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HEMISPHERES RELATION FOR BOTTOM-UP AND TOP-DOWN CONCEPT-MAPS CONSTRUCTION

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ABSTRACT

Student-teachers were instructed about the construction of concept maps. Both top-down and bottom-up approaches were presented to them. The students prepared concept-maps as exercises. They were divided into two groups. One included the students whose concept-maps were top-down. The other included the students whose concept-maps were bottom-up. These students were also tested for measuring the efficiency of the left and right cerebral hemispheres. We define "the dominance of the right hemisphere" as the difference between the standardized scores on the right hemisphere and the left hemisphere. The dominance of the right hemisphere's values of the members of the two groups were compared by the Mann-Whitney test. It was found that the dominance of the right hemisphere of the top-down group was larger than that of the bottom-up group. This result is significant at $p<0.05$ in a 2-tailed test. A theoretical explanation of this phenomenon is suggested.

1. INTRODUCTION

Concepts are related to logic. There are several approaches to logic, and in every
approach concepts are created and interrelated differently. There are two possibilities for the hierarchic setup of concept-maps: One possibility is a top-down map; the other is a bottom-up map. Therefore, individual differences in concept-mapping may be related to individual differences in the approach to logic.

It was suggested by Fidelman (1990 a) that different approaches to logic may be related to individual differences in the relative efficiencies of the hemispheric analytical and synthetical mechanisms. In the sequel a theory relating concept-mapping to the cerebral hemispheres through logic is suggested. According to this theory, top-down concept-mapping is more related to the right hemisphere relatively to the bottom-up mapping. On the other hand, bottom-up mapping is more related to the left hemisphere relatively to top-down mapping.

2. **CONCEPT-MAPS**

Every piece of knowledge consists of concepts. One of the main problems which students and teachers must overcome is how to organize this knowledge in a well-constructed manner. Novak (1984) with his idea of concept-mapping suggests a powerful instrument for solving this problem.

The concept-map is a graphical tool which consists of concepts (introduced by names) inter-linked by lines. On every line a preposition which links every two concepts in a meaningful sentence is written. The concept-maps can be divided into two types:

a. The scattered ones, without any criterion for building it, except the above mentioned constraint.

b. The hierarchic map where the concepts must be organized in such a manner so that the map can be read in one direction.

The hierarchical concept-maps can again be divided into two categories:

c. Those which begin with a general or main concept and gradually become more specific or secondary. This representation of the relationship between concepts recalls the top-down way of organizing information.

b. Maps which begin with specific concepts and move toward the general ones. This way of organizing knowledge characterized the bottom-up way of organizing information. The top-down or bottom-up direction of the map is determined by the prepositions. For example:

A bottom-up construction	A top-down construction
class	class
↑ is a member of	↓ includes a
pupil	pupil

The terms "top-down" and "bottom-up" describe cognitive strategies which indicate the order of setting up the information. The bottom-up strategy indicated that the student begins with the details before combining them. The information is processed in layers. The bottom layer contains the accepted data. More layers are then added gradually, till the top one represents the final identification of the input. This strategy is also called "data driven" (Palmer, 1975; Newell & Simon, 1972).

The top-down strategy indicates that the student begins with general knowledge about the subjects before processing the details. This type of knowledge processing is also called "concept driven" (Rumelhart & Ortory, 1977; Minsky, 1975; Schank, 1977).

Summing up, the way the student chooses to represent the concept-map reveals his/her style of processing knowledge.

3. LOGIC, CONCEPT-MAPS AND CEREBRAL HEMISPHERES

Frege's mathematical logic includes one elementary notion: "a set", and one elementary relation: "the set x is an element of the set y". Thus, Frege's system includes only sets and no atomic elements. Frege's mathematical logic is based on his axiom of abstraction: For each property there is a set of all elements having this same property. Every set has the property of being equal to itself. Therefore, the existence of the set of all sets results from the axiom of abstraction. Similarly, no set has the property of being unequal to itself. Therefore, the set of all sets which are unequal to themselves exists, and is empty. The sets of Frege's system are thus either empty or include sets (but no atomic elements) as elements. Platonism is the ontological approach which accepts the real existence of universals, i.e., ideas, concepts or properties. Some Platonic approaches deny the real existence of individual objects (having these properties) as they are perceived by us. Frege's approach is Platonic, as follows from his axiom of abstraction and from the absence of atomic elements representing individual objects.

Each set of Frege's system can be an element of another set, i.e., have properties. Nevertheless, the set of all sets is at the top of the hierarchy of sets. Since no atomic elements exist, only the empty set can be a lower limit in the hierarchy of sets. However, since the set of all sets includes itself as an element, a bottom does not always exist in the hierarchy of sets. That is, the set-theoretical axiom of foundation is not fulfilled in Frege's system.

