PERFORMANCE ON A VERBAL AND VISUO-SPATIAL TASK AS A FUNCTION OF LATERAL DOMINANCE

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PREFACE

This study was concerned with the relationship between hand, foot and eye dominance and the pattern of linguistic dominance in the brain. The primary objective was to observe the relationship between scores on the Block Design and Vocabulary subtests of the Wechsler Intelligence Scale for Children - Revised and scores made on the Harris Test of Lateral Dominance.

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Abstract

The purpose of the present study was to clarify the relationship between lateral preference and the type of cognitive tasks upon which left, mixed and right dominant groups differed. Previous studies have relied upon handedness alone, the self report of handedness and consideration of manual preference as a discrete variable to draw their inferences. Subjects were 18 right and 21 left handed 5th grade children designated by self report. Following Levy's (1969) methodology, the Harris Test of Lateral Dominance and the Vocabulary and Block Design subtests of the Wechsler Intelligence Scale for Children - Revised were administered in an attempt to replicate her pattern of results. Groups designated as left dominant by self report and on the Harris Test were expected to exhibit lower Block Design scores than right self report and Harris Test groups. Vocabulary scores were not expected to differ significantly. When foot and eye dominance in addition to handedness were used, and consideration was given to the continuous nature of hand preference data, the predictions offered by Levy's original findings were not supported. Cerebral dominance may be a function of development.

Performance on a Verbal and Visuo-Spatial Task as a Function of Lateral Dominance

The apparent duality of the Human Brain has intrigued Greek and Oriental philosophers for centuries as well as modern day neurologists, psychologists and educators. Broca, in 1861 and 1865, was able to indicate that damage to the left hemisphere resulted in a motor speech disturbance (Broca's Aphasia), whereas damage to the right hemisphere did not. Such discoveries have been supported by the results of animal studies. The first experimental hemispherectomies were performed by Goltz. These procedures revealed no personality effects in humans, and only minimal intellectual deficits after surgical removal of one half of the brain. The removal of an entire hemisphere was later adopted as an accepted mode of treatment for certain forms of epilepsy (Bogen, 1969).

Using electrophysiological stimulation of various sections of the exposed brain, Wilder Penfield reported results which subsequently have become instrumental in the localization of various sensory functions (Krech, Crutchfield and Livson, 1969). Wada in 1949 developed a procedure involving the injection of sodium amytal into one of the carotid arteries in order to study the abilities of each hemisphere of the cerebral cortex. This barbituate "knocks out" the contralateral hemisphere, leaving only one hemisphere functioning (Searleman, 1977).

Since the experiments of Myers and Sperry (1953), the study of the split-brain and its implications for cognitive functioning have assumed an important role in modern psychological experimentation. Today it is possible to demonstrate a large number of behavioral and performance symptoms which are correlated with hemispheric separation. Commissuratomized patients (those who have undergone surgical separation of the corpus collosum for medical treatment) have been observed to behave as if possessing two separate streams of consciousness. Each hemisphere is capable of its own specialized functions. Some of the major findings from studies employing the split-brain technique have emphasized the cerebral organization of language. Activities involving speech and writing appear to be governed by the left hemisphere (Gazzaniga, 1970). Information that was generated or perceived exclusively in the right hemisphere was found to be communicated neither in speech or writing. Such material (spoken and written) was capable of being expressed through nonverbal responses only.

A deficit observed following commissurotomy or right cortical injury involved the ability to perceive and manipulate spatial relations. Patients manifest difficulty in reproducing structures organized in space such as stick constructions, Kohs block designs and reproduction of drawings. When two dots were presented, one on either side of the visual midline, and were made to appear to move in different directions simultaneously, subjects responded to the direction of movement perceived by the right hemisphere. This suggested a predomination of right hemisphere percepts when line orientation and direction of movement are involved (Nebes, 1974).

