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Log-normal Distribution of Physiological Parameters and the Coherence of Biological Systems

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Abstract — The well-known fact that biological parameters, randomly selected, are distributed according to log-normal frequency curves instead of normal ones, has been traced back to a 'multiplicative Gestaltungs-principle of nature'. A further analysis shows that the basis of this principle can be assigned to the optimization of connections in a network of circuit elements, or, even more profoundly, to the formation of coherent states in living systems. The diagnosis of patients based on physiological frequency distributions provides a new powerful tool of understanding sickness in terms of deviations from a basic regulation principle.

Introduction

It is well-known that physiological parameters like blood pressure, tolerance of medicines, body size and survival rate of living populations do not follow a Gaussian (normal) distribution but a log-normal one (1). This fact has been interpreted in terms of a 'multiplicative Gestaltungs-principle of nature' (2,3). However, this have never been formulated or explained on a basic level. In this paper, after having demonstrated that the skin-resistance values follow actually a log-normal distribution (4,5; Fig.1), a first attempt of interpreting the log-normal character will be presented. The 'multiplicative Gestaltungs-principle' is traced back to the formation of coherent states in living systems (6,7). This basis constitutes at the same time a new tool of understanding certain kinds of disease in terms of their definite deviation from this optimal regulation principle.

Normal and log-normal distribution

The difference between normal and log-normal distribution can be explained in terms of the random fluctuations of, (a) either the original measurement values, like conductivity or other parameters, around some mean value, or (b) of the logarithms of these parameters, giving rise either to a normal distribution or to a log-normal one, respectively. Actually, for the measurement values x_e we always can write :

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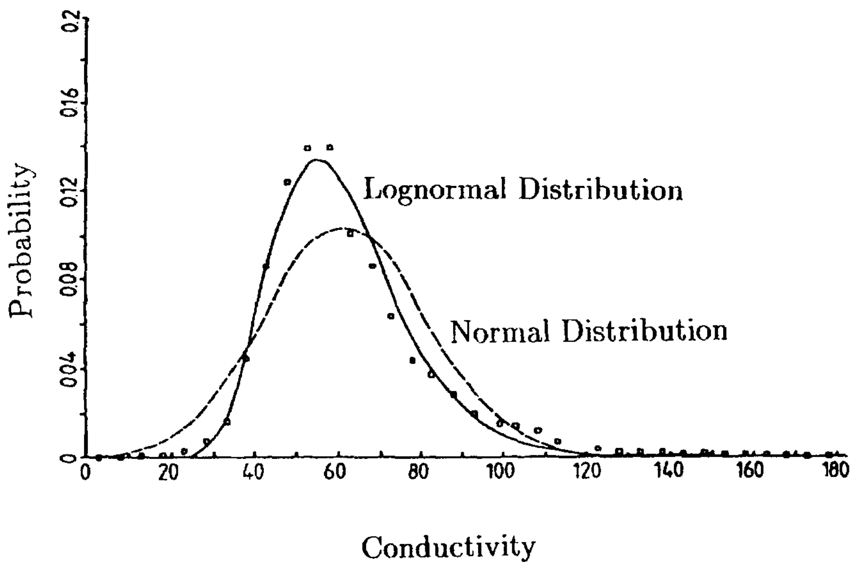

Fig. 1 The probability distribution of 18 000 skin-conductivity values of 200 healthy people follows a log-normal distribution (continuous line) instead of a normal one.

$$x_e(t) = \sum_{j=1}^{n} x_j \, p(x_j,t) \qquad \text{Eq. 1}$$

where x_j is a fixed set of values within the system under investigation and $p(x_j,t)$ represents the probability of the appearance of x_j at time t. A random fluctuation of $p(x_j, t)$ leads to fluctuations of x_e according to :

$$\Delta x_e(t) = \sum_{j=1}^{n} x_j \, \Delta p(x_j,t) \qquad \text{Eq. 2}$$

Figure 2 shows an example where x_e is the sum of n numbers which are obtained by throwing the dice n times. The values are distributed around a mean value according to a function which after normalization approaches more and more a normal distribution, the higher the number n and the more values x_e are taken into account.

