subject, and this will be all the more permissible since I had renounced from the outset to be complete in this whole field and had to give it up. Here I only want to add a few additional remarks in connection with the previous one, to what I said about dreams (chapter 43).

²⁷⁾ Among the richer complications is that of Burdach in s. Physiology, III, p. 460 ff., And probably in the following detailed work, which I do not know from my own opinion, much is to be found: Lemoine, *you are at the mercy of physiology and psychology*. 1855. Baillière. 410 pag.

According to the facts reported in section a) of this chapter, and under discussion, we have occasion to subject the scene of psychophysical activity, which is subject to the emergence of the mental images and these images, so long as they remain weak, not to a divorced one but to hold for a different one of the field of activity which is subject to the sensuous images, so however, that activities in both fields may associate with each other and transplant effects into each other. I suspect that the scene of dreams is different from that of the waking life of imagination, but in the case of very vivid dreams corresponding reflexes are made into the sphere of sensory and movement activity, as is the case with lively ideas in waking.

In itself, there is nothing improbable in that the temporal oscillation of the psychophysical activity of our organism is causally related to a spatial oscillation or circulatory movement in a similar way as we are used to it in periodic phenomena in external nature; that the peak of the main wave of our psychophysical activity, pressed down below the threshold, normally occupies a different place in sleep than the summit above it in waking, and hereby coincidentally the scope of the harmonics beyond which the dream ideas hang is different in the waking.

If it were not so, then the incoherence in which the dream life appears from the waking life of the imagination, and the essentially different character of the two, can not be explained to me. In my opinion, if the scene of psychophysical activity is the same during sleep and awakening, the dream may be merely a continuation of the waking life of perception, at a lower degree of intensity, and, incidentally, it should share its substance and its form. But it behaves very differently:

"Never again (in the dream) does the life of the day be repeated with its efforts and pleasures, its joys and pains, rather the dream aims to liberate ourselves from it, even if our whole soul was filled with an object, if our deep pain In the heart of tearing, or a task had taken all our mental power, the dream either gives us something quite strange, or he takes from reality only individual elements to his combinations, or he enters only in the key of our mood and symbolizes the reality Thus even the snooze pictures are almost never known figures, but figures, as we have almost never seen them, marvelous formations and forms, which are not easily found in the outside world. " (Burdach's Physiol. III, p. 474.)

which we can not exactly but. What the dream takes from reality, he tends to falsify. Frequently the persons appear in their former, not in their present conditions. Different times are mixed together. One misses in the process the connection between before and after. "(On the Spirit and His Relationship to Nature, by an Unnamed Author.) Berlin, 1852, p.

The experiences which we can make in the wake of the success of turning attention away from any field, prove that the mere suppression of the main threshold in the sense of our schema is only the degree, not the kind and order, of the conscious Life changes. The uncountable actions that we perform in the unconscious during the waking, that we are z. Washing, dressing, and handling, while thinking of something completely different, are in the same sense and spirit, as rational as those we perform with full consciousness and in full connection with them. Not so with what we do and imagine in the dream. Nor can this be explained by the fact that because of the end of the external senses we can no longer orientate ourselves on the external world and therefore begin to err inwardly, otherwise the silence of the night and the end of the eyes would have to express the same success; while this makes the spirit all the more collected during waking. Neither the simple suppression of the conscious psychic life below the main threshold, nor the departure from the influences of the outer world, is sufficient to explain the peculiarity of the sleep-life to the waking life. Instead of merely suppressing psychophysical activity to the exclusion of the external senses, it is as if psychophysical activity moved from the brains of a rational to that of a fool; but because both brains, or rather parts of the brain, are directly connected, and the movement itself is a coherent and consecutive one, the general psychic connection between them also persists.

It is not disputed that the order of the psychophysical activity and the connected life of conception depends not only on the arrangement, but also on the elaboration of its organ under its own influence, hence the manner in which the ideas, the feelings of an adult, of an educated person to associate and follow one another, is arranged quite differently even with the same original arrangement, than with a child, an uneducated one; but the nature of the individual ideas that we now have is related to the nature of the echoes left by our earlier life and thought. Now, the seat occupied by the psychophysical activity of imagining is waking up, accordingly worked out under the full and effective influence of a cohesive rational life with man and world, in that the psychophysical activity itself was under this influence and accordingly organized its seat. Not so with the psychophysical activity in sleep, in which only the echoes of

this life pass under the threshold. Instead of comparing it with the brains of a fool, we will compare it even more effectively with the brains of a child or a savage, only with the consideration that he is in such a relationship with that of an adult, a learned man. that, when the guards enter sleep, and the wave of psycho-physical activity is displaced, the echoes of their sensory and imaginative life pass over into the new seat as waves of dreams. As they no longer encounter any organization developed through education, they begin to err; just as a child or Wilder does not understand what an adult or educated person tells him, draws untrusting conclusions and weaves uncontrolled fantasy images out of it. Or, it is like stepping out of a city with fixed streets, houses with house numbers, etc., etc., into a wild wilderness without paths; there the gait becomes indefinite; it appears soon here, soon a game on it, but the orderly course stops. If one only closes one's eyes while awake, that is different;

Moreover, if the dream-life is a relatively more incoherent, not so rationally ordered, than the waking life, it nevertheless has its connection of a peculiar kind. Thus, when we fall asleep again after interim awakening, the dream of the first sleep in the second one is without intervening the intervening notions of being awake, which also indicates that waking and dream life have a different scene. This is especially common in nightwalkers, so that they return to the usual mode of dream life with every sleep, as with any awakening to daily business. (Burdach III, p. 474.) Thus one can easily lead a very different way of life in the city and in the countryside, and in passing from one place to another, return again and again to the same cohesive way of life. It would be impossible, however, to change the way of life at the same place. What applies here to the resettling man applies to the relocating psychophysical activity in man.

However, the circumstance that the course of ideas in dreams can not be tied to such firm paths, and that orderliness is not absolutely, but only relatively understandable, may under certain circumstances also make possible greater achievements in the dream than in waking , the imagination, especially in the dream, sometimes produces something which it would not have been able to do while awake. (For examples, see Burdach's Physiol., III., Pp. 469.) The subtraction from the exterior contributes to this. The dreaming is a poet who lets his imagination shoot the reins, and is completely immersed in an inner world and lost, so that the appearance becomes truth to him.

Let's take the consideration one last step. As the peak of the psychophysical activity, more and more humiliating, turns more and more towards a less accessible part of the sensory stimulus, it will cause an increase of the interior to which it turns against the time of awakening so that the psychophysical main wave, while as a whole dropped and below the threshold; but at one point in the interior it has risen against the time of awakening and this place has come closer to awakening. And so it is also possible that, in the abnormal and extreme case, this will go as far as the actual awakening, and with it a new awakening, divorced from sleep by ordinary waking and passing through sleep again, but then necessarily related to a deeper falling asleep in the ordinary seat of waking life. This could be the awakening to somnambulism.

If the somnambulistic waking seems more reasonable than the dream, this could be due to the fact that the inner world, which is nevertheless alien and often filled with visions, becomes, on its own, more easily comprehensible in the brighter consciousness of the new waking.

But I consider it alarming to extend the attempt to psychophysically represent the phenomena of sleep further to the particular phenomena of somnambulism. Not that it could not be hoped that psychophysics would give a light that was as yet missing in this respect; not that general thoughts about it could not be developed now. But in order to lead to something certain, many things in this field of facts as well as the psychophysical laws will have to be secured beforehand, which is not yet certain at the moment.

On the one hand, the fact that the dream-ideas may have reflexes in the field of external muscular activity and external sensations is due to the fact that sleepers not infrequently move as a result of dreams. On the other hand, according to multiple statements, vivid dream-conceptions persist even after awakening as after-images, after-sensations can. Several own and foreign experiences of the kind, face, hearing, taste sense concern, Gruithuisen in s. Contributions to Physiognosy and Eautognosie 1812. p. 237 ff. 286, which Burdach in s. Physiology III, p. 465 and J. Müller in s. Writing about phant. Ges. P. 36 reproduced in part. The following examples of personal experience are given by H. Meyer in s. Physiology of the nerve fiber S. 309 with.

"I went in the dream in a dark, narrow valley by a canal, in which the water ran cloudy and black, when suddenly came a small pale-yellow pug and barked at me violently, threatening me always to bite me, I fended off the same while, as he jumped around, I always turned to his side, I awoke to that, it was already quite light dawn, and for some time I saw the clear black after-image of the pug hovering before my eyes.

At another time I dreamed of a company; the cloth was colorful and the servants ran back and forth with the tea-boards; I caught hold of one who with great agility went out the door, when I woke up, it was already dim, and for some time I saw before me the dark image of the servant, who in a slightly bent position held the tea-board,

I had a similar appearance from a Capuchin who held a pistol in his hand.

These afterimages all seemed to me dark shadows with a few faded edges. "

According to this, the essential difference between the involuntary hallucinations, which easily transpire into dreams, and the falling asleep from the randomly generated sensory phantasms of section a), can only be based on the fact that that reflex from the seat which the summit of the main psychophysical wave under the threshold takes in sleep These are from the seat of the summit above the threshold in the waking into the sensory sphere, of which the former can take place even when approaching sleep. Thus it is explained that those involuntarily play fantastical

dream-like pictures, even if they are not yet dreams, into the waking life, whereas they are determined by arbitrariness and association according to the laws of waking.

XLV. Psychophysical continuity and discontinuity. Psychophysical step structure of the world. Linkage of psychophysics to natural philosophy and religion .

As a definite point of departure for the following considerations, which in the end turn into distant prospects, I see the following general proposition, which will, at the same time, have to be explained and justified by the facts to be added, and implicitly presupposed and presupposed if the facts everywhere permit no other interpretation and utilization than under its presupposition.

The psychologically unified and simple is linked to a physically manifold, the physically manifold merges into the unified, the simple or the simpler. Or to put it another way: the psychologically unified and the simple are the resultants of physical manifoldness; the physical manifold gives uniform or simple resultants.

