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ABSTRACT

This study was based on the following assumptions: (1) functioning of the brain's left hemisphere, because of its logical, verbal mode, facilitates conservation reasoning; (2) functioning of the brain's right hemisphere, because of its nonverbal, spatial mode, inhibits conservation reasoning; (3) visual input from the left eye will reach the left visual cortex before it reaches the right visual cortex, thereby giving the left hemisphere priority and vice versa; and (4) eye dominance is caused by hemisphere dominance. In order to test the validity of these assumptions, a series of conservation tasks (number, substance, continuous quantity and weight) were administered to a group of 82 children. The following predictions were made: A group of children who view the conservation materials with their left eye and are left eye dominant (LL) will demonstrate a greater frequency of conservation responses than a group of children who view the materials with their right eye and are right eye dominant (RR). A group of children who view with their left eye and are right eye dominant (LR) and a group of children who view with their right eye and are left eye dominant (RL), will demonstrate an intermediate frequency of conservation responses. The predicted sequence of LL.gt.LR approximately equal to RL>RR was found. LL and RR group differences were significant ($z = 2.01$, $p = .02$). (Author/MS)

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Hemispheric Dominance, Conservation Reasoning and the Dominant Eye

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Abstract

The present study was based upon the following assumptions: (1) functioning of the brain's left hemisphere, because of its logical, verbal mode, facilitates conservation reasoning; (2) functioning of the brain's right hemisphere, because of its nonverbal, spatial mode, inhibits conservation reasoning; (3) visual input from the left eye will reach the left visual cortex before it reaches the right visual cortex (presumably because the neural pathways are shorter from the left eye to the left visual cortex than from the left eye to the right visual cortex), thereby giving the left hemisphere priority and vice versa; and (4) eye dominance is caused by hemisphere dominance. These assumptions led to three predictions. A group of children who view the conservation materials with their left eye and are left eye dominant (LL) will demonstrate a greater frequency of conservation responses than a group of children who view the materials with their right eye and are righteye dominant (RR). A group of children who view with their left eye and are right eye dominant (LR) and a group of children who view with their right eye and are left eye dominant (RL), will demonstrate an intermediate frequency of conservation responses. Four conservation tasks, number, substance, continuous quantity and weight were administered to kindergarten children (n=82). The predicted sequence of LL>LR≅RL>RR was found. LL and RR group differences were significant ($z = 2.01$, $p = .02$).

Hemispheric Dominance, Conservation Reasoning, and the Dominant Eye

Recent brain research has demonstrated that each of the brain's hemispheres is specialized for different modes of processing information. The mode of the left hemisphere, in most individuals, is logical, convergent, and analytical. It is responsible for language and, in general, processes information sequentially. The right hemisphere processes information in quite another way. Its mode is holistic, intuitive, spatial, divergent, and analogical (Ornstein, 1972; Miler, 1971; Galen and Ornstein, 1972; Gassanigna, 1967). These different modes are not only located in different sides of the brain, but depending upon the situation, or problem, one hemisphere or the other may tend to dominate and control behavior (Bogen, 1969; Levy, Trevarthen, and Sperry, 1972; Nebes, 1971; Semess, 1968).

Lawson and Nordland (1975) hypothesize that Piaget's classical conservation tasks present individuals with situations that place the two hemispheres of the brain in opposition to each other so that they, in fact, compete for control or dominance in dictating problem responses. They suggest that correct conservation reasoning "requires a logical-verbal 'operational' response of the left hemisphere while nonconservation indicates a holistic, spatially or perceptually-oriented right hemisphere response" (p. 512). For example, according to Pascual-Leone (in press), a conservation of weight response might be based upon the logical-verbal coordination of the following schemes: (1) nothing has been added to or taken away from the clay ball that was flattened; (2) if nothing is added or taken away, then the amount stays the same; (3) the clay balls were originally equal in amount; and (4) equal amounts weigh the same. Therefore, the weight is still the same. A nonconservation response might be based upon a spatially-oriented answer such as: 'that one looks heavier, so it must be heavier'. Intellectual development, in the Piagetian sense, can perhaps be viewed as a gradual increase in the verbal, logical, and sequential information processing ability of the left hemisphere, and its ability to dominate or take control from the right hemisphere in situations that, in fact, call for such reasoning ability (Lawson and Nordland, 1975, p. 512).