The ability to perceive three-dimensional spatial structure in commissurotomized patients was investigated by Levy-Agresti and Sperry

(1960) through use of a modification of the Space Relations Test. Results indicated a superiority of the left hand (right hemisphere) in matching tactually presented three dimensional shapes to a two dimensional representation which when folded up would produce the shape being felt. Supporting results of a right hemisphere superiority of visuo-spatial ability have been obtained using an adapted form of the Raven's Progressive Matrices. Subjects were shown a pattern in which a piece was missing, and were required to select tactually the piece from the design which would complete the visual pattern. Here again left hand--right hemisphere scores were significantly superior (Zaidel and Sperry, 1973). Kumar (1976) has also demonstrated a right hemisphere superiority for perception of form.

Investigations concerning the nature of hemispheric specialization in normal subjects have supported a verbal-visuospatial specialization. Tests of dichotic listening have indicated that typically, it is the right ear which receives information channeled to the left hemisphere. "Due to the particular wiring of the mamalian visual pathways, all stimuli presented to one side of a visual fixation point project exclusively to the contralateral hemisphere. This allows an experimenter to present stimuli such as letters or words to either hemisphere separately" through use of a tachistoscope (Milner, 1962, p. 276). Reaction times to stimuli flashed to one visual hemifield or the other are then measured. When verbal information was exposed to the left visual hemifield (right hemisphere) and a verbal response was required, reaction times were generally longer than when nonverbal responses were required, which indicated a superiority of the left hemisphere for verbal processing (Filbey and

Gazzaniga, 1969).

Most scientifically convincing are those studies of hemispheric differences which involve the recording of brain waves in normal subjects. Electroencephalographic (EEG) results have shown that a differential activation of the right and left hemispheres may be observed while subjects are engaged in a variety of cognitive activities. Alpha waves were used as indicators of cortical deactivation, signaling the onset of a state of relaxed awareness. Consequently, smaller alpha amplitudes within a particular hemisphere would tend to occur during periods in which that hemisphere was most active. Galin and Orenstein (1972) suggested that differences could be observed between the hemisphere dominant for a given task, and the hemisphere "at rest". Such differences could be observed on verbal and visuo-spatial tasks. Changes in the distribution of EEG activity rather than changes in the absolute values of total brain activity were measured. A variety of cognitive tasks were employed to stimulate activity in either the left or right hemispheres. Results confirmed the expectation that alpha activity would increase in the right hemisphere when the subject was engaged in a verbal task, and increase in the left while subjects were engaged in visuo-spatial activities. Doyle, Galin and Orenstein (1974) conducted an extension of this study in which more tasks were included. The relationships of EEG patterns to cognitive task were examined, with results once again conforming to expectations. Alpha activity was a function of cognitive task. Furst (1976) found that those persons evidencing less right hemispheric alpha activity (and therefore more right activation), showed superior performance on visuo-spatial tasks. Additional evidence for this relationship has been found

(Surwillo, 1976).

Further experimentation has revealed that, in addition to its verbal specialization, the left hemisphere is responsible for the somesthetic and volitional experiences of the right hand, leg, ear and right half of the body (Milner, 1962; Sperry, 1968). The right hemisphere, in addition to its visuo-spatial functions, is responsible for control of the left hand, leg, ear and left half of the body. It is not surprising then, that relationships between handedness and cerebral lateralization of language have been observed. For normal right handed subjects, as mentioned previously, it is the left hemisphere which has been found to be most proficient in language skills (Sperry and Gazzaniga, 1967). The right hemisphere is most facile when required to process information concerning spatial relationships, part-whole relationships and nonverbal stimuli (Nebés, 1971; Nebes, 1974). Left handers, however, appear to have less well differentiated hemispheres with respect to linguistic capacity (Goodglass and Quadfasil, 1954).

> It has been observed that a significant proportion of all non-right handers have linguistic skills present in both hemispheres. . . . The findings from both dichotic listening tests and tachistoscopic studies have indicated that speech perception or comprehension is less lateralized, in other words, is more bilateral in the brain of the non-right hander. (Searleman, 1977, p. 507).

This results in the ability of either hemisphere to engage in complex linguistic operations (Humphrey and Zangwill, 1952; Levy-Agresti and Sperry, 1971).