The psychologically unified and simple are distinguished insofar as the unified is itself the connection of a distinguishable majority, from which, however, the consciousness of linking or linking consciousness can be abstracted as something equally simple, as one is in the unity of consciousness, the unity of an idea or simply a term, whereas the simple element no longer includes a discernible majority, and is only an element for connections, but not itself a combination of simpler things, to which a simple sound, color, and smell sensation gives examples.

Often the abstract simplicity of consciousness has been confounded with a simplicity of the whole concrete soul, useless in my opinion hypostasized by a simple, past-real soul-being.

The same sentence was expressed in the same way in Chapter 37, with the spirit, the soul, as the linking principle for the physical composition and separation (see Chapter 37), as both expressions are in fact meet, so that it can be indifferent here as before, which one wants to use.

The facts that I consider them to be the sum of, and in the sense of which they are to be understood, are the following.

The identical unity of consciousness is linked to a composite bodily system; and the reasons given in the 37th chapter (concerning the seat of the soul) do not in fact allow this to be regarded merely as the outer shell of a simple seat of the soul. With both halves of the brain we think only simply, with the identical places of both retinae we only see simply; In the simplest train of thought, there is a very complex process in our brains, according to the composite institutions; The simplest sensation of light or sound is linked to processes in us which, as excited and entertained by external oscillatory processes, must themselves be somehow of an oscillatory nature, without us distinguishing anything from the individual phases and oscillations.

As certain as it is, that unified and simple psychic resultants depend upon physical diversity, so certain is, on the other hand, that not everything physically composed, even belonging to a coherent physical system, merges into a simple psychic resultant. Whether it is in a unified, is a matter of faith, because one can ask, if not finally give the whole world a uniform psychic Resultante; but then we at least lack the consciousness of this unity.

First of all, different areas of consciousness differ in different people and animals, regardless of their bodies being parts of the same general system of material points we briefly call nature. Then, in each man and animal, the different sensory areas differ, and in the field of the face and the sensation, several simultaneous sensations can again be distinguished, and even such differences in memory can be reproduced.

In general, the psychic life of every human being and animal deals with an infinite number of partly coexisting, partly successively distinguishable phenomena, despite the fact that the entire physical system and life of it are spatially and temporally related in their own.

For the sake of brevity, we may distinguish the two cases that are differentiated here as psychophysical continuity and discontinuity. Continuity, say, takes place if a physical manifold gives a uniform or simple psychic resultant, discontinuity if it gives a distinguishable majority of such. But insofar as there is still a distinguishable majority in the unity of a more general consciousness or consciousness-phenomenon, the continuity of a more general consciousness does not exclude the discontinuity of particular phenomena.

One of the most important questions and tasks of psychophysics is now to determine the points of view under which the case of psychophysical continuity and discontinuity occurs.

Why does it matter that the various organisms have a divorced consciousness, notwithstanding their bodies are so well connected by the universal nature, as are the parts of every organism among themselves, which yet unite to a unified consciousness. It is indisputable that the connection of parts in an organism is more intimate than that of organisms in nature. But what does a more intimate connection mean? Is it also possible to make an absolute difference to a relation? And does not nature, as a whole, show so well the characters of a firm, even more indissoluble, connection than any organism in it? The same questions are repeated within each organism. Why is it that we differentiate different points of space with different facial and tactile nerve fibers, whereas everything that enters through the same fiber Differences remain; Regardless, though, the various nerve fibers are so well connected in the brain, as are the parts of the same nerve-fiber among themselves? Again, one can argue for a more intimate connection of the latter, but again similar counter-questions will be repeated above with respect to the whole organisms.

It is undisputed that the problem which exists here for psychophysics is as yet incapable of any keen solution, but a general point of view can be well laid out for this purpose, and in a consistent connection with that which deals with the

relationship between the general and particular phenomena of consciousness in the 42nd century Chapter has been established. Hence I explain it also in the schema used there, which will be all the more preferable to the abstract representation, since the schema is so definite on one side, as indeterminate on the other side, as our knowledge of the conditions of the question.

If, between the various organisms, the continuity of consciousness is interrupted, by virtue of which a multiplicity of special phenomena are combined in the same unity of soul; notwithstanding that all organisms are united by universal nature into a single system, this can only be written upon the fact that the psychophysical activity between them does not extend in the same way through nature as in them, whether in them external nature, or even beyond any nervous system, is absent altogether, or sinks below the threshold of what happens under the same principle, provided that the cessation of psychophysical activity means only the greatest possible depth below the threshold.

Insofar as we can present every system of psychophysical activity, which is linked by a general or chief consciousness, by a wave, main wave, which exceeds with its summit a certain limit, the threshold, we become aware of the physical connection of all psychophysical systems with nature their psychophysical discontinuity at the same time that we record all waves in connection; but not above, but below the threshold, according to this scheme: Here, *a*, *b*, *c*



three organisms, or rather the main psychophysical waves of three organisms, *AB* the threshold. What surmounts the threshold of every wave-crest hangs in itself and bears a certain consciousness; What is below the threshold separates the conscious as an unconscious, while still maintaining the physical connection between them.

In general, if a psychophysical main wave is connected above its threshold, then unity, identity of the main consciousness takes place, in which then the connection of the psychic phenomena, which belongs to the parts of this wave, also falls into consciousness. If, on the other hand, main waves are not connected or only under the threshold, divorce of the corresponding consciousness takes place, in which case there is no connection between the consciousness and the consciousness. In short, the main consciousness is continuous or discontinuous, uniform or discrete as the main psychophysical waves that are subject to it are continuous or discontinuous above its threshold.

From the same point of view as the case of organisms separated by external nature, the occasional case of congenital people, whose brain is not connected, unless the main wave of their psychophysical activity is indisputable only within their nervous system or even brain above the threshold, by the way decayed Organism is therefore only below the threshold.

It would suffice, the whole wave train *a* , *b* , *c* To elevate in the scheme, so that the troughs in nature with the mountains at the same time cross the threshold, they would form only depressions of one and the same above the threshold of continuous wave-train, and the discontinuity of consciousness in nature would become turn into continuity. We can not realize that. It would be enough to push the mountains together so that the valleys fell away, and the mountains above the threshold conflated; In this way the discreetly sensitive organisms would become a unitary organism. Man, too, can not realize this arbitrarily; but he himself is the realization of it. Its two halves, the right and left, are connected in this way; and prove the amount of segments of a Straltieres and other divisible animals, that several more can be connected in this way. In fact, they need only be separated again, that is, to insert a part of nature under the threshold between them, so they also fall back into two beings that are in their own right.

In support of the idea of the phenomena involved in such attempts at separation, I share here some observations:

Bonnets¹⁾ from his essay "Observations sur quelques espèces de vers d'eau douce, qui coupés par morceaux, deviennent autant d'animaux complets " With.

¹⁾ oeuvres d'hist. nat. T. I, 1779. p. 167 ff.

Bonnet describes the animal on which he made his experiments without specifying a natural historical name for it; Treviranus (the Declared and Ges. D org. Leb. I, 57. 59) describes it as a colorful Naide (*Nais variegata* or *Lumbricus variegatus* garbage.).

p. 178. "J'avois partagé un pareil ver en deux parties." "Je fis cette opération le 3. de Juin 1741. - Immédiatement après lis les deux moitiés dans une espèce de tasse de verre, de trois à quatre pouces de diamètre sur un pouce ou environ de profondeur. Je ne les perdis presque pas de vue: the remarquai que la première moitié, celle où tenoit la tête, se mouvoit comme à l'ordinaire. Main ce qui me parut bien autrement remarquable, c'est que l'autre moitié qui n'avait point de tête, se mouvoit presque comme si elle en avoit eu une. Elle alloit en avant en s'appuyant sur l' extrémité antérieure de son corps; elle avancoit même avec assez de vitesse. On voyoit que ce n'étoit point un mouvement sans direction, un mouvement produit par a cause telle que celle qui fait mouvoir la queue d'un Lézard après qu'elle a été séparée du tronc, mais un mouvement très-volontaire. On l'observoit détourner à la rencontre de quelque obstacle, s'arrêter, puis se remettre à ramper. Lorsque les deux moitiés viennent à se rencontrer, c'étoit comme si elles n'eussent jamais formé un même insecte: elles né paroisoient ni se chercher, ni se fuir. Chacune tiroit de son côté; ou si elles alloient de compagnie vers le même endroit, la première dévançoit ordinairement la seconde. Corn celle-ci ne montroit jamais mieux une variety de volonté, que lorsque je l'exposois au soleil; elle hâtoit alors considérablement sa marche. " Lorsque les deux moitiés viennent à se rencontrer, c'étoit comme si elles n'eussent jamais formé un même insecte: elles né paroisoient ni se chercher, ni se

fuir. Chacune tiroit de son côté; ou si elles alloient de compagnie vers le même endroit, la première dévançoit ordinairement la seconde. Corn celle-ci ne montroit jamais mieux une variety de volonté, que lorsque je l'exposois au soleil; elle hâtoit alors considérablement sa marche. " Lorsque les deux moitiés viennent à se rencontrer, c'étoit comme si elles n'eussent jamais formé un même insecte: elles né paroisoient ni se chercher, ni se fuir. Chacune tiroit de son côté; ou si elles alloient de compagnie vers le même endroit, la première dévançoit ordinairement la seconde. Corn celle-ci ne montroit jamais mieux une variety de volonté, que lorsque je l'exposois au soleil; elle hâtoit alors considérablement sa marche. "

"Deux jours s'étant écoulés, je crus devoir mettre dans la tasse un peu de terre et de lentille aquatique" La première moitié ne tarda pas à s'y enfoncer: mais la seconde se contenta de se cacher entre les menues racines de la lentille: Dans ce temps-là j'observois au bout antérieur de cette moitié une espèce de petit renflement, a kind of bourlet analogue à celui qui vient à une porche d'arbre dont on an enlevé circulairement une portion d'écorce: je ne le distinguai pas si bien à l'extrémité postérieure de l'autre moitié, Ce bourlet sembloit lui thonner plus de facilité pour ramper, all paroissoit plus craindre autant le frottement. "

