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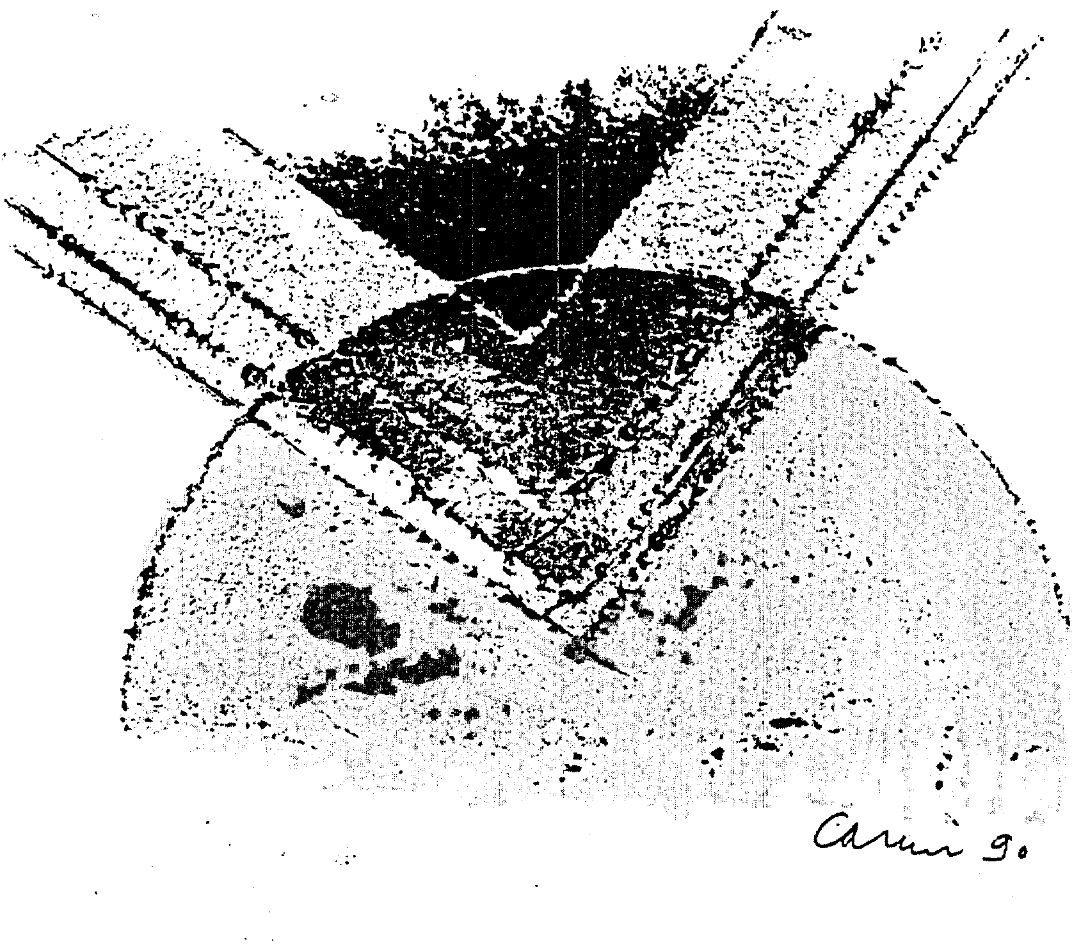

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CEREBRAL ASYMMETRY AND THEOLOGICAL PARADOXES[1]

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Abstract: *Hendrickson-Eysenck's model for intelligence according to which intelligence is related to a small probability of transmission errors in the brain, and therefore to faster transmission of neural messages, is extended twice. The first extension is to relate Hendrickson-Eysenck's model to each hemisphere separately. The second extension is a model of competition between the hemispheres in which the more efficient hemisphere transmits its message faster than the less efficient hemisphere. This competition model is applied to explain cognitive paradoxes related to Kantian ideas. Previous experimental results regarding the paradoxes of infinity which are in line with this theory are described. These experimental results are applied to explain also other paradoxes, in particular paradoxes related to Kantian theological ideas. This theory is independent of the validity of the controversial Hendrickson paradigm.*

INTRODUCTION

Kant (1950, 1964) stated that the logic of understanding applies only to experience, but not to the ideas of pure reason like infinity, which are not part of experience.

