DEGREE OF LATERALIZATION, COGNITIVE PERFORMANCE, AND CONJUGATE LATERAL EYE MOVEMENTS

by

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ABSTRACT

The present study examined the relationship between degree of lateralization, cognitive performance and conjugate lateral eye movements (CLEM). Eighty female and 40 male right handed undergraduate university students were given a CLEM test, two spatial ability tests (face recognition and mental rotations), a verbal ability test (similarities) and two dichotic listening tasks (stop-consonants and melodies). The study was divided into two separate experiments. In Experiment 1, it was hypothesized that less lateralization for verbal functions would result in an enhancement of verbal ability and a deficit in spatial ability. It was also hypothesized that less lateralization for music functions would result in an enhancement of spatial ability and deficit in verbal ability. Overall, spatial abilities were found to have little association with degree of lateralization for either verbal or music functions. The exceptions to this were counter to prediction. For verbal ability, on the other hand, the hypotheses were confirmed when subjects with reversed-lateralization were omitted from the analysis. In Experiment 2, two issues were examined. It was predicted that bimovers on the CLEM test, who show a question-type effect, would be more lateralized for verbal and music functions than bimovers who do not show a question-type effect. This hypothesis was not confirmed. It was also hypothesized that right movers would demonstrate superior verbal ability and left movers would demonstrate superior spatial ability. No differences were

observed for verbal ability or one of the spatial tests, face recognition. For the mental rotations test, a sex by CLEM interaction was observed with the pattern for females in the predicted direction and the pattern for males, in the direction counter to prediction. Other relevant findings in this study were higher mental rotation scores for males, superior face recognition ability for females and an overall question-type effect for CLEM.

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CHAPTER I

INTRODUCTION

The mid-nineteenth century discovery by Paul Broca and Marc Dax, that left hemisphere damage may lead to verbal deficits, has generated a vast amount of research on cerebral lateralization. This area of research has blossomed to the point where a search of the last 4 years of the Psychological Abstracts revealed over 6,000 published articles. The majority of these studies have examined differential specialization of the right and left hemispheres for various perceptual, cognitive and personality variables.

Overall, the research has demonstrated strong and consistent evidence for specialization of the left hemisphere for verbal processing. The evidence for right hemisphere specialization has been somewhat more equivocal (Bradshaw and Nettleton, 1981). However, generally the studies have found right hemisphere specialization for nonverbal abilities such as spatial and music processing. Despite the apparent stability of these findings, closer examination of any of these studies always reveals wide individual differences, both in direction and particularly in degree of asymmetry. Degree of cerebral lateralization, or functional hemispheric asymmetry, as it is sometimes called, refers to the idea that individuals may differ in the degree to which a particular function is lateralized to one hemisphere. As Allen (1983) points out, there are several interpretations of this concept. One view states that less lateralization refers to relatively equivalent functions in both hemispheres, for a given individual, that is, the right and left hemispheres house both verbal and nonverbal functions. A variant of this approach suggests bilateralization for only one of these functions. More recent research in this area suggests that degree of lateralization may vary for each type of ability (e.g., verbal, spatial and music) and perhaps even for specific tests of a given ability (e.g., face recognition versus mental rotation). This may be especially true in light of recent evidence suggesting that cognitive abilities such as spatial processing, may not be a unitary process. Thus, a person may be less lateralized than others on one ability (e.g., verbal) and more lateralized than others on another (e.g., spatial).

Experiment 1

In most instances, less lateralization has been viewed negatively. For example, in the late nineteenth century, the idea that less lateralization reflected inferior intellectual status had become accepted in the medical literature (Harrington, 1987). In 1880, the noted English neurologist, H. Charlton Bastian suggested that greater lateralization was associated with more advanced evolutionary development. The white races, males as opposed to females, and adults as opposed to children, were all thought to have greater asymmetry and therefore greater intellectual capacity (Harrington, 1987). For the most part, a negative conception of less lateralization still persists today. Less lateralization has been associated with spatial deficits (Levy, 1969), field dependence (Witkin, Goodenough and Oltman, 1979), dyslexia (Hynd and Cohen, 1983; Orton, 1937), stuttering (Springer and Deutsch, 1989), psychopathy (Raine, Obrien, Smiley, Scerbo and Chan, 1990), and less advanced evolutionary development (Levy, 1969, 1974).

Perhaps the most influential theory in this regard is the "crowding" effect suggested by Levy (1969, 1974). According to Levy (1974), each hemisphere typically has its own neural patterning. The left hemisphere's neural organization lends itself to "temporal analysis, abstract conceptualization, detailed feature detection, linguistic coding and phonological analysis"(p. 167). The right hemisphere's neural organization is suited for activities such as gestalt-spatial synthesis, binocular depth perception and imagistic sensory coding. These two sets of functions may be logically incompatible as only one type of neural patterning may be able to exist in one hemisphere. If language is represented on both sides of the brain, then a "crowding" effect will occur in the right hemisphere where spatial abilities reside. This results in reduced spatial ability since both verbal and spatial functions are tapping the same limited processing space. Verbal ability, on the other hand, may be enhanced by this arrangement since the neural organization of both hemispheres may facilitate this type of processing. As Levy (1974, p. 173) states, "It would appear that the possession of 'two left hemispheres' improves those skills dependent on the left hemisphere, relative to the performance achieved by a single, fully lateralized left hemisphere. Lateral specialization does not optimise each set of capacities individually, but optimises some joint function of the sets. The laterally specialized person is, in this sense a generalist, while the laterally non-specialized person is a specialist". This theory has become particularly popular because of its attempt to account for the apparent deficit of spatial skills in females.

In a later revision of this theory, Levy and Gur (1980) also suggest that less lateralization of spatial processing results in a crowding effect for verbal ability. That is, if someone has bilateral representation of spatial functions, this results in spatial and verbal functions both competing for the same processing space in the left hemisphere. This latter aspect of the theory has received little attention however. The most common approach to studying Levy's theory of crowding has been to look at select populations where "less lateralization" is thought to be more prevalent. Given that there appears to be very little agreement among researchers as to whether a population exists that demonstrates less lateralization for spatial functions, few attempts have been made to study this aspect of her theory.

One approach to testing the crowding hypothesis has been to study the cognitive performance of subjects from populations where less lateralization for language is thought to be more common, left handers and females.

Handedness

In Levy's (1969) original study, the Wechsler Adult Intelligence Scale (WAIS) performance and verbal scores of 15 right and 10 left handed male graduate science students were compared. The right handers scored significantly higher than left handers on the performance scale of the WAIS; however there were no observed differences on the verbal scale. Furthermore, the discrepancy between the verbal and performance scores was considerably larger for the left handed group. Levy interpreted these findings as support for her theory since left handers, who are thought to have more bilateral representation for language, performed more poorly on the spatial tests. Furthermore, a reanalysis of the data (1974) also revealed that left handers performed significantly better on verbal ability.

Subsequent attempts to replicate this experiment, with the WAIS, one or more of its subtests or its equivalent for children (WISC), have offered little support for Levy's theory. Most of these studies, several with much larger sample sizes and subjects of both sex, have failed to find any significant differences (Annett and Turner, 1974; Berry et al., 1980; Briggs, Nebes and Kinsbourne, 1976; Fagin-Dubin, 1974; Gibson, 1973; Gilbert, 1977; Inglis and Lawson, 1984; Johnson and Harley, 1980; Newcombe and Ratcliff, 1973; Otteson, 1980;

Piazza, 1980; Sheehan and Smith, 1986). Of the two exceptions, Epro and Granite (1979) found that right handers had superior performance while Lewis and Harris (1990) found that female left handers had superior performance. No handedness differences were observed for the males.

Overall, the evidence from handedness and spatial ability studies offers little support for Levy's theory. Table 1 shows the type of spatial tests, subject characteristics and results of all the studies which have examined this issue to date. Studies that used field dependence measures as spatial tests (e.g., Rod and Frame Test and Embedded Figures Test) are not included since the evidence on whether these are truly spatial tests is mixed. There appears to be no systematic relationship between handedness and spatial ability according to subject or task characteristics. Of the 52 studies examining various aspects of handedness and spatial ability, 8 found clear evidence favoring right handers, 3 found clear evidence favoring left handers and 27 found no differences.