"Le lendemain j'apperçus à la coupe de chaque moitié un petit accroissement reconnoissable par la différence de couleur, qui était là beaucoup plus claire que dans le reste du corps." Les jours suivons tout devint plus sensible enfin au bout d'environ une semaine, chaque moitié fut and complété La tête qui avoit poussé a la seconde, était précisément telle, quant à la forme, que celle de la première, et capable of mêmes fonctions; et la nouvelle cue de celle-ci, en tout semblable à celle de la seconde moitié; le coeur, l'estomac, les intestins, etc. s'étoient prolongés dans l'une et dans l'autre; de nouveaux anneaux avoient poussé à la suite des anciens. En mot, tout ce que le premier ver faisoit avant que d'avoir été partagé, nos deux vers qué en étoient de provence, le faisoient pareillement;même agilité, mêmes inclinations, même façon de vivre, de se nourrir. "

p. 241. "Tout cela, quoique fort remarquable, ne l'est pas néanmoins autant que ce que j'ai observé sur de semblables vers, peu de temps après leur avoir coupé la tête, Je les ai vus, à mon grand étonnement, s'enfoncer dans la boue en se servant de leur bout antérieur comme d'une tête, pour s'y frayer un chemin. J'ai vu le ver no. 2. de la Tab. II. ramper le long of the parois du vase de verre, où je le tenois renfermé, et faire effort pour en sortir, quoiqu'il n'eût ni tête ni queue. "

p. 183. Bonnet afterwards repeated these experiments in such a way that he divided the animals, instead of merely in two, in three, in four, in eight, in ten, in fourteen parts, and all or almost all reproduced head and tail; once this happened to one of the animals divided into sixteen parts. About the way the life expressions of the pieces to the reproduction but nothing is specified.

p. 191. Just as bones, once the ossification has advanced to a certain point, only grow at their ends, Bonnet, too, after several observations, found that the pieces of the divided animal are only by sprouts at the ends, not by replenish internal growth to its former size.

p. 218. "One can shorten the same animal repeatedly by head or tail, it is always regenerated, but Bonnet did not succeed in doing so over 16 times with the same animal."

p. 228. Head and tail, when cut too close to the body, never reproduce. "Je suis maintenant si persuadé, que ni l'une ni l'autre de ces parties ne sauroient devenir d'animaux parfaits, que je le regarde comme un principe dans cette matière, d'où je crois pouvoir tirer cette conséquence que la source de reproduction ne réside pas dans tout le corps de ces vers, mais que si l'on fait la section à l'une ou de l'autre extrémité, qui soit moindre qu'une ligne et demie, la partie coupée périra sans se reproire. " By contrast, pieces reproduced by $\frac{1}{2}$ bis $\frac{2}{3}$ line between these two points taken to animals lacking anything.

The totality of the facts which relate to these relations of conjunction and separation leads to the following general proposition, which enters into what was said in Chapter 37, concerning the solidary supplementation and representation of body parts in the service of the soul.

If a psychophysical system is composed of a majority of equal parts, segments, which are above the threshold, they give in their connection a unified psychic direction of the same kind, as each one is able to give for himself, thus assisting in the same achievement long they are related above the threshold, and give the same unitary power each only to a lesser extent, which may fall under the threshold if they are separated so that they are no longer connected above the threshold.

In fact, this is only the expression of the facts observed in divisible animals, in so far as the most natural interpretation of their expressions of life is valid before and after the division. The fact that the separate parts, given the same type of psychic performance, do not give them the same strength as the whole animal in the past, can be deduced from the generally lower energy of their expressions of life, which in some circumstances can go to the point of dying until it succeeds to replace separated half by reproduction, to which all divisible animals are capable.

The same thing that the experiments teach with the complete division of animals is shown by the attempts to split off or destroy only one half of the brain. In fact, after the separation or destruction of the others, if one survives life, each half of the brain still grants the same consciousness as Flourens' experiments on animals, insofar as their state of consciousness is judged by their utterances, and have taught approximate pathological experiences in humans with easier fatigue than when the mutual support takes place, as one can conclude from some strange experiences.

Ferrus reports a generale who had lost a large part of his left parietal bone due to a wound, resulting in considerable atrophy of the left brain hemisphere, manifested externally by a tremendous depression of the skull. This general still showed the same vivacity of the spirit, the same correct judgment as before, but could no longer indulge in mental pursuits without soon feeling tired. Longet, reporting this experience, says he knew an old soldier who was in the same trap. (Longet, Anat. Et physiol., Du syst., Nerv., I, 670.)

These as well as the following examples are to a certain extent pathological repetitions of the human physiological experiments conducted by Flouren on animals, and may serve to prove that in fact the same conditions apply to humans and animals in this respect.

"Diemerbroek²⁾ tells the story of a girl, which the entire right half of the brain was destroyed by the fall of a heavy stone, and in which another 36 hours, the mental and sensorial life showed undisturbed. A similar case, says Roloff³⁾ of a woman in which one found considerable destruction of the left half of the brain at the dissection, while the right hemisphere was quite normal, in this individual the psychic functions were not in the least clouded In an old woman who died of pneumonia, one found the left brain perfectly healthy, but the right atrophied almost in its individual parts, and this woman had never suffered from the lowest mental disorder⁴⁾, Longet tells of a man of twenty-nine, whose mental powers offered no appreciable deviation, despite the absence of the entire right hemisphere of the great brain, with the exception of the basal parts (Longet, Anat., And Physiol 1842. I, 669.) - Neumann cites a case in which a bullet had destroyed an entire hemisphere without robbing one's senses. "(Neumann, on the Diseases of the Human Brain, Koblenz, 1833, p. Abercrombie reports of a woman in whom half of the brain was disintegrated into a morbid mass, and who nevertheless, accounting for an imperfection of vision, retained all her mental faculties until the last moment, so that she was still a few hours before her death attended a cheerful company in a friendly home. (Abercrombie, inquiries, etc.) - A man whose O'Holloran mentions suffered such an injury to the head that a large part of the skullcap on the right side had to be taken away; and as a strong suppuration had occurred, with every bandage through the opening a great quantity of pus was removed with large quantities of the brain itself. So it went on for 17 days, and it can be calculated that almost half of the brain, mixed with matter, was ejected in this way. Nevertheless, the patient retained all his mental powers until the moment of his dissolution, just as during all this illness his mood of mind was steadily calm. that a large part of the cranium on the right side had to be taken away; and as a strong suppuration had occurred, with every bandage through the opening a great quantity of pus was removed with large quantities of the brain itself. So it went on for 17 days, and it can be calculated that almost half of the brain, mixed with matter, was ejected in this way. Nevertheless, the patient retained all his mental powers until the moment of his dissolution, just as during all this illness his mood of mind was steadily calm. that a large part of the cranium on the right side had to be taken away; and as a strong suppuration had occurred, with every bandage through the opening a great quantity of pus was removed with large quantities of the brain itself. So it went on for 17 days, and it can be calculated that almost half of the brain, mixed with matter, was ejected in this way. Nevertheless, the patient retained all his mental powers until the moment of his dissolution, just as during all this illness his mood of mind was steadily calm. that almost half of the brain, mixed with matter, was ejected this

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²⁾ Anat. Lib. 111, cap. 5th

³⁾ Nasse's Zeitschr. 1825. Issue 3. p. 173.

⁴⁾ Bell, in d. revue médic. May 1831.

It is in fact the same with both brain hemispheres as it is with two horses stretched before one and the same car. One can relax one horse, and the carriage goes on in the same sense as before, no less the other, and afterwards one would think that they are both superfluous at the same time for the passage of the carriage; the car would still go if you both relax. But then he stands still; and while both are on the cart, they are not merely there to defend themselves for the loss of the other, but also to assist in the process; for if you stretch one of them out, the carriage will slow down, or if it is about as fast due to the stronger drive of one horse, but with less duration.

For the first sight, however, it seems quite paradoxical that the omission or destruction of an entire hemisphere of the brain so little or no disadvantage to the normal course of the psychic life, but much smaller damage on one side or unequal damage on both sides of the brain often cause the greatest disturbances in it. But this, too, is easily explained by the solidarity in which the activity of the hemispheres is related to their psychic performance, and can be explained by the picture which has just been used. If one of two horses in front of a carriage becomes wild or paralyzed by local damage, the other's course is disturbed because they can only communicate; If the wild or the lame are stretched out completely, the disturbance ceases, and only the carriage goes weaker;

In the meantime, what we can not arbitrarily do and like can happen again through external or internal circumstances independent of our arbitrariness. Probably this is where the not uncommon cases occur, that madness ceases just before death, when death destroys the diseased parts of the brain, which, by their connection with healthy ones, cause a disturbance of the spiritual life, before the healthy ones. Again, this is essentially the explanation which Friedreich, in whose handb. D. General Pathol. the psych. Krankhh. P. 497 there are several cases of this kind.

Even more directly here are some curious cases where brain injury with loss of cerebral substance seems to have been beneficial to the intelligence. It is very probable that the advantage in this respect is to be considered from the same point of view as trepanation, namely, that with diminution of the cerebral substance, a detrimental pressure which the brain probably suffered before, could indeed be lessened, which preferably affects mental faculties , In fact, the individuals in whom this beneficial result was observed by the loss of the cerebral substance previously suffered from headache, dullness, or dreaminess, all of which could very well depend on pressure on the brain.

I have found 4 cases that belong here, one is in the Nov. Act. Nat. cur. II, 364; another in the north-americ. med. surg. Journ. 1830. Jan. p. 213; a third in Carresi selecta, Siena 1830. dec IX; a fourth in l'Institut. 1836. no. 134 communicated.

It is easy to overlook how the case of destruction of one half of the brain is connected with the splitting of an animal. Whether the segments of the psychophysical system that are equal or behind each other is only an insignificant difference, and whether the split-off piece is destroyed or not is equally indifferent to the survivor. There is only the difference that in man, as in the lower animals, there can not be a complete separation of the whole system in such a way that both parts live on. Incidentally, both cases agree that before the split the two parts of the creature feel in one, and support one another in the psychic performance, but also that one part may miss the other, and yet the same, only weaker, psychic achievement before there.