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[1] The editors received two contradicting to each other reviews about this paper. To promote broader discussion, they decided to publish the paper together with the objections by one of the reviewers and the author's reflections on it. Both are printed following the article.

An attempt to apply the logic of understanding to ideas of pure reason may lead to antinomies. Thus Kant predicted at the end of the 18th century the foundational crisis in mathematics which occurred about a century later. This foundational crisis is related to antinomies in mathematics, which followed the attempts of Cantor and of Frege to extend mathematics to the domain of actual infinity, which is idea of pure reason according to Kant.

The relation of the foundational paradoxes in mathematics to the hemispheric mechanisms of the human brain was studied experimentally in Fidelman (1987a, 1988b, 1990a). A cerebral process related to the cognitive process of cognizing these paradoxes is suggested there. In this sequel we shall see how these results can be extended from the Kantian idea of infinity to other Kantian ideas, in particular theological ideas.

KANT'S THEORY OF CONSCIOUSNESS

Kant (1950, 1964) defined three consciousnesses, or rather three levels of consciousness. The first consciousness is perception. There are two modes by which we perceive experience, namely, space and time. Kant formulated paradoxes by which he proved that space and time are neither finite nor infinite. Therefore both space and time include innate antinomies. Kant concluded that space and time cannot be related to the things as they are in themselves, and they must be subjective modes by which we perceive experience.

In order to understand Kant's argument we should clarify the concept of infinity. There are two kinds of infinity. The first kind is potential infinity, which is a temporal process in which after each step there is another one. Therefore there is no last step. The second kind of infinity is actual infinity, which is an infinite set, all elements of which are given simultaneously. The set of all the steps of a potentially infinite process, conceived simultaneously, is an actually infinite set. Kant's argument follows.

Conscious time cannot be finite since we necessarily ask: "What was one moment before the beginning of time?" Similarly, space cannot be finite, since we necessarily ask: "What is outside the limit of space?" Time cannot extend infinitely to the past, since if the potentially infinite chain of reasons causing a present event never began, how it is possible that this present event can occur. This argument is a variation of Zeno's Achilles and the tortoise and the runner paradoxes. Space too cannot be infinite, since experimental space is limited to some finite region. This region can be extended in a potentially infinite process in which we perceive horizon beyond horizon of experimental space. However, the termination of this potentially infinite process of extending the horizons by integrating the actually infinite Euclidean space involves a cognitive paradox of terminating and endless process.

The second Kantian consciousness is understanding. It includes *a priori* categories of transcendental logic by which phenomena are classified into those which suit the categories and are accepted as experience, and those which do not suit the categories and are rejected as hallucinations. Since space and time are no more than *a priori* subjective modes of perceiving experience, the phenomena which appear in these modes of perception cannot be the things in themselves. Therefore the phenomena must be subjective too, or at least subjective interpretations.

The third Kantian consciousness is pure reason, which extends the phenomena of experience into something which is not experience, which Kant called ideas. Unlike Platonic ideas, Kantian ideas are not real, but subjective. The logic of experience does not apply to Kantian ideas, therefore, an attempt to apply the logic of experience to ideas of pure reason may lead to antinomies. Thus Kant explained some of Zeno's paradoxes. Kant classified ideas into cosmological ideas, theological ideas, and psychological ideas. The infinite Euclidean space is not part of experience, but a cosmological idea of pure reason. Thus the cognitive paradox regarding the integration of the potentially infinite process of extending the finite regions of experience into the actually infinite Euclidean space is explained by the non-applicability of the logic of experience to ideas of pure reason. Generally, infinity is not a concept of experience, but a Kantian idea. Therefore the logic of experience does not apply to infinity.

