Hemispheric dichotomies: four modes of perceiving experience

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INTRODUCTION

Human cognition is related to certain functions of the cortex. It is well known that the left and right hemispheres of the human cortex differ in their cognitive functions. Several dichotomies have been suggested to characterize the cognitive functions of human cerebral hemispheres, some of these dichotomies are described in Bogen (1969). In this work we shall see that two of these dichotomies can explain the modes in which we perceive experience.

We shall distinguish between "I, the observer of phenomena" and "I, as a phenomenon". Empirical space and time are common to both and they contain persons, including "I, as a phenomenon", the brains of which can be investigated applying the scientific method.

THE ANALYTIC-SYNTHETIC DICHOTOMY

THE HEMISPHERIC DICHOTOMIES

Levy-Agresti & Sperry (1968) suggested an information theoretical explanation of the cognitive differences between the left and right cerebral hemispheres. They suggested that two information processing mechanisms exist in the human brain. The first mechanism, which they called "analytic", processes single details of information (namely, particulars or individual objects which may be components of a larger whole) one at a time, and it is lateralized mainly to the left hemisphere.

The second mechanism, which they called "synthetic", proceses several details of information simultaneously and integrates a new whole out of them. This second mechanism is lateralized mainly to the right hemisphere.

Ben-Dov & Carmon (1976) extended this dichotomy into a multi-stage model of the brain's functioning. According to this model the output of each hemispheric mechanism is available to the other one as input. The right hemisphere synthesizes new wholes from particulars furnished to it by the left one while this new whole is treated by the left hemisphere as a new particular. Thus more and more complex cognitive structures are constructed.

THE SUBJECTIVITY OF THE ONTOLOGIES

There are two ontological approaches. The first is nominalism which accepts only the existence of particulars which can be perceived as discrete and concrete phenomena. Nominalism denies the physical existence of properties which characterize several particulars and organize them into sets or universals. Nominalism considers properties (and likewise relations) to be fictions: there are red objects, but there is no "redness".

When a nominalist is presented with several components which have a common property, for example of comprising a car, he (or she) has two alternatives. The first is to extract single components of the car as individual concrete objects (like the extraction of details by the left hemisphere). The second is to consider the whole car as a single individual concrete object. The nominalist will not consider the car to be a set synthesized from its components as elements (this is the platonic aspect of cognition). Therefore the nominalistic aspect of cognition is analytic and not synthetic.

The other ontological approach is platonism. This approach considers ideas, or, rather, properties which our consciousness discovers in the physical world to be real. The particular phenomena or objects have not necessarily a real existence, or, at least, they are not the concrete objects which they appear to be.

A platonist physicist considers his data as quantitative measurements which represent properties. For example, the instruments may register a certain phenomenon which is called "red light". While a nominalist physicsist interprets this as the existence of a "red object", a platonist one interprets the same data as the physical

existence of the property of "redness". The physical existence of an object which is the source of this "redness" is considered by the platonist physicsist as an uncertain interpretation of the data.

A platonist philosopher observing the physical world has similar considerations. He is aware of physical properties, or ideas, which have a real existence. He doubts that the concrete phenomena are really what they seem to be, namely, concrete objects. There is the property "redness", but not necessarily red objects.

According to Quine (1953) logicism is a platonistic approach to mathematics. Frege, the founder of logicism, formulated the axiom of abstraction: "for every property exists the set which contains all the elements having this property". The existence of this set is the manifestation of Frege's platonism. Being an element of Frege's set and having the characterizing property are logically equivalent. In Frege's and other platonistic mathematical theories the existence of "atomic" elements, which are not sets, is not required. In this article we use the term "platonism" in the extreme sense of Frege.

When this approach is applied to the physical world we note that a physical object can be characterized by all its properties, and a platonist may consider this physical object to be no more than the intersection of all its properties. More specifically, a property (or a universal) can be defined as the set of all elements having this property

Therefore, a physical object, which can be characterized by all its properties, can also be characterized by the intersection of all the sets of elements such that all the elements of each of these sets have a certain property of this physical object. This intersection is a set which includes only one element, namely, the physical object. A platonist may accept the physical existence of this one-element set as the property of having all the properties of the physical object, while he may doubt or even deny the real existence of this concrete element (otherwise we shall define him as an ontological dualist, rather than as a platonist).