Several studies have reported mixed findings with regard to right versus left handedness. Yen (1975) found that male right handers demonstrated superior spatial performance while no differences were found for females. Conversely, McGee (1976) found the opposite, with female right handers showing superior spatial performance and no differences for males. More recently, Lewis and Harris (1990) found left handed females superior on three spatial tests. Males, on the other hand, showed no

Table 1

Handedness and Spatial Ability

Author	Subject	Spatial Measure	Results
Silverman, Adevai and McGough, 1966	12 right handers and 10 left handers	Mirror Tracing	R > L
Levy, 1969	15 right and 10 left handed male graduate students	WAIS	R > L
Miller, 1971	29 right and 23 mixed handers	NIIP Form Relations	R > L
Nebes, 1971	Sample 1 - 10 right and 10 left handed graduate students Sample 2 - 8 male and 8 female right	Nebes' arc-circle	Sample 1 - R > L Sample 2 - R > L

Table 1 continues

Author	Subject	Spatial Measure	Results
	handed and 8 male and 8 female left handed undergraduate students		
Gibson, 1973	132 right handed and 13 left handed academic scientists	WAIS	n.s.
McGlone and Davidson, 1973	25 male and 24 female right handers and 28 male and 22 female left handers	PMA	R > L (only for L with a higher left ear score on verbal dichotic listening)

Table 1 continues

Author	Subject	Spatial Measure	Results
Newcombe and Ratcliffe, 1973	302 male and 356 female right handers and 15 male and 11 female left handers and 92 male and 47 female mixed handers	Digit Symbol BD Object Assembly	n.s.
Annett and Turner, 1974	224 left and right handed children of both sex	WISC Maze	n.s.
Fagin-Dubin, 1974	20 left and 12 right handed children from 5 to 6 years old	WISC	n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
Petersen and Lansky, 1974	405 right and 79 left handed architecture students	Maze drawing	L > R
Kutas, McCarthy and Donchin, 1975	Sample 1 - 35 right and 17 left handers of both sex Sample 2 - 20 right and 19 left handers of both sex Sample 3 - 14 right and 14 left handers of both sex	Nebes' arc-circle	Sample 1 - n.s. Sample 2 - n.s. Sample 3 - n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
Yen, 1975	1241 female and 1236 male high school students	PMA Space Relations Form Board Paper Folding Mental Rotations	Males - R > L Female - n.s.
Briggs, Nebes and Kinsbourne, 1976	204 subjects balanced for sex and handedness	WAIS Closure Speed Cube Comparison	n.s. for R versus L or Mixed and Familial
Carter-Saltzman, Scarr-Salapatek, Barker and Katz, 1976	399 twin-pairs of both sex and handedness (children)	Raven Progressive Matrices	n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
Hardyck, Petrinovich and Goldman, 1976	7686 right and left handed children	Lorge-Thorndike Intelligence Test	n.s.
McGee, 1976	13 male and 6 female left handers and 33 male and 60 female right handers	Mental Rotations	Females - R > L Males - n.s.
Gilbert, 1977	64 right and left handers of both sex	Face Recognition BD Object Assembly	R versus L -n.s. FS+<FS- on Face Recognition
Hardyck, 1977	64 undergraduates of both sex and handedness	Nebes' arc-circle	n.s. for R versus L and Familial

Table 1 continues

Author	Subject	Spatial Measure	Results
Eme, Stone and Izral, 1978	13 male and 9 female right handers and 6 male and 5 female left handers (6 - 14 years old)	BD Object Assembly	FS+ left handed< right handed on composite spatial score
Fennell, Saltz, Van Den Abell, Bowers and Thomas, 1978	Sample 1 - 28 right handed and 42 left handed high school students Sample 2 - 41 right handed and 41 left handed college students	BD PMA	Sample 1 - n.s. Sample 2 - n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
Herrmann and Van Dyke, 1978	12 right and 12 left handed college students of both sex	Mental rotation of patterns	L > R
Epro and Granite, 1979	23 female and 17 male right handers and 8 female and 4 male left handers	BD	R > L
Sherman, 1979	Sample 1 - 39 female and 17 male right handed and 29 female left handed grade 9 students Sample 2 - 28 female and 18 male right handed and 11 female	DAT Space Relations	Sample 1 - n.s. Sample 2 - n.s. Sample 3 - n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
	and 18 male left handed grade 10 students		
	Sample 3 - 33 female and 28 male right handed and 10 female and 27 male left handed grade 11 students		
Berry, Hughes and Jackson, 1980	10 male and 10 female left handers and 10 male and 10 female right handers	BD	n.s.
Birkett, 1980	21 male and 31 female left handers and 33	Diagrammatic Section of AH4	n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
	male and 40 female right handers	Intelligence Test Form Board DAT Space Relations	
Gregory and Paul, 1980	12 right handed, 12 non-inverted left handed (LN) and 12 inverted left handed (LI) males	Tactual Performance Trail Making WAIS	n.s. LI is <LN and R LI is <LN and R on Picture completion n.s. on overall WAIS Performance and Subtest
Gregory, Alley and Morris, 1980	10 male and 10 female inverted left handers (LI)	DAT Space Relations	LI is < LN and RN

Table 1 continues

Author	Subject	Spatial Measure	Results
	31 male and 33 female non-inverted left handers (LN) 34 male and 32 female non-inverted right handers, (RN)		
Johnson and Harley, 1980	30 male and 30 female right handers and 30 male and 30 female left handers	BD	n.s.
		Picture Arrangement	n.s.
		Spatial Thinking	Strong L<R and weak L
Otteson, 1980	64 male and 72 females	Object Assembly	n.s.
		BD	n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
Piazza, 1980	16 male and 16 female right handers and 16 male and 16 female left handers	BD	n.s. for R versus L and Familial
Swanson, Kinsbourne and Horne, 1980	18 left and 18 right handers of both sex	PMA	n.s.
Bradshaw, Nettleton and Taylor, 1981	24 male and 24 female right handers and 24 male and 24 female left handers (balanced for FS)	WAIS	FS+ L < FS- L, FS+ R and FS- R
Freedman and Rovegno, 1981	20 male and 20 female right handers and	Mental Rotations	R > L

Table 1 continues

Author	Subject	Spatial Measure	Results
	20 male and 20 female left handers		
Porac and Coren, 1981	1283 undergraduates	Mental Rotations	Dichotomous method - L > R Strong R versus mixed and L - n.s.
Burnett, Lane and Dratt, 1982	124 females and 229 males	Spatial Visualization	L > R Sex X Familial X Hand Cubic Interaction
Sanders, Wilson and Vandenberg, 1982	565 European, 221 Japanese and 93	Mental Rotations Card Rotations	Males - L > R Females - R > L

Table 1 continues

Author	Subject	Spatial Measure	Results
	Chinese subjects of both sex (L, mixed and R)		Sex X Handedness X Ethnicity Interaction
Charlton, 1984	40 male and 40 female right handers and 16 male and 16 female left handers	Perceptual Organization Test	n.s.
Inglis and Lawson, 1984	847 male and 863 female right handers and 93 male and 77 female left handers (16 to 74 years old)	WAIS-R	n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
Bryden, 1986	30 male and 30 female right handers and 30 male and 30 female left handers	Form Board Mental Rotations	n.s. for R versus L or Familial
McKeever, 1986	225 right handers and 134 left handers of both sex	Stafford Identical Block Test	R > L
Sheehan and Smith, 1986	25 strong-right, 20 weak-right, 8 strong-left and 14 weak-left handed boys aged 11-13.	PMA BD Ravens Progressive Matrices	n.s.

Table 1 continues

Author	Subject	Spatial Measure	Results
O'Boyles and Hoff, 1987	15 male and 15 female right handers and 15 male and 15 female left handers	Mirror Tracing	Sex by Handedness by Hand-used interaction
Ardila, Correa, Zuluaga and Uribe, 1988	8 right handers, 8 left handers and 8 forced left handers (FL)	DAT Space Relations	FL < R or L R versus L - n.s.
French and Attree, 1989	107 female and 22 males	NFER General Ability Tests	n.s.
Levander, Schalling and Levander, 1989	49 male and 53 female right handers	Perceptual Maze Test	L > R

Table 1 continues

Author	Subject	Spatial Measure	Results
	and 48 male and 54 female left handers		
Lewis and Harris, 1990	14 male and 14 female right handers and 14 male and 14 female left handers	Mental Rotations	Females - L > R Males - R > L
		Water Level	Females - L > R Males - n.s.
		BD	Females - L > R Males - n.s.

