

HANDEDNESS, EYEDNESS, HAND-EYE DOMINANCE & ACADEMIC PERFORMANCE

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Abstract

A three-year prospective, longitudinal, multi-school study was undertaken to investigate if either handedness, eyedness, their same or opposite side status (unilateral or crossed hand-eye dominance) was related to specific aspects of elementary school academic performance. Some 540 subjects, in 1st through 5th grades comprised the initial group. Testing on the reading sub-test of the Iowa Test of Basic Skills (Iowa) was done three times over the course of the study. Subjects' hand and eye dominance, performance on the Visual Motor Integration Test (VMI) and Wold Sentence Copy Test (Wold) were evaluated six times over the course of the study. Not all of the initial subjects were available for subsequent testing.

There was no significant relationship found between any portions of the reading sub-tests of the Iowa and handedness or eyedness. The group of unilateral hand-eye dominant scored significantly higher than those with crossed hand-eye dominance on the Iowa's reading comprehension and total reading scores. Significantly better performance was found for right handed, right eyed individuals as well as unilateral dominant subjects on the VMI. Handedness was not significant in performance on the Wold, but the right eyed and unilateral dominant scored significantly better than their left eyed and crossed dominant counterparts.

Speculations are given on the meaning and clinical implications of the findings.

Key Words

crossed dominance, Iowa Test of Basic Skills, laterality, visual motor, Visual Motor Integration Test (VMI), Wold Sentence Copy Test

Introduction

A longstanding debate has existed about the influence of handedness and eyedness on academic performance.¹⁻¹³ Some have indicated that hand dominance as well as hand-eye dominance, particularly crossed or mixed dominance, are factors in academic performance.^{1,6-11,13} Others consider these factors of no significance in academic performance.^{2-5,12} Left handed children have long been considered to be different.^{11,14} Some cultures consider the left hand to be dirty and the terms *sinister* and *gauche* both refer to being wrong or left sided.¹⁵

The left hander in a right handed world finds that most activities, e.g., reading and writing, which proceed from left to right are opposite his natural tendency, but many left handed children quickly learn to adapt.¹⁶⁻¹⁸

Left handedness, as a detriment to learning, can be explained neurologically.¹⁴⁻¹⁶ All motor functions of the body are controlled by the opposite cerebral hemisphere and therefore the right hand is governed by the left cerebral hemisphere. The left hemisphere has been identified as

the hemisphere that processes language in right handers and in many left handers.^{19,20}

And, tactile stimulation of the left hand reaches the right hemisphere and vice versa¹⁹⁻²¹ The specialization of the left side of the brain for language skills coupled with the left sensory motor area of the hand may somehow give the right hander a language advantage over the left hander. A delay or an inability to develop a clear hand dominance has also been implicated in strabismus.²²

My search of the literature did not reveal much information on a relationship between eye dominance as a major factor in school performance.^{4,23} There are, however, a number of individuals who state that hand-eye dominance is a factor, particularly in crossed dominance.^{9-11,14-16} Crossed dominance refers to the dominant eye being on one side of the body while the dominant hand is on the other.^{6,9,10}

It is difficult to develop a logical neurological model for eye dominance or for hand-eye dominance as a factor in reading or writing.⁴ The neurology of the eye is not like that of the hand since the eye does not have complete decussation of its nerve fibers. Only the nasal fibers of each eye cross at the optic chiasm and therefore each has input to both cerebral hemispheres at the level of the striate cortex. This makes the eye's visual field, not the physical eye, the more significant factor.²² The left visual field is projected to the right striate cortex by the left eye's nasal fibers and the right eye's temporal fibers.

There is good evidence that the perceptual span of the left and right central visual fields of an individual is asymmetrical.²³ Cultures that read from left to right perceive more letters/characters to the right of fixation than to the left, and cultures that read from right to left have an asymmetrical pattern in the opposite direction.²⁴ These differences are consistent with that culture's direction of the visual attack when reading. If one accepts that the right hander has an advantage since it is controlled by the language hemisphere, then the nasal aspect of the right eye and temporal aspect of the left eye would feed the left hemisphere, which processes more characters when reading left to right. This would be true for cultures where the reading proceeds in this direction.