It is not disputed that the organic connection of the parts themselves is one of the conditions that contribute to the vital preservation of each individual, and thus to the preservation of psychophysical activity above the threshold, but in the higher creatures this solidarity is much stronger than in the lower ones.

If both halves of a person divided in the longitudinal center line could survive at all, ie that the psychophysical activities still persist in both halves above the threshold, we would undoubtedly do as well doubling a human as animal soul by separating the laterally corresponding and representative halves can be achieved in animals by separating the successive corresponding segments are able to achieve.

It would, however, be idle to think much about how the two halves of a divided person would behave in survival, since the case can not be realized. They would undoubtedly begin with the same state of mind, of the same faculties, of knowledge, of memories, of the same consciousness in general, but, according to the condition in which they came into different relations, develop differently.

It seems to have been embarrassing to what extent the success of the cleavage attempts on lower animals should be taken. Obviously, two souls emerge from one through division of the body on which one soul previously hung. So the process does not seem to be different, except that the soul is shared with the body in two. But the concept of the simplicity of the soul contradicted; and I have already quoted (chapter 37) how, on the part of the view of the simple soul-seat conceived on this concept, it was preferred to assume, instead of a division of the soul, the awakening of a new soul in one of the halves, but also what prevents this he agrees.

The thing is that with the abstract category of simplicity one is not sufficient to cover the essential conditions under which the soul can enter. However simple one may call the soul, it is certain that the intensity of its consciousness can increase and decrease, come down to half, and double, and sink completely below zero. After this it is easy to say the actual and sharply significant; the soul is number-doubled in number, split in intensity, but with the possibility of the remission of the loss of

intensity which each one has suffered as a result of splitting off, if the reproduction of his bearer is great enough.

It may also be the case that of the two separate parts, only one remains above the threshold, the other sinks just below it; then only one lives on; like that, when you cut off a piece of the brain; or that by the separation they both sink below the threshold at first, but gradually rise above it again, then separate consciousness only appears after some time; or that both are constantly sinking below the threshold; or that if the two separate parts are psychophysically different, the quality of the state of consciousness for the separate parts also becomes different .

Among which of the various possible cases are the plovers and so many related experiments, whether a head without a trunk, or a headless head in higher animal classes and man, may still be felt for some time, are questions which, according to the discussion in chapter 37 not yet sure to decide. So far we do not know whether a psychophysical movement above the threshold can reach into the spinal cord of any living creature, nor whether it can be preserved after separation from the head, nor what differences exist between different animal classes; and as ingenious as the attempts made and the discussions plowed on them are, there still remains the possibility of various interpretations.

Among the splitting processes, which result in an extensive duplication of souls, is the birth of man and of the higher animals. But this doubling can not be achieved here by separating two similar subsystems which are connected above the threshold, but by dividing one below the threshold, the organism of the child, from the other above the threshold even crossing the threshold. For the stimuli of the external world belong to the conditions which an otherwise disposed system can raise above the threshold, as the awakening from sleep proves, and therefore the separated child, irrespective of it, is deprived of a condition of life by separation of the connection with the mother. but only with this separation can awaken.

So much of the relations of psychophysical continuity and discontinuity of the main consciousness to spatial relation. But for each individual there is still a continuity of the principal consciousness through the succession of time, which expresses itself as the continuation of the identity or unity of it through the course of time, and establishes the connection between a series of successive phenomena in the same soul. Here it may be strikingly found that the temporary lowering of the main wave in sleep below the threshold does not cause a corresponding interruption of the continuity of the principal consciousness in the individual, as the spatial sinking below the threshold between the individuals, since rather after each new awakening the new one Consciousness in continuity with the old feels.

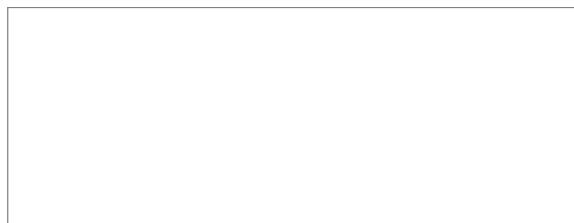
As little as the continuity of the main consciousness in time is interrupted by the sinking of the main psychophysical wave in sleep, so little is the case by the transition to completely different matter, and by the change of forms, as empirically proved by the fact that the organism It is continually renewed by the metabolism, and the body of the old man in general consists of completely different matter and matter combined in other forms than that of the child, without somehow interrupting the

continuity of the main consciousness. In general, as far as we can learn about it, there are only ways of temporarily letting this continuum go unconscious, sinking the soul into sleep, but not canceling continuity,

A condition exists here. In the course of time, the soul can change from a material system to a completely different one according to substance and form; but do not skip it; but the new matters have to enter the old psycho-physical system, however, the leak old, done gradually as in the metabolism, or the old psycho-physical movement must be *in continuo* on Plant on new matters, as in the exchange of attention suddenly happens.

This can be an important implication. The idea that in the transition to a future life we will be transferred to other planets, the sun, or into the distant heavens, that is, that our psychic life will henceforth associate itself with the psychic life going on there has no bottom. But, if there is a future persistence, it can only be based on the fact that the main wave of our psychophysical system on which our main consciousness depends depends on the part of the earthly system to which it now hangs, or in which it now exceeds the threshold , to pass on to another part or to a large part of this system in continuo, which possibilities to discuss here however not the place is.

The continuity and discontinuity relationships that take place for the main waves may be repeated for their harmonics, and of course this will be to make the distinction and non-distinction of what is in the consciousness. A main wave, which is in itself above the main threshold *AB* , can nevertheless carry harmonics, which are connected below their threshold *A' B'* ; according to the following scheme:⁵⁾



⁵⁾ This scheme represents the elevation of the harmonics above the threshold in the same direction as the elevation of the sub-waves, abstracting from the fact that harmonics may exceed the threshold by motion in opposite directions than the same direction; which does not matter here.

That all the harmonics *a , b, c ... are* related above the same principal threshold in a principal wave, assigns them to the same principal consciousness, and submerges them, but at the same time being discontinuous above their own threshold, distinguishes them within this principal consciousness.

Earlier (chapter 34) I have asserted this view in relation to the extensive sensations. In intense sounds, as in sounds, distinctness was dependent on the effect of attention.

If corresponding fibers of the retina give only one identical sensation, not two, if both halves of the brain are always united in one thought, then they, that is, the activities in them, will have to be connected not only above the main threshold but also above the upper threshold.

It is not disputed that the distribution of psychic power to two equal halves of the brain in man and the higher animals, and to a majority of successive or symmetrical circles of similar segments in the lower animals, has its important teleological significance, and thus becomes an example of the innumerable Examples that we can find in the institution of the organism, that the best possible means are achieved with the least possible expenditure of resources, and that with the same institution a majority of purposes is fulfilled at the same time.

For this institution fulfills the purpose that injuries can not easily put mental integrity at a disadvantage by having a part to represent and, in many animals, to link the other's replacement; secondly, in lower animals it appears as one of the means of multiplying souls; third, it makes possible, in accordance with the principles developed in chapter 21, to do more with a given quantum of psychophysical activity than if it were to one point or, if admittedly, what has not yet been proved, that the points of view valid for discrete points of view remain valid also for those who are *in continuity*.

Let us conclude the considerations which we have attached to our schema in this and an earlier capital, with some considerations of the most general nature, which, in conjunction with those of the following chapter, may be suitable for looking ahead to the great significance of psychophysics ,

Our main waves, to which our main consciousness hangs, bear waves on which our particular phenomena of consciousness hang. But can not our main waves be considered as the harmonics of a larger main wave? Physically they really are, why not psychophysically? for the whole activity of the earthly system can be represented by the scheme of a great wave, to which the activity systems of the individual organic creatures belong only as small harmonics; and the activity systems of the individual world bodies are again only harmonics of the general system of the entire movements of nature. The step structure, which continues into us, continues beyond us.

Now, if the harmonics in us, in which the distinguishable phenomena of consciousness are within us, are only discontinuous above their threshold, but continuously above our main threshold, then not even the main waves to which our main consciousness hangs become intermittent above their threshold, but continuously over to be a deeper main threshold? This would imply that there is still a more general one to our main consciousness, which embraces our own as well as its peculiarities, just as our own again embraces its peculiarities.

The consequence of this conception leads to the view of a consciously omnipresent God in nature, in which all spirits live, weave and are; how he carries in them, with the personal bodies of the individual, spiritual intermediate stages between him and us, which contain the creaturely spirits as united as they are in turn carried in the divine spirit, and like the creaturely spirits again their sensory circles and these carry their special sensations in themselves. This view can be further developed and supported on the basis of the analogies and connections which the stepwise construction already offers in man himself.

Hereby the prospect of our own continued existence after death comes into relation from several sides. Particularly close to the following point of view:

If an image in our eye, linked to harmonics, leaves an echo of memory after its extinction in the eye, which enters into a more general and higher realm of memories and thoughts of general or chief consciousness, we may believe that something similar will encounter our main waves so long as they are in turn harmonics above a lower threshold, and that our spirits thus enter after death into a higher spiritual kingdom in God.

This view, too, can be further developed and supported on the basis of analogies and contexts which our life on this side presents. But this as well as that for now is rather a matter of natural philosophy and of a religious view of nature, as a matter of psychophysics, which, according to its present state, is only able to provide a starting point for it.

You can find these views in detail in my book "Zend-Avesta or the Things of Heaven and the Hereafter from the Viewpoint of Nature." 3 parts 1851, and shorter in the new: "On the soul question" 1860, presented. The beginning and the first arrangement of the present Scripture have themselves developed only in connection with the considerations set forth in them; and so it may be natural that she goes back to the views expressed there on her way.

XLVI. Question about the nature of the psychophysical movement.

Although we have been able to treat the most important questions of internal psychophysics to a certain extent, without requiring other presuppositions about the nature of the psychophysical movement than that it shares the most general conditions of bodily movement as a bodily movement, the final question may be its Nature can still be considered in a few words.

