A Study of Thinking

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With an Appendix on Language

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been described by Stevens (1934). It is conceivable that there could be a linguistic community in which the specific term "density" existed outside the technical circle of acousticians and that it referred to the same attribute as the one isolated by Stevens. The difference between this community and the English-speaking community would not be in terms of the capacity to *discriminate* density from other attributes. Peoples who have but one word for green and blue are capable of discriminating the difference between the two hues, so that capacity is not in question. Indeed, it would also be possible to describe linguistically what is denoted by the word "density" in English, although it might be necessary to use a paragraph of connotative or metaphorical prose in doing so. The difference would lie, most probably, in the *habitual tendency to use the attribute* in making everyday discriminations and in searching out defining attributes.

We have perhaps been somewhat unsystematic in describing the various factors that may lead an individual to prefer to utilize certain cues in making categorial and other kinds of inference, for the subject is one that is too little explored to lend itself to ready ordering. The "rational" validity of cues, the requirements of the situation, certain forms of innate and acquired cue-preference hierarchies, systematic preference, and linguistic codability are all in need of further study as determinants of criteriality. One rather introspective point serves to conclude the discussion. However acquired, cue preference seems to be accompanied by certain subjective states often enough reported to warrant a word here. To use the term originally employed by Katz (1935) to characterize the "impressiveness" of colors, preferred cues seem to take on an *eindringlich* quality. They "look" right and they look more impressive. In concept-attainment experiments using such "meaningless" attributes as color, shape, etc., the attribute values that eventually turn out to be defining of the correct concept seem to take on an "impressive" or figural property while the others seem to "recede" in figural value. When meaningful materials are used as instances, faces varying in certain features or airplane silhouettes differing in wing, tail, and engine construction, certain properties—the human forehead, for example, and also the wings of the airplanes—appear to be more impressive even at the outset and before the concept has been attained. Analysis of cue preference in these latter experiments indicates that subjects utilize these "impressive" cues more than their ecological validity warrants. We do not pretend to know what these subjective changes in the appearance of attributes "mean" or whether they can be conceived of as anything more than the resultant of other processes, yet no account of the factors producing increased

~~utilization of cues for inference can be complete without some mention of this interesting and admittedly puzzling introspective datum.~~[*]

CATEGORY TYPES: CONJUNCTIVE, DISJUNCTIVE, AND RELATIONAL

It is usually the case for one to infer identity or some other significate not from a single attribute exhibited by an instance but from several attributes taken together. That is to say, we do not attempt to infer illness *only* from abnormal body temperature, but from a whole set of clinical signs taken in combination. The question of how attributes or cues are combined for making inferences now concerns us. The principal distinction we wish to make is between *conjunctive, disjunctive,* and *relational* concepts, each involving a different mode of combining attributes.

To render more concrete the description of types of categories, we refer to the array of instances contained in Figure 1. Each instance is made up of figures and borders. The figures vary in shape (square, circle, or cross), in color (red, green, or black), and in number (single, double, or triple). The borders vary in number (one, two, or three). Thus, the instances comprise the combinations of four attributes, each with three values. Each instance in the array exhibits one value of each of the four attributes. We may speak of a "category" of instances or a concept in terms of the defining properties of some subset of the instances. For example, "all cards with one red figure" is a concept, so too "all cards with two figures and/or with circles," so too "all cards possessing the same number of figures and borders." The three examples turn out to be drastically different kinds of concepts, and we turn now to a consideration of their difference.

A *conjunctive category* is one defined by the *joint presence* of the appropriate value of several attributes. A typical conjunctive category in the universe of Figure 1 may be defined by the *conjunction* of three figures, redness, and circles, i.e., all cards containing three red circles. Three exemplars of this category are to be found in the figure. All others fail to qualify. Most experiments on concept attainment deal with such conjunctive categories, and procedures such as the Vigotsky Test and the Wisconsin Card Sorting Test are based on them as well.

The *disjunctive category* may be illustrated by that class of cards in Figure 1 that possess three red circles, *or* any constituent thereof: three figures, red figures, circles, three red figures, red circles, or three

[*] The closest analogue we can find in the literature on the subjective analysis of attention and "clarity" is the concept of *derived primary attention* proposed by Titchener (1915) to account for the increased subjective prominence or "attensity" of objects to which we have learned to attend habitually.

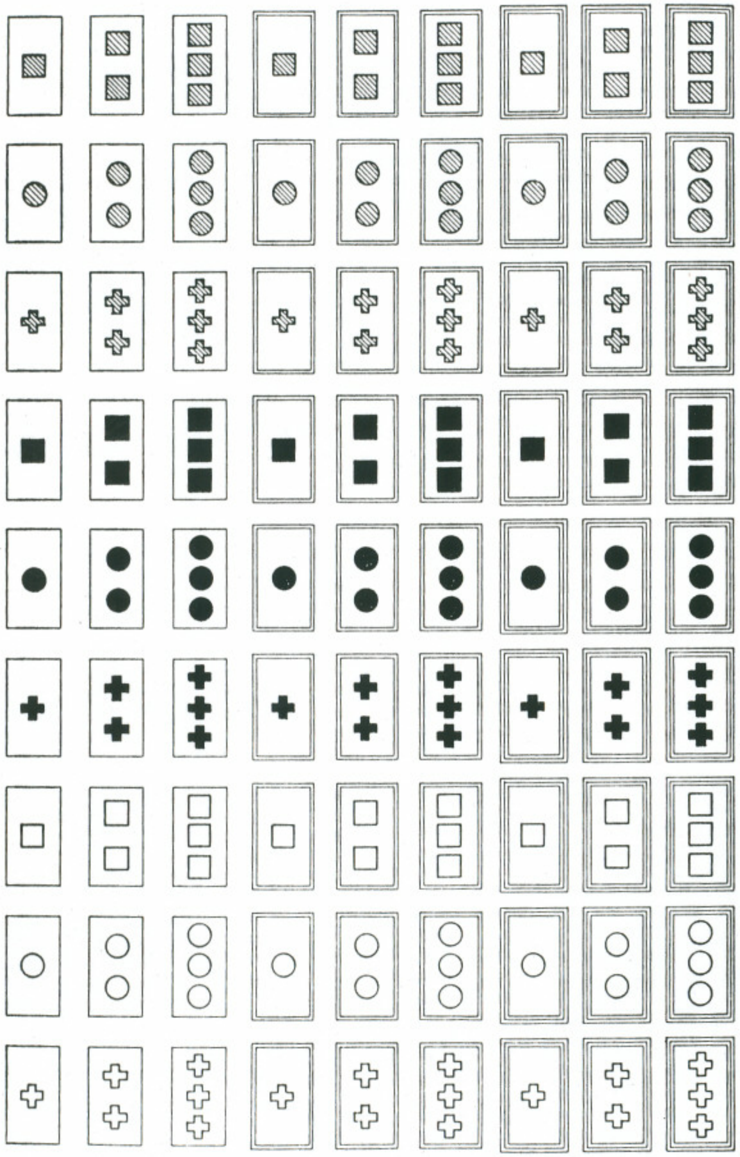

Figure 1. An array of instances comprising combinations of four attributes, each exhibiting three values. Plain figures are in green, striped figures in red, solid figures in black.

circles. The class comprises 57 instances. Any fraternal or civic organization with a membership requirement such as "Anyone residing in *or* paying taxes in Altavista shall be eligible for membership" exemplifies a disjunctive category. A strike in baseball is also disjunctive. A strike is a pitch that is across the plate and between the batter's knees and shoulders *or* it is any pitch at which the batter strikes but fails to send the ball into the field. Similarly, a "walk" occurs either when four balls have been pitched *or* when a pitched ball strikes the batter.

The difficulty with disjunctive concepts is their arbitrariness; the lack of any apparent relation between these attributes which can substitute for one another. This feeling of arbitrariness may be one source of resistance to the categories used by clinical psychologists. A concept such as "stable personality" or "serious disturbance" can only be defined disjunctively, with sometimes one set of signs serving as the cue and sometimes others. Hammond (1955) and Todd (1954) have commented on the role of such vicarious functioning of cues in clinical judgment.

The relational concept or category is one defined by a specifiable relationship between defining attributes. Thus in the universe of Figure 1, we may define as a class all those instances containing the *same* number of figures and borders, or those cards with fewer figures than borders. Income tax brackets (after deduction), each specifiable as a class, are defined in terms of the relationship between number of dependents and level of income. "Effective stimulus" is defined in psychology as an energy change at a receptor surface capable of discharging the receptor: a relationship between two states.