This problem of Frege's ontology regarding an element which is a physical object was formulated by Dummet (1981, p. 169): "It would therefore be for him nonsense to say that an object is compounded out of its properties, that is, the concepts under which it falls, or that it is merely the sum of those properties; and just as much nonsense to deny this and maintain that the object was a featureless *supositum* in which its properties inhered." On the other hand the nominalists accept the physical existence of this element, but not of the one-element set.

Frege considered sets and properties (like the colour red) to be objects, i.e., to be elements of other sets (Dummet, 1981, p. 169). Therefore the above mentioned ontological problem of the nature of a physical object, i.e., whether it is a set having one element, or it is the single element of this set, can be solved in a platonist valid mode.

A platonist may consider the one-element set to be identical to its single element. This involves abandoning the set-theoretical axiom of foundation, but it solves the ontological problem. On the other hand nominalists do not accept the existence of sets and properties as real objects.

The empirical world which "I, as an observer of phenomena" perceive comprise both nominalistic particulars (or details) and platonic properties and relations. Empirical persons, including "I, as a phenomenon" perceive the world, according to the scientific experiments which are performed by the "observer of phenomena", in these two ontological modes. Let us consider these empirical persons.

It was suggested in Fidelman (1985) that the existence of two different ontological views, nominalism and platonism, is due to the existence of two different hemispheric data processing mechanisms. When sensory data arrive at first to the left hemispheric mechanism they are perceived by consciousness as distinct objects, i.e., a nominalistic perception of the world. When the same data arrive at first to the right hemispheric mechanism they are perceived by consciousness as properties, i.e., a platonistic perception of experience. According to the stages model of Ben-Dov & Carmon (1976) The higher cognitive conception of the world is performed by the same hemispheric mechanism at a later stage of data processing by the brain. Therefore nominalistic and platonistic ontologies may be related, as high cognitive conceptions, to the left and right hemispheres, respectively.

Thus both nominalism and platonism are subjective and innate modes of perceiving experience. These modes of perception are due to neurological mechanisms and therefore persons (as phenomena) cannot perceive or conceive the world in different modes. Therefore these modes may be interpreted as given to the persons a priori. However, the brain includes both left and right hemispheric mechanisms, each person perceives experience as both concrete particulars and properties. Therefore the difference between persons with nominalistic tendencies and persons with platonistic tendencies is only in emphases, and hemispheric dominance may be one of the factors which determine these emphases.

It may be conjectured that persons whose left hemispheric mechanism is more developed than their right one will prefer nominalism rather than platonism, while persons whose right hemispheric mechanism is more developed will prefer platonism. In the next section we shall see how this conjecture was tested experimentally and how a relation was found between nominalism and the left hemispheric mechanism, and between platonism and the right hemispheric mechanism.

To explain further the subjectivity of the two ontological modes of perception let us return to the "observer of phenomena". He observes that his empirical world, as well as the empirical world of the subjects of his psychological experiments, comprise both particulars (details) and universals. Therefore he may infer that, indeed, the left hemispheric mechanism extracts existing details and presents them to consciousness, while the right hemispheric mechanism synthesizes existing universals and presents them to it. Therefore the left and right hemispheric mechanisms seem to be, indeed, analytic and synthetic, respectively.

However, two different cerebral mechanisms present the *same* data to consciousness in two different modes. Therefore the "observer of phenomena" has two alternatives. The first is that the hemispheric mechanisms are merely detectors, which detect particular objects on one hand and properties on the other hand, from the sensory data. The second alternative is that the hemispheric mechanisms are interpretors which interpret the same data as particulars on one hand and as properties on the other hand. There is one argument in favor of the first alternative: the observation that the empirical world of the "observer of phenomena" and of the subjects of his psychological experiments are similar. However, if the "observer of phenomena" identifies himself as an observer with himself as a phenomenon, the two empirical worlds, of himself as an observer and of himself as a phenomenon, become one. Therefore he cannot compare the empirical world of his consciousness with an external empirical world. He remains with the knowledge that his cerebral mechanisms present his consciousness with two ontological modes of perceiving experience which may be merely interpretations, and therefore may be subjective.