In a different, but not unrelated field, researchers for many years have attempted to relate right and left eye dominance to right and left brain hemispheric dominance. According to Wold (1968), Orton (1928) was the first to argue that the hemispheric dominance of an individual could be determined by his eye dominance. Lavery (1947 a, 1947 b) also believed that eye dominance was an indicator of hemispheric dominance. For example, if a person was right eye dominant, this would indicate that the left hemisphere was the dominant one for processing visual input. This right eye association with the opposite hemisphere, the left hemisphere, was assumed since anatomical evidence clearly indicates that there is a crossing over of nerve pathways from the right hemisphere to the left side of the body and vice versa.

However, Stern (1954), Money (1962), and Flax (1966) claim that the concept of a dominant eye with a dominant hemisphere is anatomically inconsistent. They point out that, although there is a crossing of the optic nerve (the optic chiasma), from the right eye to the left hemisphere and from the left eye to the right hemisphere, the nerve pathways semi-decussate, that is, they split and go to both hemispheres as shown in Figures 1 and 2.

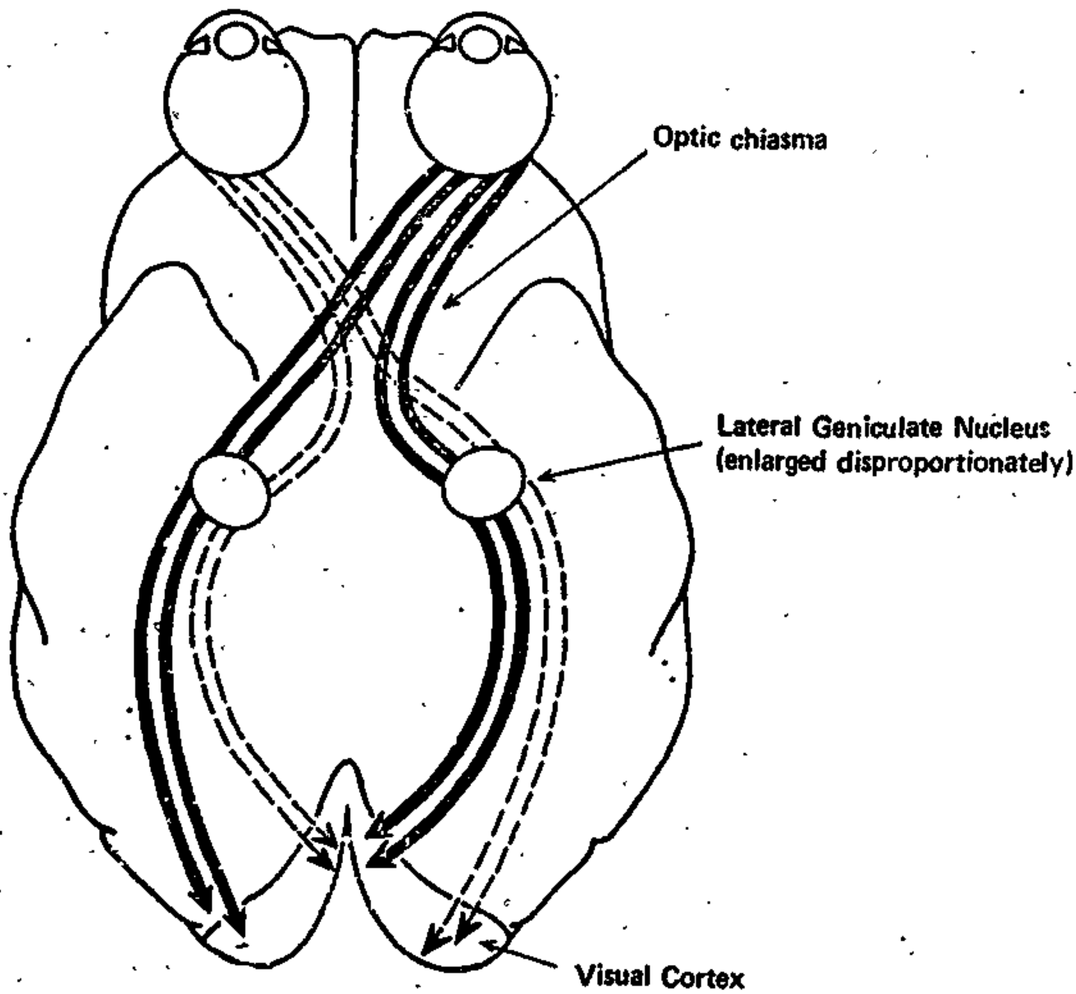

Figure 1. A schematic representation of the anatomy of the visual pathway (ventral view). Each eye sends neural impulses to both hemispheres; however, the pathways from the right eye to the right visual cortex are shorter than those from the right eye to the left visual cortex. Likewise, the pathways from the left eye to the left visual cortex are shorter than those from the left eye to the right visual cortex.