The research goal of this study was to investigate relationships between hand lateralization, eye lateralization, agreement of hand-eye lateralization, visual-motor integration and reading performance.

Research background

The Institute for the Study of Epidemiological Research in Vision and Education (I-SERVE) is a cooperative effort between the Oklahoma Center for the Study of Literacy at Northeastern State University and the College of Optometry at Northeastern State University. The I-SERVE mission is to identify factors that impact academic performance, particularly in the visual realm. Research support is dependent on grants. I-SERVE undertook a three-year prospective, longitudinal epidemiological study of visual, motor and academic characteristics of a defined sample of Oklahoma children.

Subjects

The current study was part of a larger epidemiological endeavor that evaluated 540 children over the course of three consecutive years. The original sample consisted of 284 males and 256 females, and ages ranged from 5 to 12 years.

Methods

Evaluations were performed on handedness, eyedness and two tests of visual motor integration by optometrists trained in these procedures once in the fall and once in the spring for three consecutive years. We began with children in the first three grades and followed the available

children until most were in the third to fifth grades. Over the course of the three years we conducted 2668 total evaluations on each subject's dominant hand, dominant eye, the hand-eye relationship, visual-motor integration, and performance on a standardized reading test.

Hand dominance was determined by asking the child to tell or show the examiner which hand was used in writing. Eye dominance was determined by "hole in the hand test." This is accomplished by asking the child to sight the examiner's nose through a hole formed by the two hands. The hole is constructed by folding the two hands over one another so that the palms face outward and the thumbs overlap, forming a small hole between the junction of the two thumbs and hands. The examiner was at a distance of 4-5 feet directly in front of the subject.

These lateralization findings along with the agreement of hand-eye lateralization were compared to performance on the reading subtest of the Iowa Test of Basic Skills (Iowa)^a and the Visual Motor Integration Test (VMI)^b and Wold Sentence Copy Test^c (Wold). Both the VMI and the Wold have been shown to be statistically significant predictors of academic performance.²⁵

The Iowa is a standardized academic test which was adopted by the Tahlequah Public School system as their standard measure of scholastic achievement. The reading sub-test of the Iowa yields one of 21 different sub-test scores, although not all sub-tests are always administered to individual children.²⁶ The Iowa was administered each year by the school system, in the spring of the year, to ascertain grade placement in a number of academic areas. These Iowa results were then made available to this researcher.

The VMI is a normed paper and pencil test which consists of a series of 24 symbols which are reproduced by the child. The VMI scoring manual gives directions on scoring as well as age norms. It is considered a visual-motor (vision guides, hands reproduce) test. The Wold is also a visual-motor test where the child is asked to copy a standard sentence. The child is presented with a sheet of paper containing the printed sentence. The child copies the sentence as quickly and as accurately as possible on the lines below the printed sentence. The score is the number of correct symbols per minute.

Results

Handedness and eyedness

A total of 1746 observations of hand and eye preference were made on the sample in the six testing periods over the three years of the study. There were no significant differences between the genders as to handedness or eyedness or hand-eye dominance. All data was therefore pooled for the subsequent analysis.

A total of 90.4% of the children in the study were right handed. One child changed his hand dominance from right to left between the second and third grade. Some 63.4% of the individuals were right eye dominant.

The dominant eye changed considerably between testings. 48.2% of the children demonstrated the same dominant eye through the three years while 51.8% switched eye dominance at some time in the course of the three years. The children who began the study in the first grade were compared to those who started the study in the third grade. Significantly more of the former group (.001; 1 tailed Fisher Exact Test) changed eyes than did the latter group. An ANOVA by age approached moderate significance (.108), with the older children showing less of a tendency to change eye dominance.

In terms of hand-eye dominance, we found that 59.9% of the children were right handed/right eyed, 6.1% were left handed/left eyed. Thus, 66.0% demonstrated unidominance. Of the crossed dominant group, 30.4% were right handed and left eyed while the remainder were left handed and right eyed.