There is an additional argument against the "detectors theory" alternative. This alternative is appropriate for ordinary cognition, but not for a profound scientific cognition which explains also the "microscopic" physical phenomena. We can conceive models for "microscopic" physical phenomena only through our everyday experience. Therefore two contradictory models were suggested to explain them. The first is the corpuscular model and the other is the waves model. The first model is nominalistic in the sense of Democritus and of Hilbert (1983) and it is perceived analyticaly and it is left-hemispheric. The second model is continuous, therefore it cannot be perceived analytically and it is synthetic and right-hemispheric.

According to the waves model there are no real particles and therefore no real concrete objects. The world contains only waves which are the real essense of observed phenomena: having a certain color, having an electrical charge, having a mass, etc. Therefore this model presents the world as containing only pure properties which are not related to real concrete and discrete objects located at determined places in space. For example, the properties of a particular red car are the waves of red light, the waves of gravitation, the superposition of all the waves related to its elementary particles comprising a pack of waves having approximately the shape of a car (representing the property of being a car), etc. Therefore this model is closely related to the platonistic perception of the world as mere properties.

There is a duality in physics: packs of waves can behave approximately as corpuscles and corpuscles can be distributed probabilistically like waves. Nevertheless, the two cognitive models are contradictory and at most one of them can present the real character of physical phenomena. If one of the two models is correct, it explains the whole of physical phenomena, including the ordinary phenomena of everyday experience. Therefore at most one of the hemispheric mechanisms is a detector, while the other one is an interpretor.

The conclusion is that an ontologically dualistic real world is impossible. However, the "detectors theory" may claim a more plausible claim, that the real world is neither nominalistic nor platonistic but each of them is a partial aspect of the real world, which is detected by the relevant hemispheric mechanism. If this claim is true, then both hemispheric mechanisms are interpretors, since the real ontological nature of the world is unconceived by us.

EXPERIMENTAL EVIDENCE

An experiment regarding the relation between the ontological approaches to the physical world and the left and right hemishpheric mechanism is described in Fidelman (1989) and is discussed in Fidelman (1987, 1988). The experiment was conducted with students of a course on philosophy of mathematics. The course included a presentation of two ontological approaches to the physical world.

The first approach is that of the ancient Greek Eleatic school which was founded by Parmenides, who established cosmology on logic. Parmenides's ontological principle, that what is thinkable (logically) exists, was presented as a source of Plato's ontology. It was explained to the students that Parmenides's view that the world is a full, homogenous, directionless, motionless and spherical geometrical space is similar to Eistein's unified fields philosophical doctrine. According to Einstein's doctrine the world is a finite four dimensional sphere full with force-lines. No motion is possible in it since time is one of its geometrical dimensions, and there is no external time. The only difference between Einstein's and Parmenides's worlds is that Einstein's cosmos is not homogenous. However, according to the second law of thermodinamics the world will be homogenous in the future. Therfore, according to the principles of conservation and symetry (which were first formulated by Parmenides) the world is homogenous also at present. The difference between this conclusion and experience was explained by the existence of force-fields undetected by our senses and instruments (like the until recently undetected neutrio) such that the sum of all these forces at every point is homogenous. It should be stated that this theory was presented only for experimental purposes, and though this model is possible, it is not claimed that it really describes the world.

The second approach is Democritus's atomism. This school perceived the world as empty space in which tiny concrete objects, atoms, move. This view is nominalistic and is similar to modern elementary particles and quantum theories. The dialogue between the Eleatics and the atomists was presented to the students in terms of two alternative solutions to Zeno's paradoxes.

Twenty two students participated in this experiment. They were asked in the course's examination three questions about their preferred explanation, the Eleatic or the atomistic, to Zeno's paradoxes, and which approach to the physical world they prefer: the Eleatic-Einsteinian one or the atomistic one. They also were tested for the development of their cerebral hemispheres, the hemispheric tests are fully described in Fidelman (1985), a short description follows.