If, however, instead of following the 'additive' principle (Eq. 1), the measurement values $x_e(t)$ depend on the product of single probabilities according to :

$$x_e(t) = f(x_1,x_2,\ldots,x_n) \prod_{j=1}^{n} p(x_j,t) \qquad \text{Eq. 3}$$

we can write

$$\ln x_e(t) = \ln f(x_1,x_2,\ldots x_n) + \sum_{j=1}^{n} \ln p(x_j,t) \qquad \text{Eq. 4}$$

such that

$$\Delta \ln x_e(t) = \sum_{j=1}^{n} \frac{\Delta p(x_j,t)}{p(x_j,t)} = \sum_{j=1}^{n} \lambda_j \Delta p(x_j,t) \qquad \text{Eq. 5}$$

where

$$\lambda_j = \frac{1}{p(x_j)} \text{ and } p(x_j,t) = p(x_j).$$

Consequently, the logarithms of x_e according to Equations 3–5 follow in case of an explicitly time-dependent function $p(x_j)$ the same mathematical dependence as x_e itself according to Equation 2. This means that a normal distribution based on an 'additive' principle turns into a log-normal one, as soon as this additive principle turns into a 'multiplicative' principle due to Equation 3 under some constraints on the time-behaviour of $p(x_j,t)$. Figure 3 shows an example. Note that in any case the $p(x_j,t)$ for j = 1,2,...n, are subjects of completely random fluctuations.

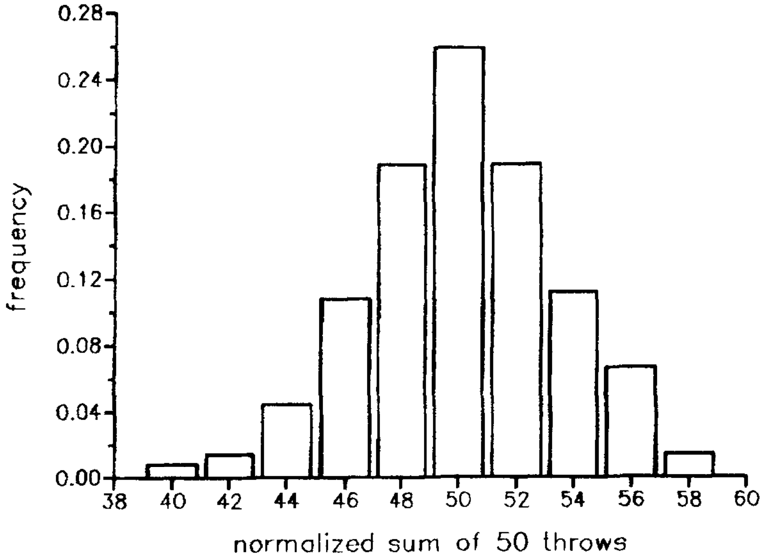

Fig. 2 The (normalized) sum of 50 throws of a dice follows approximately a normal distribution.

Organization of possibilities

Any biological system can be considered as consisting of a network of n equal or essentially equal subunits (like molecules or cells) which are coupled together in such a way that the interactions and the distribution of the interactions over all the units determine the values of the physiological parameters at any instant. For the purpose of our discussion it is not necessary (and, of course, also not possible) to specify the nature of the subunits and their interactions.

Let us, for a first glance, distinguish two limiting

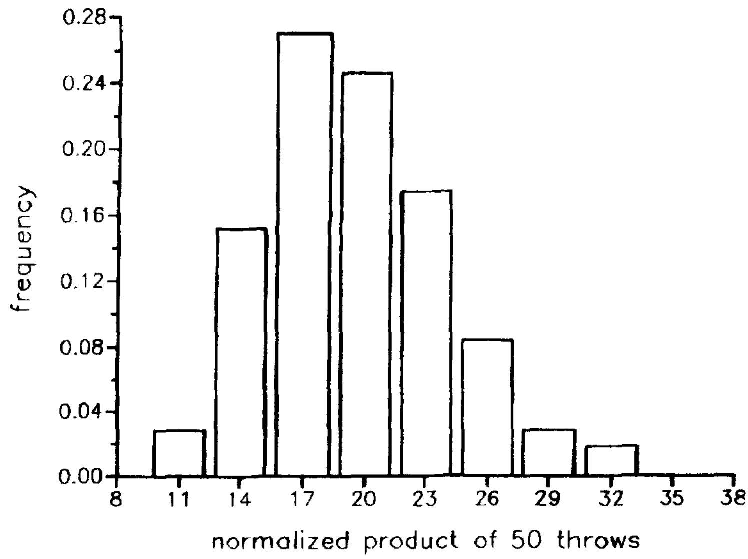

Fig. 3 The (normalized) product of 50 throws of a dice follows approximately a log-normal distribution.

cases, i.e.