Noting experimental evidence of the relationship between handedness and language laterality, Levy (1969) proposed to test her hypothesis that "during the evolution of hominids, Gestalt perception may have been lateralized to the mute /right/ hemisphere as a consequence of an antagonism between functions of language and perception" (p. 276). This suggested that persons with bilateral language centers (left handers) could be expected to perform poorly upon tasks of perception. Such measures tap the abilities of the right hemisphere. Due to the antagonistic nature of verbal and visuo-spatial functions, the presence of linguistic ability in the right hemisphere was expected to interfere with their operation, thereby resulting in the lower scores of left handers. In order to test this possibility, Levy administered the Wechsler Adult Intelligence Scale (WAIS) to ten left and fifteen right handed graduate students. Handedness was assessed through self report. Use of the WAIS was based upon the results of previous investigations in which it had been found that the verbal items of this battery reflected left hemispheric functions. Abilities of the right hemisphere were well represented in the nonverbal (Performance) items (Reitan, 1955; Reitan and Fitzhugh, 1971).

Use of the WAIS had been found to produce results in brain damaged persons which supported Levy's hypothesis. Both left and right handed groups obtained approximately the same mean Verbal IQ's. However, a significant difference was observed between the Performance IQ's of both groups, with left handers exhibiting significantly lower scores. Left handers also produced significant differences between their Verbal and Performance IQ's (twenty-five IQ points), whereas right handers did not (eight points). Similar patterns of scores on verbal and visuo-spatial tasks have been obtained (Wittenborn, 1946; Mefford, James and Wieland, 1967; Miller, 1971).

Attempted replication of these results using Levy's methodology with children as subjects contradict the previously mentioned findings. Fagan-Dublin (1974) sought to analyze the developing relationship between language lateralization and handedness in children. Following the above format, the Wechsler Intelligence Scale for Children (WISC) was used to measure verbal and perceptual abilities of left and right handed subjects, five to six years of age. Linguistic laterality was inferred from a variety of methods as well as handedness. The results indicated that lateralization of verbal and visuo-spatial functions does not occur prior to the fifth or sixth year. The authors suggested that

> There are no inherent disparaties between verbal and nonverbal abilities associated with lateral dominance or handedness. Rather, when one considers that previous studies showed a performance inferiority (or verbal superiority in left handed subjects with probable verbal-analytical specialization, one might suggest that, in possible competition between the hemispheres for verbal and nonverbal abilities, training might be the critical factor in favoring the development of one over the other. (p. 73).

Such reasoning may partially explain studies which indicate that lateralization is not completed until puberty (Zangwill, 1960; Lenneberg, 1967; Witkinson, 1976).

Many studies of cerebral dominance in children have concentrated upon developing a theoretical explanation of learning disabilities.

Such data, however, has been sparse and contradictory. Witelson (1976) has maintained that poorer verbal task performance related to some lack of cerebral dominance. A bilateral representation of visuo-spatial abilities may exist resulting in the interference of verbal abilities for dyslexics and poor readers. Zangwill (1960) has noted a greater incidence of left handedness or lack of hand preference among children with these types of learning disorders. Guyer and Friedman (1975) found that children diagnosed as learning disabled exhibited poorer performance upon those cognitive tasks related to left hemispheric functions (i.e., field independence, hand awareness, and long term word recognition). Tasks used to tap the abilities of the right hemisphere were no more difficult for learning disabled children than for control subjects. The authors maintained that learning disabled children may attempt to use their nonverbal (right hemispheric) abilities to approach verbal school tasks, thus corroborating the above theories.

In opposition to the above findings, reading and writing disorders have been found to coexist with difficulties in spatial judgment which may be caused by the interference of visuo-spatial abilities by bilateralized verbal functions. In accordance with Zangwill, Pizzamiglio (1976) described the difficulties exhibited by four subjects with Block Design and spatial tasks on Thurstone's Primary Mental Abilities, thereby indicating that reading may be connected not only to linguistic, but to visual information as well.