Table 1 continues

NOTE. BD = Block Design; WAIS = Wechsler Adult Intelligence Scale; PMA = Primary Mental Abilities; WISC = Wechsler Intelligence Scale for Children; FS+ = Familial Sinistrality; FS- = No Familial Sinistrality; DAT = Differential Aptitude Test; R = Right; L = Left.

handedness differences on two of the tests and right handers were superior on the third. Several complex interactions involving sex and handedness have also been reported, with ethnicity (Sanders et al., 1982), reasoning (Harshman, et al., 1983), familial sinistrality (Burnett et al., 1982) and hand-used (O'Boyle and Hoff, 1987) as third variables. Despite the few studies that have reported sex differences, it should be noted that most studies have not found sex differences.

In addition to studies examining conventional comparisons between right and left handedness, several studies have looked at variables related to handedness. Inverted writing position, forced left handers, strength of handedness and familial sinistrality have all been examined. Of these, familial sinistrality has received the most attention. Two studies (Bradshaw et al., 1981; Eme et al., 1978) have found that left handers with familial sinistrality have inferior spatial ability. However several others (Briggs et al., 1976; Bryden, 1986; Hardyck, 1977; Piazza, 1980) have found no differences. One variable that warrants greater consideration is the type of scoring method used to determine handedness. Porac and Coren (1981) found left handers superior to right handers on the mental rotations test when they used a dichotomous scoring method. However, these differences disappeared when the subjects were classified as extreme right handed versus non-right handed (weak right, ambilateral and left handed).

Studies on handedness and other cognitive abilities have also reported few differences. In their review of handedness, Hardyck and Petrinovich (1977) cite 14 studies examining the relationship of handedness to reading ability. Of these, 13 found no differences(Allison, 1966; Balow, 1963; Balow and Balow, 1964; Coleman and Deutsch, 1964; Dearborn, 1931; Gilkey and Parr, 1944; Hildreth, 1934; Koos, 1964; Sabatino and Becker, 1971; Wittenborn, 1946; Witty and Kopel, 1936; Wolfe, 1941 a,b; Woody and Phillips, 1934) and one found superiority for left handers (Jones, 1944). Similar findings have been reported with other verbal tests. No differences have frequently been reported with tests such as the WAIS and Peabody Picture Vocabulary Test (Annett and Turner, 1974; Caplan and Kinsbourne, 1981; Eme et al., 1978; Fagin-Dubin, 1974; Hardyck et al., 1976; Heim and Watts, 1976; Hicks and Beveridge, 1978; Inglis and Lawson, 1984; Johnson and Harley, 1980; McKeever and Van Deventer, 1977; Miller 1971; Natsopoulos and Xeromeritou, 1985; Nebes, 1976; Newcombe and Ratcliff, 1973; Sanders et al., 1982; Sheehan and Smith, 1986; Sherman, 1979).

Testing the crowding hypothesis by looking at the cognitive performance of left and right handers may be problematic. Although estimates vary, data from sodium amytal testing suggests that 95 to 99 percent of right handers compared to 70 percent of left handers show left hemisphere language lateralization (Rasmussen and Milner, 1975). Of the remaining left handers, half are thought to have bilateral representation of language and the other half, reversed lateralization, that is the right hemisphere is specialized for language and the left hemisphere for nonverbal functions. Given that only 15 percent of left handers are less lateralized for language, handedness may not be a sensitive enough measure. Furthermore, it is difficult to determine whether any cognitive differences, should they exist, are attributable to the 15 percent of subjects who are less lateralized or the 15 percent who have reversed lateralization.

Sex Differences

A complete review of the studies examining the relationship between sex and cognitive abilities is beyond the scope of this paper. The three cognitive abilities most often examined, in this regard, are verbal, mathematical and spatial abilities. In general, females have traditionally been thought to be superior at verbal skills while males have been considered superior at mathematical and spatial abilities (Halpern, 1986; Maccoby and Jacklin, 1974). However, more recently reviews of the literature have begun to question these reports.

Hyde, Fennema and Lamon (1990) performed a meta-analysis of 100 studies on gender differences in mathematics performance. Their review revealed that developmental trends and the type of mathematics task are important considerations. Females were found to be superior at computation in the elementary and middle school years, however this difference disappeared beyond this age group. For understanding of mathematical concepts, no differences were observed at any age level. During the elementary and middle school years, females demonstrated a very slight advantage for problem solving. This shifted to a moderate advantage for males at the high school and college levels. These authors concluded that where gender differences occur, they are small in magnitude. Also, they reported that studies showing greater differences are usually looking at more selective populations such as college students, graduate students and mathematically precocious individuals. When general, unselected populations were examined, there was a slight advantage favoring females.

To further complicate this issue, Kimball (1989), in her review of mathematics achievement, presents an interesting contradiction to the often cited male advantage for some types of math ability. She reported that girls at the junior high and high school level usually have superior math grades. To some extent, this pattern continues at the university level with the research showing either a female advantage or no differences. Overall, on the basis of these reviews, it seems safe to conclude that the traditionally reported male advantage for mathematical ability is less robust than previously thought.

The research on gender differences in verbal ability has yielded similar results. In a meta-analysis of 165 studies, Hyde and Linn (1988) examined the effect size of studies looking at vocabulary, analogies, reading comprehension, essay writing, anagrams and general verbal ability. Females generally showed a slight advantage on most of these tests with the largest difference being speech production. However, given the small effect sizes, Hyde and Linn concluded that gender differences in verbal ability are virtually nonexistent. Furthermore, no developmental trends were observed.

The cognitive ability which has received the most attention with regard to the crowding hypothesis is spatial ability. It has often been argued that females have inferior spatial skills because of the crowding effect resulting from their bilateral representation of language. However several recent reviews have questioned the existence of gender differences in spatial ability. As with other cognitive abilities, the magnitude of the differences, developmental trends, and the type of spatial task need to be considered.

According to Caplan, MacPherson and Tobin (1985), only about half the studies on sex differences and spatial ability report significant differences, though usually in favor of males. In addition, they point out that these differences tend to be low in magnitude and specific to only some spatial ability tests.

Linn and Petersen (1985) performed a meta-analysis on three different predetermined categories of spatial tasks, spatial perception, mental rotation and spatial visualization. Spatial perception included tasks such as the rod and frame test (RFT) and water level task. They reported small differences on these tasks, favoring males. The mental rotation classification included tasks such as the mental rotation test (Vandenberg and Kuse, 1978), the spatial test from the PMA and the Flags and Cards from the French Kit. This classification yielded large gender differences with males especially superior on the mental rotation test. The spatial visualization category included tasks such as the embedded figures (EFT), block design, hidden pictures, paper folding, paper form board and the spatial tests from the DAT and the Guilford-Zimmerman. No differences in effect size were observed for this category. Also, overall, the authors concluded that where gender differences were observed, the differences existed across the life span.

The Linn and Petersen results should be viewed with some caution, however. The possible drawback to their analysis is the use of predetermined categories for spatial tasks. While a classification scheme of this sort may be useful for helping us conceptualize how all the different tests relate to one another, there is very little consensus in the literature as to how many categories there are, the nature of the categories or how we should determine the categories. Indeed, the main problem that haunts the spatial ability literature is the vast number of spatial ability tests and their often low correlations with one another. A further qualification, may be their use of so many field dependence tests. While tests such as the EFT, RFT and HPT may have a spatial component they were primarily designed to test field dependence and may also involve other components.

Overall, the reviews of gender differences suggest that while there is an advantage for males on some spatial ability tests, the magnitude of most of these differences is small. The spatial test which usually yields the greatest gender differences is mental rotations. One possible exception, which was not addressed in the reviews, is face recognition. Several studies have found that females are better than males on face recognition (Bahrick et al., 1975; Gilbert, 1977; Witryoll and Kaess, 1955). This poses an interesting problem for the crowding hypothesis. Why should crowding of the right hemisphere lead to inferior spatial skills on only a few spatial tests and possibly superior skills on at least one spatial test (De Renzi, 1983)?

Along similar lines, if the crowding hypothesis is correct, than we should expect to find deficits in other nonverbal abilities that are typically associated with the right hemisphere. There have been very few studies examining the relationship between gender and music abilities. However, where differences have been reported, they have usually been small (Shuter-Dyson and Gabriel, 1982).