The neuropsychological test for the right hemisphere was the enumeration of dots or forms presented simultaneously during scores of MS (milliseconds). The number of dots or forms varied between three to ten. The test for the left hemisphere was the enumeration of dot or English letters presented one after another temporally. The stimuli were presented one at a time during scores of MS. The temporal intervals between the presentations were selected at random and their durations were scores of MS. We define the variable "dominance of the right hemisphere" as the difference between the standardized score of a student on the right hemispheric test from the standardized score of the same student on the left hemispheric test.

The scores on the hemispheric tests were compared with the students' preferences of philosophical schools by the non-parametric statistical test of Mann-Whitney. The results were that students with a more dominant right hemisphere preferred the Eleatic platonistic school, while students with a less dominant right hemisphere preferred the nominalistic school of Democritus. The result was significant at $p<0.05$ in a two tailed test. This result is in line with the conjecture.

Another experiment which also was conducted with students of the course on philosophy of mathematics is described in Fidelman (1990). The second part of the course on philosophy of mathematics included a presentation of two schools, formalism and logicism, which have metaphysical-realistic ontological approaches.

The first school is Hilbert's formalism. Hilbert's approach is based on the modern view that the physical world is composed of "tiny building blocks": atoms of matter, electrons of electrical charge and quanta of energy. Therefore, there are no infinitely small quantities (i.e., no continuity). Moreover, according to relativity theory the universe is not infinitely large. This view is similar to that of Democritus and is virtually nominalistic. However, Hilbert's ontology is more complicated.

Hilbert (1983, pp. 191-192) agreed with Kant's view that mathematics is derived from intuition. But unlike Kant, who argued that this intuition is of a priori given space and time, Hilbert believed that mathematics is based on "certain extralogical concrete objects, which are intuited as directly experienced prior to all thinking". These objects are used as symbols of a calculus of predicates for mathematics. Mathematics is the concrete symbols and formulas themselves, and not the meaning of these formulas. Therefore Quine (1953) characrerized formalism as a nominalistic approach to mathematics.

However, in order to manipulate the concrete objects, to construct formulas out of them and to derive new formulas by inference rules, more than the concrete objects is needed. As Hilbert (1983 p. 192) stated: "For logical deductions to be certain, we must be able to see every aspect of these objects, and their properties, differences, sequences, and continguities must be given, together with the objects themselves, as something which cannot be reduced to something else and which requires no reduction." That is, properties and mutual relations of the objects as well as the objects themselves are intuited a priori. Therefore, despite Quine's opinion,

Hilbert's formalism is not a pure nominalistic approach, since properties and relations of the concrete objects, the existence of which is denied by the nominalists and accepted by the platonists, exist according to Hilbert. However, the concrete (nominalistic) character of the mathematical calculus is emphasized by Hilbert. In the course on philosophy of mathematics formalism was presented according to Quine's interpretation and its nominalistic aspect was emphasized.

The second school in philosophy of mathematics which"was presented to the students is logicism. It was classified in Quine (1953) as a platonic approach. Logicism was founded by Frege. Frege's approach to logicism is, indeed, extremely platonistic. Only sets exist in Frege's system, but not atomic elements. The elements of each set are other sets, including an empty set. Moreover, Frege's platonism is manifested by his abstraction axiom: for every property there exists the set which contains all the elements which have this property. Later Russell found a contradiction in Frege's system, and substituted it with a logicistic system of his own, which is called the "theory of types" and is presented in Russell's and Whitehead's *Principia Mathematica*.

However, Russell's ontological view, as presented in Russell (1956) which was first published in 1911, simultaneously with *Principia Mathematica*, is not entirely platonistic. Russell believed at that time in the existence of both universals and particulars. This approach may be called ontological dualism[1]. This is the ontological approach in *Principia Mathematica* - both sets and atomic elements exist in the theory of types. However, the platonistic aspect, i.e., the application of Frege's abstraction axiom, is emphasized. Logicism was presented to the students according to Quine's interpretation, emphasizing its platonistic aspect.

Twenty six students participated in the experiment. They were tested for the development of their hemispheric mechanisms using the same hemispheric tests which were applied in the previous experiment. They were asked which approach to philosophy of mathematics, formalism or logicism, they prefer. It was found by a statistical test that students with a more dominant right hemisphere preferred platonistically presented logicism, while students with a less dominant right hemisphere preferred nominalistically presented formalism. The result is significant at $p<0,05$ in a two-tailed test. This result is in line with our conjecture.