Reading, handedness, eyedness (Table 1)

The total performance reading scores from the Iowa were compared to each eye, each hand, and each hand-eye dominance group. No significant differences in total reading performance were found for the factors of hand or eye. Total reading score was found to be significantly better in the unidominant subjects than in the cross dominant subjects ($p=.033$; 2 tailed t test). The total reading score is calculated from scores on the sub-tests of vocabulary and comprehension. Considering each of these two sub-test scores, it was found that comprehension was significantly better in the unidominant group ($p=.035$; 2 tailed t test) but vocabulary was not significantly different. There was no significant differ-

Table 1
Comparison of Handedness, Eyedness and Hand-Eye Dominance
and Three Academic Tests

Test	Right Hand vs Left Hand	Right Eye vs. Left Eye	Unidominant vs. Cross Dominant
1. Total Reading Score on Iowa	NS	NS	S
1-A. Vocabulary on Iowa	NS	NS	NS
1-B. Comprehension on Iowa	NS	NS	S
2. VMI Score	S	S	S
3. Wold Score	NS	S	S

*Significance at $\leq .05$
 NS=not significant
 S=significant*

ence between the types of cross dominance (right eye/left handed individuals when compared to the left eyed/right handed individuals).

VMI, handedness, eyedness (Table 1)

The VMI scores were compared to handedness, eyedness and cross dominance. The right handed individuals performed significantly better on the VMI than did the left handers ($p = .001$; 2 tailed t test). Likewise, the right eyed subjects did significantly better than did the left eyed subjects ($p = .001$; 2 tailed t test). Crossed dominant children did significantly poorer on the VMI than did the unidominant children ($p = .008$; 2 tailed t test). When we compared the left hand/right eye subjects to the right hand/left eye subjects, we found no significant difference between these two sub-groups of crossed dominant children on the VMI.

The Wold scores were compared in the same manner as the VMI. The right handed subjects were no better on the Wold than the left handers. This was not the case when we compared the dominant eye to performance on the Wold. Left eyed children performed significantly slower on this test than the right eyed children ($p = .001$; 2 tailed t test). The crossed dominant children also did poorer on the Wold than the unidominant children ($p = .002$; 2 tailed t test). The right handed/left eyed children and the left handed/right eyed children were compared to one another. No significant difference was again found between these two sub-groups of crossed dominant children.

Discussion

Since Orton first raised the issue in 1937, others have speculated on the rela-

tionship between lateral dominance and academic performance.^{10,14} The present study has demonstrated that when the Iowa Total Reading Score is taken as the criterion for academic performance, the dominant hand and dominant eye do not significantly impact this score. Crossed dominance did, however, significantly negatively impact reading performance, specifically in reading comprehension and total reading score.

Crossed dominance negatively impacted the test performance of visual motor skills. Handedness and eyedness impacted some of the visual motor functions as tested by the VMI and the Wold. As stated earlier, both of these tests have been shown to be reliable predictors of classroom achievement.²⁵ The right unidominant group performed superiorly to the left unidominant and cross dominant children on the VMI. Right eyed and unidominant children were likewise better performers on the Wold. There was no significant difference between right and left handers on the Wold. Taken as a whole, these data support the notion that crossed dominance is related to poorer academic performance, in terms of reading and visual motor skills. The results are more mixed when evaluating handedness and eyedness. It is interesting, however, that of the two visual motor tests, both found right eyed individuals to be superior, but only the VMI found right handers performing better than left handers.

There is anatomical asymmetry among primates.^{26,27} The right cranium is slightly forward of the left cranium so that the left cranium extends behind the right in the occipital area. A lateral preference/asymmetric motor dexterity of one

side over the other is a characteristic of vertebrates.^{13,27-30} The right hand is dominant 70% to 99% of the time.^{12,31} Humans have been overwhelmingly right handed (90%) since the Cro-Magnon man.³⁰ The ancient Egyptians were mostly right handed, but handedness also appears to be influenced by culture.³⁰ These observations of anatomical asymmetry and the historical dominance of the right hand suggest that right dominance must have some advantage in the real world.

Handedness appears to be set by first grade. Gesell and Ilg reported handedness to be established by age 5 years⁵ while Bathurst reported hand preference at an earlier date and is said to remain stable from infancy.⁸ Delayed development of a dominant hand has been argued by Coren is related to delayed physical and hormonal development.³² He also has stated that as a person matures, the trend is for the individual to become more right dominant.¹⁷ Only one of the subjects in this study showed a change of hands from left to right: thus, the present study supports hand dominance to be set by age 5.