It is sometimes possible to describe the same grouping or class of instances in terms of two different combinations of attributes. One way of combining attributes may prove to be equivalent to another in terms of the groupings that result by use or application, i.e., it may turn out that one rule for combining attributes may prove to be equivalent to another. Such cases are of interest, particularly in the sciences where they are capable of generating theoretical controversy of the kind that produces more heat than light.

An arbitrary array of 16 instances helps to provide an illustration. The array is made up of a set of cards (they are cards used in experiments which will be considered later). Each card has on it a small figure and a large figure. The small figure may either be a triangle or a rectangle, and whichever it is, it can also be black or yellow. So too the large figure: a rectangle or a triangle, yellow or black. Thus, there are four attributes, each with two values. Each card exhibits one value of each attribute. The array of instances can be numbered for convenience as follows:

	Large Figure			
	Triangle		Rectangle	
Small Figure	Yellow	Black	Yellow	Black
Triangle				
Yellow	1	2	3	4
Black	5	6	7	8
Rectangle				
Yellow	9	10	11	12
Black	13	14	15	16

Thus, instance 1 contains a large yellow triangle and a small yellow triangle; instance 7, a large yellow rectangle and a small black triangle.

What is interesting about this array and many others as well is that one can define the *same* subset of instances with different concepts, indeed, different *types* of concepts. Take, for example, the subset of instances 2, 4, 5, 7, 10, 12, 13, 15. This subset can be defined by five different concepts:

1. Two figures of opposite color.
2. One yellow figure.
3. One black figure.
4. Black figure and yellow figure.
5. Small black with large yellow *or* small yellow with large black.

In this subset, each of these definitions—some conjunctive, some disjunctive, and some relational—define the same class.

What is particularly instructive about this example is that it underlines the "invented" or "constructed" nature of a concept or category. For the way in which a person will categorize *new instances encountered* will depend drastically upon the type of concept he has constructed out of the instances in this array. While it is true that all of the concepts noted in the foregoing describe the same subset of instances, the different concepts lead to different modes of categorizing once one gets outside this array. A person operating with the concept "two figures of different color" would consider an instance containing a green circle and a purple circle to be an exemplar of the concept. None of the other concepts would lead to the inclusion of such an instance. Indeed, each of the concepts listed would at one point or another diverge from the others in dealing with new kinds of instances.

We may conclude, then, by noting that when one learns to categorize a subset of events in a certain way, one is doing more than simply learning to recognize instances encountered. One is also learning a rule that may be applied to new instances. The concept or category is, basically, this "rule of grouping" and it is such rules that one constructs in forming and attaining concepts. In this sense, conjunctive, disjunctive, and relational categories are different types of rules for grouping a set of attribute values for defining the positive or exemplifying instances of a concept.

PROBLEMS IN HANDLING MULTIPLE-SIGNAL ATTRIBUTES

In preceding pages we have dealt with a variety of the properties of attributes and attribute combinations that affect the manner in which they may be used as a basis for inferring the categorial identity of things. The defining and criterial status of attributes, their immediacy and proneness to masking, their linguistic codability, the nature of their ranges and transition values, and finally the manner in which they may be combined: all of these have concerned us in turn. We come now to the problem of the number of attributes that are exhibited by an array of instances to be categorized and the number of attribute values that are actually used by an individual in discriminating one class of objects from another.

The number of criterial attributes affecting categorization makes a difference in two ways. The first is with respect to *learning* a category, and the second is in *utilizing* the category after it has been learned. The former problem must be postponed for a moment because it involves other considerations shortly to be introduced. The latter is a matter of immediate concern. If there are a dozen criterial attributes affecting one's categorization of a class of objects, the process of scanning the values of each attribute prior to reaching an inferential decision about the identity of the object would be both a strain and time-consuming regardless of how the attributes were combined in terms of a concept type. In the ordinary behavior of a person, there is likely to be a tendency toward the reduction of such strain since time pressures usually are operative. Under pressure of time or under conditions of stress, the individual will not "attend to" or take into consideration all of the attributes that might be considered under more leisurely conditions.

There appear to be two principal ways in which the strain of weighing many attributes can be reduced. One is by reduction in the number of attributes considered; the other by a process of combining or recoding attributes into attribute configurations.

CHAPTER 5

Reception strategies in concept attainment

Up to this point, our concern has been almost exclusively with the means whereby an individual may *select* instances in such a way as to isolate easily and efficiently the attributes that are useful for inferring a conjunctive grouping. What is perhaps most distant from life about this procedure is its Olympian quality. The universe is spread before one and one has freedom of choice as to what one will take as an instance for testing. There are perhaps times when an experimentalist in science has the good fortune to work on problems that have this feature. More likely, his plight is that he must make sense of what happens to come along, to find the significant groupings in the flow of events to which he is exposed and over which he has only partial control. *His major area of freedom is in the hypotheses he chooses to adopt, not in the manner in which he can choose instances to test.* The clinician's condition is perhaps more typical than that of the experimentalist.

Take again as an example the problems of neurophysiology, familiar from the last chapter. A clinical neurologist in the course of his practice encounters a patient with a damaged brain exhibiting the set of speech defects called aphasia. Now the concept of aphasia need not be "formed" for it already exists. The aphasia case is referred to him by an examining diagnostician. The diagnostician's statement that the case "shows aphasia" is the criterion of a positive instance. The research neurologist is now trying to find out about the neural correlates of aphasia. He must, in other words, seek the neural defining attributes of the class of patients known as aphasics. If one wishes to say that the neurologist is trying to find the "causes" of aphasia, this in no sense changes the basic problem, which is to find

what neural conditions lead to the inference of aphasia with maximum certainty.

If the experimentalist were engaged in such a pursuit and could find laboratory animals capable of speech and on whom surgery might be performed, then he would be in a position to act much as our subjects of the last chapter. This would take the form of systematically removing areas of the brain in certain combinatorial orders until the answer was forthcoming. But the clinician has to take his cases as they come. He must employ a *reception strategy*.

Let us begin at the beginning of modern neurology by taking Paul Broca as our subject: a gifted neurologist of the mid-19th century.* He has a chance to carry out an autopsy on an aphasic patient. He finds massive damage in that portion of the brain at the base of the third frontal convolution (since named, in his honor, Broca's area), "the speech center." But this describes only part of the properties of the "instance." For Broca's exact description of the patient's lesion shows a softening of the brain in the left hemisphere all the way from the frontal lobe dorsally to the parieto-occipital junction, extending downward as far as the superior portion of the temporal lobe. One can sum this up more simply by saying that there is much more destroyed than Broca's area alone. It is at this point that Broca is able to exercise his major freedom: the freedom to formulate an hypothesis. He could attribute the aphasia to *all* of the destroyed areas or to any part thereof. He takes his option and proposes that aphasia is caused by damage to a speech center: the famous "Broca area." Perhaps there is reason in the fact that this is the area of most concentrated degeneration. Nonetheless, the die is cast. The neural defining attribute of aphasia is this particular "speech center."

At the other extreme we have Flourens, who adopts another option. No *specific* lesion is taken as a defining attribute of aphasia. If the aphasic's brain shows specific damage, it is the interaction of the damaged areas and the intact areas together that create the final common path of aphasia.

What is of great interest about these two innovators is that each has a line of descendants, call them the localists and the totalists. The former seek always a specific area where possible: some set of limited defining attributes, adding new attributes only when forced by the

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* In the interest of exposition, we shall take certain liberties with the history of this complex field. If the reader finds that our historical license leads us to over-exaggeration, he will, we hope, forgive us and treat our examples as fictional rather than real figures.

burden of much evidence. The list of localists, requiring oversimplification in its compiling, includes such names as Fritsch, Hitzig, Bianchi, Flechsig, and Adrian. The totalists have wanted to stay as close as possible to the whole cortex as an explanation, and it is only with the greatest reluctance that they will subtract any of its attributes as irrelevant. Here too we find a distinguished list: Goltz, Munk, Hughlings Jackson, Head, Goldstein, Lashley. The interesting thing about each group is not only that they attempt to proceed as they do but that they urge the absurdity of proceeding in any other way.

In point of fact, one could begin either way—adopting either a part or a whole hypothesis—and arrive at the same conclusion provided one did not become rigidified before the process of proof was completed. Here we must leave real neurology, for the issues are too tangled. But if one works with the kind of schematization used in the last chapter, it is possible that, when one encounters an aphasic, one may base an hypothesis on the state of *all* areas or upon the state of *one* particular area. What is even more important than the starting hypothesis is what one does with it when one encounters new instances that differ from it. For an hypothesis is not a final declaration so much as it is something to be tried out and altered. We shall be considering in this chapter the manner in which, in the kinds of problems we have been discussing, hypotheses are changed to conform to the arbitrary stream of events to which they are exposed.