Studies comparing males and females on cognitive performance may also be problematic. This avenue of research depends on the assumption that females are less lateralized for language. Although most of the studies on sex differences and cerebral lateralization argue that females are less lateralized (Lewis and Christiansen, 1989), this notion is not universally accepted. A considerable number of studies have reported no sex differences. For example, approximately half of the verbal dichotic listening studies have not found significant differences for sex. Where differences are reported however, they almost always report that males are more lateralized (Springer and Deutsch, 1989). Another note of caution is that when significant differences are reported it is usally due to males showing significant asymmetries while females do not show significant asymmetries. According to Segalowitz (1983), most studies have failed to examine the interaction between sex and degree of laterality and when they have, the interaction has rarely been significant. Given these considerations, some researchers (Fairweather, 1976; Kimball, 1981) have suggested that there are no convincing sex differences in cerebral lateralization. Despite these qualifications, the prevailing attitude is that females are less lateralized for language, and perhaps for spatial abilities (McGlone, 1980; Segalowitz, 1983; Springer and Deutsch, 1989). It should be noted however, that Levy herself, views males as less lateralized for spatial processing (Levy and Gur, 1980).

Perceptual Laterality

To date, there have been surprisingly few studies that have attempted to directly examine the relationship between degree of lateralization and cognitive performance. In most cases, studies that have examined the relationship between laterality and cognitive performance have looked at direction rather than degree of lateralization. In other instances (e.g., Fennell et al., 1978), direction and degree of laterality have been confounded such that no definitive conclusions can be drawn about either.

Of the few exceptions, a study by Birkett (1980) looked at the relationship between handedness, perceptual laterality and spatial ability. Twenty one male and 31 female left handers and 33 male and 40 female right handers were administered a visual half-field test for delayed form recognition and three spatial ability tests, the diagrammatic section of the AH4 general intelligence test, the spatial relations test of the DAT, and the revised Minnesota paper form board test. Of the four handedness by gender subgroups, only left handed males showed a relationship between degree of lateralization and spatial ability. More lateralized subjects, in either direction (left or right hemisphere superiority), had higher scores on the AH4 test.

One problem in drawing inferences from this study however, is that males in both handedness groups did not show an asymmetry on the form recognition test. Females, on the other hand, showed a right visual field advantage, suggesting left hemisphere processing. This study, and a number of other tachistoscopic (Hannay, Rogers and Durant, 1976) and brain damage studies (Bisiach and Faglioni, 1974; Faglioni and Spinnler, 1969), bring into question whether delayed form recognition is a visuospatial task that is processed by the right hemisphere, left hemisphere or both. Thus, it would be difficult to ascertain from this, which function is supposed to be crowded or interfered with.

A recent study by Kraft (1983), examined the relationship between degree of lateralization and cognitive performance with 12 to 14 year old children. One hundred and sixteen right handers were given two dichotic listening tests, a verbal test using digits and a nonverbal test using environmental sounds. They were also administered nine subtests from the revised Wechsler Intelligence Scale for Children (WISC-R). No relationship was observed for verbal or nonverbal degree of lateralization and verbal and nonverbal cognitive performance.

In another study with 10 to 16 year old children, Waber (1977) gave 40 males and 40 females a dichotic test of phoneme identification and three verbal and three spatial tests. The three verbal measures were digit symbol, PMA word fluency and Stroop color naming while the three spatial measures were block design, PMA spatial ability and embedded figures. No relationship was observed between degree of lateralization and any of the cognitive performance measures.

In an unpublished study by Bryden (1979, cited in Bryden, 1980), 20 female and 20 male left handers were administered the space relations and verbal reasoning subtests of the DAT. Degree of lateralization was assessed by both verbal (stop consonant pairs) and nonverbal (cartoon faces) visual half-field tests. Overall, there was very little support for a relationship between degree of lateralization and cognitive ability. Only two correlations were significant, with superior spatial ability associated with less lateralization for stop consonants in females and superior verbal ability associated with less lateralization for stop consonants in males. The former finding is counter to the prediction of Levy's theory.

Bryden also examined Levy's theory from a slightly different approach. The subjects were classified as either complementary or noncomplementary. Complementary specialization referred to situations where the subjects had opposite asymmetries for the verbal and nonverbal laterality measures. For example, the subject may show left hemisphere lateralization of language and right hemisphere lateralization of nonverbal processing. Noncomplementary specialization referred to situations where the subject showed the same side of lateralization for both verbal and nonverbal laterality measures. For example, the subject may show left hemisphere lateralization for both verbal and nonverbal lateralization measures. It was reasoned that if Levy's assumption is correct, those subjects who have one hemisphere sharing both verbal and nonverbal processing (noncomplementary) should show spatial deficits.

Bryden compared complementary and noncomplementary subjects with respect to scores on the verbal and the spatial ability measures. There was marginal support for the idea that complementary subjects tend to score lower on verbal ability, while noncomplementary subjects tend to score lower on spatial ability. However, as Bryden points out, the results of this study should be viewed with caution in view of a number of methodological problems. Bryden suggested that factors such as low reliability of the measures and experimenter effects hinder our drawing any definate conclusions from the study.

Bryden's alternative approach to studying the crowding hypothesis by looking at complementary and noncomplementary specialization arose from an earlier study by McGlone and Davidson (1973). They tested 30 right and 39 left handed individuals of both sexes, on a visual-half field (dot enumeration) and dichotic listening (verbal memory) test which were thought to involve the right and left hemisphere respectively. A comparison of complementary and noncomplementary subjects revealed no significant differences on the PMA spatial relations test.

Thus, overall there has been very little empirical support for Levy's theory. The few studies which have directly examined this issue offer little support. Similarly, a review of handedness and gender differences studies revealed mixed results with the bulk of the studies reporting nonsignificant results. As noted earlier, indirect studies using handedness or sex as an index of cerebral organization may also be problematic. Given the paucity of direct studies on this issue, more direct studies must be conducted before any conclusions regarding the crowding hypothesis can be reached.

Experiment 2

Another area of research where the concept of degree of lateralization may be important, is conjugate lateral eye movements (CLEM). In 1954, Teitlebaum noted the tendency of subjects to avert their gaze in a horizontal direction during tasks requiring mental concentration. In addition, these conjugate eye movements were found to be consistently to the left or right for a given individual. Day (1964) observed a similar tendency when subjects were asked reflective or thought provoking questions in a face to face interview. Day reported that subjects often turned their eyes to the left or the right when they started to formulate an answer and that individuals showed consistent directional preferences. He also suggested that left movers differ from right movers in certain aspects of personality, cognition and physiology (Day, 1964,1967a,1967b). Among his findings, Day noted that left movers are more attentive to subjective, internal, visceral experience and prefer a passive, auditory mode of attention. They also show greater amplitude and lower frequency EEG. Right movers, on the other hand, are characterized by an active, visual or haptic mode of attention and are more externally directed.

These observed differences and others lead Bakan (1969) to suggest that they may reflect individual differences in preferred hemispheric functioning. That is, left movers show a relatively greater reliance on right hemisphere functioning and right movers a relatively greater reliance on left hemisphere functioning. A review by Ehrlichman and Weinberger (1978) has cast some doubt over the proposed link between lateral eye movements and hemispheric functioning, particularly with regards to individual differences. However, since their review, a number of supportive studies have been published, many of these pertaining to the underlying physiology, a trend which Ehrlichman (1987) has also noted recently.

In a review of this literature, Charlton, Bakan and Moretti, (1989) conclude that there is substantial neurophysiological evidence for a link between CLEM and cerebral hemispheric asymmetry.

Fritsch and Hitzig (1870), using monkeys, were the first to report that electrical stimulation of the frontal eye field of one hemisphere elicited eye movements in the contralateral direction. That is, stimulation of the eye field of the right hemisphere causes both eyes to deviate to the left and stimulation of the left hemisphere produces a deviation to the right. Since then, a number of studies have confirmed this relationship in both monkeys (e.g., Ferrier, 1886; Robinson and Fuchs, 1969) and humans (e.g., Bender, 1964; Penfield and Boldrey, 1973). The frontal eye field in humans is commonly thought to be located in the middle frontal gyrus where Brodmann's areas 6, 8 and 9 meet (Crowne, 1983).

In response to the electrical stimulation studies, Ehrlichman and Weinberger (1978) offered several criticisms of the neurophysiological explanation of the hemispheric model of CLEM. First, they stated that there is now some question as to whether the frontal eye fields actually play a critical role in the initiation of saccadic eye movements. One reason for questioning their function is that electrical stimulation in the surrounding areas of cortex has also been shown to elicit eye movements. However, this may be expected, for as Crowne (1983, p. 235) noted "the frontal eye field has extensive reciprocal connections with surrounding areas of frontal cortex". The lowest stimulation thresholds though, are in the frontal eye fields.