A theological idea is an explanation of experience, which is not a part of experience. Paradoxes concerning theological ideas, which are expected by Kant's theory of consciousness, are the main concern of this article.

CEREBRAL FUNCTIONING

According to Levy-Agresti and Sperry (1968) the human brain includes two data processing mechanisms. One is an analytical mechanism which processes one datum after another temporally, and is lateralized mainly to the left hemisphere. The other one is a synthetical mechanism which synthesizes several data into a simultaneously perceived new whole. This synthetical mechanism is lateralized mainly to the right hemisphere. The output of each mechanism is available to the other one as input for further data processing (Ben-Dov and Carmon, 1976).

According to the findings of Hendrickson (1972, 1982), Hendrickson and Hendrickson (1980) and Haier *et al.* (1984) the more intelligent a person is, the smaller is the probability of transmission-errors in the synopses of the person's brain. According to Eysenck (1982, 1984) and Eysenck and Eysenck (1985) a neural message in the brain is not sent just once, but repeatedly, until it is received identically a certain number of times, and only then it is accepted as a correct message. Therefore, the more intelligent a person is, the faster the required number of identical transmissions is received, and the faster the message is accepted. Fidelman (1989, 1990a, c, d) extended this theory to each of the hemispheric mechanisms. Thus the more efficient a hemispheric mechanism is, the faster a neural message is transmitted in it.

According to Hebb (1949) the brain contains web-like multiple neural connections through which neural messages pass circularly and reverberate until they fade out and cease as a result of neural fatigue. Hebb related such neural pulses to short-term memory. Such a neural pattern related to an acquired skill is called 'engram'. Long-term memory is related to changes in the transmission efficiency of the synopses caused by temporary engrams. These changes create permanent engrams. This theory is confirmed by the possibility of eliciting memories in human subjects by stimulating the cortex with brief electrical pulses (Woody, 1982, pp. 277-280).

THE INTEGRATION OF ACTUAL INFINITY

Fidelman (1987b, 1988b, 1989) performed experiments in which the relation of the integration of a potentially infinite process into an actually infinite set to the hemispheric mechanisms is investigated. The results of these experiments are discussed theoretically in Fidelman (1987c, 1988a, 1990c, d, 1991). In these experiments students learned concepts of actual infinity, and their scores on understanding these concepts were correlated with their scores on tests for the efficiency of the hemispheric mechanisms. We define the difference between the standardized scores on the tests for the right and left hemispheres as "the dominance of the right hemisphere". The difference between the standardized scores on understanding actual infinity and potential infinity were correlated with the dominance of the right hemisphere.

The results of these experiments were that the scores on understanding actual infinity have:
(1) Large positive correlation coefficient with the scores on the right-hemispheric test.
Larger positive correlation with the dominance of the right hemisphere.
Small negative correlation coefficient with the scores on the left-hemispheric test.

These results were explained in Fidelman (1989, 1990a, c, d) as follows: Potentially infinite process is an analytic and temporal process which is related to the left-hemispheric mechanism (Fidelman, 1987b, 1989). Therefore it is related to a left-hemispheric engram. On the other hand, the integration of this process into an actually infinite set is a synthetical task of the right hemisphere. The integration of the actually infinite set which terminates the endless process which is cognized by the left hemisphere, also terminates the left-hemispheric engram related to this process without a last step. This termination of the left-hemispheric engram is performed by a right-hemispheric engram related to learning that the actually infinite set exists, and it is related also to unlearning that the potentially infinite process cannot terminate. This process of unlearning is related to a cognitive conflict described in Zeno's Achilles and the tortoise and the runner paradoxes.

The left-hemispheric engram related to the potentially infinite process is a neural message. Its acceptance reinitiates this message. On the other hand, the right-hemispheric engram related to the integration of the actually infinite set of all the steps of the potentially infinite process terminates the left-hemispheric engram. Therefore, the integration of the actually infinite set involves a competition between these left-hemispheric and right-hemispheric engrams which will deliver its message first: The left-hemispheric engram its message of reinitiation, or the right-hemispheric engram its message of termination (Fidelman, 1989, 1990a, c, d).