1. The units behave like perfect individuals, such that:

$$\underbrace{\textcircled{1}+\textcircled{1}+\cdots+\textcircled{1}}_{n-\text{times}} = n \qquad \text{Eq. 6}$$

or

2. The units are strongly coupled to each other by a stiff link, such that only a single one new entity results from coupling of always n units.

$$\underbrace{\textcircled{1}+\textcircled{1}+\cdots+\textcircled{1}}_{n-\text{times}} = 1 \qquad \text{Eq. 7}$$

The circle around the numbers denotes the symbolic character of this kind of mathematics.

Since the measuring values of x of any physiological parameter will depend on the coupling forces and their distribution between, say n units, in the case of Equation 6 a normal probability distribution p(x) is expected in view of the independence of all the links in the measuring circuit, while Equation 7 will give rise to a δ-function-like distribution, able for only one measuring value. However, Equations 6 and 7 are only limiting cases of couplings between n units, i.e. $\binom{n}{1}$ and $\binom{n}{n}$. The most general case can be written as:

$$M = \sum_{j=0}^{n} p(n,j)\binom{n}{j} \qquad \text{Eq. 8}$$

where p(n,j) is the probability of distributing j couplings over n units in such a way that all possible kinds of couplings $\binom{n}{j}$, where j runs from 0 to n, are taken into account, and not only the couplings (Eqs. 6 and 7) which correspond to $\binom{n}{1}$ and $\binom{n}{n}$ respectively. Since the normalization of p(n,j) requires :

$$\sum_{j=0}^{n} p(n,j) = 1 \qquad \text{Eq. 9}$$

the cases of Equations 6 and 7 can be assigned to p(n,1) = 1 and p(n,n) = 1, respectively. However, if all possible couplings $\binom{n}{j}$ get the same chance, we then have $p(n,j) = \frac{1}{n}$, hence p(n,j) does not depend on j. The value M takes then its maximum which is $M = \frac{2^n}{n}$, corresponding to the highest capacity in occupying the possible links. This can be looked upon as an optimization of the regulation of the system, since the possible links are used with highest possible efficiency. In fact, this kind of organization leads always to a log-normal distribution as soon as n, the 'number of degrees of freedom', follows a normal one.

In order to understand the point behind this strategy, i.e. that p(n,j) does not depend on j, take the case n = 3 as an example. Figure 4 shows the maximum number of different possibilities of connecting 3 units. The first case corresponds to the highest individual freedom, where no coupling takes place. The members remain individuals, giving rise to a normal distribution. In that case we have the symbolic equation $\textcircled{1}+\textcircled{1}+\textcircled{1} = 3$.

In the second case, all members are strongly coupled together such that their individuality gets completely lost. This case is described by the symbolic relation $\textcircled{1}+\textcircled{1}+\textcircled{1} = 1$. There are further possibilities between these limiting behaviours, e.g. the cases given in the Diagram and shown in Figure 4.

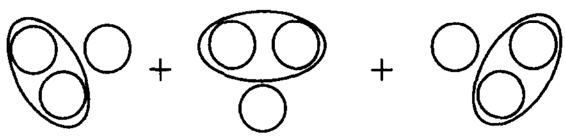

Diagram — Further possibilities

All possibilities can be described by the binomial coefficients $\binom{3}{1}$, $\binom{3}{2}$ and $\binom{3}{3}$. The case $\binom{3}{0}$ has been omitted here for simplicity.