The first and obvious thing about an hypothesis is that it can have any one of four fates when exposed to a new event to which it is relevant. Let us bring Paul Broca back on the scene. He has declared his hypothesis on the relevance of the speech center. Each new patient he sees can have his speech center intact or destroyed. Again, each patient he sees must either have the symptoms of aphasia or not have them. Broca's world, then, is made up of four contingencies.

	Speech Area	Symptomatology
1.	Destroyed	Aphasia
2.	Intact	Aphasia
3.	Intact	No aphasia
4.	Destroyed	No aphasia

It is apparent that two of the contingencies confirm, or at least fail to infirm, Broca's hypothesis. A patient with the speech center destroyed and the symptoms of aphasia confirms it. One with the center

intact and without aphasia at least fails to infirm his hypothesis. Two of the outcomes are damaging to Broca's hypothesis. A patient with speech center intact and aphasia is as infirming as one whose speech center is destroyed but who shows no sign of aphasia. Let us adopt the language of medicine, for the moment, and speak of any case as positive which shows the signs of illness we are investigating; its absence negative. Whether it is positive or negative, a case can confirm or infirm the hypothesis in force. In this fashion of speaking, then, the four contingencies that Broca can meet are:

1. Positive confirming: Aphasic with speech center destroyed.
2. Positive infirming: Aphasic with speech center intact.
3. Negative confirming: Nonaphasic with speech center intact.
4. Negative infirming: Nonaphasic with speech center destroyed.

A good reception strategy consists in being able to alter hypotheses appropriately in the face of each of these contingencies. At an even more primitive level, obviously, it consists in being able to recognize their existence and to formulate hypotheses in such a way that, whatever the contingency met, one will know how and whether to change one's hypothesis.

A PARADIGM AND TWO STRATEGIES

Three things are required to reproduce in the laboratory a task comparable to the examples we have given. *First,* one must construct an array of instances that are alike in some respects and different in others, so that there are multiple ways in which the instances in the array may be grouped. *Second,* instances must be encountered by the person in an order over which he has no control. *Third,* the subject must know whether each instance is positive or negative in the sense of exemplifying or not exemplifying a concept. *Fourth,* the subject must be given freedom to formulate and reformulate hypotheses on each encounter with an instance. Given these requisites, a task is easily set. A grouping or a concept to be attained is chosen, and the subject is shown in succession exemplars and nonexemplars of this concept. His objective is to formulate an hypothesis that will distinguish an exemplar from a nonexemplar among the instances he encounters.

We begin with instances such as those illustrated in Figure 1, composed of the combinations of three values of each of four attributes—cards each showing four properties, such as "two red squares and three borders" or "one black cross and two borders." We decide upon a "concept:" say "all black figures." We present one instance at a time to the subject, telling him whether or not it exemplifies the concept, whether it is positive or negative. After each card, the subject is asked to indicate his best hypothesis concerning the nature of the correct concept. Thus, following the presentation of any given card, he offers an hypothesis. The experimenter makes no comment. The next card the subject encounters must perforce represent one of the four possible contingencies. It may be *positive* or it may be *negative*. Whether it is one or the other, it also has the property that it *confirms* or *infirms* the subject's previously held hypothesis about the nature of the correct concept.

Before examining the behavior of subjects dealing with such problems, it is perhaps well to consider the ideal strategies that are applicable. Logically, they are identical to the strategies discussed in the last chapter. First, there is a focussing strategy which, as before, is useful both for maximizing information yield and for reducing the strain on inference and memory. The surprisingly simple rules for the alteration of hypotheses with this strategy are best presented with the aid of an illustration.

The clinician begins, let us say, with an aphasic showing a badly damaged brain—Areas I to VI destroyed. He takes as his first hypothesis that destruction in *all* six areas must be responsible for aphasia. If he should encounter a positive-confirming instance (another aphasic with like destruction), he maintains the hypothesis in force. If he should meet a negative-confirming instance (a non-aphasic with some or all of the areas intact), he still maintains his hypothesis. The only time he changes is when he meets a positive-infirming instance. An example of one such would be an aphasic with Areas I to III intact, and Areas IV to VI destroyed. Under these circumstances, he alters his hypothesis by *taking the intersect between his old hypothesis and the new instance:* those features common to the two. The features common to the old hypothesis and the new positive instance can be readily seen:

Old hypothesis: Areas I, II, III, IV, V, VI destroyed produce aphasic.
New positive instance: Aphasic with Areas I, II, III, intact; IV, V, VI destroyed.

Thus the clinician chooses as his new hypothesis: "Areas IV, V, and VI destroyed produce aphasia."

Now consider the rules in their barest form. The first one is of central importance. *Take the first positive instance and make it in toto one's initial hypothesis.* From here on, the rules can be simply described. They are:

	Positive Instance	Negative Instance
Confirming	Maintain the hypothesis now in force	Maintain the hypothesis now in force
Infirming	Take as the next hypothesis what the old hypothesis and the present instance have in common	Impossible unless one has misreckoned.* If one has misreckoned, correct from memory of past instances and present hypothesis

By following this procedure, the subject will arrive at the correct concept on the basis of a minimum number of events encountered. The strategy has only two rules in addition to the initial rule that one begin with a positive instance *in toto* as one's hypothesis. These two rules are:

1. Consider what is common to your hypothesis and any *positive-infirming* instance you may encounter.
2. Ignore everything else.

It is apparent, of course, that focussing in the present case is analogous to the focussing strategy under conditions where the subject chooses the order of the instances that he will consider. In both types of problems, the first positive card encountered is used *in toto* as a guide, in the reception case as the basis for all subsequent hypotheses, and in the selection case as the point of departure for all subsequent choices of instances whose positive or negative character will systematically delimit the concept. In focussing where one chooses instances, the problem-solver tests attribute values of the focus card one at a time as a means of seeing which features of the initial focus card are relevant to the concept. In the reception case, one embodies this focus card in one's initial hypothesis and then evaluates its attribute values in the light of subsequent instances encountered.

In the interest of brief nomenclature, we shall refer to the ideal strategy just described as the *wholist strategy* since it consists in the adoption of a first hypothesis that is based on the whole instance initially encountered, followed by an adherence to the rules of focussing just described. From time to time, we shall also use the expression *focussing* to describe the strategy.

* For a fuller exposition of this point, see pages 149–150.

As in the selection case, scanning strategies are also possible here. Again, they may take one of two forms. The first is the simultaneous process described in the last chapter where a person attempts to use each instance to make all possible inferences about the correct concept. A first positive card "eliminates these 240, and renders possible these 15 hypotheses," etc. This is the "simultaneous" form of the scanning strategy, so called because all alternative possible hypotheses are entertained simultaneously. It is of little interest to us primarily because we find no behavior conforming to it. Nor, for that matter, did we observe the kind of "lazy" successive scanning that can be described in ideal terms as formulating one hypothesis at a time and holding on to it so long as confirming instances are encountered, changing only when an infirming instance is encountered to an hypothesis not yet tested. Then one starts afresh to test the new hypothesis with no reference to instances used for the test of prior hypotheses. This of course is successive scanning in its pure, discontinuous form.

The type of scanning strategy that best describes the behavior of our subjects is, as before, a compromise between these two forms. It is a strategy that begins with *the choice of an hypothesis about part of the initial exemplar encountered. When this hypothesis fails to be confirmed by some subsequent instance, the person seeks to change it by referring back to all instances previously met and making modifications accordingly.* That is to say, he bets on *some* feature of the exemplar, choosing it as his hypothesis about why the instance is an exemplar of the category—why it is correct. So long as the next exemplars also exhibit this feature, the hypothesis is retained. Or if nonexemplars do not show it, it is also retained. But as soon as an instance infirms the hypothesis, the hypothesis is changed. The change is made with as much reference as possible to what has gone before. He now seeks to formulate an hypothesis that will be consistent with all instances thus far encountered. To do so requires either a system of note-taking or a reliance on memory. Let us look more specifically at the way contingencies are handled.

Confirming contingencies are handled as in the ideal wholist strategy. The subject maintains the hypothesis in force. The two infirming contingencies present a challenge to the strategy in that both of them require him to go back in his memory over past instances encountered.

To sum up, the rules of the scanning strategy are as follows. Begin with *part* of the first positive instance as an hypothesis. The remaining rules can be put in the familiar fourfold table.