The competition between the left hemispheric and the right hemispheric engrams is a probabilistic process. It should be noted that the inter-hemispheric commissures are axons of left- and right-hemispheric neurons. Therefore, the smaller is the probability of transmission-errors in the left-hemispheric mechanism, the larger is the probability of the left-hemispheric engram to deliver its message of reinitiation first. On the other hand, the smaller is the probability of the transmission-errors in the right-hemispheric mechanism, the larger is the probability of the right-hemispheric engram to deliver its message of termination first. Since this process is probabilistic, every person will, probably, unlearn at least that a potentially infinite process does not terminate.

The Hendrickson paradigm is controversial. However, our theory does not depend on this paradigm. The foundational paradoxes of mathematics were explained originally in Fidelman (1987a, 1988a, b) without applying the Hendrickson paradigm. The only difference between the two explanations of the foundational paradoxes in mathematics is that the original explanation related the cognitive conflicts to neural inhibitions of one hemispheric mechanism by the other one, while the later explanation related these cognitive conflicts to competitions between left-hemispheric and right-hemispheric engrams.

THE PARADOX OF ALL ORDINALS

Ordinal numbers are properties of single elements: first, second, etc. The process of creating larger and larger finite ordinal numbers is a potentially infinite process, therefore this process is related to the left cerebral hemisphere. The integration of the actually infinite set of all the ordinal numbers is performed by the right-hemispheric mechanism.

The concept of ordinal numbers was first extended by Cantor to infinite ordinal numbers. Von Neumann defined the extended ordinal numbers (ordinals) as follows:

(a) The empty set is an ordinal;

(b) For every ordinal *n* the set including as elements *n* itself together with all the elements of n, is also an ordinal, which is the immediate successor of the ordinal n;

(c) A set of ordinals without a last element, which includes together with each of its elements also all the elements of this element, is also an ordinal. This new ordinal is called a limit ordinal and it is the immediate successor of the given set of ordinals. A limit ordinal does not have an immediate predecessor.

The order between von Neumann's ordinals is defined by the property of being an element of a set: An ordinal *n* is larger than an ordinal *m* if, and only if, *m* is an element of the set n.

Thus the series of von Neumann ordinals consists of:

(I) The empty set *0*, which is the ordinal 0;

(II) The set including as its only element the empty set *0*, which is the ordinal 1;

(III) The set including as its elements only the ordinals 0 and 1, which is the ordinal 2; Etc.

(IV) The infinite set including all the infinite ordinals 0, 1, 2, ... etc., is the first limit ordinal and it is denoted by w. The limit ordinal w is the first infinite ordinal. It has not an immediate predecessor;
(V) The set including all the finite ordinals and w as its only elements is denoted $w+1$, and it is the immediate successor of w;
(VI) The set including all the elements of $w+1$ and $w+1$ itself, as its only elements is the ordinal which is the immediate successor of $w+1$, and it is denoted by $w+2$; Etc.

Thus after each limit ordinal there is a new series infinite of succeeding ordinals without a last element, which leads to the construction of a new limit ordinal. Therefore there is no last limit ordinal and no last ordinal.

This observation leads to the following paradox. Since there is no last ordinal, the set *0* of all ordinals fulfils condition (c) of von Neumann's definition of ordinals. Therefore, for the set of all ordinals, 0 is a limit ordinal. According to the definition of order between ordinals by the property of the smaller ordinal to be an element of the set which is the larger ordinal, the set of all ordinals is the largest ordinal. Nevertheless, according to (b) of von Neumann's definition of ordinals, the set of all ordinals *0* has an immediate successor which is larger than 0. This is a contradiction.