Log-normal distribution and coherence

In several papers it has been substantiated that coherent states in the strong sense of its physical definition provide the basis of biological regulation (6). From Equation 8 we know that the log-normal distribution of physiological parameters can be traced back to the highest efficiency of using always all possible couplings between n identical elements which are considered to be responsible for the physiological state. Consequently, there should be a connection between the coherent state and the log-normal distribution, that is between the photocount statistics (PCS) of the coherent state and the Bernoulli distribution of Equation 8. It is well known that the PCS of a coherent state is subject of a Poissonian distribution :

$$p(n,k) = \exp(-k)\frac{k^n}{n!} \qquad \text{Eq. 10}$$

This means that if the mean value of an ergodic and stationary coherent photon field is k, the probability of measuring n photons (more generally n bosons) follows the Poissonian distribution (Eq. 10). Now let us imagine that two identical units which we considered as representing the elements of the physiological state 'communicate' via coherent bosons with identical mean values $k_1 = k_2 = k$. An observer of this communication measures again the PCS and by registering N bosons there is the possibility that N_1 originated from source 1 and $(N - N_1)$ originated from source 2, where the number N_1 runs from 0 to N. Consequently the PCS of the connected units follows :

$$p(N,2k) = \sum_{N_1=0}^{N} p_1(N_1,k) \cdot p_2\left([N - N_1],k\right)$$

$$= \sum_{N_1=0}^{N} \exp(-k)\frac{k^{N_1}}{N_1!}\exp(-k)\frac{k^{(N-N_1)}}{(N-N_1)!}$$

$$= \exp(-2k)\frac{(k)^N}{N!}\sum_{N_1=0}^{N}\binom{N}{N_1} \qquad \text{Eq. 11}$$

$$p(N,2k) = \exp(-2k)\frac{(2k)^N}{N!} \qquad \text{Eq. 12}$$

This Bernoulli distribution of Equation 11 which is responsible for the connection of the two photon fields provides at the same time (Eq. 1) the conservation of the coherence of the coupled fields and (Eq. 2) the perfect use of all the possibilities in the interaction of the sources.

Of course, since a coherent state is completely delocalized, the highest possible number of ways to distribute n bosons over n elements is to distinguish the sequence of the elements by use of the phase relations of the bosons and to get thus the number n! combinations for all the n elements. Consequently, apart from unimportant questions of normalization, we can provide that the highest possible number of ways to dis-