When Frege's logic is applied to the physical world, the Platonic axiom of abstraction implies the existence of the set of all elements having a certain physical property. For each physical property of a physical object exists the set of all physical objects having this property. Each physical object has some property distinguishing it from any other object. Otherwise, these objects would have been identical. Therefore, a physical object is the single element of the intersection of all the sets of objects having the properties of this object. However, atomic elements do not exist in Frege's logic. This causes, according to Dummett (1981, p. 169) an ontological contradiction in Frege's approach to the physical world. Dummet quotes Frege's definition of properties: "I call concepts under which an object falls its properties." Dummett stated that this definition implies the following ontological problem in Frege's theory: "It would therefore be for him nonsense to say that an object is compounded out of its properties, that is, the concept 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 suppositum in which its properties are inhered".

It was suggested by Fidelman (in press) that this ontological problem in Frege's theory can be solved in a Platonic valid manner. The physical object p, which is the single element of the set P of the intersection of all the sets of objects having each of tified with the set P itself: p=P. This implies the abandoning of the set-theoretical axiom of foundation regarding the physical world. That is, there is no bottom in the hierarchy of properties (concepts) in the physical world, since physical objects are not "atomic" elements.

The hierarchy of physical properties has an upper limit which is the property of being a physical property and it is analogous to the mathematical set of all sets. We suggested that the hierarchy of physical properties has no bottom (otherwise an ontological contradiction occurs). We saw also that Frege identified properties with concepts. Therefore, Frege's concept of the physical world cannot be characterized as a bottom-up concept-map.

According to the axiom of abstraction, in both mathematics and physics, a Platonic concept, i.e., property, implies the existence of the set of all elements having this property. Then the property is virtually identified with the set of all elements having this property. Thus the existence of the elements having the property follows from the existence of the set of all elements having this property. Nevertheless, it is possible in Frege's system to define a property as being one of several given elements, and thus obtain the existence of the set S of all elements having this property by the axiom of abstraction. This is, apparently, a bottom-up construction. However, the ontological existence of this set S results also from its being an element of the set of all sets. Platonists may consider the existence of S as resulting primarily from its being an element of the set of all sets, and they may consider its bottom-up construction as a secondary reconstruction. Therefore the hierarchy of concepts in Frege's system is organized according to Platonic ontology, top-down rather than bottom-up.

Russell's theory of types is another approach to mathematical logic which is different from Frege's approach. Russell's system includes both sets and atomic individual elements which are not sets. The logical structures are constructed in Russell's system as follows: The theory of types includes one kind of variables which are both individual and predicative. However, an upper index is added to each variable. This index is called the type of the variable, and it is defined inductively according to the domain in which the variable is defined:

1. Atomic individual elements have the type O.
2. If we have defined n relations having the types

$t_1, t_2..., t_n$

Then a relation between these relations has the type

$t = (t_1, t_2..., t_n)$.

Each variable has an upper index which denotes the type of the domain of the variable. This upper index is called the type of the variable and it is defined by induction:

1. A variable which designates an atomic element has the type O:

X^0

2. If we have an ordered n-tuple of variables for which types were already defined:

s, t..., v

then a variable defining a relation between them has the type:

w = (s, t..., v)

and we shall designate this relation by:
$X^w (X_1^s, X_2^t ..., X_n^v)$.
Thus, a hierarchy of relations and variables designating these relations is defined.

Frege's axiom of abstraction is applied in theory of types in order to construct more and more complicated sets. However, a type must be constructed for each predicate which defines a set before applying the axiom of abstraction. Therefore, sets must be constructed in an upward direction, beginning from atomic elements.

The construction of types and of sets is a potentially infinite, never ending process. Therefore, Russell's system does not include a set which is a top like Frege's set of all sets. Russell's logic applies to the physical world as well as to mathematics. We may conclude that Russell's logic can be characterized by a bottom-up concept-map.

According to Levy-Agresti & Sperry (1968) the left cerebral hemisphere processes data analytically, while the right hemisphere synthesizes several data into a new whole. These new wholes can now be processed analytically by the left hemisphere as individual elements (Ben-Dov & Carmon, 1976). Individual "atomic" elements are single data, which are processed analytically. On the other hand, sets are new wholes which are synthesized from individual elements. Therefore, it was suggested by Fidelman (1990a) that Frege's logic, which accepts sets but not atomic elements, is related to the right hemisphere rather than to the left one. On the other hand, Russell's logic, which accepts both atomic individual elements and sets, is related to both hemispheres. Russell's logic is thus more related to the left hemisphere and less related to the right hemisphere, than Frege's logic. Experimental results, which are in line with this suggestion, are described in Fidelman (1990a).