	Positive Instance	Negative Instance
Confirming	Maintain hypothesis now in force	Maintain hypothesis now in force
Infirming	Change hypothesis to make it consistent with past instances: i.e., choose an hypothesis not previously infirmed	Change hypothesis to make it consistent with past instances; i.e., choose hypothesis not previously infirmed

For describing this procedure we shall use the expression *part-scanning strategy* or, on occasion, *part strategy.*

Let us now briefly sum up the differences between the two strategies:

1. Part-scanning obviously makes more demands on memory and inference than does the focussing strategy. The wholist's hypothesis is modified at each step to incorporate the information gained from the instances he has encountered. He need never recall either his past hypotheses or the relation between these. *For his present hypothesis is a current summary of all these.* Only when he must recover from an error is recourse to memory necessary. The part-scanner must fall back on memory or the record every time he encounters an infirming instance.

2. The scope of one's initial hypothesis—whether a part or a whole hypothesis—will alter the probability of encountering the four different contingencies. This is a straightforward matter of arithmetic that will be made clear later in the chapter. The most dramatic feature of this "arithmetical fate" of the two strategies is that a wholist who follows all the rules of his strategy will *never* encounter the most psychologically disrupting of the contingencies: the negative-infirming case.

3. To succeed, the scanner must remain alert to all the characteristics of the instances he is encountering, for he may have to revise his hypothesis in the light of these. Such a degree of alertness and spread of attention is not required of the focusser. If he stays with the rules of focussing, he need pay no heed to the characteristics of the instances encountered after he has used them to correct his hypothesis. If you will, the scanner must keep a continuing interest in nature; the focusser need only be preoccupied with his hypothesis.

So much, then, for the ideal strategies. Specifically, we have three objectives in the research to which we now turn.

1. The first is to examine the degree to which performance corresponds to the ideal strategies, the degree to which one acts like a

Broca or a Flourens from problem to problem and from contingency to contingency.

2. The second is to examine change in performance over a long series of problems varying in the cognitive strain they impose.

3. Finally, we wish to raise some questions about the effectiveness of the two strategies under varying work conditions. We know, for example, that scanning is more dependent upon memory and inference that is focussing. What difference does this make for success and failure in attaining concepts?

AN EXPERIMENTAL DESIGN

Our experimental operations can be sketched rapidly so that the present design may be contrasted with some of the classical studies. At the outset the nature of the task is fully described for the subject. As noted earlier, an array of instances is constructed. The subject is presented instances from this array one at a time, and each is designated as either positive or negative. The first instance presented is always positive. The subject is asked after each instance to state his hypothesis concerning the correct concept: what it is that the first positive card exemplifies. Instances are presented until the subject has had at least as many instances as would be required logically to eliminate all hypotheses save the correct one. At no time does he have more than one instance before him, and should he ask about instances previously encountered, the experimenter demurs. No such aids as paper and pencil are permitted him. Moreover, it is explained at the outset just what it is about the instances that need be considered: the shape of the figure they contain, the color of these figures, their number, etc.*

For the reader not well acquainted with the literature on concept attainment, we should like to point out here several crucial differences between the conduct of this experiment and of classical experiments in this field which have also used arbitrary sequences. First no effort was made to conceal the nature of the subject's task. He knew that his job was to find out the "correct concept." He knew what a concept was: a grouping of instances in terms of common properties. He knew what properties of instances were worth considering. And he knew, finally, that what he was seeking was a conjunctive concept, and that only one concept was to be attained in each problem.

* We are particularly indebted to Mrs. Mary Crawford Potter for aid in designing and executing this experiment as well as devising techniques of analysis for it.

In these respects, the procedure differed from the procedure originally introduced by Hull (1920). In the Hull procedure, the subject was *not* told what his task was. Rather the task was presented as a study in rote learning. The subject had the task of learning to associate names or nonsense syllables with instances that were presented to him. There might, for example, be five different concepts, illustrated by an array of instances; and the subject's task was to "learn" that particular cards were labeled "DAX," others "CIV," etc. If he did not figure it out for himself, he might never realize that "DAX" cards were so labelled because they shared certain common attribute values. The test of whether the subject had attained the concept was, at least in Hull's study, whether the nonsense syllables could be applied to a series of new cards that illustrated the various concepts but which had not been presented before. In sum, *incidental* concept attainment was being studied. William James urged that the psychology of religion begin with the investigation of "the most religious man in his most religious moment." We wanted at the outset to see concept attainment at its best.

There is one other crucial difference between our procedure here and earlier ones, a difference whose importance has already been lucidly remarked upon by Hovland (1952). In studies inspired by Hull's procedure, it was not made clear to the subjects what it was about the instances presented to them that might be relevant. The different attributes and their values were, in short, left uncontrolled. Thus, Hull used a set of pseudo-Chinese characters, a particular radical of which was the defining attribute of the correct concept. It is apparent that the number of attributes a subject might consider as possibly relevant are close to limitless: any component stroke, angularity, or curvedness of components, thickness of strokes, crowdedness of strokes, number of right angles, number of strokes, number of disconnected lines, width, length, and symmetry of characters, predominance of vertical or horizontal strokes, "movement" or "stillness" of the arrangement of strokes.

So long as the experimenter does not know to which and to how many component attributes the subject is attending, it is impossible to control or understand the amount of information being presented to the subject by any one instance or combination of instances. One cannot know when the subject has had an informationally adequate series of instances—adequate to eliminate all but one, the correct concept. Nor is it possible to study the effect of the number of defining attributes in the concept as compared to the number of noisy irrelevant attributes. To be sure, the use of such characters in concept-attainment studies provides highly useful knowledge—knowledge about the manner in which subjects abstract attributes from a complex situation. But the *process* of how concepts are attained, given the abstraction of attributes, is greatly obscured. Perhaps most serious of all, where the experimenter does not know to what attributes the subject is attending, he cannot know whether the instance he is presenting a subject is positive-confirming, positive-infirming, negative-confirming, or negative-infirming. And moreover, in order to know the contingencies with which the subject is coping, it is necessary to have the subject state his hypothesis after each instance rather than merely respond in terms of a set of labels.

These points of design reflect our concern with the necessity of externalizing the decisions a subject makes en route to the attainment of a concept, a concern discussed in Chapter 3. It was a deliberate choice on our part to use a known number of attributes, each with a known number of values—known to both the experimenter and the subject. If you will, then, this is concept attainment with the perceptual-abstraction phase by-passed.

Details of Procedure. The instances were cards containing various shapes, colors, and numbers of figures; and various kinds, colors, and numbers of borders. The six attributes and their values comprising the problems were:

Number of figures: one, two, or three.
Kind of figures: square, circle, or cross.
Color of figures: red, blue, or green.

Number of borders: one, two, or three.
Kind of borders: solid, dotted, or wavy.
Color of borders: red, blue, or green.

Subjects were run in groups of about ten. They were first shown a sample of several stimulus cards and the experimenter points out how the cards vary in their attribute values. It was then carefully explained to the subject that a concept is a combination of attribute values, e.g., "all cards containing crosses," or "all cards containing one green figure." Thus, the experimenter points out, certain cards represent positive instances of the concept. For example, the card containing "one green circle with three borders" (1G○3b) is a positive instance of the concept "cards containing one green figure." By the same token, the subject was informed about the meaning of a negative instance as a card not exemplifying the concept.

We then said: "I will now show you a sequence of cards and tell you whether each is a positive or a negative instance of the concept I have in mind. *After each card, please write down your best guess of the concept.*" Each subject was provided with a response sheet. Each problem was done on a single sheet, the last entry on the sheet being the subject's final answer. If the final answer corresponded to the correct concept, the subject was considered to have attained the concept. Cards were presented one at a time for only ten seconds. No hints were given and once a card had been shown and removed, the subject was not reminded of what it had been. The subjects were instructed to write down on their score sheets only their hypotheses and nothing else. It was not possible for them to refer back to previous hypotheses since the subjects were asked to cover them, as soon as they are written down, by a card. This covering card was also a "code card" containing abbreviations for the subjects to use in writing their response.

Sampling of Subjects and Problems. The subjects, 46 Harvard and Wellesley undergraduates, were given 14 problems to solve. The problems varied in the number of possibly relevant attributes with which the subject had to deal and in the number of attributes that defined the concept. The number of possibly relevant attributes varied from three to six and the number of attributes that actually defined the correct concepts varied from one to five.

The attributes used for any given problem were chosen at random, with the restriction that all six attributes were used equally often in the 14 problems. When, for example, a problem involved the use of three attributes, subjects were told what these were and the other attributes were kept at a constant value so as not to distract subjects from their task. The attributes that defined a concept were similarly chosen at random, with the same restriction as mentioned before.