In an experiment described in Fidelman (1987a, 1988b, 1990a) the scores of students on understanding the paradox of all ordinals were correlated with their scores on hemispheric tests. The results were:
(1) A small negative correlation coefficient with the score on the right-hemispheric test;
(2) A large positive correlation coefficient with the score on the left-hemispheric test;
(3) A larger negative correlation coefficient with the dominance of the right hemisphere.

These results are not limited to the paradox of all ordinals. They apply also to the understanding of other foundational paradoxes in mathematics, and to the understanding of cognitively similar mathematical concepts (diagonal processes, the concept of limit ordinal, compactness of theorems), see Fidelman (1987a, 1988b, 1990a, b). These results were interpreted as related to the following cognitive and hemispheric processes:
(a) The right hemisphere integrates the set *0* of all elements having a certain property *P*. In the case of the paradox of all ordinals the property *P* is to be an ordinal;
(b) The left hemisphere extracts an additional element having the property *P* which is not an element of the set *0*. In our present example the additional element is the set *0* itself, since the assumption that it is an element of itself leads to a contradiction;
(c) The right hemisphere, which integrated the set *0*, 'objects' to the disintegration of the set *0* as the set of all ordinals, as follows from its being an ordinal. The left hemisphere 'overcomes' this 'objection'.

The right hemisphere participates in this process twice:

(i) The right hemisphere integrates the set 0 of all the ordinals. This integration is positively and weakly correlated with the scores on the right hemispheric test;
(ii) The right hemisphere 'objects' to the disintegration of the set of all ordinals. This 'objection' causes a large negative correlation coefficient between the scores on the right-hemispheric test and the scores on understanding the paradox.

The superposition of these two effects is a small negative correlation between the scores on the right-hemispheric test and the scores on the understanding of the paradox.

This pattern is similar to the pattern obtained regarding the paradox related to the integration of actual infinity described above. The only difference is that the role of the two hemispheres is interchanged. It was first suggested in Fidelman (1990a) that the understanding of foundational paradoxes in mathematics is related to a competition between the right and left-hemispheric engrams which will deliver its message first: the right-hemispheric engram delivers its message of reinitiating the integration of the set of all ordinals, or the left-hemispheric delivers its message of disintegrating the set of all ordinals and terminating the left-hemispheric engram. Since this process is probabilistic, the unlearning of the previously learned concept of 0 as the set of all ordinals will, probably, be achieved at last by every person.

THE IDEA OF A PRIMARY REASON

The idea of a primary reason for the experimental world is an example of a theological idea in the Kantian sense. The Kantian understanding includes the category of causality: we have an innate feeling that everything is caused by some reason. However, no chain of finite reasons can satisfy our tendency to seek a reason fro everything. If a finite series of reasons was terminated by a primary reason in the past, we necessarily ask: "What is the cause of this primary reason?" Therefore, the series of causes must be potentially infinite. This leads us back to Kant's antinomy that time cannot be finite or infinite. We saw above that this kind of antinomy is related to the objection of the left hemisphere, to the integration of the actually infinite set of all the steps of the potentially infinite process.

After the integration of actual infinity by the right hemisphere it is possible to conceive a primary cause of the experimental world which had caused the infinite series of causes of present events. The order relation of this primary cause to the infinite series of causes is like that of the ordinal w to the infinite series of all the infinite ordinals preceding it. But then we necessarily ask: "What is the reason for this 'primary' reason (which has the ordinal w)?" Thus each previous reason has its own cause, and we obtain a paradox equivalent to the paradox of all the ordinals: The series of all causes of the experimental world (which is equivalent to the set of all ordinals) has no first cause (this is equivalent to the non-existence of a largest ordinal). Yet there is a cause which is primary to all the causes in this series (equivalent to the ordinal which is an immediate successor of the set of all ordinals). Thus the idea of primary reason is related to an antinomy.