According to Frege concepts, properties and sets are virtually equivalent. Therefore, concept-maps are logical structures. The construction of a bottom-up concept-map involves, at first, the analytical perception of some individual elements. Then, a property common to several of these elements is and the set of all these elements is synthesized as a new whole comprising these elements. Then, this new whole, i.e., this new set, is processed analytically as a single individual element, and so on. This process is similar to the construction of logical structures in Russell's theory of types.

On the other hand, the process of construction top-down concept-maps cannot begin with an analytical perception of atomic elements. This process begins with the conceiving of a concept which is virtually the set of all the elements having a certain property. Then, each element of this set is conceived as a new concept, i.e., as the set of all the elements having a certain property, and so on. This process can be described by Frege's logic rather than by Russell's logic.

Therefore, the suggestion of Fidelman (1990a), that Russell's logic is more related to the left hemisphere than Frege's logic, and that Frege's logic is more related to the right hemisphere than Russell's logic, may be applied to concept-maps. We may hypothesize that the construction of top-down concept-maps is related to the right hemisphere more than the construction of bottom-up concept-maps. On the other hand, we may hypothesize that bottom-up concept-maps are more related to the left hemisphere than top-down concept-maps. Experimental testing of this hypothesis is described below.

4. **THE EXPERIMENT**

4.1 The Subject

The research population included 43 student-teachers in technology and science or in service teachers who participated in training courses. Their ages varied between 20 and 35. The subjects participated in a teachers' skills course, the syllabus of which included learning about concept-mapping.

The subjects were asked to construct hierarchical concept-maps and were classified into two groups according to the type of the concept-maps which they constructed. The first group included those who constructed only top-down concept-maps. This first group comprised 36 subjects (16 males and

20 females). Fifteen of the male subjects were right-handed, and one male subject was bilateral. The female subjects included thirteen right-handed subjects, three left-handed subjects and two bilateral subjects. The two remaining female subjects were right-handed, but their handedness was changed in their childhood by education.

The second group included seven subjects. Six of them constructed only bottom-up concept-maps. The remaining subjects constructed one bottom-up concept-map and one top-down concept-map. This second group included one male subject and six female subjects. All the seven subjects of the second group were right-handed.

All the subjects were tested by neuropsychological tests measuring the efficiencies of the right and left cerebral hemispheres.

4.2 Teaching Concept-Maps

As an introduction to concept-mapping the student-teachers were taught the definition of concepts. We define concepts as a regularity in events on objects designated by some label (Novak, 1984). The second stage was a lecture about the nature and uses of concept-maps. The students were taught how to link the two concepts by a preposition in both direction, top-down and bottom-up, equally, i.e., the two styles were represented without giving preference to any of the styles.

Then, the students were asked to choose a page in a school science book (according to their specialization), pick out the main concepts and organize them hierarchically, according to the indicated direction (Novak, 32-33).

The student-teachers worked on the construction of the concept-maps as homework, so that they had enough time to think about the organization of the maps. They were told that both ways the bottom-up or top-down styles are valid and equal (we did not use these terms).

The maps were checked and divided into two groups: those who, according to the linking words, built a top-down map, and the others who built a bottom-up map. We repeated this exercise twice.

The maps consisted of ten to twenty concept items. Maps that did not contain all the suitable propositions were not taken into account.

4.3 The Hemispheric Tests

4.3.1 General

The hemispheric tests were presented by an IBM PC computer with a super VGA monitor. The distance between the eyes of the subjects and the center of the monitor was 60 cm. The trials were presented within a circle around the center of the monitor, and fell on the subject's retina at an angle of no more than 6^{0} 40'.

Before each trial, a fixation in the shape of a cross appeared for half a second at the center of the monitor. During the first half of the fixation's presentation time, the subjects heard a varying sound which attracted their attention. The hemispheric tests and the concept-maps were checked by different testers.

4.3.2 The Right Hemispheric Tests

Two tests for the right hemisphere were applied. The first test was the enumeration of dots presented symmetrically (subitizing) during 120 milliseconds (MS). The number of dots varied between two and six. Each number between two and six was applied twice as the total number of the presented dots. The order of the presentations was determined at random, but was identical to all the subjects. The dots were distributed at random around the center of the monitor, but each subject saw exactly the same presentations.

The relation between this test and the right hemisphere was shown by:

1. Presentations of dots in the center of the visual field of brain damaged subjects (Kimura, 1963, and Warrington & James, 1967).
2. Tachistoscopic presentations of dots in the two visual fields of normal adult subjects (Kimura, 1966, McGlone & Davison, 1973, and Boles, 1986). Young & Bion (1979) found a relation between this test and the right hemisphere of normal children.
3. A relation between this test and the right hemisphere was found in brain-split patients (Sergent, 1987, Table 2).

References of more experimental evidence to this relation is reviewed in Fischer (1992), p. 194.