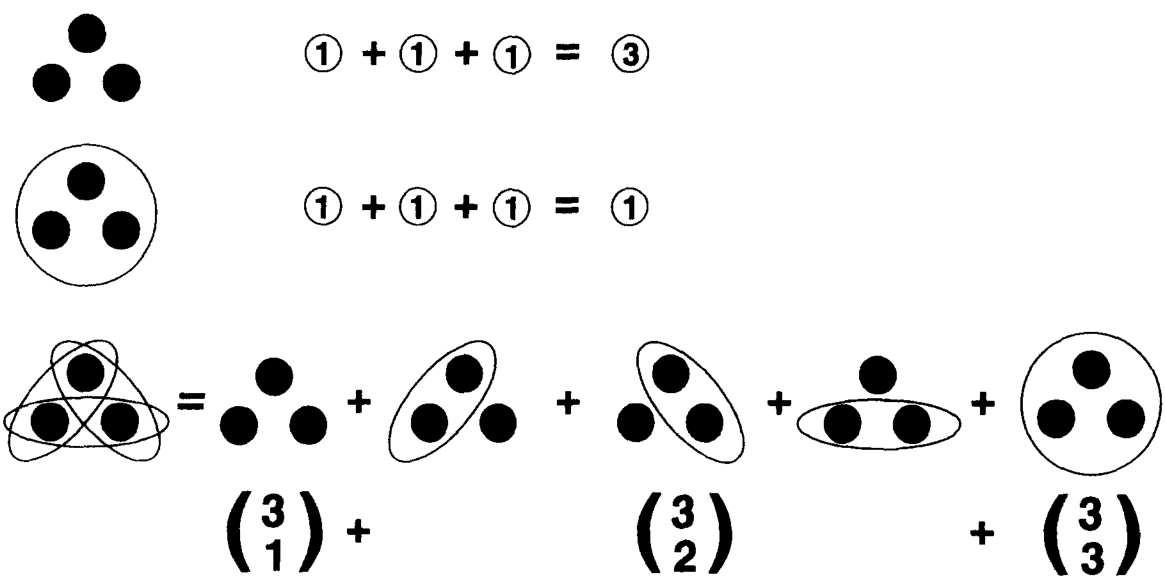

Fig. 4 The organization of links between 3 elements can be analysed in terms of Bernouli-coefficients. No link at all provides the individuality of the elements (upper symbol). It is described by $\binom{n}{1}$. A stiff link between all elements reduces the number of degrees of freedom to 1 (middle symbol). It is described by $\binom{n}{n}$. The complete organization involves also the cases $\binom{n}{2} \ldots \binom{n}{n-1}$. The lower symbols show this in the case of $\binom{3}{2}$ besides that of $\binom{3}{1}$ and $\binom{3}{3}$

tribute n bosons of a coherent field over the whole system is then

$$n!\,p(n,k) \propto k^n \qquad \text{Eq. 13}$$

as a consequence of Equation 10.

This means that if the biological system represents a coherent state where the information of the bosons in terms of using the possibilities becomes optimized, the random fluctuation of the number n of bosons (following a normal distribution) causes a log-normal distribution of physiological parameters, where we tacitly assumed that the physiological parameter reflects just the number of ways to distribute the bosons over the system. This is reasonable since the 'information' of the 'physiology' can originate in that case only from the distribution of bosons over the matter, that is the pattern of excited states.

If, on the other hand, p(n,k) describes the probability distribution of registering n bosons of a chaotic field with mean value k, the enumeration of the highest possible number of ways to distribute n bosons over n elements has to be based on $\binom{n}{1}$ in the series of Bernoulli-elements. This can be understood as follows : as soon as chaotic bosons excite n units (say molecules), the memory about the sequence of excitations gets lost in view of the loss of the phase relations. Instead of n! possible ways of different excitations as in the case of a coherent field we have only n possibly different ways in the case of a chaotic field. This reflects just the loss of information due to the loss of phase relations. Consequently, after registering n counts we are then unable to decide in what sequence originally distinguishable elements may have emitted the n bosons. p(n,k) of a chaotic field has then to be multiplied by n instead of n! when we look for the number of ways how to distribute n bosons over n elements. Consequently, apart from bunching phenomena (which are not considered here), the number of ways to distribute n chaotic bosons over a system becomes:

$$np_{chaot.}(n,k) = n\,\frac{k^n}{(k+1)^{n+1}} \infty\, n \qquad \text{Eq. 14}$$

Since chaotic fluctuations of the boson number n following a normal distribution will in this case of a chaotic field cause again a normal distribution of physiological parameters.

Our studies have shown that the 'degree of health' correlates significantly as well with the agreement of the probability distribution of the skin resistance values to a log-normal distribution as with the disagreement to a normal one. In particular, cancer patients show the tendency of displaying a normal distribution of their skin resistance values (8).

References

1. Sachs L. Statistische Auswertungsmethoden. Berlin: Springer, 1969.
2. Schuermann H, Schirduan M. Untersuchungen über Fragen der Penicillin-Dosierung. Klin Wschr 1948; 26: 526.
3. Gebelein H, Heite HJ. Über die Unsymmetrie biologischer Häufigkeitsverteilungen. Klin Wschr 1950; 28: 41.
4. Popp FA. Neue Horizonte in der Medizin. Heidelberg: Karl F. Haug Verlag, 1987.
5. Rossmann H, Popp FA. Statistik der Elktroakupunktur nach Voll I, II: Ärztezeitschrift für Naturheilverfahren. Medizinisch Literarische Verlagsgellschaft mbH, Uelzen, 1986; 1: 51-59, 1986; 9: 623-630.
6. Popp FA, Li KH, Gu Q, eds. Recent Advances in Biophoton Research and its Applications. Singapore-London: World Scientific, 1992.
7. Popp FA. Evolution as the expansion of coherent states. In: Rubik B, ed. The Interrelationship between Mind and Matter. Southampton, PA: The Temple University, Marketing Graphics: 1992.
8. Popp FA. Zur Theorie der Elektroakupunktur. Erfahrungsheilkunde 1990; 4: 240-248.