No experiments, known by the author, were performed regarding the relation of this paradox of primary reason to the hemispheric mechanisms. Nevertheless the cognitive similarity between this paradox of primary reason and the paradox of all the ordinals, may lead to the conclusion that understanding the paradox of primary reason too is related to a competition between a left-hemispheric engram and a right-hemispheric engram which is won by the left-hemispheric engram.

THE IDEA OF THE ALL-MIGHTY

There is a paradox regarding the concept of the all-mighty: "Can the all-mighty create a stone so heavy, that he himself will not able to lift it?" If he cannot create such a stone he is not all-mighty. If he can create such a stone, he is unable to lift it.

This paradox is equivalent to the foundational paradoxes in mathematics, like the paradox of all the ordinals. At first the set of all abilities is integrated. Then an additional ability, the ability not to be omnipotent, is extracted. This additional ability, the ability not to be omnipotent, cannot be an element of the set of all abilities. (This is equivalent to the observation that there is one ordinal, the set of all ordinals, which cannot be an element of the set of all ordinals.) This is a contradiction.

There is no experiment known to the author showing that understanding the paradox of the all-mighty is related to the dominance of the left hemisphere over the right one. Nevertheless, there is a cognitive similarity between the paradox of the all-mighty and foundational paradoxes in mathematics, like the paradox of all the ordinals. This cognitive similarity may indicate that understanding the paradox of the all-mighty too is related to a competition between a right-hemispheric engram and a left-hemispheric engram, which is won by the left-hemispheric engram.

CONCLUSIONS

We observed that there is a cognitive similarity between kantian cosmological ideas, theological ideas, and ideas of infinity. All these ideas involve cognitive and logical paradoxes. Kant explained these paradoxes by the non-applicability of the logic of experience to the non-experimental ideas of pure reason. We reason now that these paradoxes may be explained by the lack of coordination between the hemispheric mechanisms when they process data related to infinity as follows. The right hemisphere integrates the set S of all elements having a certain property P, like the set of all ordinals. Then this newly integrated whole is available to the left hemisphere as a new single element. This new element has the property P which defines the set S, but it is not an element of S, since it was constructed after the construction of the set S. Yet it has the property P which defines S. Thus a paradox is created.

The paradoxes of the primary reason and of the all-mighty have a similar cognitive structure. Let us analyse, for example, the paradox of the all-mighty. The right hemisphere integrates the set of all abilities. Then the ability of not having all these abilities is defined. But this ability could not be defined before the construction of the set of all abilities. Yet this newly defined ability is an ability, which leads to a paradox.

An explanation which combines both Kant's explanation and the hemispheric explanation to the existence of these paradoxes can be obtained from Darwin's theory of evolution. The hemispheric mechanisms evolved in order to cope with the phenomena of experience. Therefore the hemispheric mechanisms are coordinated regarding these phenomena, since otherwise we could not be able to function in the experimental world and our species would have become extinct. However, there has been no evolutionary pressure to evolve coordination between the hemispheric mechanisms regarding ideas of pure reason which are not a part of experience. Therefore coordination between the hemispheric mechanisms evolved only regarding the phenomena of experience.

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ONE OF THE REVIEWS RECEIVED BY THE EDITORS

... The author's concept of hemispheric asymmetry seems naive and outdated, and Eysenck's ideas about the link between intelligence and transmission speed are controversial, to say the least (the author does at least recognize the controversial nature of Hendrickson's work). Even the reference to the formation of long-term memories reckons without the extensive modern literature on long-term potentiation.

Even more critically, Fidelman gives no indication of how he measured cerebral dominance, or even how he measured the understanding of actual and potential infinity. He does not tell us how many subjects he tested. He refers to "large positive correlations", but does not tell us how large or whether they were statistically significant. The same problems arise ... in the discussion of the understanding of the paradox of all ordinals. Although we are referred to other publications, these may not be accessible to the reader, who is therefore being asked to accept some rather implausible findings on trust. The theory of competition between the hemispheres also seems to me to betray a very simplistic view of how thinking is mediated in the brain. I would be more convinced of the theory itself, perhaps, if the author could develop his model in terms of neural networks, and then show some of the effects he claims by simulation.