According to Bruce and Goldberg (1984), the most direct evidence for questioning eye field function comes from studies showing an apparent lack of neural activity prior to spontaneous eye movements of monkeys in the dark. However, as they point out, there is strong evidence of presaccadic activity for purposeful eye movements. These purposeful eye movements may be in response to factors such as visual stimulation, a result of postsaccadic neural activity or of an anticipatory nature (Bruce and Goldberg, 1984). On this basis, lateral eye movements in response to reflective questions would also appear to be purposive since they occur in response to a particular stimulus. This notion may be further substantiated by the finding (Roland, 1984) that verbal commands and auditory signal discrimination produce strong activation of the frontal eye fields.

A second criticism of Ehrlichman and Weinberger's (1978) is that if cognitive activity causes hemispheric activation there is no clear indication as to how this "spills" over to the frontal eye fields. However, as noted above, reciprocal relations between surrounding areas may exist. For example, according to Roland (1984), the auditory or visual association cortex are often coactivated with the frontal eye fields. Therefore, there is considerable evidence of a spill over.

Another line of evidence which is consistent with the electrical stimulation experiments is ablation studies. Damage to the frontal region of one hemisphere often results in the ipsilateral deviation of the eyes to the damaged side (Ferrier and Yeo, 1884). Similarly, studies of unilateral brain damage (Luria, 1973) have demonstrated a neglect of the visual field contralateral to the damaged hemisphere. This phenomena however, is usually restricted to cases of right hemisphere damage.

Further support for a relationship between CLEM and hemispheric activation comes from sodium amytal tests. Wada and Rasmussen (1960) observed that the injection of the barbiturate, sodium amytal, to one hemisphere, resulted in decreased eye movements in the direction contralateral to the anesthetized hemisphere. This also resulted in unilateral neglect similar to that observed in brain-damaged patients.

Another psychophysiological measure which has been related to CLEM is bilateral electrodermal recordings. Two studies, using right-handed males, (Erwin, McClanahan, and Kleinman, 1980; O'Gorman and Siddle, 1981) found no relationship between direction of eye movements according to question-type and bilateral skin conductance asymmetries. However, these findings may not be surprising given recent reviews (Freixa i Baque', Catteau, Miossec and Roy, 1984; Hugdahl, 1984, 1988) suggesting an unclear and, often, inconsistent relationship between electrodermal recordings and hemispheric asymmetry.

Another source of evidence for a relationship between CLEM and hemispheric activation is EEG and Evoked potential studies. Two early studies found little confirmation of this relationship. An experiment by Brown (1972) found at best, only marginal support. In experiment 1, he reported a trend for visual evoked potentials at parietal sites, with right movers showing greater left-hemisphere activation and left movers showing greater right-hemisphere activation. In a second experiment, this relationship was not confirmed. It shoul also be noted, however, that this second experiment also failed to find any asymmetries in evoked potentials for type of stimulus. Therefore, this brings into question whether one should expect right or left movers to demonstrate an asymmetry. In a study of bilateral alpha activity, Morgan, McDonald and MacDonald (1971) found no differences between left and right movers on proportion of right versus left hemisphere alpha activity. This held for both base line and verbal and spatial task conditions.

More recently, Shevrin, Smokler and Kooi (1980) compared visual event related potentials of right and left movers as they looked at a checkerboard reversal stimulus. It was found that the event related potentials were of greater amplitude in the occipital region of the right hemisphere for left movers and in the corresponding area of the left hemisphere for right movers. The authors suggested that "individuals may be characterized by a certain disposition such that lateralization of brain response is correlated with a preferred direction of looking" (p. 695).

From a slightly different perspective, Anderson (1977) found a relationship among left frontal activation, eye movements and verbal processing. The evoked potentials and EOG showed the largest asymmetries for a verbal dichotic listening task and smaller asymmetries for a speech task. A control task yielded negligible asymmetries. Further support came from a recent doctoral dissertation (Winkleman, 1984). Winkleman found evidence that average potentials in the posterior parietal-occipital regions were greater in the hemisphere contralateral to the direction of eye movements in both rapid eye movement sleep and waking.

Several recent studies on alpha asymmetry also support a link between lateral eye movements and contralateral hemispheric activation. Meyer (1977) compared right and left movers on alpha power at both occipital and parietal sites during performance on a verbal (Similarities) and spatial task (Block Design) from the Wechsler Adult Intelligence Scale (WAIS). He found that left movers exhibited significantly greater right-hemisphere activation at the parietal sites.

More recently, Neubauer, Schulter and Pfurtscheller (1988) assessed lateral eye movements by both EOG and observation during concurrent measurement of EEG alpha at temporal-anterior, frontal, central, temporal-posterior, parietal and occipital sites. Significant hemispheric differences were only observed at the temporal-anterior site. As predicted, left movers showed greater right hemisphere activation while right movers showed greater left hemisphere activation. No hemispheric asymmetries were found for the bidirectionals.

Warren and Haueter (1981) reported similar results for an analysis of right/left hemisphere alpha ratios. Thirty-two students were asked 20 questions of a verbal, spatial, mathematical and visual nature while EOG and parietal and occipital EEG alpha were measured concurrently. They reported an increase of left-hemisphere activation following right eye movements and increased right-hemisphere activation following left eye movements. In another study of individual differences, Newlin, Rohrbaugh and Varner (1982) looked at parietal EEG alpha power ratios for right-handed adults. As predicted, they found that a tendency toward right lateral eye movements was significantly associated with greater left-hemisphere activity.

A review of the EEG and evoked potential studies offers considerable support for a hemispheric interpretation of CLEM. Another more direct measure of hemispheric activation is cerebral blood flow. Gur and Reivich (1980), using the Xenon 133 inhalation method, compared 10 right moving versus 11 left moving, right-handed males on cerebral blood flow averaged across three conditions: 1)base line 2)covert response to spatial stimuli 3)covert response to verbal stimuli. Left movers were found to have significantly more right than left-hemisphere blood flow. Conversely, right movers showed a trend toward greater left-hemisphere blood flow, though this was not statistically significant. These results are particularly relevant to an individual-differences or trait-approach to CLEM and hemispheric asymmetry. However, the notion of the coactivation of brain regions for lateral eye movements and cognition was not specifically tested because the Xenon inhalation method is not well suited for examining frontal-eyefield activation (Gur, Gur, Rosen, Warach, Alavi et al., 1983).

Therefore, in an extension of their earlier study, Gur et al., (1983) compared 8 right-handed males on a verbal (Miller Analogies) or spatial (Benton's Line Orientation Test) test, using positron emission tomography. As predicted, they found significant differences between the verbal and spatial conditions at superior temporal, inferior parietal, inferior frontal and frontal-eye field regions. The spatial task was associated with higher right-hemisphere metabolic activity and the verbal task was associated with greater left hemisphere metabolic activity. As Gur et al., (1983, p. 605) pointed out "Our results in FEF [Frontal Eye Field] provide the first experimental demonstration that lateralized metabolic activity, produced by different types of cognitive tasks (verbal and spatial), also produces similarly lateralized metabolic activity in a motor region".

Overall, there appears to be substantial neurophysiological evidence for a link between CLEM and cerebral hemispheric asymmetry. Converging lines of evidence from electrical stimulation, ablation, brain damage, sodium amytal testing, EEG, evoked potentials, cerebral blood flow and positron emission tomography all support this notion.

Hemisphericity and Hemispheric Specialization

Two different approaches have been adopted to study CLEM, an analysis of the type of question asked and an individual differences model. According to Kinsbourne (1972), the type of question asked (usually verbal versus spatial) will determine which hemisphere will be activated. The emphasis here is on hemispheric specialization. This model suggests that verbal questions will elicit eye movements to the right and spatial questions will elicit eye movements to the left.

Bakan (1969, 1971, 1978), on the other hand, has stressed the idea that individuals vary in their preferred direction of gaze. Those individuals who consistently look to the right during cognitive activity are thought to show a greater reliance on left hemisphere processing and those who look to the left show a greater reliance on right hemisphere processing. The tendency to rely on one hemisphere more than another may result in individual differences in perception and cognition. This has also been termed "hemisphericity" (Bogen, 1969). By far, the most convincing evidence for CLEM being a measure of hemisphericity was a cerebral blood flow study of Gur and Reivich (1980). Right movers showed greater metabolic activity in the left hemisphere and left movers showed greater activity in the right hemisphere. Further substantiation for this idea also came from a number of EEG studies showing a link between individual differences in eye movement patterns and hemispheric activation.