Attempts to draw inferences about cerebral laterality (generally via Levy's methodology), have too often relied upon one type of performance, namely handedness. As such inferences provide a novel and potentially important application of cerebral dominance theory to explain the causes of learning disability, clarification of the relationship between manual preference and contralateral hemispheric representation of speech becomes essential.

An inherent assumption of most investigations is the existence of bilateral language potential in all left handed subjects. This raises a number of problems. Firstly, results of sodium amytal testing (see earlier discussion of Wada) indicate that not more than twenty per cent of left handers exhibit bilateral linguistic capacity (Searleman, 1977). In addition, researchers have failed to employ consistent criteria when assessing left handedness, which partially explains the above findings. Annett (1970) has offered a solution to this problem through identification of six primary actions which were found to correlate most highly with manual preference. These were writing, throwing a ball, using a racket, striking a match, hammering and using a toothbrush. These findings suggested that handedness varies along a continuum from individual to individual, as opposed to being a dichotomous variable. Consequently, "many individuals recorded as left handed in the neurological literature were probably more skilled in the right than the left hand." (Annett, 1970, p. 218). Failure to consider strength of preference then, may partially account for inconsistent or nonsignificant findings such as those reported by Heim and Watts (1976). "Experimenters must begin to measure and classify the handedness of subjects in a way that more accurately appriases the true handedness distribution." (Berman, 1971, p. 382).

Berman has suggested that, along with failure to treat handedness as a continuous variable, earlier research which attempted to correlate handedness alone with verbal or intellectual functions was decidedly wrong in approach. Results of a study in which foot, eye and ear dominance as well as hand preference were used to infer linguistic laterality led to the conclusion that rather than reliance upon measures of hand preference "a reliable indicator of . . . all body lateralization must be considered." (Berman, 1971, p. 382).

A second major area of difficulty involves the use of intelligence tests to study cerebral dominance. As one examines correlations of Wechsler subtests with total verbal and performance scores, it may be observed that Performance subtests do not possess as high a loading on the nonverbal factor as Verbal subtests do on the verbal factor. It may be concluded then, that the Performance scale is not as good a criterion measure for inferring the abilities of the right hemisphere as the Verbal scale is for the left hemisphere. To counter for this effect in testing, Parsons, Vega and Burn (1969) selected the Vocabulary and Block Design subtests to infer cerebral linguistic patterns. These tests have been found to possess highest loadings on verbal and perceptual organization factors respectively (Kaufman, 1975). Adult subjects with lateralized brain injury were used for testing. It was suggested that left hemispheric damage would lead to impaired language performance (Vocabulary score), whereas right hemispheric damage would result in impaired visuo-spatial performance (Block Design score). Results indicated that groups with damage to the left hemisphere did indeed score significantly higher on the Block Design subtest than the right damaged group, and as opposed to the Vocabulary subtest. The reverse trend was observed in the right hemisphere damage group. It It was concluded then, that use of the Vocabulary and Block Design subtests may alone be sufficient to infer cerebral laterality.

Levy's format, one which has assumed a primary role in the study of cerebral laterality, exhibits all of the previously mentioned problems. To recapitulate, difficulties exist when one considers the selectivity of her subjects, the use of self report to classify handedness as a dichotomous rather than continuous variable with no consideration of strength of preference. It is felt that use of handedness alone is insufficient when measures of foot and eye dominance would provide additional generalizations to linguistic laterality, thereby increasing the validity of such generalizations. Briggs, Nebes and Kinsbourne (1976) have suggested that, rather than reliance upon handedness alone, subjects should be classified as to strength of preference for their right and left hands. Thus, the contribution of ambidextrality would be determined. Annett (1970) felt it is those individuals "who have not developed any lateral preference [ambidextrals] who are most deviant from the right handed pattern, e.g. they are most likely to have bilateral language representation." (p. 317). A potential area of difficulty lies in Levy's use of all subtests of the WAIS when use of the Vocabulary and Block Design subtests, both with highest loadings on verbal and perceptual factors, may have sufficed.