The paradoxes themselves are not without interest, but any attempt to link them to brain function, given our current state of knowledge, must be very precarious indeed. ...

U. FIDELMAN'S REFLECTIONS ON THE ABOVE OBJECTIONS BY ONE OF THE REVIEWERS

The referee had six reasons for objecting my work.

(1) "The author's concept of hemispheric asymmetry seems naive and outdated."
I do not agree with this statement. The hemispheric paradigm exists (Fidelman, 1994). Unexplained phenomena in behavioural sciences are explained by it. For example, the contradicting findings regarding the Hendrickson paradigm, which are the second reason for his objection to my work, can be explained by the hemispheric paradigm.

(2) "The controversial nature of Hendrickson's work."
Eysenck himself gave up the Hendrickson paradigm after finding negative correlations between IQ and electrical measures of the brain's activity which are supposed to increase when the probability of transmission-errors in the brain decreases, while in other experiments this correlation is positive. However, these negative correlations originate mainly in the right hemisphere. Moreover, the right hemisphere consumes less energy than the left, therefore it is less active electrically. Therefore, it was suggested in Fidelman (to appear, a) that the samples in which positive correlations were obtained include mainly left-hemispheric subjects, while the samples in which negative correlations were obtained include mainly right-hemispheric subjects.

(3) "Eysenck's ideas about the link between intelligence and transmission-speed are controversial."
The brains of more intelligent subjects consume less energy (Haier *et al.*, 1988). There are two possibly complementary theories explaining this finding. The first is Eysenck's theory, since a smaller number of repeating a neural message requires less energy. The second is the theory of Jensen (1982). Jensen explained the negative correlation between IQ and reaction-time (RT) by relating intelligence to the speed of transmission of neural messages. He suggested that this speed is determined by the neural conductivity. In analogy to electrical wire, neural conductivity is reciprocal to electrical resistance and to the heat production of the brain. Jensen suggested that the mean of RT is related to the speed of the neural message, while its standard deviation (SD) is related to another factor. Fidelman (1994) suggested that this another factor is related to the transmission errors in the brain. Jensen (1982, p. 877) performed a meta-analysis of 33 independent samples and found that of the total variance of IQ accounted for by both the mean RT and its SD, about 61 per cent is common to both measures, 13 per cent is specific to the mean RT, and 26 per cent is specific to the SD. That is, 74 per cent of this variance originates in the mean RT, and it may be explained by the speed of the neural message. The 61 per cent of the variance of intelligence common to both the mean and the SD of RT, may be related to the transmission-errors, i.e., to the Hendrickson paradigm and Eysenck's theory, and only 13 per cent of the variance, specific to the mean RT, may be explained by Jensen's theory. That is, 61/74 which is 82 per cent of the variance related to neural speed may be explained by Eysenck's theory.

(4) "The reference to the formation of long-term memories reckons without the extensive modern literature."

This article is not a review of literature. I prefer that the limited number of references will give credit to the great pioneers who first discovered the biology of memory, like Hebb, rather than to less important researchers, only because they published more recently.

(5) "Although we are referred to other publications, these may not be accessible to the reader."

Many libraries give presently the service of providing xerocopied journal-papers from all over the world. Moreover, I am ready to send to each reader copies of my publications.

(6) Suggestion to the author to "develop his model in terms of neural networks, and then show some of the effects he claims by simulation".

The electrical activity of the brain increases together with the intensity of the sensory stimulus. This pattern is typical to analogue computers, and not to the representation of the intensity by a code in digital computers (Robinson, 1993). Therefore a digital-computer model of the brain may be irrelevant to the brain's real functioning. Moreover, Gödel's theorem shows that no mathematical, physical or computational model of the entire function of the brain is possible (Fidelman, to appear, b). Neural networks models succeeded in simulated at most low cognitive functions of the brain, and not very high cognitive processes like mathematical diagonal processes.

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