The instances used for each problem were such as to approximate as closely as possible the following desiderata. *First,* that just enough instances be given so that the subject have sufficient information for attaining the concept with no redundant instances included in the series. *Second,* that the total number of instances presented for each problem be the same. *Third,* that the ratio of positive to negative instances presented in the various problems be the same. *Fourth,* that each problem occur equally often in the first, second, third, or fourth quarter of the series of problems. While we were able to come close to these prescriptions, it was combinatorially impossible to realize them completely. Subjects had to be divided into four subgroups and given slightly different sets of problems. The nature of the instances presented in the set of problems given to one subgroup is set forth in Table 1.

TABLE 1

The 14 Problems Given Subjects in One Subgroup

	Problems													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Attr. values of concept	1	2	1	2	3	3	1	2	3	4	1	2	3	4
Total attributes in array	3	3	4	4	4	4	5	5	5	5	6	6	6	6
Informative pos. instances*	3	2	3	3	2	2	3	3	3	2	3	3	3	3
Redundant pos. instances	0	1	0	0	0	1	0	0	0	1	0	0	0	0
Informative neg. instances	1	2	2	2	3	3	2	2	3	4	1	2	3	4
Redundant neg. instances	2	1	1	1	0	0	1	1	0	0	2	1	0	0
Total instances presented	6	6	6	6	5	6	6	6	6	7	6	6	6	7

But the fit to our prescription was not bad at that. All but three of the problems in this set contained six instances, and these three were only one away from this number. Four of the problems involved instances comprising exactly one full informational cycle with no redundant instances; the others contained one positive redundant instance, and sometimes one or two negative redundant instances. The balance of positive and negative instances was practically constant throughout. Finally, nearly all the possible combinations of ratios of defining to total attributes were represented all the way from one defining attribute value for a three-attribute array to four defining attribute values for a six-attribute array.

ADHERENCE TO STRATEGY

Two ideal strategies have been described in terms of a set of rules for constructing a first hypothesis and for changing it upon encountering various contingencies. The general question we wish to ask is whether, on the whole, subjects adhere consistently to the rules of these strategies or whether, if you will, their behavior is random. The question is reminiscent of one asked years ago by Krechevsky (1932) about maze-learning in the rat: is it a chance performance or systematic, this process of finding the way to a correct solution?

Three concrete questions can be put. Problems are begun with either the "part" hypothesis of the scanner or the "whole" hypothesis of the focusser. Are subjects consistent from problem to problem in using a whole or a part initial hypothesis? Given an initial hypothesis of one or the other type, to what extent do subjects follow the remaining rules of the ideal strategy that would permit them to reach a correct solution with minimum information? Where does a subject's performance diverge from the ideal strategy?

* This includes the positive instance, i.e., the initial card presented.

Regarding consistency in the utilization of part and whole hypotheses on a series of problems done by a single subject, there is a very marked tendency for the subject to use one or the other approach consistently. In this type of problem, at least, people are either consistently like Broca or like Flourens. The relevant data are presented in Figure 3.

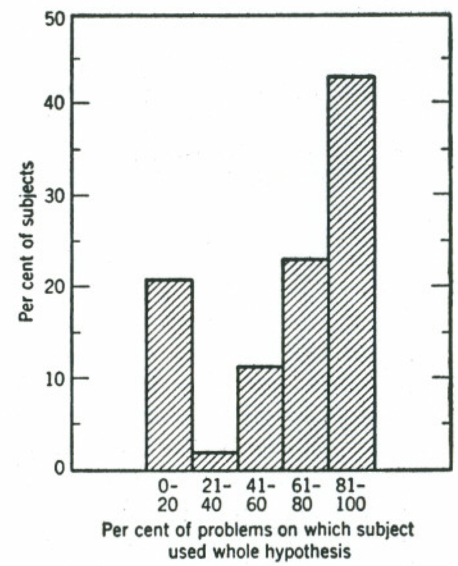

Figure 3. The percentage distribution of subjects with respect to the relative frequency with which they used initial whole hypotheses in dealing with problems.

We also see in this figure that it is the exception for subjects to use the two forms of initial hypothesis with equal frequency. It is rather interesting, too, that the whole hypothesis is preferred to the part hypothesis.* In fact, about 62% of the problems were begun with whole hypotheses. A word must be said about the strength of this preference.

Upon being shown an instance exhibiting, say, four attribute values, there are 15 opening hypotheses possible. Of these, one contains all

* In a partial replication of this experiment, with subjects run individually and with no time pressure, the same preference for whole hypotheses was found.

four attribute values, and 14 contain fewer than all four of these. The larger the number of attributes in an instance, the greater the number of alternative hypotheses possible. But always, there is only one of these alternatives that contains all the attribute values on the instance—the so-called whole hypothesis. Thus, the probability of choosing a whole hypothesis by chance alone diminishes as the number of attributes used increases. The best way of showing the strength of our subjects' preference for whole hypotheses is to consider the proportion of whole hypotheses actually used and the number expected by chance.

TABLE 2

Percentage of Problems Begun with Whole Hypotheses and Percentage Expected by Chance

Number of Attributes in Array	Percentage Begun with Whole Hypothesis	Percentage Expected by Chance
3	70	12
4	65	7
5	59	3
6	70	2

The first question posed was whether subjects are consistent from problem to problem in their preference for either part or whole hypotheses. The answer can be given in three parts: *a.* They are consistent from problem to problem. *b.* There is a preference for whole hypotheses far in excess of chance. *c.* Both the consistency and the preference hold for problems of varying complexity.

Why this preference for whole hypotheses? Two explanations suggest themselves. The first is that when the number of attributes to be dealt with is relatively limited, a person may be willing to deal with them all at once. Perhaps had we gone well above the subjects' immediate memory-and-attention span, there might have been a tendency to break the task down by dealing with packets of attributes. A second explanation takes us back to the preceding chapter where the role of verisimilitude was discussed. In the kind of abstract material used here, it is not likely that subjects will have any strong preferences about the relevance of particular attributes in the array. They have no favorites to ride. In consequence, there is no preformed tendency to concentrate upon any particular attribute.

So far we have concerned ourselves with the nature of the initial hypotheses adopted after presentation of the illustrative positive card. Consider now the way in which these initial hypotheses are modified in the light of contingencies subsequently encountered.

The Meeting and Handling of Contingencies: Wholists. Recall the four rules for the ideal focussing strategy, the ideal ways for a wholist to handle the four contingencies.

Contingency	Ideal procedure
Positive confirming (PC)	*Maintain* hypothesis now in force
Negative confirming (NC)	*Maintain* hypothesis now in force
Positive infirming (PI)	*Change* hypothesis to whatever the old hypothesis and the new instance have in common
Negative infirming (NI)	*Change* hypothesis on the basis of memory of past instances

How often are these rules followed by subjects who begin with a whole hypothesis—the wholists? The ideal rules are followed on:

54% of encounters with PC contingencies.
61% of encounters with NC contingencies.
54% of encounters with PI contingencies.
10% of encounters with NI contingencies.

The first three contingencies are handled ideally with a frequency far in excess of chance, and we shall return later to the question of what constitutes chance performance. But ideal handling of the negative-infirming contingency is strikingly rare. Why?

For the wholist to deal with the negative-infirming contingency, he must change his hypotheses on the basis of his memory of past instances encountered. In short, he must backtrack. This is the only contingency where focussers must use memory in this rote way. In practice, wholists do attempt to remember past instances when they meet a negative-infirming contingency, but to remember correctly and to extract the implications from what they have remembered is a task most often beyond them. Actually, the contingency should never arise—if the other rules are followed. Since focussing does not tend to orient the person toward literal remembering of past instances, it is not surprising that the contingency is only dealt with successfully in about 10% of encounters. The scanner, whose behavior we shall examine in detail shortly, is more memory-oriented. He deals successfully with this contingency on 26% of his encounters with it.

The focusser's departure from the rule for handling positive-infirming contingencies takes a simple form. The contingency is ideally met with the intersect rule: take that which is common to the old hypothesis and the infirming positive instances before one. On occasions, subjects are tempted to ignore this rule and to maintain their old hypotheses unchanged. More often, they "underintersect." Underintersecting consists in using for one's new hypothesis only *some* of the features common to the old hypothesis and the new infirming positive instance.

The lack of complete adherence to the ideal rules for handling confirming instances (either positive or negative) brings to light an intriguing feature of subjects' performance. The rule for both confirming contingencies is: "Maintain unchanged the hypothesis in force." The fact is that for some subjects at least it is difficult to maintain hypotheses in their present state when new instances come along. The involved subject often feels that he is making progress only when he changes his hypothesis in response to new instances. Maintenance seems to be equated with "no progress." He is, if you will, too "participant," too devoted to the idea that change is progress.