The second test for the right hemisphere is similar to the first. The only difference is that the dots were replaced by new forms which had not been presented to the subjects previously. These new forms were constructed from segments and were similar to letters. A relation between this test and the right hemisphere of normal subjects was found by Kimura (1966).

4.3.3 The Left Hemispheric Tests

Two tests were applied to test the left hemisphere. The first test was the enumeration of dots presented one after the other temporally at different places around the center of the monitor. Each dot was presented during 120 MS. The temporal intermissions between the presentations of the dots varied at random between 120 MS and 180 MS. All the subjects received exactly the same presentations. Every number between two and six was applied twice as the total number of the presented dots. The order of this presentation was determined at random, but was the same for all the subjects.

The second test for the left hemisphere was similar to the first. The only difference was that all the dots were presented at one specific spot at the center of the monitor. Theoretical and experimental evidence for the relation between these tests and the left hemisphere is presented in Fidelman (1990b).

4.4 <u>Results</u>

Each correct answer on each of the four hemispheric tests received the score 1. The score for each hemisphere is defined as the sum of the scores on the two tests for this hemisphere. Thus the maximal score for each hemisphere was 20.

The hemispheric battery was originally designed for children. Therefore, it was not sensitive when applied to adults, since it was too easy. The top-down group included 36 subjects, 23 of them (64%) obtained the maximal score 20 on the right hemispheric tests. The bottom-up group comprised 7 subjects, 3 of them (43%) obtained the maximal score 20 on the right hemispheric tests. This result is in line with our hypothesis that the top-down group is more right-hemispheric than the bottom-up group.

Two subjects of the top-down group, i.e., 6%, received the maximal score 20 on the left hemispheric tests. One subject of the bottom-up group, i.e., 14%, received the maximal score 20 on the left hemispheric test. This finding is in line with the hypothesis that the bottom-up group is more left-hemispheric than the top-down group. However, these two last results are not significant.

The scores of the top-down group and the bottom-up group on the right and left hemispheric tests were compared by the non-parametric test of Mann-Whitney. The size of the sample enabled the use of the normal approximation. The findings were that the top-down group scored more on the right hemispheric tests at a 1-tailed significance of $p=0.17$. The bottom-up group scored more on the left hemispheric tests at a 1-tailed significance of $p=0.094$. Both these results are in the direction of our hypothesis, but they are not significant enough for acceptance.

There are two factors which diminish the probability of accepting the hypothesis for each of the hemispheric scores. The first reason is the small sensitivity of the battery. The second reason is the small number of bottom-up subjects. However, we do not expect that the efficiency of one of the hemispheric mechanisms alone determines the preference between top-down and bottom-up concept-maps. This preference is determined by an interaction between the hemispheric mechanisms. We may expect that the dominant hemispheric mechanism determines the type of concept-maps preferred by the subject.

Therefore, the difference between the standardized scores of each subject for the right and left hemisphere was computed. We call this difference "the dominance of the right hemisphere". We compared the dominance of the right hemisphere of the subjects of the two groups by subjecting them to the Mann-Whitney test. It was found that the dominance of the right hemisphere of the top-down group was larger than that of the bottom up group. The Z value was 2.1383. This result is significant at $p<0.05$ in a 2-tailed test.

We noted above that the lowering of the hemispheric scores as a result of the non-sensitivity of the tests acts against the acceptance of the hypothesis. A larger percentage of the subjects having an efficient right hemisphere received lower right hemispheric scores in the top-down group than in the bottom-up one. An opposite effect existed regarding the left hemispheric scores. These effects of the selective decreasing of the hemispheric scores exists also regarding the standardized scores. Therefore, we may expect that with more sensitive hemispheric tests, the last result would have been more significant.

5. DISCUSSION

We saw above that the formation of concepts in Russell's logic is bottom-up. On the other hand, in Frege's logic concepts can be formed both top-down and bottom-up, though the top-down formation is the primary one, at least according to the Platonic views. Therefore, Frege's logic is more related to top-down concept-maps, and less related to bottom-up concept-maps than Russell's logic.

We found experimentally that there is a relation between the "dominance of the right hemisphere" and the preference of top-down concept-maps over bottom-up concept-maps. This finding is in line with the suggestion of Fidelman (1990a) that Russell's logic is less related to the right hemisphere, and more related to the left hemisphere, than Frege's logic.

Our findings may be applied to education. Two different curricula can be prepared for every learning subject. In the first curriculum the concepts can be presented in the top-down approach. In the second curriculum the concepts can be presented in the bottom-up approach. It is possible to classify pupils according to their more efficient hemispheric mechanism. The pupils having a more efficient right hemisphere may learn according to the top-down approach. Pupils having a more efficient left hemisphere may learn according to the bottom-up approach. Thus, all the pupils may learn in the approach most suitable to their brain. There is a possibility that this classification may increase the learning achievements of the entire population.

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