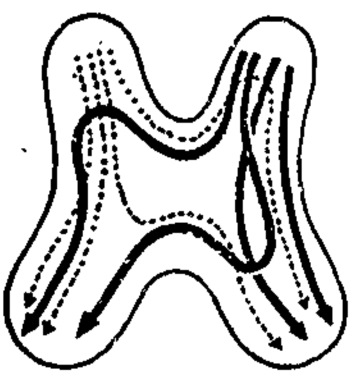

Figure 2. Nerve fiber distribution in the chiasm. The nerve fibers that cross (i.e., those that connect the right eye with left visual cortex and those that connect the left eye with the right visual cortex) make loops at the chiasm before entering the opposite nerves. This looping increases the fiber lengths. The fibers that do not cross follow direct routes through the chiasm.

This semi-decussation of the optic nerves (as contrasted to the complete decussation of the nerves of the arms and legs, etc.) confounds attempts to relate eye dominance to hemisphere dominance. A further factor that has clouded the situation has been the ambiguity surrounding the meaning and measurement of ocular dominance. Walls (1951), over twenty years ago, pointed out that there were then at least 25 different criteria for ocular dominance. To date, then, the relationship between hemispheric dominance and ocular dominance is uncertain.

The Present Hypotheses

We believe that the recent research concerning the different modes of intellectual functioning of the two cerebral hemispheres, and the view of correct conservation reasoning requiring a left hemisphere response, can be used to explain the relationship of eye dominance and hemispheric dominance if one makes the following assumptions:

1. The right hemisphere (in right-handed individuals)* processes information in a perceptual, holistic manner.

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*The modes of the hemispheres may be switched to the opposite sides in some individuals. This is correlated with handedness so that in about ten percent of left-handed individuals the right hemisphere is the linear language containing hemisphere. This condition exists in less than one percent of the right-handed individuals (Penfield and Roberts, 1959).

2. The left hemisphere (in right-handed individuals) processes information in a linear, logical, sequential manner.
3. Conservation tasks present individuals with situations that place the two hemispheres into competition for control in processing information and dictating responses.
4. Visual input from the right eye travels to both the right and left visual cortex, however, it will reach the right visual cortex prior to reaching the left visual cortex because the optic nerves to that visual cortex are shorter than the ones that cross over to the left visual cortex. Similarly, visual input from the left eye travels to both the left and right visual cortex, however, it will reach the left visual cortex prior to reaching the right visual cortex because the optic nerve connections to that visual cortex are shorter than the ones that cross over to the right visual cortex. See Figures 1 and 2.
5. If vision is blocked in the left eye so that visual input reaches the right visual cortex before it reaches the left visual cortex, the right spatially-oriented hemisphere will be more likely to gain control over the left logically-oriented hemisphere to process visual information and dictate a response. Similarly, if vision is blocked in the right eye so that visual input reaches the left visual cortex before it reaches the right visual cortex, the left logically-oriented hemisphere will be more likely to gain control over the right spatially-oriented hemisphere to process visual input and dictate a response.

6. Individuals, for what are likely genetic reasons, are predisposed to process information in the right or left hemisphere. In a sense, they can be considered right or left hemisphere dominant individuals (Sperry, 1975).
7. Eye dominance is caused by hemisphere dominance. Right eye dominance is caused by right hemisphere dominance and left eye dominance is caused by left hemisphere dominance (right eye dominance is not caused by left hemisphere dominance and left eye dominance is not caused by right hemisphere dominance as suspected by Orton, Lavery, and others).

Testing the Hypotheses

In order to test the validity of the above assumptions, a series of conservation tasks were administered to a group of eighty-two children who were randomly assigned to one of two conditions. Children either viewed the conservation materials with their right eye (left eye patched) or they viewed the conservation materials with their left eye (right eye patched). Of the children who viewed the materials with their right eye, two subsequent groups were formed--right eye dominant children and left eye dominant children. Of those that viewed the materials with their left eye, two similar groups were formed.