The results of both experiments are in line with our hypothesis that there are cerebral mechanisms which present the world to our conciousness in the nominalistic and platonistic modes of perception. The experimental result does not tell us anything about the real nature of the world.

However, if the possible modes of perception are the result of neural mechanism we cannot perceive, or even imagine, the world otherwise. This philosophical consequence is in line with Kant's conclusion that we cannot know anything certainly about the things in themselves.

THE TEMPORAL-SPATIAL DICHOTOMY

THE HEMISPHERIC DICHOTOMY

Carmon & Nachshon (1971) suggested another dichotomy to characterize the cognitive function of the cerebral hemispheres. They suggested that "the division of labor between the hemispheres is not in terms of specific stimuli but rather in terms of different perceptual dimensions." That is, the left hemisphere is specialized in recognizing temporal order, while the right one is specialized in spatial perception. The authors tried to explain hemispheric specialization by this dichotomy. Thus they suggested that speech is related to the left hemisphere not becuse of its verbal features but because it is based on temporal analysis.

THE SUBJECTIVITY OF THE SPATIAL AND TEMPORAL MODES OF PERCEPTION

Kant stated that space and time are the modes in which information is received by a subject (the form of the subject's receptivity). He argued that *when space and time are considered to be features of the world as it is in itself* then insoluble paradoxes or antinomies are generated. This is one of the reasons why he concluded that space and time can exist only with reference to the world as it is cognized by a subject and not with reference to the world as it may be in itself.

Both "I, the observer of phenomena" and "I, as a phenomenon" perceive the empirical world in the Kantian modes of perception: space and time. This empirical world contains persons, including "I, as an observer of phenomena", the brains of which can be investigated by psychological experiments. Let us consider these empirical persons.

Ben-Dov & Carmon (1976) suggested that Kant's subjectivity of space and time can be derived from neurology. They suggested a multi-stage model for the cognitive functioning of the brain which is based on the analytic-synthetic dichotomy of Levy-Agresti & Sperry (1968). According to this model the brain's hemispheric mechanisms process data at several stages. After every stage the output of each hemisphere is available to itself and the other hemisphere for further processing. Thus more and more complicated codes are constructed. For example, reading one letter after another as single items (by adults) is performed by the left hemisphere. The next stage in reading is the integration of several letters into a word which is performed by the right hemisphere. Then the left hemisphere reads one word after another (each word as a single item). At the next stage the right hemisphere integrates several words into a single sentence, etc.

Ben-Dov & Carmon suggested further that when data from the outer world arrive at first to the left hemisphere they are presented to consciousness one after another temporally, and when the same data arrive at first to the right hemisphere they are presented to consciousness simultaneously and spatially. Moreover, time and space themselves are no more than the mode in which data from the outer world is presented to consciousness after the first stage of processing by the left and right hemispheres, respectively. Thus Ben-Dov and Carmon suggested to obtain the subjectivity of Kant's modes of perception from neurology. That is, neurological mechanisms impose a spatial and temporal representation of the world on human consciousness. They concluded that we cannot know whether the world as it is in itself has any spatial or temporal characteristics.

In order to explain further the subjectivity of space and time let us consider again the "observer of phenomena". His empirical world, as well as that of the subjects of his psychological experiments, is perceived in the spatial and temporal modes of perception. He infers from these psychological experiments that the left and right hemispheric mechanisms present the phenomena to consciousness temporally and spatially, respectively. Therefore he infers that the hemispheric mechanisms present consciousness with the true organization of the empirical data, namely, in temporal and spatial arrays.

However, later the "observer of phenomena" notices that the *same* data are presented to consciousness by the two cerebral mechanisms as organized in two different modes: data which are first processed by the analytical mechanism are organized one after another temporally (analysis of individual objects must be done one at a time), while data which are first processed by the synthetic mechanism are organized simultaneously and therefore spatially (the new synthesized whole is perceived simultaneously which, at least for some sensory modalities, is necessarily spatially). The "observer of phenomena" has two alternatives. The first is that the hemispheric mechanisms are detectors of real spatial and temporal aspects of the world. The second alternative is that the hemispheric mechanisms are interpretors which interpret the sensory data as organized spatially and temporally (probablly by organizing the data in these modes).