Given the above problems, it was the purpose of the present study to attempt a replication of Levy's methodology and results using the self report of handedness, but with the following deviations from her procedure. Firstly, children were used as subjects. At the age of two years, left hemispheric lesions have been found to result in greater language impairment than with lesions of the right hemisphere. Language appears to be quickly lateralized in either the left or right hemisphere by the age of five years. Evidence exists which has signified that children five years of age and over depend very little upon the right hemisphere for language (Krashen, 1973). The same percentage of brain injuries to the right hemisphere resulting in aphasia found in adults were found with older children. Such results have been supported by dichotic listening scores in which the right ear shows an increasing advantage over the left for verbal material by four or five years (Kimura, 1967).

Use was made of the Vocabulary and Block Design subtests of the Wechsler Intelligence Scale for Children - Revised (WISC-R). It was questioned whether use of these two subtests would be sufficient to produce a pattern of results similar to those of Levy (1967) who used the entire Wechsler Scale. Lastly, a well documented measure of hand, foot and eye dominance as well as the self report of handedness was used to differentiate left and right dominant groups. This test included most of the six primary activities identified by Annett (1970).

It was hypothesized that a relation should exist between the self report of handedness and performance on the Vocabulary and Block Design subtests. Right handers were expected to exhibit significantly higher Block Design (BD) scores than the left handed group. In addition, no significant difference was expected between scores on the Vocabulary (VOC) and Block Design (BD) subtests in the right handed group. Left handers, it was predicted, would evidence significantly lower BD scores than the right handed group, as well as a significant difference between scores obtained on the VOC and BD subtests. The above pattern has been established using the entire Wechsler Adult Intelligence Scale. It was believed that this pattern would also be found when using children as subjects since by eleven years of age lateralization may be complete. Should results fail to conform to the expected pattern, it was felt that support would conceivably exist for theories proposing a culmination of cerebral dominance development at or beyond puberty.

Groups designated through hand, foot and eye dominance were expected to produce results paralleling those of the self report of handedness group. However, the discrepancies in general between groups on the VOC and BD subtests were expected to be more exaggerated than those of the self report group. A dominance measure which includes foot and eye as well as handedness tasks, it was felt, would prove to be more valid for inferring patterns of linguistic dominance. Any measure used which takes the continuous nature of handedness into account, and which provides an index as to strength of preference, will succeed in differentiating true left handers from ambidextrals. The "weeding out" of left handers with strong right preferences was expected to account for amplification of differences between scores on verbal and visuo-spatial tasks as well as between experimental and control groups.

Finally, a relationship between strength of preference and visuo-spatial performance (BD) was expected. The stronger the preference for the left hand, the worse should be the expected performance upon tasks requiring visuo-spatial skill.

Method

Approach

The purpose of the present study was to investigate the possible relationship between hand, foot and eye dominance, and performance on appropriate verbal and visuo-spatial tasks.

Subjects

The subject population consisted of all 5th grade children of the Owasso and Jenks public school systems for a total of 632. From this population, a total of 39 subjects, 21 left handers and 18 right handers, were randomly selected on the basis of self report.

Apparatus

A short questionnaire was used for self report of handedness (see appendix). Hand, foot and eye preferences were assessed using the Harris Test of Lateral Dominance (Psychological Corporation). This test includes measures of hand preference, simultaneous writing, handwriting, tapping, dealing cards, strength of grip (optional, total eye dominance, kicking, stamping and total foot dominance.* The Vocabulary subtest of the Wechsler Intelligence Scale for Children - Revised (WISC-R) was used to assess linguistic functioning of the left hemisphere. The Block Design subtest of the WISC-R was used to assess the visuo-spatial abilities of the right hemisphere.

Procedure

A short (5 minute) questionnaire was administered within the classes of all 632 5th grade students of the Jenks and Owasso school districts. Students were instructed to answer questions with either "left hand" or "right hand", whichever hand they used best. Questionnaires were coded to insure anonymity. 20 left handers and 20 right handers were randomly selected from their respective groups through of the Table of Random Numbers. Subject mortality and inadvertent substitution yielded groups of 21 left and 18 right handed subjects.