This led to the following predictions: (1) Of the four groups, the group that viewed the materials with the left eye and were left eye dominant (LL) should demonstrate a higher frequency of conservation responses than the other three groups. This is because the left hemisphere (the logical, verbal, sequential hemisphere) presumably receives the visual input first, thereby giving it an advantage over the right hemisphere, and in these children the left hemisphere is presumably the dominant one. In other words, these children tend to process information in the left, logical, verbal hemisphere in the first place. (2) The group that viewed the materials with the right eye and are right eye dominant (RR) should demonstrate a lower frequency of conservation responses than the other three groups. This is because the right hemisphere (the spatial, holistic hemisphere) presumably receives the visual input first, thereby giving it an advantage over the left hemisphere, and it presumably is the dominant hemisphere. (3) The remaining two groups (the left eye vision and right eye dominant group (LR) and the right eye vision and left eye dominant group (RL) will demonstrate a similar frequency of conservation responses and this frequency will be intermediate to the LL and RR groups. This is presumably because in the LR group the visual input will reach the left hemisphere first, thereby increasing the probability of a conservation response. This effect, however, will be partially cancelled because in these children the right hemisphere is the dominant one and it may gain control even so. In the RL group the visual input presumably will reach the right hemisphere first, thereby decreasing the probability of a conservation response. This effect, however, will be partially cancelled because in these children the left hemisphere is the dominant one and it may gain control even so.

Method

Subjects

Eighty-two right handed children (40 males and 42 females) who ranged in age from 5.3 years to 6.3 years, mean age = 5.8 years, served as subjects. The children were enrolled in kindergarten classes from two schools located in upper-middle class neighborhoods in the San Francisco Bay Area.

Procedure and Tasks

The conservation tasks administered were conservation of number, substance, continuous quantity, and weight. Subjects were seated at a table with the conservation materials directly in front of them. Prior to administration of the tasks a pair of plastic goggles, that had either the right or left lens coated with black paint, was fitted on the subject. The goggles allowed viewing of the conservation materials with the right or left eye only. In order to assign subjects randomly to one of the two treatment groups (right or left eye viewing), alphabetically ordered class rosters were obtained and each name was numbered consecutively. All the even numbered names formed one treatment group while all the odd numbered names formed the other treatment group.

The tasks were individually administered in the order in which they are listed below. All conservation questions were asked in a counter-balanced order. Since each task has been employed by previous investigators, only brief descriptions of the tasks and materials used are included.

For weight (e.g., Elkind, 1961), two balls of clay were presented to the subject. One ball was then transformed into a pancake shape.

For continuous quantity (e.g., Goldschmid, 1967) two identical beakers (100-ml) were filled with equal amounts of water. The water from one beaker was then poured into a 50-ml pyrex graduated cylinder.

For substance (e.g., Elkind, 1961) two balls of clay were used. One ball was transformed into a 'hot dog' shape.

To measure number (e.g., Goldschmid, 1967) two rows of plastic poker chips were placed on the table. Each row contained six chips. One row was shortened by pushing the chips together while the other row was lengthened by spreading the chips apart.

For subjects to be judged conservers they had to respond correctly to the conservation questions and offer valid explanations for their answers, e.g., identity--they are the same because you did not add anything or take anything away; inversion reversibility--it is the same because you could pour the water back into the glass to the same level; reciprocity reversibility--it is the same because it is shorter but it is also wider. One point was awarded for a conservation response. No points were awarded for a nonconservation response.

On a separate occasion and subsequent to administration of the conservation tasks, subjects were interviewed again to determine whether they were right eye dominant, left eye dominant, or neither. Although there is some ambiguity regarding the criteria for distinguishing the dominant eye, Walls (1951) proposed that the dominant eye should be defined as--that eye which one ascertains the direction of a point with reference to the self. The most appropriate method to measure this with this age group was determined to be an alignment test similar to that suggested by Lavery (1947-a).

To determine the dominant eye, a pencil was held by the examiner directly in front of himself and in front of the subject at a distance of about one meter. The subject was told to align the pencil with the examiner's nose by directing him where to move his hand. The dominant eye is the one that the subject uses to sight with. This eye, the pencil, and the examiner's nose will be in direct alignment. It is true that two images of the pencil are present under these conditions, but this is usually not observed by the subjects. The more marked the degree of ocular dominance, the less likely the subject is to observe the second image. However, if the subject did note two images and consequently demonstrated no clear ocular dominance, he was removed from the sample. About 10% of the children originally tested showed no clear ocular dominance.

Results

Of the 82 subjects, 49 were right eye dominant and 33 were left eye dominant (59.8% and 40.2%, respectively). These percentages are similar to those obtained by Rengstoff (1967) when he compared six different samples, totaling 5,546 subjects in an age range of 5 to 75 years. Overall, he found 66% right eyed and 34% left eyed. These percentages did not vary significantly with age.