An argument in favour of the "detection theory" is that the empirical worlds of the "observer of phenomena" and of persons which are phenomena are similar. However, when the "observer of phenomena" identifies himself as an observer with himself as a phenomenon, the empirical worlds of these two become one. Therefore he has only the empirical world of his consciousness, and no empirical world which is external to it. He knows that the spatial and temporal organization of his experimental world may be an interpretation of the hemispheric mechanisms, and he cannot compare this interpretation with an external empirical world. Therefore he must conclude that the spatial and temporal organization of phenomena may be subjective.

There is another argument against the detection theory. Ben-Dov & Carmon (1976) suggested that the left hemispheric analytical mechanism organizes phenomena one after another successively in time. Therefore it is impossible that between every two temporal phenomena there is a third one. Since continuity is defined as the existence of a third point between any two points, time cannot be continuous and it is necessarily quantisized. If time is quantisized, motion too must be quantisized. Therefore motion must be "jumps" between states of rest in space. That is, objects cannot move in a continuous space, but they "jump" from one position to another in a space which is discrete and quantisized, at least concerning motion. The ordinary space is continuous, therefore it cannot be perceived analytically like the quantisized space. Therefore the ordinary continuous space is perceived synthetically. Thus ordinary continuous space is necessarily pereived by the right hemisphere, which is in line with the findings of neuropsychology. Space cannot be both continuous and quantisized. Therefore at least one of the following possibilities is necessarily true:

1. The successive temporal organization of phenomena is subjective.

2. The continuous spatial organization of phenomena is subjective.

The idea of spatial presentation as synthesis was known to Kant himself. In a marginal note in Kant (1965, p. 170) (P. 160 in the original second German edition of Critique of Pure Reason) Kant wrote: "Space, represented as object (as we are required in geometry), contains more than mere form of intuition; it also contains combination of the manifold, given according to the form of sensibility, in an intuitive representation, so that the form of intuition gives only a manifold, the formal intuition gives unity of representation... it (this unity) presupposes a synthesis which does not belong to the senses but through which all concepts of space and time first become possible."

It should be noted that Kant's concept of time is ambivalent. On one hand there is a continuous aspect to time, like that of a spatial line; to this aspect Kant referred in the last part of the former remark as "a synthesis... through which all concepts of space and *time* first become possible". On the other hand there is a discrete aspect of time, which arises from Kant's notion of temporal succesion. Kant established arithmetic on this discrete (or analytical) aspect of temporal intuition, while he established geometry on spatial intuition. Since Kant's space and time are subjective, Kant's mathematics too is subjective, and its ontology is conceptualistic in the sense of Quine (1953).

THE EXPERIMENT

The conjecture that space and time are subjective and originate from the hemispheric mechanisms was tested experimentally by the same method as the previous two experiments. This experiment is described in Fidelman (1990) and is discussed in Fidelman (1987, 1988).

Two schools emerged in the 20th century from Kant's approach to mathematics, namely, that mathematics is obtained from intuition of the two modes of perception, space and time. These two schools were presented to students of a course on philosophy of mathematics who were tested for the development of their hemispheric mechanisms.

The first school is Brouwer's intuitionism, see Brouwer (1983). Brouwer agreed with Kant's approach, but did not trust the spatial intuition as a reliable source for mathematics. Therefore he established the whole of mathematics solely on the intuition of succession in time. Thus geometry, for example, is received from arithmetic as analytical geometry. Intuitionism, like Kant, considers mathematics to be a subjective creation of consciousness. Quine (1953) characterized intuitionism as a conceptualistic approach.

The second school is Frege's geometrical approach to mathematics which is presented in Frege (1979) and was developed after Russell's paradox proved the inconsistency of Frege's logicistic approach. Unlike Kant Frege did not accept the aspect of time as discrete instances occuring one after another, he accepted time only as a linear continuum which is equivalent to an additional geometrical line. Therefore Frege considered temporal intuition to be superfluous for establishing mathematics and he established the whole of mathematics on spatial intuition alone. Like Kant's and Brouwer's mathematics, Frege's geometrism too is conceptualistic.