*The test is to be used with subjects at and above seven years of age.

Subjects were then individually administered the Block Design, Vocabulary subtests of the WISC-R and the Harris Test of Lateral Dominance in one half-hour sitting.

The Harris Test reports a C reliability coefficient (coefficient of contingency) of .894 on the hand dominance tests. Split half reliabilities on these tests (Spearman-Brown formula) using 100 records of unselected nine year old children, were .85 for test 2 and .88 for test 3. Test-retest reliabilities based upon group administration in college classes with groups ranging from 65 to 124 subjects was reported as .83 for test 3; .76 for test 4; and .75 for test 5 with a 20 second limit.

The reliability of the eye dominance tests was computed, again using the above sample of unselected nine year old children. The coefficient of contingency yielded an estimated rating of .83 for total eye dominance.

Face validity is assumed to exist. Concurrent validity is supported by Harris through statements which document the sensitivity of hand dominance tests to the presence of mixed dominance and directional confusion. Eye and foot dominance tests are adaptations of tests which have been in use for some time and were felt by Harris to be neither better nor worse than existing tests of similar nature. Harris cites evidence of the existence of construct validity from the results of a study in which clinical cases of reading disability, as a group, were clearly distinguishable from unselected school children by their performance upon the hand dominance tests. The eye and foot dominance tests were not found to differentiate these groups.

The Harris Test of Lateral Dominance yields scores only in the form of Likert - type ratings of handedness. Ratings on the Harris Test range from strongly left handed, through mixed left, mixed and mixed right to strong right handed. In order to obtain a numerical score for statistical and comparative purposes, an Index of Strength of Preference was computed according to the method devised by Berman (1971). There were a total of twelve tasks involving thirty-one measurements of hand, foot and eye dominance. Eighteen were for hand dominance, ten were for eye dominance and three were for foot dominance. Total right and left responses for each area were calculated and total right minus total left scores for each body area were obtained. This produced a total differential score for each body area measured. (Berman, 1971).

To compensate for the different numbers of tasks in each area, the foot dominance differential was multiplied by 6.0 and the eye dominance differential by 1.8. This allowed each subject a maximum potential score of 18.0 in each body area. To eliminate negative numbers, +54 was added to each score resulting in a range of scores from 0 (responses for tasks being all on the left side of the body), to 108 (responses for tasks being all on the right side of the body). For purposes of group comparison a division of scores was made such that scores of 0 - 35.70 (0% - 29%) were designated as left dominant, 35.64 - 71.28 (30% - 70%) as mixed dominant and 71.28 - 108.0 (71% - 100%) as right dominant. These divisions were based on percentages suggested by Harris (1974).

Results

Comparison of the Characteristics of Subgroups

Examination of Table I shows the distribution of subjects into left, right and mixed categories as a function of the self report of handedness and scores on the Harris Test of Lateral Dominance. It may be noted that the Harris Test was responsible for the identification of many self-styled strong left and right handers who were, in fact, mixed dominants (15 subjects) when foot and eye dominance were also taken into consideration.

Table I

Distribution of Ss into Left, Right and Mixed Groups as a Function of Self Report (SR) and the Harris Test of Lateral Dominance (HT).

	Left Dominant			Mixed Dominant			Right Dominant		
	M	F	Tot	M	F	Tot	M	F	Tot
HT	6	7	13	7	8	15	8	3	11
SR	11	10	21	0	0	0	10	9	18

Note. N = 39

Further examination of the data (see Table II) indicated the number of self reported left handers who were in fact strongly right dominant (2), as well as mixed dominant (6). Self reported right handers were also redistributed when foot and eye dominance was taken into account. Here it was found that 9 subjects were actually mixed dominant.

Table II

The Distribution of Self Report (SR) groups into Left, Right and Mixed Dominant Groups as a Function of Harris Test Scores (HT).