Frequencies and percentages of conservation responses given on the four conservation tasks for each of the four groups of subjects are shown in Table 1. As predicted the LL group demonstrated a higher percentage of conservation responses than the RR group on each conservation task. The Mann-Whitney U test (Siegel, 1956) was used to analyze group differences for significance. For all analyses, subjects were ranked on the basis of total number of correct conservation responses given on all four tasks. Possible scores ranged from zero correct to four correct. The LL group demonstrated significantly more conservation responses than the RR group ($z = 2.01$, $p = .02$)

Insert Table 1

about here

As predicted the LR and RL groups generally demonstrated a similar level of success on the tasks. Group differences were not significant ($z = .22$, $p = .41$). Also as predicted, the LR and RL groups demonstrated a lower percentage of conservation responses than the LL group. The only exception occurred on the conservation of substance task where the RL group had a slightly higher percentage of conservation responses (RL = 52.9%, LL = 43.8%). The Mann-Whitney U test was used to test the significance of group differences between the LL group and the combined LR and RL groups. The obtained z of 1.22 failed to reach significance ($p = .11$).

On all but one task, the conservation of weight task, the RR group demonstrated lower percentages of conservation responses than the other three groups. Group differences between the RR group and the combined

LR and RL groups were also analyzed for significance using the Mann-Whitney U test. The obtained z of 1.03 failed to reach significance (p = .15).

Discussion

Although minor discrepancies occurred, the predicted trend of LL > LR ≅ RL > RR was found, therefore, the hypothesized relationships among hemisphere dominance, conservation reasoning, and eye dominance have been corroborated. Additional support for the hypothesis of inter-hemispheric differences in problem solving comes from the work of Golding, Reich, and Wason (1974). They assumed that input from the right hand is predominantly processed by the left hemisphere and input from the left hand is predominantly processed by the right hemisphere. In their study, college students attempted a tactile version of a deductive logic problem (the Wason 4-Card Problem, Wason [1966]) using concealed wooden blocks. Subjects who gained input about the blocks with their right hand (left hemisphere) performed better than those who gained input from their left hand (right hemisphere). Their results, as well as the results of the present study, suggest that, not only does the left hemisphere facilitate performance, but the right hemisphere inhibits it. Pribram (1971) offers an interesting hypothesis concerning how this might occur. He suggests that the corpus callosum (the neural fibers connecting the right and left brain hemispheres) may function to suppress activity in the opposite hemisphere. Pribram states:

> ...perhaps the connections, rather than functioning to associate, tend to separate through suppression the various parts of cerebral mantle. Clinical documentation shows that during simultaneous excitation of two points on receptor surfaces, one point dominates, while the other is suppressed (Teuber and Bender, 1951) ... the hypothesis that is suggested states that cortical dominance is due to a similar inhibitory suppressive mechanism (pp. 362-364).

Although little is known about how such a suppression mechanism might work, this hypothesis seems consistent with our results.

To reiterate, the finding that left eye vision and left eye dominant individuals (LL) performed significantly better on conservation tasks than right eye vision and right eye dominant individuals (RR) is consistent with the Lawson and Nordland (1975) view, that intellectual development, in the Piagetian sense, is largely a function of the left hemisphere's verbal and linear functioning and its ability to dominate the right hemisphere's more spatial and holistic mode of operation. The hypothesis advanced by Languis (1975), that Piagetian operations are right hemisphere functions, only subsequently transferred to the left hemisphere for verbalization, is not compatible with these results. Any final judgment of this issue now, however, would be premature.

To our knowledge this is the first time ocular dominance has been related to intellectual development. Previous investigations (e.g., Grave, 1957; Markow, 1963; Wold, 1968; Rengstorff, 1968) have focused primarily on mixed hand and eye dominancy and its possible relationship to writing, reading, and speaking difficulties. To date, these studies are inconclusive. Although the present study does not address itself to the mixed dominancy issue, it does raise the possibility of differences between right and left eye dominant persons and general verbal abilities and certain cognitive styles such as field independence and field dependence.

Table 1

Frequency and Percentage of Conservation Responses for Each Group on Each Conservation Task

Group [a]	Conservation Tasks [b]				Combined Tasks
	Num.	Sub.	Cont.	Wgt.	
LL	(81.3) 13/16	(43.8) 7/16	(43.8) 7/16	(31.3) 5/16	(50.0) 32/64
LR	(47.6) 10/21	(38.1) 8/21	(42.9) 9/21	(23.8) 5/21	(38.1) 32/84
RL	(47.1) 8/17	(52.9) 9/17	(29.4) 5/17	(11.8) 2/17	(35.3) 24/68
RR	(46.4) 13/28	(25.0) 7/28	(25.0) 7/28	(14.3) 4/28	(27.7) 31/112

[a] LL = left eye vision and left eye dominant, LR = left eye vision and right eye dominant, RL = right eye vision and left eye dominant, RR = right eye vision and right eye dominant.

[b] Num. = conservation of number, Sub. = conservation of substance, Cont. = conservation of continuous quantity, Wgt. = conservation of weight.

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