The hemisphericity model assumes that the evidence for hemispheric specialization is correct. That is, generally, that the left hemisphere is specialized for verbal abilities and the right hemisphere for non-verbal or spatial abilities. On this premise, one might expect persons who primarly use their right hemisphere (left movers) to be better at spatial abilities because they are using the hemisphere most appropriate for the task. Conversely, persons predominantly using their left hemisphere (right movers) should be better at verbal tasks.

Question Type Studies

Since Ehrlichman and Weinberger's (1978) publication, a substantial number of question-type studies have been conducted. In their review, they reported on 19 experiments concerned with question-type. Of these, 9 found more right eye movements for verbal versus spatial questions, 9 found no differences and 1 found a significant relationship in the opposite direction. The present review will report on all the relevant experiments which have been conducted since their review. Overall, the results are comparable to those of Ehrlichman and Weinberger's. As can be seen from Table 2, 17 studies (20 experimental conditions) reported a significant question-type effect favoring right eye movements for verbal versus spatial questions. However, 24 studies (29 experimental conditions) reported no differences while 1 (Richardson, 1978) found a significant relationship opposite to that predicted (see Table 3).

According to Gur et al (1975), a question-type effect is more likely to occur when the experimenter sits behind the subject. They suggested that increased anxiety in a face to face interview may result in the subject relying on characteristic-hemispheric activation. On the surface, there appears to be little support for this contention. Two studies utilizing a behind condition found the predicted relationship whereas 3 others found no difference. This is in contrast to Ehrlichman and Weinberger's review which reported a question-type effect for all 3 studies using a behind-condition.

Table 2

EXPERIMENTS FINDING THE PREDICTED QUESTION TYPE EFFECT

Study	Subjects	Condition
Barkoczi and Komlosi, 1983	9 males and 12 females	front
Combs, Hoblick, Czarnecki and Kamler, 1977	49 males and females	front
Daly, 1981	30 boys and 30 girls	front
Dewitt, 1977	74 males and 112 females	front
Erwin, McClanahan and Kleinman, 1980	32 males	alone
Gur, 1978	12 males and 12 females	front
		behind
Hugdahl and Carlgren, 1981	20 males and 20 females	alone
Jones, Chew, Allman, Marble, Mitchell and Combs, 1980	20 males and 11 females	front
Katz and Salt, 1981	16 males and 9 females	front
Lenhart, 1985	24 males and 24 females	front

Study	Subjects	Condition
OGorman and Siddle, 1981	28 males	front
		behind
Raine, Christie and Gale, 1988	26 males and 17 females	front
Schweitzer, Becker and Welsh, 1978	31 males and females	front
Segalowitz and McNaughton, 1980	Exp 1 and 2 -5 males and 5 females each	alone
Warren and Haueter, 1981	32	alone
Woods and McCormick, 1979	51 males	front
Yutrzenka, 1981	16 males and 32 females	alone

Table 3

EXPERIMENTS NOT SUPPORTING THE PREDICTED QUESTION TYPE EFFECT

Study	Subjects	Condition
Ahern and Schwartz, 1979	10 males and 10 females	alone
Berg and Harris, 1980	48 males	front
		behind
Dalby and Gibson, 1981	15 boys	front
de Bonis and Freixa i Baque, 1983	15 males and 13 females	alone
De Gennaro and Violani, 1988	40 males and 40 females	alone
Deijen, Loriaux, Bouma and Orlebeke, 1986	29 males and 29 females	front
		behind
Diener, 1982	10 males	alone
Gumm, Walker and Day, 1982	50 females	front
		behind
Hatta, 1984	18 males and females	alone
Hoffman and Kagan, 1977	41 males and 39 females	front
Huang and Byrne, 1978	27 females	front
Jamieson and Sellick, 1985	32 males	front

Study	Subjects	Condition
Krikorian and Rafales, 1982	16 males and 16 females	alone
Lenhart, 1985	24 males and 24 females	front (close distance)
Lenhart and Katkin, 1986	10 males and 10 females	front
MacDonald and Hiscock, 1985	20 males and 20 females	alone
McCallum, 1981	54 male and female children	front
Paradowski, Brucker, Zaretsky and Alba, 1978	17 males and 17 females	front
Pierro and Goldberger, 1982	34 males and 43 females	front
Reynolds and Kaufman, 1980	29 male and 23 female children	front
Richardson, 1978	31 males and 57 females	front
Sackheim, Weiman and Grega, 1984	Exp 1-63 males-Exp 2-84 males and 90 females	front
Saring and Von Cramon, 1980	12 males and 18 females	alone
Tomer, Mintz, Levi and Myslobodsky, 1979	52 females	alone
Wyler, Graves and Landis, 1987	Exp 1-23 males and 23 females	front
	Exp 2-10 males and 10 females	front

It should be noted however, that one of the nonsignificant studies used only female subjects. As mentioned earlier, females may be less lateralized and therefore they may be less likely to exhibit a question-type effect. Indeed, all of the question-type studies which used only female subjects, reported nonsignificant results. Furthermore, although Gumm, Walker and Day (1982) reported no differences for either condition, a discriminant function analysis indicated more question-type effect for the behind-condition. Similarly, while Gur (1978) found differences for both conditions, they were more dramatic in the behind condition.

Overall, the results reported here and in Ehrlichman and Weinberger (1978) support a weak but positive relationship between CLEM and hemispheric asymmetry. Generally, the findings appear to be more pronounced in males and in the experimenter -behind-condition. Several other factors may mediate this relationship. One of the most important, is the content validity of the questions. For example, do spatial questions truly reflect spatial ability. As discussed earlier, this is a problem which plagues the cerebral lateralization literature. One obvious problem with spatial questions is that they also involve a verbal response. Secondly, spatial questions which require counting may be using both hemispheres since there is evidence to suggest that mathematical skills involve both hemispheres (Troup, Bradshaw & Nettleton, 1983). Studies that combine verbal and numerical questions on the assumption that they are both left hemisphere questions may run into similar problems. If one truly wants to assess the validity of CLEM using question type studies then a valid set of questions must be obtained. Third, and perhaps the most important of all, an individuals lateral eye movements may be the product of both hemisphericity and the type of question. In any given CLEM experiment, whether studying question-type or hemisphericity, there may be a diminished effect. That is, question-type results may be weakened by the influence of a subject's characteristic hemispheric arousal. Conversely, the classification of subjects into right and left movers may be especially difficult if the subject is responding more to the type of question asked.

Hemisphericity

Distribution Characteristics

Traditionally, subjects who consistently avert their gaze in one direction for at least 70 percent of their scorable lateral eye movements have been classified as right or left movers (e.g., Bakan, 1969; Gur & Gur, 1974). Most studies have used this criterion, although some have used other cutoff points ranging from .51 to .90. Therefore, the distribution of right, left and bimovers may vary somewhat according to which cutoff points are used. Ehrlichman and Weinberger (1978) have suggested that the typical distribution of right movers, left movers and bimovers is multimodal with a fairly equal number in each group. However, recent evidence suggests a greater number of left movers than right movers in the general population with the number of bimovers fluctuating from study to study, perhaps because of differing cutoff points, sampling error or methodological problems (Graves & Natale, 1979; Gumm, et al., 1982; Hoffman & Kagan, 1977; Hugdahl & Carlgren, 1981; Joffe, 1982; Moretti, 1982; Paradowski, Brucker, Zaretsky & Alba, 1978; Pierro & Goldberger, 1982; Reynolds & Kaufman, 1980; Sandel & Alcorn, 1980; Spanos, Pawlak, Mah & D'eon, 1980). It should also be noted that some studies have found different distributions (Gallagher & Joseph, 1982; Huang & Byrne, 1978; Sackheim, Weiman, & Grega, 1984; Tomer & Mintz, 1980). The finding of more left movers in the general population is consistent with the findings from cerebral blood flow studies. According to Gur and Reivich (1980) blood flow studies often report greater right hemisphere flow in unselected groups of subjects.