The question is essentially divided into two:

- 1) Can the psychic only relate to the movements of a particular substratum?
- 2) Can the psychic only be linked to a particular kind, arrangement, form of movement?

As for the first question, it is possible to think of it, and many have thought of submitting to the psychic a very exclusive substratum, which is just intended to carry

out the movements subject to the psychic, without any of the known physical ones Substrates can be identified, and it has probably been added to these substrates the name nerve ether.

The main reason for this is probably that none of the known physical agents or substrates has been thought to be carriers of the psychic; but one does not see what an unknown physical agent, should it otherwise reach beneath the physical space, could do more, upon which its psychic charm should rest. But if one wishes to get out of the range of physical agents altogether, one gets completely into the dark in a word, which should mean neither physical nor psychological, and leaves the basic presupposition of psychophysics itself, which is that the psychic changes are in law with physical associated; In fact, they are in fact related to such; The removal of the substrate into a hyperphysical area thus does nothing more than to pull us away from the ground under our feet.

It is undisputed, without falling back on very general views, as we have stated at the beginning of this work, something unexplainable, and at least in the field of psychophysics itself, which merely adheres to factual points of view, not explainable, as a physical substrate in general his mode of movement can become carriers, indeed only external stimuli of consciousness phenomena; but explanatory power is not augmented, but the enigmatic is multiplied only by a puzzling mystery, if we want to fake a new physical agent as its bearer, without being able to specify what it is to make suitable to others, and for no other reason to have his existence as the need to explain what can not be explained by it.

Let us further note: how shall the suppressed peculiar nervous ether get on its nerves, and how shall it leave it in death, if it is not given a more general distribution about the nerves and the organisms? Should he at first emerge new, in the end pass away? Then he stops being a physical.

All these difficulties are avoided if one assumes that the movements of the same universal ether, which is diffused by external nature as well as by organisms, can carry sensation, general phenomena of consciousness, under certain conditions which are fulfilled in our organisms. Also, this is probably the view of most of those who have a clear view on these things.

Preferably, to claim an imponderable agent in front of the ponderable substrates, we can be made by the following points.

Through experience we are bound to regard the nervous system as the main focus of our psychic phenomena. But the device of it is not capable of allowing movements of the weighable similar to those of the blood in our veins, while it does not prevent any movement of an imponderable agent in it. The excitability of all nerves by electricity, and others also by light and heat, suggests that the play, which can be excited by the movement of the imponderable cord, also affects the unpredictable; The phenomena of electric fish and Dubois' investigations are supported by others. Also, the nervous system appears only as a supplement to the circulatory system, which carries drippable fluids, and the respiratory system, which conducts air if we hold it to be essential,

From the other side, however, one must not overlook the fact that, due to the nature of the nerves, molecular oscillations of the weighable are as little excluded as the unpredictable, and that in a system of weighable and imponderable parts, oscillations of the one can not take place to take with others; furthermore, that the nervous system can not operate without the help of the circulation, and that an increased activity presupposes an increased activity of the circulation and of the chemical processes it maintains, in which necessarily weighable parts compete; finally, that the nature of the stimuli does not determine anything, in that the nerves can also be excited by mechanical and chemical stimuli; and it is just as possible

I therefore believe that there are no decisive reasons in experience for linking the activity of the nervous system in general, and consequently also its psychophysical activity, to the imponderable. But even if the imponderable agents had an advantage, it would always be probable that they would receive it not through a peculiarity of their substance, but only through their mode of motion, inasmuch as neither such rapid vibrations nor rapid movement propagation in the realm of the weighable are known as unpredictable. The fact that the mass disappears from the psychophysical elementary formulas and that only the state of motion disappears (T. II, Chap. 16) is, in fact, very well suited to support the assumption that the state of motion in this area depends in the first place.

To make assumptions about these points would be useless; it is enough to have recalled the possibilities. In any case, even though the imponderable substances by their mode of movement should retain a preferential importance for the psychic phenomena, the weighable will always remain the most important for the organization of the systems, which determines the form of these movements. And certainly, in a future most general mathematical formulation, both organization and movement will not be independent of each other.

According to every view we may cherish, the substratum of the psychic remains a world-wide and universal system-bound system, and the second question now challenges us, whether the psychic is limited to a particular kind, arrangement, Form of movement can make.

Since we know that movements which are in fact suitable to carry the phenomena of consciousness, yet only need to sink to a certain degree of liveliness, so that the consciousness is extinguished; Thus, naturally, we have the possibility of making the quantity of consciousness, to which existence and not-being belongs, dependent only on quantity, not on the quality of psycho-physical activity, but rather on the quality of the phenomena of consciousness put.

According to this, every movement, under whatever form and on which substrate it occurs, would, if. if it exceeds a certain value with its velocity of either first or second order (where between the 30th and 32nd chapters is still the choice), there is a contribution to consciousness, whether to ours or to others or to a general consciousness; and every particular form of motion, that is, the order and sequence of speed-moments, be able to carry a psychic phenomenon of an associated form, when the moments entering into this form together exceed a certain magnitude value.

In such a way we spare ourselves the magical spell, the *qualitas occulta*, which is supposed to enable only this or that exceptional form of movement for psychic performance, and a general psychophysics, not merely particular for humans and animals, will be possible, in a corresponding sense, as we have a general physics and mechanics valid for the whole world. We will explore the laws of psychophysics in humans and will be able to transfer them to the world. The conscious and the unconscious in the world will present only two cases of the same formula, which at the same time is decisive for their relation and their transition into each other.

Of course, such a view can not be proved otherwise than by the fact that it gives full satisfaction in a developed psychophysics.

I can not lead this proof already now; but I believe that with the advancing development of psychophysics he will naturally lead himself, the first attempt of which I conclude with this distant prospect.

Historical and accessories.

XLVII. Historical.

Facts in the field of psychophysics have always been observed, and so far no one can speak of a definite beginning of this doctrine. If, however, I should name someone who first conceived, combined and even added so many new facts in such a context to a series of such facts, psycho-physics would have been misled into becoming a coherent exact science I call none other than EH Weber, to whom, with greater clarity and in greater publicity than any one before him, not only did he ever suspect that there was a field of measure, but he also proposed this idea to a greater extent and more successfully than anybody brought him to execution. Apart from the enrichment of psychophysics by many special facts,

His investigations are partly in his *Programmata collecta*, Fasc. III, 1851, partly compiled therefrom and expanded many times in his treatise on sense of touch and common sense (reprinted from Wagner's physiological dictionary), whose title is far too narrow for its content. Some supplements can be found in the reports of the Saxon Societät, 1852, p. 85 ff.

In so far as his statements and attempts relate to the psychophysical Basic Law, to which I have attached his name, I have been informed by you in the ninth chapter, and also by the other merits of previous observers to the establishment of this law, namely Bouguer, Arago, Masson, Steinheil, which all refer to the sensation of light, has been well thought out. If a complete history of psychophysics is given here, there

would be many more names to associate with estimable investigations in the field of psychophysics. And indeed, among the most recent researchers of general consensus, Helmholtz may, on account of his many astute investigations and important discoveries in the realm of light, sound, the theory of nerves, and Dubois may be mentioned above all because of his groundbreaking investigations into the electrical forces governing the nervous system, since the latter, although useful for now only in physiology, should once have been among the most important documents of internal psychophysics. However, as this book prefers to refer to the psychic theory of measurement, I also limit myself in the following to the fact that what preceded it in the first place, caused it itself, and determined its course.

To the experimental precedents of the same in this respect, the mathematical by the already mentioned in the preface to the first part of this writing researchers Bernoulli (Laplace, Poisson), Euler (Herbart, Drobisch), Steinheil (Pogson) to commemorate, provided that all the mathematical function , whereby psychic and physical magnitudes are interlinked in the sense of Weber's law, Bernoulli had already set forth earlier with regard to the dependence of the *fortune morale* on the *fortune physique*, Euler on dependence of the sensation of the pitches on the vibrational numbers, Steinheil in Regarding the star sizes, which can be translated into sensation quantities, from the photometric values of the stars.

Bernoulli's principle concerning the dependence of the *fortune morale* on the *fortune physique*, first established by Bernoulli in 1738, is discussed in Th. I, p. 236, and the succession which Bernoulli found in it by Laplace and Poisson Service.

Perhaps it is alienating to find this principle here for psychophysics. In fact, however, it must be subordinated to a sufficiently general version of it. For a *fortune morale* , as already asserted before, means nothing other than the enjoyment which the soul has of external goods of fortune, the *fortune physique* the means which produce this enjoyment from the outside, and the former takes the place entirely the sensation, the latter the stimulus; also the *fortune morale* is treated in the same sense as a function of the *fortune physique* of Bernoulli, as of us the sensation of the stimulus, and it is the same law that links both.

The determination of the function for the dependence of the sensation of the tonal intervals on the ratios of the numbers of vibrations by Euler is in his *Tentamen novae theoriae mus.* 1739. p. 73, ie only one year later than the establishment of Bernoulli's Principle. Later, Herbart ¹⁾, independently of Euler, arrived at the same conception of tonal intervals, and finally not only newly established them by Drobisch ² , but also repeatedly emphasized their interest, and made further developments of which we were one of them most interesting T. II, Chap. 30 have been reproduced without these investigations have so far found the deserved attention.

¹⁾ Main points of metaphysics. Götting. 1807. §. 14. Works III, 46.)

²⁾ Abhandl. the Jablon. Gesellsch. 1846. p. 109 and
Abhandl. d. Kings. Sächs. Gesellsch. 1852. Volume IV, p. 1. (Pogg. Ann. XC.
375.)

The connection of the star magnitudes with the photometric intensities of the stars by a logarithmic function is independent of Steinheil 3) (1837) and Pog-son 4) (1856), not directly on Weber's law, but on the related experiential Having been based on a geometric series of photometric intensities of stars to the arithmetic series of sizes.