		HT Groups			
		L[a]	M[b]	R[c]	Total
SR	L	13	6	2	21
Groups	R	0	9	9	18
	Tot.	13	15	11	N = 39

[a]Left = Harris scores of 0 - 35.70

[b]Mixed = Harris scores of 35.71 - 71.27

[c]Right = Harris scores of 71.28 - 108.00

Lateral Dominance and Task Preference

It was hypothesized that self reported (SR) left and right handers, as well as left and right dominant groups based upon Harris Test scores (HT) should evidence no significant difference between their Vocabulary (VOC) scores, but that a significant difference should exist between the groups when considering their Block Design (BD) subtest scores. Left handers (SR) and the left dominant (HT) groups were expected to 1) show a significant difference between their VOC and BD subtests, and 2) obtain significantly lower BD scores than the SR right handed and HT right dominant group. This pattern of results was obtained by Levy when use was made of the Wechsler Adult Intelligence Scale, adult subjects and the self report of hand preference. Use of a more objective measure of handedness as well as foot and eye dominance (the Harris Test of Lateral Dominance) was expected to ellicit a similar, although more exaggerated, pattern of differences between left and right dominant groups.

Mean scores on the VOC and BD subtests of the Wechsler Intelligence Scale for Children - Revised (WISC-R) are summarized in Table III.

Table III

Mean Number of Correct Responses on the VOC and BD Subtests as a Function of the Self Report of Handedness (SR) and Harris Test Scores (HT).

	$\bar{X}$ VOC			$\bar{X}$ BD			
	L	M	R	L	M	R	
SR	9.48	----	9.56	9.57	----	9.33	
HT	10.15	8.33	11.18	9.85	8.60	10.46	N = 39

Pearson r correlations were calculated to estimate the strength of relationships between 1) left, mixed and right dominant groups (HT) and VOC scores; 2) left, mixed and right dominant groups (HT) and BD scores; as well as between 3) left, mixed and right dominant groups (HT) and the difference between VOC and BD scores (see Table IV).

Table IV

Pearson r Correlations Between Harris Test Scores and VOC, BD Subtest Scores, and the Difference Between VOC and BD Subtest Scores.

	VOC	BD	Difference	
HTL	-.33	-.33	.39	N = 13
HTM	.13	.48	.31	N = 15
HTR	.02	.003	-.28	N = 11

All groups failed to evidence significant correlations between hand, foot and eye preference and performance on the VOC and BD subtests. Any difference between groups, then, are most likely the result of chance factors.

The Student - T test was then used to assess the significance of existing differences between the VOC scores of right handers (SR) and left handers (SR). Left handers, as was expected, did not differ significantly from right handers on this subtest ($t = .0947$, $df = 37$).

Contrary to expectation, comparisons between scores on these subtests did not yield a significant difference between right and left groups (SR and HT). Differences between the BD scores of the right handed (SR) and left handed (SR) groups also failed to reach significance ($t = .0900$, $df = 37$). This pattern was repeated by the HT left and right groups in which the difference between right dominant (HT) and left dominant (HT) VOC scores failed to reach significance ($t = -1.245$, $df = 22$). Left and right dominant (HT) BD scores also exhibited a nonsignificant relationship ($t = .3159$, $df = 22$).

Discussion

Comparison of the scores of right, mixed and left dominants as designated by the self report of handedness (SR), and the Harris Test of Lateral Dominance (HT) to scores obtained on the Vocabulary (VOC) and Block Design (BD) subtests of the WISC-R, revealed no significant correlations between lateral preference groups. Contrary to expectation, when foot and eye dominance as well as handedness were taken into consideration, left dominant groups (SR and HT) did not exhibit the predicted discrepancies between their scores on the VOC and BD subtests. These findings did not support Levy's original data or predictions. It may be argued that the use of the entire WISC-R would have provided a more valid estimate of hemispheric functioning. However, other results (Berman, 1971; Briggs, Nebes and Kinsbourne, 1976) have indicated that use of all Wechsler scales does not produce score patterns which would suggest a performance superiority of right over left dominants on the Performance subscales.