Earlier reports have stated that women are more likely to be bimovers (Bakan, 1978; Duke, 1968; Libby & Yaklevich, 1973). If bimovers are, as some authors have noted (Bakan, 1978), less lateralized, than this finding would be congruent with the hemispheric specialization literature that suggests that women are less lateralized (Bryden, 1979; Flor-Henry, 1980; Hutt, 1979). However, this may not be the case. A review of the literature reveals no specific pattern. Women have also been found to make more right lateral eye movements (de Bonis, 1983; Lefevre, Starck, Lambert & Genesee, 1977; Schweitzer, 1979; Schweitzer, Becker, & Welsh, 1978), or more left lateral eye movements (Beveridge & Hicks, 1976; Sackheim, et al 1984). In addition, a number of studies have found no sex differences (Etaugh, 1972; Etaugh & Rose, 1973; Spanos, et al, 1980; Weiten & Etaugh, 1973).

Reliability

The test-retest reliabilities for CLEM have in most cases been shown to be high. An early investigation by Duke (1968) reported that subjects exhibit a consistent direction of eye movement about 86 percent of the time. Since then, numerous investigations have found reliabilities ranging from .61 to .93 (Bakan and Strayer, 1973; Bratsky, 1979; Crouch, 1976; DeWitt, 1977; Etaugh and Rose, 1973; Hoffman and Kagan, 1977). Similarly, inter-rater reliabilities have consistently been shown to be high with estimates ranging from 76 to 100 percent (Ahern and Schwartz, 1979; Gum, 1982; Gur, 1975;Hantas, Katkin and Reed, 1984; Krikorian and Rafales, 1982; Swinnen, 1984; Thompson, 1982; Tucker and Suib, 1978). Overall, these data suggest that CLEM is a reliable characteristic of individuals.

CLEM and Task Performance

The two variables which are most noted for demonstrating hemispheric asymmetry in the specialization literature are spatial and verbal tasks. Therefore, in the following section, we will restrict ourselves to an examination of hemisphericity studies using tasks purported to measure these abilities. In comparison, there have been a greater number of studies on spatial abilities rather than verbal abilities.

Bakan and Shotland (1969) found that right movers demonstrated faster reading speed than left movers. In a confirmation of this study, Ogle (1972) later extended these findings to show superior performance by right movers in both silent and oral reading conditions. In addition, right movers were found to be better at concept identification (Weiten & Etaugh, 1973) and auditory number span (Owens & Limber, 1983). Conversely, no relationship was observed for the Quick vocabulary test (Hiscock, 1977).

Several studies have utilized the WAIS. Tucker and Suib (1978) compared right and left movers on four subtests, Information, Vocabulary, Block Design and Object Assembly. As predicted, right movers demonstrated greater verbal scores and left movers demonstrated better spatial scores. Similarly, Moretti (1982) found right-moving males significantly better than left-moving males on a verbal comprehension factor. No significant differences were observed for females on verbal comprehension or for either sex on a perceptual organization factor. Stern and Baldinger (1983) compared young (18 to 32 years) and old (60 to 72) subjects on two WAIS subtests, Block Design and Vocabulary. Although there were no differences for the young subjects, old-left movers were significantly better on both subtests. Although these findings were contradictory for the Vocabulary test, a comparison of left and right movers on a composite verbal/spatial ratio did support a hemispheric interpretation. The composite verbal score consisted of vocabulary, word fluency and scrambled word tasks whereas the composite spatial score contained Block Design, shape memory and map memory. Old-right movers had higher verbal to spatial ratios than old-left movers.

Hoffman and Kagan (1977) also used a composite index with the WAIS subtests, Object Assembly, Block Design and Picture Completion combined with two common measures of field dependence, the RFT and the EFT. They found that male bimovers showed the worst performance. Furthermore, a comparison of consistent (right and left) male movers and male bimovers showed consistent movers were significantly better on the Block Design, Picture Completion, RFT and EFT. No differences were found for females on any of the comparisons. A degree of caution should be exercised here however as the composite is not a pure measure of spatial ability.

The WAIS measure most used in CLEM studies is Block Design. In addition to the aforementioned studies, Swinnen (1984) found that superior Block Design performance was associated with left moving while Otteson (1980) found similar findings for female but not male subjects. Lastly, a study by Davies (1982) reported no differences on either the Block Design or Digit Span.

Although there are a few discrepancies in the literature, overall, results from both the WAIS and verbal studies appear to support a hemispheric interpretation. The strongest support from

WAIS studies appears to be from those utilizing a verbal/spatial comparison.

Studies looking at other spatial measures have been more equivocal. Although Bilsker (1980) and Swinnen (1984) found a significant relationship between left moving and superior performance on the Gestalt Completion test, Spanos et al. (1980) and Charlton (1984) found no relationship. Similar results were found for the Perceptual Organization test, with Bilsker (1980) finding a positive relationship and Charlton (1984) reporting no differences. Along similar lines, Jean (1983) reported that left movers were significantly faster than right movers at face recognition whereas Davies (1982) found no relationship. Left moving has also been associated with better scores on a horizontality task for females but not for males (Ray, Georgiou, & Ravizza, 1979). In an investigation of spatial and non-spatial syllogisms, Tomer and Mintz (1980) found left movers demonstrated superior performance on both. Furthermore, on reflection, they presented evidence showing that the supposedly non-spatial syllogisms probably had a spatial component. Thus, their results are wholly consistent with the right hemisphere, spatial ability interpretation.

A number of studies have failed to establish a relationship between CLEM direction and tasks thought to measure spatial abilities. No relationship was reported for the Minnesota Spatial Relation tests (Gur, 1973), a spatial relation test from the DAT (Hiscock, 1977), or for memory for spatial locations

(Bruce, Hermon & Stern, 1982), maps, irregular shapes (Stern & Baldinger, 1983), or spatial orientation (Otteson, 1980). One interesting finding is an opposite effect for three common spatial tests. Glackman (1976) found a significant correlation between right moving and the Shepard-Meltzer mental rotation task, a card rotation task and a paper formboard task.

Bimovers

Bimovers are by far the least understood of the three classifications. As noted earlier, bimovers were thought to be less lateralized (Bakan, 1978). This was assumed on the grounds that they showed no consistent direction of gaze and therefore appeared to use both hemispheres equally. For this reason, many CLEM studies have omitted bimovers. A study by Gur, Gur and Harris (1975) shed new light on this issue. They found two types of bimovers, discriminators and nondiscriminators. The discriminators were subjects who responded to the type of question asked. Verbal questions elicited rightward eye movements indicating left-hemisphere activation and spatial questions elicited leftward eye movements indicating right-hemisphere activation. Because an equal number of spatial and verbal questions were presented, these subjects demonstrated a fairly equal number of right and left eye movements. Nondiscriminators, on the other hand, showed no evidence of differential hemispheric activation according to the questions asked. Rather they seemed to move their eyes in a random pattern. Thus, there may be two types of bimovers, those responding to question-type and hence showing greater lateralization for verbal and spatial stimuli, and those showing no question-type effect indicating less lateralization. This may explain the failure to find sex differences. Furthermore, this would lead to different predictions regarding performance levels on other variables. For example, one might expect the discriminating bimovers to exhibit superior performance on both spatial and verbal tasks because they are supposedly using whichever hemisphere is appropriate for the particular task. The nondiscriminating bimover may be expected to perform better or worse depending on whether one views less lateralization as a deficit or not.

The bimover poses another problem for CLEM research. Numerous studies have used linear correlations to look at the relationship between CLEM and other variables. This may result in a nonsignificant correlation. There is no reason to suppose that bimovers should have scores in between right and left movers on any particular variable. In fact, given the present discussion, it seems unlikely they would score between right and left movers on other variables. Therefore, it may be more fruitful to look for a non-linear relationship.

Hypotheses and Rationale

Experiment 1

The purpose of Experiment 1 will be to examine the relationship between degree of lateralization and cognitive performance. According to Levy (1969), individuals who are less lateralized for language are more likely to have inferior spatial skills. Bilateral representation of language may result in verbal and spatial functions competing for the same, limited processing space of the right hemisphere. This may result in good verbal abilities but inferior spatial abilities.

Along similar lines, in a further elaboration of this theory, Levy and Gur (1980) suggest that the bilateral representation of spatial functions will result in a 'crowding' of the left hemisphere. Therefore, individuals who are less lateralized for spatial functions or other nonverbal functions, should have good spatial abilities and depressed verbal abilities.

On the basis of the preceding argument, the following hypotheses are proposed.

Hypothesis 1

It is predicted that individuals who are less lateralized on a verbal dichotic listening test will have lower scores on two measures of spatial ability, face recognition and mental rotations.