3) Elements of the brightness measures in the Abhandl. the baier. Acad. 1837. Volume II, p. 22.

4) Notices of the royal astr. Soc. 1856. p. 14, hereafter in the reports of the Saxon Soc. 1859, p. 68.

The establishment of the logarithmic function according to these relations has, of course, not been done by all the named researchers from the point of view of a psychic measure, but according to other particular aspects; and since that time has not been referred to a psychic measure, which is easily explained by the nature of the examinations and cases which led to the establishment of this function.

Thus it is self-evident that, if the logarithmic expression for the dependence of the *fortune morale* on the *fortune physique* can presently be regarded as being under the general psychic measure principle, this must have been grounded from another angle, but could not be substantiated by it.

Of course, measuring the sensation of the intervals of sound according to their dependence on the ratios of the numbers of vibrations could, of course, be no occasion at all, since the sensation of the intervals of sound, exceptionally of other psychic magnitudes, already has its measure in it; No one, however, seeks to measure a cubit by which the toll is already divided, and by another, where they are not separated. Instead of being able to seek a measure of the psychical through the physical, it was only necessary to relate an already independent physical and psychic measure to each other. Thus, in fact, Euler's task has been taken, which, before entering into this relation, after consulting with the relations of sensation, says: "Ex quo intelligitur, intervallum ita esse definiendum, a and b , b and c can be set equal to the interval between a and c .

Herbart and Drobisch, too, make use of the mathematical relation between the sensation of intervals and the vibrational relations, but without seeking the measure of the first in it and utilizing this relation in their mathematical psychology in the sense of a psychic measure; but developments are likely von Drobisch contain everything that can be deduced for the teaching of sound intervals, especially from this relationship.

What of the Tonintervallen, applies in a sense also of the intervals of the star sizes. The practiced eye of the astronomers, after another exception, had been able to determine these intervals without regard to the underlying photometric conditions; It

was not first necessary to find the measure of the sensation of light, but only its relation to the physical measurements given from the other side, and to make practical use of them for astronomy; and according to the conventional way of ordering the star sizes, the expression of this relation even took on the opposite sense, as it would have to have been if the meaning of a measure of sensation had been sought in it, as long as the star magnitudes decrease thereafter, while the photometric intensities increase.

According to this, it may be said that the problem of psychic measure was, in a sense, solved earlier than posited, as long as the solution was already contained in the establishment of the logarithmic function by the named researchers.

To a certain extent, of course, only; For once the solution referred only to a few limited fields, without any aspects and facts which would have permitted a generalization; secondly, the solution was based entirely on Weber's law, irrespective of the limitations to which it is subject, and without a generalizing principle even in cases where this law does not apply; Thirdly, because of the lack of consideration for the fact of the threshold of irritation and of difference, the measure was given merely for sensory differences, not for absolute sensations and perceived differences, and henceforth merely the difference formula, not the measure-formula and the difference-measure-formula; and fourthly, there was a lack of criteria

After these relations, as well as by a more precise statement and extension of the psychophysical methods of measurement, I believe that psychophysics has been extended in this work; With this enlargement a lot of new prospects, but at the same time new problems have opened up, such as the elementary construction of the measure of sensation, the investigation of which inner physical differences depend on the psychic differences of the different senses, the representation of some of the principal relations of the senses inner psychophysics, but are still far from a complete solution.

After that, there should still be some interest, and even some points of instruction, in describing the beginning and the course taken by this whole investigation.

To begin with a comparison, think of someone standing on a circular periphery; he is looking for a cause she is one step away from him; but he stands with his back against it, and runs through the whole long circle, until at last, after overcoming many difficulties in the sought-after thing, he is astonished to see that he only had to turn around to have her equal, and certainly not quite the same to have in it when he first thought. This happened to me with the search for the psychic measure. But may I not regret the path I have taken? For this way has allowed me to see the full implications of the measure principle, which the short path from Weber's Law and Euler's formula to the general psychic measure principle would not have been able to do. As far as I had to go backwards afterwards, so far it leads forward.

Always attached to the view of a thoroughgoing connection between body and soul and presenting it in the form of a double mode of appearance of the same basic nature, as I have briefly stated in the first chapter of this book, I found myself in the course of writing a work (Zend-Avesta), which is based on this view, the task of

finding a functional relationship between the two modes, or in other words, in a similar way, as the physics of the dependence of the color and intensity of light, the pitch and tone strength of the outside physical conditions, so to determine the same from the internal physical conditions to which the sensation directly attaches.

First of all, paying attention to quantitative relations, as long as physics makes all qualities dependent on quantitative relations, and without having a clear idea of the dimensions of psychic quantities, I first thought that the intensity of mental activity might well be the change of strength the bodily activity which I regard as measured by their living power. I carried this idea around with me for a long time; but it led to nothing, and I finally let her lie down. Later I came to a schematic explanation of certain basic relations between body and soul and between lower and higher spiritual through the relation between arithmetical series of lower and higher order (see Zend-Avesta II, 334); for the same purpose, In many respects, the idea of reproducing the expression for the true relation of dependency between soul and body instead of a merely schematic representation, which explains well enough the circumstances, but which does not express precisely, forced itself on me anew; but the scheme of the geometrical series led me now (Oct. 22, 1850 in the morning in bed) through a somewhat indefinite train of thought, the relative increase of the bodily living force,

or . When β The living force means to make the measure of the increase of the associated spiritual intensity. It occurred to me that if the living force of the body can be thought of summing up its absolute increments from a certain initial value, the soul, too, will add up the relative growth of the physical movement into its belonging, the psychic intensity as Integral absolute psychic increases can be considered, which belong to the relative increments on the physical side. Hereby was the fundamental formula, and as an integral of it, the measurement formula was given immediately. As a first confirmation, I immediately remembered that, according to everyday experience, the intensification of the sensation of light lags behind the intensification of the physical light-stimulus, and the surges that are given are all the weaker, the more strongly they arise, without me knowing the exact expression of this fact in Weber's law, with which only a sharp proof of the formula becomes possible. But with this first confirmation, which was still generally held in general, it seemed to me that I confess I am opening up a tremendous perspective; and even today I see this perspective in front of me, after this writing has only taken a small step into the area that opens it. without knowing the exact expression of this fact in Weber's law, which makes a sharp proof of the formula possible. But with this first confirmation, which was still generally held in general, it seemed to me that I confess I am opening up a tremendous perspective; and even today I see this perspective in front of me, after this writing has only taken a small step into the area that opens it. without knowing the exact expression of this fact in Weber's law, which makes a sharp proof of the formula possible. But with this first confirmation, which was still generally held in general, it seemed to me that I confess I am opening up a tremendous perspective; and even today I see this perspective in front of me, after this writing has only taken a small step into the area that opens it.

Initially gave me the fact to provide that, after the measurement formula sensation y already rather disappears as the living force β on which it depends, until I represent this circumstance in the phenomena of sleep and unconscious sensations, and hereby find a new conspicuous confirmation of the formula, which greatly strengthened my conviction of the fertility and fertility of it. To this end, I recalled from the treatise of Drobisch (1846) that although Euler, Herbart, and Drobisch had not attained much the same function for the intensity of the sensation, but for the pitch of the notes to which I have been guided by those considerations, and if so Both did not seem synonymous, so at least there was a supportive moment in it, since the amount of notes also contains a quantitative moment.

Of course, no psychic measure was established with all this; Rather, the whole contemplation suffered from the lack of a keen fundamental concept for the psychic measure. I suppose that the increases in sensation are proportionate to the relative gains of the living force of the psychophysical movement or stimulus stimulating it; but what proves, yes, what is meant by the fact that they are proportional to them as long as we do not yet have a psychic standard; What do the formulas based on

such an assumption mean [] and [] as long as this is not the case?

In setting up the function for the pitches by Euler and his successors, this difficulty was not lifted because it did not even come to light. Euler's formula does not refer at all to the absolute size of the sensation, but to its differences, not to strength, but to height; But, as already noted, the differences in pitch are very different in this from the differences of intensity, their definite measure in themselves; No one doubts that the difference in sensation from one octave to another is equal, and the application of this duty of musical scale with its subdivisions is familiar to everyone. Therefore it was sufficient for Euler to show that the sum of the perceived intervals between the tones a and b , b and c the interval between a and c could be equated to invoke the immediate experience of each, as it happens. But to which experience could one provoke, when it was necessary to claim the corresponding relation for the intensity of the sensation, in order to justify a measure of this, which it does not carry by itself, to this relation? I was not yet aware of Steinheil's study of the star sizes, and would have been of little use here, since it was not based on either a law or a convention on the order of star magnitudes, which was not proved to be psychophysical coincides; as Steinheil himself did not relate his formula to Weber's law.

The fundamental formula and Maßformel if already set, so hovering so to speak still in the air.

From the beginning, I sought to meet the difficulty of the following consideration. Decrease and increase, equality cases, borderline cases in the sensory area can be judged without having any measure of sensation, but our formulas include many inferences concerning such cases, such as that the sensation disappears at a finite stimulus value and at high stimulus levels for a given stimulus Stimulus growth grows relatively little. Insofar as these conclusions of the formulas are still valid in the experience without measure of sensation, we can establish a measure of

these formulas ourselves, in that a general application in those relations is possible only under the presupposition of correct dimensional relations, that is, correctly orienting us in experience between stimulus and sensation can take place in the formulas.

To this day, I still do not consider this consideration to be inadmissible, but it lacked, as I like to admit, the sharpness which I finally (chapter 7, 17, 31) believe in establishing the psychic measure by referring back to the observation to have given equality cases of small sensory differences in the different parts of the stimulus scale; nor were the general conclusions of the formulas, which were already provable without measure, far from being so broad as to regard the object as adequately supported.

In the meantime, after the subject matter had progressed so far, in 1850 I sent to Professor W. Weber in Göttingen a treatise on it with a request for a judgment on it, acknowledging the still very great deficiency in the justification and execution of the The subject nevertheless expressed the hope that the idea may be "a happy one".