Consider now the frequency with which wholists actually encounter the various contingencies *en route* to attainment. The average problem contained five contingencies: five instances encountered after the initial illustrative card. Of these,

0.3 were PC contingencies.
3.0 were NC contingencies.
1.6 were PI contingencies.
0.1 were NI contingencies.

It is quite evident, then, that the principal contingencies to be coped with are negative confirming and positive infirming, constituting 4.6 of the average of 5 instances encountered on each problem.

To determine which of these two important contingencies—positive infirming and negative confirming—created more trouble for users of the wholist strategy, the following analysis was carried out. Problems handled by the wholist strategy are separable into four types:

a. Those in which *both* contingencies were handled appropriately.
b. Those where *neither* was handled appropriately.
c. Those where PI contingencies *were* handled appropriately, but NC *not.*
d. Those where NC contingencies *were* handled appropriately, but PI *not.*

Table 3 sets forth the number of problems of each type and the proportion of each type successfully solved. In brief summary, handling both contingencies appropriately leads to virtually certain success. Handling neither appropriately always leads to failure. If one does not handle the positive infirming contingency properly, failure is as likely as if one violated both critical contingencies. Such a violation is far worse than improper handling of a negative confirming contingency, after a violation of which recovery and success follow half the time.

TABLE 3

Handling of PI and NC Contingencies by Focussers

Response to Contingencies	Number of Problems	Per Cent Solved
Both contingencies always handled appropriately	103	97
Neither contingency ever handled appropriately	160	20
PI appropriate; NC not	54	48
NC appropriate; PI not	37	22

In brief, then, the handling of the positive infirming contingency by the intersect rule is the heart of the wholist strategy, for it is by this rule that the subject is enabled to alter his hypotheses in a manner such that it summarizes and keeps current all the information he has encountered to date.

The Meeting and Handling of Contingencies: Partists. How do scanners fare when they meet the various contingencies? The rules of the ideal scanning strategy are as follows:

Contingency	Ideal procedure
PC	*Maintain* hypothesis now in force
NC	*Maintain* hypothesis now in force
PI	*Change* to a hypothesis consistent with memory of past instances
NI	*Change* on same basis as for positive infirming

How often do partists follow these rules? They follow them on:

66% of encounters with PC contingencies.
52% of encounters with NC contingencies.
50% of encounters with PI contingencies.
26% of encounters with NI contingencies.

As with the wholists, the widest divergence from the rule comes in dealing with the taxing contingency of a negative infirming instance. Consider, as we did before in the case of the wholists, how the partists come to deviate from the ideal strategy.

Faced with confirming contingencies, either positive or negative, a subject should maintain his hypothesis unchanged. As with the wholists, however, many partists find it difficult to maintain a hypothesis unchanged in the presence of a new instance. They too feel that change is progress, that use should be made of each instance presented them.

Why is a negative-infirming contingency so difficult to deal with for a partist? Adherence to the ideal rule is not striking: 26% as against 50% for an infirming positive instance. For one thing, a negative infirming contingency contains a "double negative." The card illustrates what the concept is *not*, and it also tells you that your present hypothesis is *not* right. In this sense, a negative infirming contingency provides highly indirect information. Furthermore, such an instance provides one with no new base on which to ground a new hypothesis. A positive infirming contingency provides at least a set of attribute values upon which a new hypothesis can be formed.

Consider now the frequency with which scanners encounter the various contingencies en route to attainment. The average problem contains five contingencies. Of these:

0.6 were PC contingencies.
2.7 were NC contingencies.
1.3 were PI contingencies.
0.4 were NC contingencies.

As with the focussing strategy, the contingencies most frequently encountered are negative confirming and positive infirming, constituting 4.0 of the average of 5 contingencies met per problem per subject.

To determine which of these contingencies was the more crucial for users of the scanning strategy, we again divided problems into the four familiar groups:

a. Those in which *both* contingencies were handled appropriately.
b. Those where *neither* was handled appropriately.
c. Those where PI contingencies *were* handled appropriately, but NC *not*.
d. Those where NC contingencies *were* handled appropriately, but PI *not*.

Table 4 sets forth the number of problems of each type met and the proportion of each successfully solved.

TABLE 4
Handling of PI and NC Contingencies by Scanners

Response to Contingencies	Number of Problems	Per Cent Solved
Both contingencies always handled appropriately	22	73
Neither contingency ever handled appropriately	85	8
PI appropriate; NC not	52	31
NC appropriate; PI not	29	7

In sum, handling both of these two contingencies appropriately is associated with a high rate of success. Handling neither appropriately almost always leads to failure. If one does not handle the positive infirming contingency appropriately, failure is as likely as if neither contingency had been appropriately responded to.

Once again it is the handling of the positive infirming contingency that is the heart of the strategy. For the focusser, its handling in terms of the intersect rule was the way in which he could so modify his hypotheses that each hypothesis was a summary of the information encountered up to that point. For the scanner, the use of the positive infirming contingency is equally crucial: it provides a base on which to build a new hypothesis and a score card against which memory of past instances can be checked.

THE EFFECTIVENESS OF THE TWO STRATEGIES

Which strategy leads more often and more efficiently to success? Complete adherence to the ideal rules of either, of course, leads with inevitability to success. But there are deviations from the ideal rules: all wholists do not always adhere to the rules of focussing, nor partists to scanning.

If one can compare the success of partists and wholists, taking their strategic behavior as we find it, the advantage lies with the wholists. But the real question is: *which strategy is the more effective under what conditions?* Does the effectiveness of each strategy vary with the over-all difficulty of the problem to which it is applied, and is there a difference between the two in this effectiveness? Recall that the problems given to subjects varied in difficulty: difficulty depending upon the number of attributes to which one had to attend. For the larger the number of attributes represented by instances to be dealt with, the larger the number of hypothetical concepts in terms of which the instances may be grouped. If *A* attribute values are present in a first positive instance presented, the number of possible hypotheses about the correct concept will equal the sum of *A* values taken one at a time (for one-value hypotheses), taken two at a time (for two-value hypotheses), up to *A* at a time (for *A*-value hypotheses). The number of possible concepts for each case used, then, is:*

Three-attribute problems = 7 possible concepts.
Four-attribute problems = 15 possible concepts.
Five-attribute problems = 31 possible concepts.
Six-attribute problems = 63 possible concepts.

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* The formula for the number of hypotheses after a first positive instance is: $H = \sum_{i=1}^{A} \binom{A}{i}$, where H is the number of hypothetical concepts possible after a first positive instance and A is the number of attributes in the array.

It is quite evident that the task of keeping track of possible hypotheses increases considerably in difficulty with an increase in the number of attributes in the array.

Figure 4 indicates that the number of attributes in a problem is indeed a source of increasingly difficulty. It is not surprising that the wholists were more effective with problems at *all* levels of difficulty. The fact of the matter is that it is easier for a subject to follow all the rules of focusing, and the superiority of the wholist does indeed derive from this kind of total adherence. For all levels

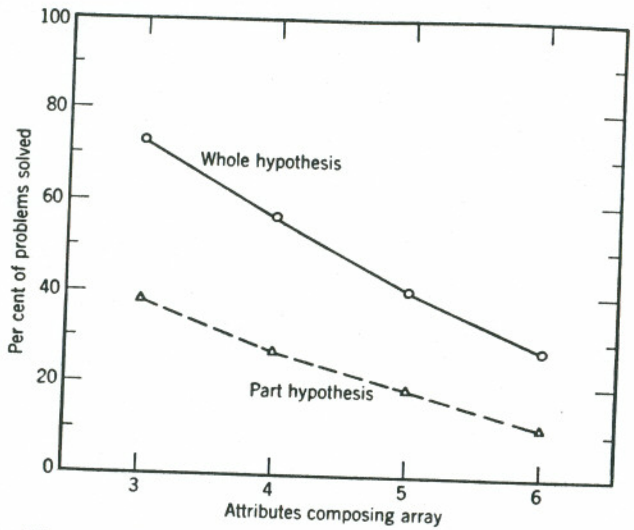

Figure 4. The percentage of problems begun with whole and with part hypotheses that are solved as a function of the number of attributes represented in the problem.

of difficulty, there were more people who seemed able to adhere to all the rules of focussing than those able to follow through with memory-bound scanning. The only explanation we can give as to why the partists who relied on scanning did not "fall apart" faster when problems grew more difficult than did wholist focussers was that the pace of the experiment was too fast. With an increased number of attributes in the instances, and with instances coming one after the other at a rapid rate, the focusser was as likely to get confused in remembering his hypothesis as the scanner was in recalling past instances. We have no direct evidence in support of the explanation, but it seems reasonable.