The twenty six students of the course on philosophy of mathematics who participated in the experiment were asked which of the two approaches to mathematics, Brouwer's intuitionism or Frege's geometrism, they prefer. The answers were compared with their hemispheric dominance, which was measured as described above, in Mann-Whitney's non parametric test. It was found that students with a less dominant right hemisphere preferred intuitionism, while students with a more dominant right hemisphere preferred geometrism. The result was significant at $p<0.05$ in a two tailed test.

This result is in line with our conjecture. It seems that hemispheric dominance is one of the factors which determine which Kantian mode of perception, adjacency in space or succesion in time, is favored by individual persons.

The philosophical consequence of this experiment is in line of Kant's view that we cannot know whether the world as it is in itself has spatial and temporal features. Space and time, our extentional modes of perception, as well as platonism and nominalism, our ontological modes of perception, are enforced on us by neurological mechanisms. Therefore we cannot imagine or even conceive the world in other modes.

CONCLUSIONS

The relation between the above ideas and constructivism is discussed in Fidelman (1991). Knowledge is constucted by the hemispheric mechanisms as follows: Data received through the senses are processed one item after another analytically by the left-hemispheric mechanism. Then the right-hemispheric mechanism synthesizes (or constructs) new wholes (or constructions) out of several sensory data. Then these new wholes are processed

analytically as single items by the left hemisphere, and so on. Thus more and more complex cognitive stuctures are constructed. These structures are perceived in two ontological and two extentional subjective modes of perception. The construction of these cognitive structures is achieved by cooperation between the hemispheric mechanisms.

It is discussed in Fidelman (1991) that in addition to the construction of structures by interhemispheric cooperation there are cognitive conflicts between the hemispheres, which are related to cognitive contradictions and paradoxes. The contradictions between the spatial and temporal modes of perception, and between Platonism and nominalism, are examples of such conflicts. When a conflict terminates by one hemisphere's "overcoming" the other one, a new cognitive stucture may be constructed.

For example, potential infinity is a temporal process in which after each stage there in another one, and therefore it does not terminate. The integration of a potentially infinite process into actual infinity involves the termination of this endless process, and it is related to a cognitive conflict. This conflict was first described by Zeno in his Achilles and the tortoise and the runner paradoxes. The construction of an actually infinite set from all the stages of a potentially infinite process is achieved by the right hemisphere's "overcoming" the left one. Thus the structure of temporal stages which *do not terminate* is dismantled and is replaced by a simultaneously conceived structure of an actually infinite set.

Cantor's diagonal process is also related to the dismantling of cognitive structures. For example, the set U of all sets is synthesized by the right hemisphere. Cantor proved by a diagonal process that for every element S of U, the set of all subsets of S is larger than S. Therefore U cannot be an element of U, since otherwise it would have been larger than itself. This contradicts the definition of U as the set of all sets. After the synthesizing of U by the right hemisphere, U is extracted by the left hemisphere as a new single element. This single element has the property of being a set, though it is not an element of U. Thus the left hemisphere dismantles U as the set of all sets. In this example a paradox is created. This paradox destroys naive set theory. Cantor's diagonal process always dismantles some set as the set of all elements having a certain property. However, in many diagonal processes a new stucture is constructed from the debris after this dismantling. For example, the existence of transfinite stuctures is proved by diagonal processes.

This view extends constructivism from the construction of cognitive structures to include also the dismantling of cognitive structures and the reconstruction of new ones. Experimental evidence for this view is described in Fidelman (1991).

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[1] We may infer from the above quoted statement from Hilbert (1983, p. 192) that Hilbert considered the concept of concrete objects as well as their properties and relations to be given from a Kantian-like intuition. Therefore his view is close to our conjecture that particulars and universals, or rather nominalism and platonism, are modes of perceiving experience. However Hilbert did not state that the intuition of concrete objects and of their properties is subjective, like Kant's temporal and spatial modes of perception. Therefore we may interpret Hilbert's ontology to be ontological dualism, like that of Russell. The ontological difference is only in emphasis: Hilbert emphsized the concrete objects and is close to nominalism, while Russell's theory of types emphasizes sets and is close to platonism.