It is not disputed that one will read without interest and instruction a passage of his reply to it, which for myself has become authoritative in the whole continuation of the investigation.

as it was reproduced by Fresnel and coincided with the discovery of the interference phenomena, I call happy. In your present field, the discovery of such fact may be very unlikely, but possible, as existing facts prove; For example, fifths and fourths are exactly the fifth in the octave, the major third and the minor third complement each other, which are independent of all acoustic theories based on immediate sound sensation. It is only through such facts by which they are supported that those ideas really take root in science. But just as Euler developed the idea of the wave theory before such supporting facts existed, so you are entitled to the development of your idea and the use of the existing for your support! But the real success will depend on if you are lucky enough to find supportive new facts soon. As long as this is not the case, evolution itself must be more general. "

Filled with the thoroughness of these remarks dictated by a deep insight, I contented myself at that time with informally and briefly communicating that idea in a work which does not claim the character of exact investigation,⁵ but since then has always sought that fact which W. Weber rightly sought called for making the idea a happy one, long without being able to find one. Finally, as a fundamental experiment, I came to the more precise proof of the formula, which was earlier based on more

vague considerations [redacted], which as a fundamental formula forms the starting point of the measure, those attempts with the light, which one finds in the 9th chapter; I soon made appropriate weight tests, which have occupied me for several years. then I discovered that what I sought, and thought he had laboriously worked out, in what I have so far overlooked, clear and experiential proof of the law, what it was for me, by the brother of him who gave me that hint , was already present to certain limits; the support of Volkmann, the finding of Masson's experiments, the

result of the study of the estimation of the star sizes, added to widening the field of experiential probabilities of Weber's Law, and the consideration of a little noticed date of everyday experience, in which the whole night-side of the soul hangs, has provided the still missing supplement to the experiential documents, which seemed to me necessary to establish the psychophysical measure function. For this purpose, the method of correct and false cases and the method of median errors could be applied to psychophysical methods of measurement and exploited as such, thus expanding the means for more general determination of the experimental documentation.

4) Zend-Avesta II, p. 368.

Now I would like to have handed this painstaking way of making the idea of the psychic measure a "happy one".

As you can see, the corridor leading to the psychic measure was the opposite of what his presentation here took. It was an aspect of internal psychophysics that gave rise to this first, and the facts of external psychophysics were at first merely subsidiary to support that viewpoint. Here the starting point has been taken from external psychophysics and only a few steps have been taken into internal psychophysics. In the beginning, the problem was not to find a psychic measure, but to seek a functional relationship between the physical and the psychic, which correctly represents the general interdependence of the same. Here is the psychic measure of what was found in this way

As little as I was fortunate enough to embark on this course from the beginning, I have so little succeeded in bringing the simplest basic points of it to the degree of clarity and evidence that at least the greater part of them here, I hope, and it will scarcely be seen in most of the chapters of this Scripture how much effort and reworking it has cost. I also want to cite some of this.

The interpretation of the positive and negative sign of the psychic values on the conscious and the unconscious was easily presented as a necessary one, and so at the beginning I believed that I had to take it as a generally applicable one. But this interpretation does not fit in with the general case of sensory differences; and this seemed to me to be a dubious mathematical incongruity, which, I believe, shows itself perfectly exalted in the discussion of the Twenty-third Chapter. For a long time I was embarrassed that the summation of positive and negative values of consciousness gives useless results for different points, spaces, or times, whereas the summation of positive and negative values can happen on their own. But the discussions in the 20th chapter are, in my opinion, sufficiently convincing that, on the contrary, it so perfectly penetrates into the familiar modes of application of mathematics that one could see in it a support for its applicability to psychic magnitudes. The fact that the growth of a stimulus is to be taken quite differently, as it grows to the stimulus on the same point or on another point, at first as an increase under the logarithm sign, secondarily as the logarithm of the increase, has come to my mind only after many a futile effort To bring clarity to clarity (see chapter

22). One of the gravest, and for the longest time confusing, ambiguities which, even in the course of the printing of this work, has completely disappeared but, fortunately, had no substantial influence on its earlier chapters, was that I According to the presentation in Chapter 22, the difference between differences in sensations in the strict sense and perceived differences could not be made clear, without which distinction the meaning of the threshold of difference remained unclear, and the difference-measure formula could not be established with certainty in addition to the difference formula. In the elementary construction of the psychic measure and the main chapters of internal psychophysics, I have often wavered over basic concepts, and I must not boast of having eliminated all wavering here; Rather, it must acknowledge that there are first links to more precise, more general, and more secure findings. The distinction between sensory differences in the strict sense and perceived differences did not make it clear, without which distinction the meaning of the threshold of difference remained unclear, and the difference-measure-formula beside the difference-formula could not be established with certainty. In the elementary construction of the psychic measure and the main chapters of internal psychophysics, I have often wavered over basic concepts, and I must not boast of having eliminated all wavering here; Rather, it must acknowledge that there are first links to more precise, more general, and more secure findings. The distinction between sensory differences in the strict sense and perceived differences did not make it clear, without which distinction the meaning of the threshold of difference remained unclear, and the difference-measure-formula beside the difference-formula could not be established with certainty. In the elementary construction of the psychic measure and the main chapters of internal psychophysics, I have often wavered over basic concepts, and I must not boast of having eliminated all wavering here; Rather, it must acknowledge that there are first links to more precise, more general, and more secure findings. and the difference measure formula besides the difference formula was not safe to set up. In the elementary construction of the psychic measure and the main chapters of internal psychophysics, I have often wavered over basic concepts, and I must not boast of having eliminated all wavering here; Rather, it must acknowledge that there are first links to more precise, more general, and more secure findings. and the difference measure formula besides the difference formula was not safe to set up. In the elementary construction of the psychic measure and the main chapters of internal psychophysics, I have often wavered over basic concepts, and I must not boast of having eliminated all wavering here; Rather, it must acknowledge that there are first links to more precise, more general, and more secure findings.

XLVIII. Additions.

a) Addition to an experiment proposed in the 30th chapter.

I have since employed myself in attempting to find out whether two identical and equally strongly struck strings sound equally intense at different levels of tension and

pitch, but unfortunately without decisive success. But I share the essentials with it, since perhaps others can be guided by the failure of these attempts to better employment of the same.

On the monochord of the local physical cabinet, which was given to me by Prof. Hankel, to whom I am particularly indebted for his support in these experiments, four steel strings, two of the same nature, were stretched horizontally next to each other. The unbroken oscillating length of the same was at all 1.52 meters. Two, *d* (thin), had close to 0.4 mill., The other two, denoted by *D* (thick), between 0.7 and 0.8 mill. Thickness. Both the strings *d* and *D* were each one octave higher than the other.

The attack of the two strings belonging to the same pair took place in some experiments by means of the same brass hammers specially prepared, which fell down on both strings from the same height and were caught by the hand in the rebound¹⁾; in others, according to a suggestion of Volkmann, more expediently by bullets, which rolled down from the strings set obliquely to the strings and jumped off on their own accord. The attack was both in the same distance, a few inches, from the end of both strings.

¹⁾ They should still be leathered, but after some preliminary experiments the use of the bullets seemed more advisable.

The two hammers were mounted in the same frame at one end of the monochord, parallel to each other and in the same direction as the strings, so as to reach across the longitudinal direction a few inches from the end of the monochord. The grooves, which were hollowed out in one board and parallel to each other, were also obliquely inclined to the longitudinal direction of the strings, the longitudinal axes of the channels corresponding to the string spacing above the monochord, so that the lower end of the strings was only slightly elevated above the strings. The strength of the attack was then easier to regulate than the hammers fitted to a certain height of elevation through the crookedness of the gutters and the point from which the ball was allowed to roll. The bouncing balls were caught in a cloth presented.

The pitch of the strings was determined by comparison with a tuning fork which gave the once-struck *b* (contained between the staves). From the strings *d* deeper agreed with shortened to $1/8$ markedly with the fork match was thus undiminished 3 octaves; from the strings *D*, the deeper agreed with shortened to $1/9$ bis $1/10$ consistent with the fork.

With the unhardened strings *d*, with both the hammers and the wooden and ivory globes, and the soft inclination of the channels against the horizon, the high string was shown to be strongly overweighted against the lower one, which seemed relatively unharmed; This overweight was also present in the vicinity of strong clays,

as well as in removal and, if necessary, partial ear closure, in that the deep tone was only weakly or not heard at all, if the high was still distinct.

Even with the unstripped strings *D*, the overweight of the high string in the near and far still took place when the same moderate attack was used as in the experiments with the string *d*. But the difference, in my own opinion as well as the opinion of all the co-observers, was decidedly smaller, so that I suppose that he would disappear altogether if the thickness of the strings were still right. However, it required no modification of the thickness. For as the channels were steeper, so that the ball rolled with greater force from the top to the strings, the difference in strength between the high and low strings became ambiguous. Again, the judgment of others agreed with mine.

It was now, while in the previous attempts, the attack of the high and low string was the same, the attack of both strings *D* made so different that the tone seemed equally intense or rather the difference ambiguous. I stood behind an obstruction so against the apparatus that I could not see it, but the sound was heard strongly, and a fellow observer changed the height from which he let the balls roll down, so long for both strings, until I pass through my accusation explained the difference in intensity to be ambiguous. This confirmed the previous result. With gentle inclination of the gutters, with a moderately strong impact, the ivory ball had to run along the whole length of the gutter to the tuned-in string, while after the tuned-up it ran down only about halfway to find the intensity difference ambiguous. With a much steeper position of the channels, the difference became ambiguous, if the bullet went down the length of the gutters along both strings; yes, even the deeper string seemed to need a shorter way. Both at the gentle and steep slope, the trial was repeated twice with corresponding results. But if at the steep inclination the balls were allowed to roll down from a very low point of the gutters, which was the same for both strings, then the intensity of the high string again became decidedly overweight. The inclinations of the gutters have been neglected; their statement could not be of any use, since absolute determinations from these experiments do not emerge at all. Both at the gentle and steep slope, the trial was repeated twice with corresponding results. But if at the steep inclination the balls were allowed to roll down from a very low point of the gutters, which was the same for both strings, then the intensity of the high string again became decidedly overweight. The inclinations of the gutters have been neglected; their statement could not be of any use, since absolute determinations from these experiments do not emerge at all. Both at the gentle and steep slope, the trial was repeated twice with corresponding results. But if at the steep inclination the balls were allowed to roll down from a very low point of the gutters, which was the same for both strings, then the intensity of the high string again became decidedly overweight. The inclinations of the gutters have been neglected; their statement could not be of any use, since absolute determinations from these experiments do not emerge at all.