Under what conditions would one expect wholist focussing to show

marked superiority to partist scanning? The results thus far presented indicate a general superiority of the former over the latter. It seems reasonable, does it not, that the more difficult one made the task of remembering instances, the more marked would this superiority be. Take, for example, the "time strain" imposed by the ten-second presentations used in the experiment just described. What if the subjects had been run individually and had been allowed to get instances for testing at their own pace and with as much time registering on instances as they wished? An exploratory study of just this kind has been done (Austin, Bruner, and Seymour, 1953). The same strategies emerge, the same proportion of wholists and partists, although the degree of adherence to ideal strategy is greater under these relaxed conditions. It is interesting to compare the behavior of subjects in this experiment with that of the time-pressured subjects with whose behavior we have been principally concerned in this chapter. Consider the effectiveness of wholists and partists on comparable three- and four-attribute problems. *Without time pressure and proceeding at their own pace, wholists and partists do equally well:* 80% of problems done by wholists were solved correctly; 79% done by partists. But *with time pressure,* 63% of problems done by wholists were solved; 31% done by partists. In short, time pressure has a relatively small deleterious effect on the success of focussing, but a major effect on the success of scanning—literally halving its effectiveness.*

The reasonable conclusion, akin to the conclusion of the preceding chapter, is that the more a task increases the strain inherent in a strategy, the more hazardous will such a strategy become. If one increases the number of alternatives to be kept in mind (e.g., Bruner, Miller, and Zimmerman, 1955), or cuts down redundancy, or increases stress and time pressures, it seems reasonable to expect that a strategy requiring feats of memory and inference will suffer more than one not requiring such feats.

STRATEGIES AS DESCRIPTIVE OF BEHAVIOR

Early in the chapter the point was made in passing that the behavior of our subjects conformed moderately well to the ideal strategies we had described and that, moreover, the degree of conformance

* There are several small differences between the major study where time pressure was applied and the pilot study without time pressures: principally that the problems worked under time pressure had fewer redundant instances than the leisurely problems. This probably contributed additionally to the differential effectiveness of the two strategies.

found was massively in excess of what one would expect by chance. It is to this question that we must finally return. How well is behavior described by referring it to the yardstick of ideal strategies?

The first and most obvious point to be made is that the ideal strategies that have served us so steadily in this chapter are essentially refined versions of what we have observed our subjects doing. They were not invented by us in an *a priori* manner. Our description of ideal strategies is a description of what, it seemed to us, our subjects were trying to "bring off."

There are sources of evidence that are considerably stronger than this mild "intuitive" point. The first has to do with the agreement that exists between the theoretical frequencies with which various contingencies should be encountered if subjects are conforming to ideal strategies and the actual frequencies with which contingencies were encountered. The second is the analysis of *total adherence* to ideal strategy: the number of cases in which ideal strategies were followed in their entirety, and the likelihood that such adherence could have occurred by chance.*

Expected and Observed Encounters With Contingencies. For purposes of discussion, we shall concentrate on a problem in which the instances presented the subject contain four attributes, each of them capable of exhibiting one of three possible values. Let us say that the four attributes are number, color, and shape of figures and number of borders. Given a first positive instance on a problem, one may choose as an hypothesis one, two, three, or four values of the initial positive card. In this experiment the correct concept may in fact be defined by any one, two, or three of these values. No concept is defined by all the attribute values in the initial illustrative card. We know, of course, that the larger the number of values defining a concept, the fewer the positive cards. In our present array, 27 of the 81 cards would be positive if the correct concept were defined, say, by the single value "red." Only 3 cards in the 81 possible would be positive if three values defined the concept.

Now the question to be examined is how many instances representing the four contingencies would be expected by chance, given the adoption of an initial hypothesis marked by different numbers of attribute values, when the correct concept itself is defined by different numbers of attribute values. More concretely, what contingencies should a wholist or partist encounter? There may be one-, two-, three-, and four-value hypotheses in the face of one-, two-, or three-value concepts. Begin with the presentation of a first instance, a positive card exhibiting one of three possible values of each of four attributes. The correct concept, let us say, is defined by one of the attribute values on the first card. The first card is "2R○1b" and it exemplifies the concept "R." Suppose the subject now adopts a one-value hypothesis consistent with the first instance. This could be either "2," "R," "○," or "1b." Now we ask, what is the chance that a next card, chosen at random from the array of possible instances, will be positive confirming, positive infirming, negative confirming, or negative infirming? We know that one-third or 27 of the cards in the array are positive, i.e., contain a red figure. Now the chance that any of these will be positive *and confirming* will be as follows. If the subject has the right hypothesis, "R," all 27 positive instances will be confirming. If he has any of the three wrong one-value hypotheses, say "1b," only nine of these will be confirming: the nine instances that contain both "R" and "1b." Thus, the average theoretical frequency of positive confirming encounters on the first instance after the illustrative card is:

$$\frac{9+9+9+27}{4} = 13.5$$

It is in this way that the values contained in Table 5 are computed. They represent the average theoretical frequency with which a second instance in a series will fall into one of the contingencies when this second instance has been picked at random from the array of 81 possible instances.

It can readily be seen from this table that there is *no* chance of encountering a negative infirming contingency on the second instance if one begins by adopting a four-value hypothesis (a whole hypothesis). The smaller the number of values in one's initial hypothesis, the greater the likelihood that the next card will be negative infirming. This is true regardless of the number of values actually defining the concept. Contrariwise, the likelihood of encountering a negative confirming instance increases as the number of values in one's hypothesis increases.

If we now examine the behavior of our subjects, it will be apparent that partists do encounter more negative *infirming* instances than wholists, and that wholists meet more negative *confirming* instances. Similarly, wholists will show a higher ratio of positive infirming to posi-

* The data presented in this section are taken from the previously mentioned study by Austin, Bruner, and Seymour (1953) in which subjects were allowed to proceed at their own pace and without time pressure. It is with this study that we began our investigation of reception strategies in concept attainment.

TABLE 5

Number of Instances in the 81-Card Array That Will on the Average Fall Into Each of the Four Contingencies When the Subject Has Adopted Different Numbers of Values of the Initial Positive Card as His Hypothesis

Attribute Values Defining Correct Concept	Contingency	Attribute Values in Hypothesis: 1	2	3	4*
1	PC	13.5	6.0	2.0	1.0
	PI	13.5	21.0	25.0	26.0
	NC	40.5	51.0	53.5	54.0
	NI	13.5	3.0	0.5	0.0
2	PC	6.75	4.0	2.0	1.0
	PI	2.25	5.0	7.0	8.0
	NC	51.0	66.7	71.0	72.0
	NI	21.0	5.3	1.0	0.0
3	PC	2.5	2.0	1.5	1.0
	PI	0.5	1.0	1.5	2.0
	NC	53.5	71.0	76.5	78.0
	NI	24.5	7.0	1.5	0.0

tive confirming contingencies than will partists. Table 6 shows the average number of different contingencies encountered by subjects on problems begun with whole or with part hypotheses.

TABLE 6

Average Contingencies Encountered per Problem by Subjects Beginning With Whole and Part Hypotheses†

Contingency	Initial Whole Hypothesis	Initial Part Hypothesis
PC	0.7	1.0
PI	1.3	1.0
NC	3.4	2.8
NI	0.4	1.0
Total contingencies	5.8	5.8

In general, there is quite fair agreement between the incidence of contingencies we would expect to occur if subjects followed the two ideal strategies and the incidence we observe to occur in the problems begun with part and whole hypotheses.

The major difference lies in the expected and observed frequency of encountering a negative infirming contingency after starting with

* For this array adoption of a four-attribute hypothesis constitutes the wholist approach.

† Based on 355 problems begun with whole hypotheses; 214 begun with part hypotheses.

a whole hypothesis. If the wholist strategy is fully followed, negative infirming contingencies cannot occur. But they are encountered on an average of 0.4 times per problem per subject. These negative infirming contingencies arise from subjects' occasionally departing from the rules of the strategy. Outside of this one discrepancy between the general observed and expected incidences of contingency encounters, the agreement is more than sufficient to demonstrate the utility of describing and analyzing performance in terms of its conformance to ideal strategies.

The Incidence of Complete Adherence to Strategy Rules. To what degree, given a part or whole hypothesis, do subjects conform respectively to the rules of the scanning and focussing strategies—the strategies ideally suited for modifying such hypotheses? The bare findings can be stated quickly. Of the problems that were begun with a whole hypothesis, 47% were followed up on all subsequent contingencies with complete adherence to the rules of focussing. Of problems begun with a part hypothesis, 38% were followed through with complete adherence to the rules of scanning.