A second factor of significance associated with these findings is the distribution of handedness. Most studies have relied upon self report as a basis of division into discrete left and right handed groups. Hand as well as foot and eye preference appears to be a variable of a continuous, rather than dichotomous nature. Gilles, MacSweeney and Zangwill (1960) have noted atypical lateral preference patterns. Left handed writers were described who were found to exhibit right hand preferences for a variety of other activities. Annett (1970) has also reported upon the continuous nature of handedness.

> The question of how the division between right and left is made is of fundamental importance for questions of the relation between handedness and cerebral dominance. This relation is often summarized with the statements that whereas right handers show consistent manual preference and contralateral hemispheric representation of speech, left handers are inconsistent in preference and unpredictable as to side of speech representation. The inconsistency and unpredictability appear to be functions of the 'oddity' of left handers. . . . The fact that more left than right handers appear to violate the rule of contralateral representation is probable a function of the criterion used to separate the two groups. (p. 317).

The extreme variability of groups separated into right and left dominants makes any generalizations to linguistic dominance subject to exceptions. Such variability is revealed through inspection of the data of the present investigation. When foot and eye dominance as well as hand dominance was used to establish the individual's strength of preference, as a continuous variable, scores ranged from 2.0 to 33.0 in the left dominant group, 39.6 to 75.6 in the mixed dominant group, and 81.4 to 108.0 in the right dominant group.

Additionally, based on extensive examination of clinical populations, it is estimated that 50% to 70% of left handed and ambidextrous individuals have linguistic abilities dominant in the right hemisphere. Only 15% of nonright handers tested through injection of sodium amytal into one of the carotid arteries had bilateral speech representation (Searleman, 1977). The indicated existence of such a small population of individuals with bilateral language potential may serve to partially explain the lack of significant findings between lateral preference (SR and HT) groups.

It has been argued that a family history of left handedness is a variable influencing the occurence of bilateral speech representation (Hécaen and Sauguet, 1971). Studies which have failed to discover significant effects between handedness and linguistic laterality have neglected to take familial left handedness into account. The findings of Briggs, Nebes and Kinsbourne (1971), however, did not support Levy's predictions when family history as a variable was considered. Left and mixed handers were not found to be inferior to right handers on visuospatial as compared to verbal abilities. Research also indicates that "a family history of language backwardness is not uncommon, as is also a familial history of left handedness." (Zangwill, 1976, p. 310). These factors working together, it is felt, would most likely have produced sizable differences in scores, whereas consideration of family history of handedness alone would have failed to appreciably alter the nature of the present results.

A final factor, one which appears to be the most likely variable affecting the outcome of the present study, is the subjects' age. Examination of the scores of SR as well as HT groups at this (11 year) age level tends to lend credence to literature which suggests culmination of the development of cerebral laterality does not take place until at least puberty (Lenneberg, 1967; Zangwill, 1960). Satz, et.al. (1975) have indicated that no laterality exists by 5 years, but that there is an increase after age 5 to puberty.

> By adulthood, the functional abilities of the two hemispheres are well differentiated and fixed. . . . The development of essentially normal language skills following the [surgical] removal of either hemisphere in children reflects the equipotentiality and plasticity of the immature brain, whereas the two separate and distinct syndromes following left and right hemispherectomy in adults attest to the specialization and rigidity of the adult brain. (Searleman, 1977, p. 514).

Witkinson (1976) has indicated developmental differences associated with sex. The right hemisphere appears to be more specialized for spatial processing in boys by age of 6 years. Girls, on the other hand, showed bilateral representation in visuo-spatial processing until at least adolescence (13 years). It appears, then, that physical development as well as sex of the subject may account for the lack of significant results at this age. Further research is indicated to investigate this possibility in which measures would be taken at various age levels to determine when or if differences in verbal and visuo-spatial tasks would occur as a function of lateral preference.

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Appendix I

Questionnaire

First name ____.

Last initial ____.

Code number ____.

With which hand do you write your name? _________________.

With which hand do you throw a ball? ____________________.

With which hand would you draw a circle? ________________.

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