A co-observer also started this experiment with me. The odd thing was that he quite consistently valued the high tone more intensely than I did, invariably declaring the high tone more intense at a point where I found the intensity difference between high

and low tone ambiguous, and even if I already found the deep tone a bit more intense, the high for something more prevalent explained. This difference of opinion was also found in some other occasional experiments. By the way, he found the difference of the success between the strings *D* and *d* and the difference between the gentle and steep inclination of the channels in the same sense as I and the other observers.

The fact that the deep string begins to sound relatively more intensely in the case of stronger absolute stops could be regarded as evidence of the transferability of Helmholtz's theorem (II, chapter 30), which was proved in the field of light-sensation, to tones. Only then, by weakening the sound by means of distance and ear-locking, would the high tone become predominant again, which could not be stated at all. The same is true of this view.

As with the increasing strength of the attack on the part of the ivory bullet the preponderance of the high tone diminished and became itself ambiguous, one would have thought that by exchanging the ivory bullet with a hollow rubber bullet, especially when rolling down from a lower point, by virtue of the weak stop In this case arises, the high tone should have come all the more overweight. But on the contrary, the low tone unexpectedly came into decided preponderance, according to my own and all co-watcher judgments.

The hollow rubber balls, since they give the purest clay, would have recommended the most to these attempts at all, if they were to be obtained without a high seam. But this makes that the rolling down in individual experiments is not quite comparable, even if the general success in the just-stated sense was completely decisive.

Thus, depending on the thickness of the strings, the strength of the attack, the material of the striking body, the high, sometimes the low, tone soon became overweight, so much so that not even the conjecture remained in any particular direction over the result sought. The change of overweight seemed to be mainly due to the fact that, as the proportions of the string and the attack are better or worse, a lesser or greater part is used by the living force of the attack to produce a sound accompanying the sound.

I have only quoted the attempts made with the unabridged strings, which were most copied; but various attempts were also made with strings shortened by the reduction of a common bridge, which, however, gave variable results depending on the change in circumstances. Now, while I believe that with even more carefully designed apparatuses, the noise can be removed even more, it would be difficult to achieve a very pure result.

I thought of trying, instead of striking strings, blowing a whistle to be shortened with a punch by means of a stream of constant strength. But as the whistle no longer responds when shortened beyond a certain limit, it seemed to me that a corresponding difficulty could be expected here as well as in the strings, only in a different form.

b) Addition of some recent studies by Helmholtz into psychophysics

The investigations recently published in the second book of the physiological optics of Helmholtz, when the 22nd sheet of this volume was printed, meet on several sides with the content of this work, partly in agreement, partly in divergent form; Namely in relation to: 1) the measure of the sensation of light; 2) the concept of the lifting phenomenon in the contrasts; 3) an important optical hypothesis. While the authority of Helmholtz, which is justifiably so great, allows me to put weight on the points of agreement, it at the same time causes me to go a little further into the apparent or real points of the deviation.

As we approach the first point, the limits of Weber's Law, of course, at very low and very high degrees of brightness, to which I have referred in the first part, must also extend to medium degrees; or more accurately, if the law at the borders is quite inaccurate, it may not be exactly accurate in the middle degrees. However, so long as the deviation was not noticeable within the limits of the ordinary use of the eyes, there was no need to include corrections or modifications in the formulas based on that law for ordinary use, but one could accept the approximation that they accorded , as was done in the formulas used by Steinheil and Pogson in the star size estimates, whose relation to Weber's Law I have set out in detail in the two essays cited in T. I, p. In fact, in the previous observations of Bouguer, Arago, Masson, Steinheil, Volkmann, my own, and in the star size estimates, a deviation from Weber's law at medium levels of brightness has not been noticeable, which grants the certainty that here really a law valid for average degrees of brightness is present. However, even in my first essay, p. 513 f. as well as in this paper T. I, p.162 an experience of Herschel as inviting to a more detailed investigation, which seemed to prove that for very experienced eyes under favorable circumstances deviations could also be felt, which are not noticeable under other circumstances; and the same is now more clearly evident from Helmholtz's new investigations in the second book of his Physiological Optics, pp. 309 ff., which, as in the sense of influence, must express the limits of the law to the middle, rather than a constant relative sensitivity which requires the Weber law, for a certain intensity grant a maximum of relative sensitivity; while Weber's law "remains as a first approximation to the truth," as Helmholtz himself puts it. which the limits of the law must express to the middle, instead of a constant relative sensitivity, which requires the Weber law, for a certain intensity afford a maximum of relative sensitivity; while Weber's law "remains as a first approximation to the truth," as Helmholtz himself puts it. which the limits of the law must express to the middle, instead of a constant relative sensitivity, which requires the Weber law, for a certain intensity afford a maximum of relative sensitivity; while Weber's law "remains as a first approximation to the truth," as Helmholtz himself puts it.

If I am not mistaken, the reason why Helmholtz has recognized a deviation from the law between boundaries, where it has not been recognized by a large number of former observers of good name, is that he has recognized the slightest differences in light that have been recognized so far have been, for the smallest detectable difference varies with him between $1 / 117$ and $1 / 165$ of intensity; while the previous

observations in the examination of the law only $\frac{1}{64}$ bis $\frac{1}{100}$ have shown and the highest indication which takes place at all, by Arago $\frac{1}{131}$ is (see T. I, p. 172). But it is a natural condition, if not necessary in itself, that where the smallest differences of light are still discernible, even the smallest differences between differences in light are still perceived; and therefore it is easily conceivable that, where the eye or procedure is less sensitive than Helmholtz's, the approximation of the law seems to be sufficient, which has no longer seemed adequate with him.

In principle, however, the only question that would be important here is whether by Helmholtz's investigation the fundamental validity of Weber's law is attacked in such a way that the deviations are pushed to the upper and lower limits instead of the reasons given by me can be sought in the relation of sensation to movement itself. This is certainly not the case; rather, in this respect, it allows the state of affairs that I set out to exist completely. The reasons for the deviation on the upper and lower limits given by me, T. I, p. 163, 165, are not merely hypothetical, but no less factual than the deviations themselves; it would also be highly unlikely that the complicated form of a law which Helmholtz has fully substituted in a formula; which the deviations are intended to include, as the Basic Law should exist.

By referring to his own work on the experimental part of Helmholtz's investigation, I content myself here with communicating the formulas which he substitutes for those who deviate from Weber's law to those based purely on Weber's law are supportive; where I translate the letter designation into that commonly used in this writing.

Our fundamental formula based on pure Weber's law is



where γ is the sensation, β the stimulus, K is a constant independent of β . To account for the downward deviation Helmholtz substituted (as was already done by me on the 35th and 31st Chapter) for β to be a constant β_0 increased value of the light stimulus, and to account for the deviation to the top he sets the



constant K of β depends by β assumes where B present as very large. This gives as a fundamental formula with regard to the limits instead of the



above:

what results from integration:



and thereafter a maximum value of sensitivity β follows.



The statement of [redacted] grounds is based on the indisputably formally justified, though perhaps not completely true, according to the nature of the upper limit, assumption of the simplest functional form of β , in which one naturally has to stand, as long as the phenomena do not raise a definite contradiction. For my part, one could only add that the Helmholtz formula, in order to be transferable from the measure of the sensation of light to the measure of the sensation of differences in light, just as the formulas of Steinheil and Pogson, or the introduction of the threshold of difference in. Cape. specified manner would require.

I sincerely acknowledge in the study of Helmholtz a progress which psychophysics has undergone in the field of the doctrine of light by this distinguished researcher, and I can not wish for anything more than to gain more and more by further such advances in determination and development. But if, before the publication of his investigation, the rumor had come to me that Helmholtz attacked the mathematical basis of my psychophysics in it, there can probably only be a misunderstanding here, to which I forego and what I have deliberately emphasized in the preface, also wished to meet for the future; at least I can not find anything of the kind in his own account. Only then would this be the case if the validity in principle of Weber's law, or the even more general principle of measure on which this document is based in the last instance, would be called into question; instead, I see in Helmholtz's investigation the first factual recognition of a measure of sentiment based on this principle; because, if formulas of that kind existed earlier, they were not given that meaning.

The second point concerns the question, which is particularly important for the theory of feelings and the mathematical treatment of the sensation of differences, whether the elevation of impressions by contrast is based merely on an act of judgment or on a change of sensitivity. I have declared myself the second alternative in this part (chapter 24); but find that Helmholtz in his new study (pp. 392, 406, 414) declares himself to be the first in the simultaneous contrast with respect to the phenomena of elevation. The reasons for my opinion, which still seem to me to be overweight, are found in my treatise on contrast-sensation, which I have indicated in the preface, and I content myself with referring here, with the remark that

The difference with regard to the second point was all the more welcome to me because I met Helmholtz in relation to the third. The hypothesis that objectively simple color-rays produce a subjective mixture of colors in the eye (PI. II, p. 301), I had dared not put up without hesitation, however necessary it appeared to me from various points of view; I find that same hypothesis, in part with Helmholtz's viewpoint, in line with mine, and the independence of the two sides should help to support them. However, the form under which Helmholtz set up the same (with a drop on Young's hypothesis of three types of nerve fibers, which resemble three basic colors) deviates significantly from that in which I have presented the same; but the deviation holds itself in a region in which the conjecture must complete the conclusion, so that a quarrel about it would be almost idle, because it would be hard

to decide before hand. But it will be easy to see from the connection what has led me to the form I prefer and still allows me to adhere to it; but I am far from seeing proof in this connection.