This incidence of complete and correct adherence is strikingly high. It is even more so when we inquire how they compare with what one would expect by chance. What is the chance expectancy for strict adherence?

There are various chance models that one can employ here: robots endowed, if you will, with differing amounts of inference and memory ability. A completely stupid robot, one who is as random as we can make him, would emit an hypothesis after each instance with no bias. For example, he would not even pay attention to the card being presented to him. This means that for a four-attribute array, he would choose indifferently among the 256 possible hypotheses in terms of which the array of instances may be subdivided into categories. If five instances are presented, and he must do something about his hypothesis each time an instance is encountered even if only maintain it, then the chances of obtaining any particular set of five hypotheses over the five instances would be one in 256^5 and this is a very small fraction indeed. And this, of course, is the probability that hypotheses would be changed consistently according to rule over five instances.

But surely this is too stupid a chance model to be anything but trivial. Let us construct a robot whose only rational property is that he emits an hypothesis upon the presentation of an instance that is consistent with that instance. On the first instance and indeed on every instance, his chances of choosing a particular hypothesis would be a function of the number of consistent hypotheses possible given any one instance. For three-attribute arrays, there are 8 such; for four-attribute arrays, 15; and for five- and six-attribute arrays, 31 and 63 respectively. Thus the chance of a particular hypothesis after any given instance would be $\frac{1}{8}$, $\frac{1}{15}$, $\frac{1}{31}$, and $\frac{1}{63}$ respectively. The chance expectancy that a focusser will follow all the rules consistently on a four-attribute problem containing 5 instances would be $(\frac{1}{15})^5$ or once in 15^5 problems. This is still astronomical, and is considerably greater when one goes to problems based on arrays with still more attributes and still larger numbers of instances. The modest example just taken gives us a prediction that only once in 759,375 problems should we expect to find the rules adhered to strictly throughout a problem. This is for a robot who has good enough sense to emit only hypotheses that are consistent with each instance placed before him.

One could go beyond the last model proposed and construct robots with better inference capacities and with the ability to store information from past instances. But this can only end in the construction of a model that shows the same rate of adherence as our subjects. While this might be a useful exercise in model construction, it is not within the range of our task. Our effort has been to show, simply, that the rate of adherence to the rules of strategy was greatly in excess of what one would obtain from people behaving in a random fashion.

RECEPTION STRATEGIES IN PERSPECTIVE

We began with the contrast between two great figures in the history of brain anatomy, Broca and Flourens; the one starting with the assumption that specific areas of the cortex provide one with the proper stuff for hypotheses about brain functioning, the other with the conviction that one must begin with the concept of the whole brain. The burden of the studies reported in the chapter is that one can proceed rationally from either initial position to the discovery of what features of the brain are indeed relevant to what kinds of mental functioning. But whichever way one starts, there are certain consequences that follow, for with each initial preference there goes a distinctive and appropriate strategy.

The task one faces in dealing with an arbitrary sequence of instances is one in which the major freedom of the problem-solver is in formulating or altering his hypotheses about what is common to an array of instances. Here is a patient with lung cancer: he smokes, lives in a city, has immediate kin with a history of cancer, and has had

chest colds frequently during the last ten years. *All* or *some* of these must be taken initially as a relevant hypothesis about the "cause" of cancer of the lung. From then on, "freedom" consists in the handling of four contingencies: a problem-solver will encounter exemplars and nonexemplars of the category for whose definition he is searching, and each of these will perforce confirm or infirm the hypothesis he is entertaining at the time of encounter. What the problem-solver must learn is how to modify his initial hypothesis upon encountering each kind of contingency. And this task, we have seen, is bound by the nature of his initial hypothesis. In the main, the focussing strategy appropriate to an initial whole hypothesis is less demanding both on inference and memory than the scanning strategy required to make good an initial part hypothesis.

It appears that far more people prefer to start with a whole hypothesis than with any other form of hypothesis. Moreover, people are consistent from problem to problem in their initial approach. It further appears that, whether one prefers a whole hypothesis or a part one, one is likely thereafter to conform to the rules of the appropriate strategy overwhelmingly in excess of chance.

Because the appropriate scanning follow-up to a part hypothesis is more mnemonically and inferentially demanding than the focussing follow-up to an initial whole hypothesis, the former strategy may be considered more vulnerable to all those conditions that would make record-keeping difficult. An experiment illustrating one such condition has been reported. The condition is the effect of time pressure: reducing the time available for the subject to weigh, consider, or generally reflect on the nature of instances encountered. When such time pressures are applied, we find that the damage done to the user of the memory-bound part hypothesis is more severe than the damage to the wholist. The former cannot apply the rules of his strategy as effectively and one finds a sharp decrement in the proportion of problems that are successfully solved.

We have examined in these pages the manner in which a human being deals with the task of sorting out events that come to him in a haphazard sequence, finding out which of the events are significant and which are not. The experiment has utilized highly stylized materials—slips of cardboard with designs varying in certain properties printed on them—but the task is not so different from the task of the traveler learning what type of inn can be trusted by its externals and without the pain of sampling the service, or of any person who must learn what something is by means short of trying it out directly.

There are certain interesting ways in which our experiments differ from comparable problem-solving in everyday life. One of these is in the sheer concentratedness of the task. We are rarely flooded at such a rate with new instances to absorb. On the other hand, our subjects are required to retain only one concept at a time and are shielded from other distractions. Our subjects must also perform without the aid of such enormously important cultural tools as pencils and paper with all that these can do for us in extending the highly limited range of memory and attention. Interestingly enough, however, we find that allowing the use of pencil and paper and easy access to a record of past instances does not necessarily give an advantage in performance. (Cf. Goodnow, Bruner, Matter, and Potter, 1955.) Another difference between our procedures and what happens outside the laboratory we know from the preceding chapter. The materials with which our subjects deal do not lend themselves to thematizing, to encoding in the form of little plots or themas. This abstractness of the materials is, we know, a mixed blessing. On the one hand, it saves the problem-solver from his preconceptions as to what is relevant. But on the other hand, it prevents him from using the wonderfully diverse methods of conserving information through assimilation to familiar themes, the methods whose strengths and weaknesses are so vividly told in Bartlett's classic *Remembering* (1932) and more rigorously recounted in the studies of Miller and Selfridge (1950) and others who have applied information theory to memory phenomena.

Finally, the point will undoubtedly occur to the reader that the motivation of our subjects was either different from or "less than" what one might expect to find in ordinary life where the consequences or payoff attendant on attaining a concept may be greater. Certainly motivation is "different." Intuitively, having watched our subjects struggle and strain, we think it unlikely that it is any "less"—whatever "more or less" can be taken to mean. The sense in which the motivation of our subjects is "different" from what one would be likely to find in a "real-life" situation is worth a word in passing.

Our subjects were quite clearly "trying to succeed" and the task obviously aroused achievement needs and other extrinsic motives. But what is more important, they were trying to get information, to attain a concept. That this is a powerful motive, nobody will deny. We need not go into the question of the primary or secondary status of such a need. All we need know is that our subjects were impelled by it. As we remarked in Chapter 3, the "reinforcement" or satisfaction of such a need is the act of acquiring the information sought.

This keeps our subjects going. In so far as other motives are also aroused in the situation, the "act of getting information" takes on broader significance. It may mean to the subject "I am a bright fellow" or "I'll show this psychologist!" Such extrinsic consequences of information-getting may, of course, alter the patterning of the behavior observed in our subjects. It is conceivable that had we exposed our subjects to the kind of status stress employed by Postman and Bruner (1948) in their study of perceptual recognition, there would have been less incidence of adherence to strategy. We do not know. Obviously, our experiments are neither a proper sampling of real-life situations nor of the kinds of stress that can be applied to subjects. Such research remains to be done. The paradigm we have used will serve, we hope, to make that later research more technically feasible.

One other feature of motivation distinguishes our subjects from, say, the average scientist working on a comparable scientific problem. Our subjects had no passion to prove that a particular attribute was *the* correct attribute in the sense that Broca was impelled to prove that a particular brain center was responsible for human speech. This is a matter of importance, and it seems not unreasonable to extrapolate from experiments in the preceding chapter, that had there been such an investment in a particular attribute there would have been far more part-scanning. The preference for wholist focussing probably reflects a certain dispassionateness among our subjects with respect to the attributes that were used in the experiment.

Finally, one general point needs to be made. In dealing with the task of conceptualizing arbitrary sequences, human beings behave in a highly patterned, highly "rational" manner. The concept of strategy has made it possible to describe this sequential patterning. It is only when one departs from the analysis of individual acts-at-a-moment that the sequentially coherent nature of problem-solving becomes clear.