Wold et al found that 12.7% of children in his study were left handed.³¹ Other studies have reported that normal children are over 90% right handed.⁵ The 90.4% of children in the present study identified as right handed agree with these studies. Children under 7 years of age are reported to have already developed both hand and eye preference.^{35,36} Moreover, crossed dominance is mostly due to left eyedness. VanCamp and Bixby reported that 88% of their sample were right handed but of this group, 43% were left eyed.³⁶ Of the mixed laterality group (43% total), 38% were right handed and left eyed while the remainder were left handed and right eyed. The present study found similar percentages.

What causes some to be left handed, left eyed or cross dominant? At present, the answer escapes us. Handedness has been reported to be linked to the amount of testosterone in female rats and humans and suggests handedness exhibits a genetic, possibly sex linked, influence.³⁷ The present study did not, however, find a significant gender difference in the number of children who were left handed, left eyed or cross dominant.

Left handedness and incomplete hand dominance is more prevalent in children who were premature or where there was

prolonged labor. Left handed and/or incomplete hand dominance children are also more likely to have sustained respiratory dysfunction at birth, RH incompatibility, be a breech birth, be a low birth weight baby, involved in an instrument assisted birth, and/or Caesarian birth. Left handed children are also more prevalent when the age of the mother is older and when the one minute Apgar score is low.¹⁹

More time is required to develop hand lateralization in the learning disabled population.^{9,35} Left handedness and confused dominance appear to be linked to delayed development. Hellerich and Boos reported that unilateral hand dominance actually becomes less prevalent with age and that dominance is not a factor in academics.³⁸

The left cerebral hemisphere, in addition to controlling the right hand, is known to be more proficient in sequential, serial, temporal and analytical while the right hemisphere is better at simultaneous, spatial, parallel, gestalt and holistic skills.^{33,34} Left handed (more likely right cerebral hemisphere) people are said to gravitate to visual-spatial professions such as architecture.^{19, 33}

The assumption that visuo-spatial skills are processed primarily by the right cerebral hemisphere would cause one to hypothesize that left handers would demonstrate superior performance to right handers in visuo-motor activities.^{19,33} This was not the case in the present study. Could this indicate that the VMI and Wold, traditionally thought to be visuo-spatial functions, are not mediated by the right cortical hemisphere but by the left? It remains to be seen if these left handers will, at some future time, develop superior visuo-spatial skills.

Eye dominance has been reported to be established by 3 years of age.²⁰ Like handedness, eyedness is mostly right (71%).³⁹ Nevertheless, analysis of the present study's data indicates that eye dominance is not always established by school age. Over half (51.8%) of the current sample showed different eye dominance sometime in the three years. It is worthwhile to speculate, however, that eye dominance could change depending on the task and the test. Further, it is possible that the hole in the hand test is not the optimal way to evaluate true eye dominance.

The results of this study have at least two implications. The first is that in read-

ing and/or learning disability, the patient's handedness, eyedness and uni- or crossed hand-eye dominance should be considered as potential contributory factors. The second implication is whether the educator and/or optometrist should seek to change any crossed hand-eye dominance to unidominance. I propose that it would be more logical for both professions to first incorporate ergonomic techniques recommended by Harmon and others such as modifying paper/book placement, lighting, pencil grip and seating arrangement in the classroom.^{40,41} It may be that the left handed, left eyed individual and the cross-dominant individual are performing more poorly because of these mechanical/ergonomic factors^{14,16} and that cerebral dominance plays a minor or even insignificant role in the lowered scores on the visual motor tests. Certainly, it would seem to be more prudent to attempt to change these easily modifiable factors with ergonomics, lenses, prisms and incorporating basic visual motor activities before one engages in a program of some- how modifying eye/hand dominance.

Summary of findings of this study

1. There was no significant difference in the total reading score between right and left handers between grades 1 through 5.
2. There was no significant difference in the total reading score between right and left eyed children between grades 1 and 5.
3. There was a significant difference in the total reading score and reading comprehension scores between unidominant and crossed dominant children between grades 1 through 5. The unidominant children scored higher.
4. Right handed children, right eyed children and unidominant children did significantly better on the VMI than their counterparts.
5. Right eyed children and unidominant children did significantly better on the Wold than their counterparts.

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