Hypothesis 2

It is predicted that individuals who are less lateralized on a verbal dichotic listening test will score higher on a measure of verbal concept formation, the similarities subtest of the WAIS-R.

Hypothesis 3

It is predicted that individuals who are less lateralized on a music dichotic listening test will score lower on the similarities subtest of the WAIS. The rationale for this is that bilateral representation of any nonverbal abilities, whether they be spatial or music, should result in depressed verbal ability. In either case, a crowding of the left hemisphere should take place.

Hypothesis 4

It is predicted that individuals who are less lateralized on a music dichotic listening test will score higher on two measures of spatial ability, face recognition and the mental rotations test.

Experiment 2

The second part of the present study will attempt to answer two questions. On the one hand, the experiment will be examining the relationship between CLEM and cognitive performance. According to this model, right movers show a greater reliance on left hemisphere processing while left movers show a greater reliance on right hemisphere processing. As noted earlier, a substantial number of studies have found an association between right moving and superior verbal performance, suggesting that their greater reliance on the left hemisphere leads to enhanced verbal ability. Although the evidence is more equivocal, there have also been a number of studies reporting an association between left movers and superior spatial ability.

On this basis, the following predictions are:

Hypothesis 5

Left movers will obtain better scores than right movers on the two spatial tests, face recognition and mental rotations. No predictions will be made with regard to bimovers.

Hypothesis 6

Right movers will obtain better scores than left movers on Similarities, a verbal concept formation task. Again, no predictions will be made for bimovers.

The second aspect to be looked at in this part of the study is the relationship between CLEM and degree of lateralization. As noted earlier, according to Gur et al., (1975), there may be two types of bimovers. Discriminating bimovers are those subjects who show no directional gaze preference because they respond to the type of question that is asked. Spatial questions elicit eye movements to the left while verbal questions elicit eye movements to the right (although the opposite is possible) resulting in a lack of directional preference. Nondiscriminating bimovers, on the other hand, are those subjects who show no directional preference for eye movements and do not respond in any systematic manner to the type of question that is asked. These subjects may be less lateralized than discriminating bimovers. On this basis, it is hypothesized that:

Hypothesis 7

Nondiscriminating bimovers will be less lateralized on both a verbal and a music dichotic listening test.

CHAPTER II

METHOD

Subjects

The subjects were 40 male and 80 female right-handed undergraduate university students.The males ranged in age from 16 to 45 and the females ranged in age from 18 to 49. The subjects were volunteers solicited from undergraduate psychology courses. No credit or monetary compensation was given for participation in the experiment. The subjects were told that the experiment was about the relationship between cognitive and perceptual performance and cerebral lateralization. However they were not informed of the specific hypotheses. Sixteen other subjects were omitted from the analysis because of one or more problems. Subjects were omitted if they had any self-reported hearing problems, were not right handed or failed to properly complete one or more of the experimental tasks.

Procedure and Design

All of the subjects were tested individually. The test session was preceded by a brief outline of the experimental procedure and then the subjects were required to complete a consent form. All of the subjects were tested in the same room and the tests were given in one session. The total time required to complete the session ranged from one hour to one hour and fifteen minutes. The subjects were administered a verbal and a nonverbal dichotic listening test, 3 cognitive ability tests (2 spatial and 1 verbal) a handedness questionnaire and the Conjugate Lateral Eye Movement Test (CLEM) in the following order.

CLEM

For the administration of the CLEM test, the subjects were asked to sit facing the experimenter at a distance of approximately 75 centimetres. The walls facing the subject were white and contained no markings that might influence the subjects direction of gaze. Subjects were told that there were no correct answers but rather that I was interested in their personal interpretation of the questions. Furthermore, they were asked to sit up straight and face the experimenter. Subjects were told that proper posture was important since it may influence perceptual and cognitive performance. These instructions were necessary in order to ensure that the subjects did not turn their heads or avert their gaze prior to being asked questions.

The CLEM test was composed of 10 verbal questions and 10 spatial questions derived from previously published studies (See Appendix A). The verbal question set was primarily made up of definitions, spelling and proverb interpretation while the spatial set consisted of questions requiring visualization or imagery. Spatial questions requiring counting (eg., how many windows are there in your house) were not included because it is not clear that these require left hemisphere processing (Galin and Ornstein, 1974). Questions which appeared too easy were also omitted because of evidence suggesting they may be less likely to elicit eye movements (Ehrlichman and Weinberger, 1978). Furthermore, the questions were structured so that reflection on the problem could not commence until the complete question had been given. The verbal and spatial questions were asked in an alternating order. That is, all spatial questions were odd numbered and verbal questions were even numbered.

The subject's initial eye movement, immediately following each question, was recorded. Only lateral eye movements were recorded. Trials on which the subject stared ahead, shifted his/her eyes vertically, closed them, had the head turned or did not try to answer the question, were not included. At least 75 percent of the questions had to yield scoreable lateral responses in order for the subject to be included in the study. A laterality score (percentage of left eye movements) was computed by taking the number of left movements, dividing by the total number of movements and multiplying by 100.

For any analysis involving classification of subjects, subjects who looked to the left on at least 70 percent of the trial were considered left lookers while subjects who looked to the right on at least 70 percent of the trials were considered right lookers. Subjects falling in between these points were classified as bimovers. For some of the analyses, bimovers were further subdivided into discriminators and nondiscriminators according to a method proposed by Gur et al. (1975). "If the larger proportion of movements to one direction in the verbal set was the smaller proportion of movements to that direction in the spatial set, the differences in the 2 sets of proportions were added together"(pg. 38). The subject was classified as a discriminator if their summed differences in proportions were at least 70 percent. The subjects were classified as nondiscriminators if their scores fell below this 70 percent criterion or more obviously if the larger proportion of movements to one direction in the verbal set was also the larger proportion of movements to that direction in the spatial set (yet still low enough not to be classified as a right or left mover).

For example, a subject is given 20 questions. For the verbal questions, the subject looks to the right on 8 questions and to the left on 2 questions. For the spatial questions, the subject looks to the left on 6 questions and to the right on 4 questions. The difference in proportions for the verbal questions is 80% - 20% = 60%. The difference in proportions for the spatial questions is 60% - 40% = 20%. The summed differences in proportions is 60% + 20% = 80%. This subject would be classified as a discriminating bimover because their score exceeds 70% and the predominant directional response is opposite for verbal versus spatial questions.

During the questioning period the experimenter was careful not to reveal that he was recording the subject's eye movements rather than answers to the questions. To ensure that this had been achieved, the subjects were asked at the end of the experiment whether they were aware that their eye movements were being monitored.

Verbal Dichotic Listening Test

The subjects were given a verbal dichotic listening test with 60 trials of stop consonant-vowel pairs. A practice trial was shown to the subjects to ensure the task was understood. The subject's task was to identify the correct stimuli from the left ear for half the trials and the right ear for the other half. The subjects were required to circle the appropriate response on an answer sheet which contained the stimuli that were presented to the left and right ears as well as 4 other alternatives. The six alternatives for each trial were ba,da,ga,pa,ta and ka. Half the subjects of each sex started with the right ear while the other half started with the left ear. This forced attention method was chosen over the more traditional free-report technique because it negates any attentional confounding (Bryden, 1982; Hugdahl and Andersson, 1986). Furthermore, the headphones were reversed at the half way mark to ensure equivalent sound intensity and quality for both ears. The headphones were a Sony DR-S3 model, the amplifier a Sony TA 1066 and the Cassette deck was an AKAI GX R88.

Handedness Inventory

Handedness was measured with a shortened version of the Edinburgh Handedness Inventory (Olfield, 1971). A laterality quotient was obtained by taking the sum of the right handed responses and subtracting them from the sum of the left handed responses, then dividing by the sum of both and multiplying by 100. Only right handed subjects were included in this study. Subjects with scores of 60 or over were classified as right handers. The mean handedness score was 99.3 for all subjects.

Familial sinistrality was also recorded. The subjects were asked to note whether any members of their immediate family were left handed. Any subjects with one or more left handed family members were classified as FS+ while those without left handed family members were classified as FS-.

Spatial Performance Measures-Mental Rotations and Face Recognition

The mental rotations and face recognition tests were chosen for several reasons. First, both tasks are thought to involve greater right hemisphere processing. Secondly, sex differences have been found for both tasks, with males showing superiority on the mental rotations tests and females showing superiority on face recognition tests. Given that Levy's theory is often used to explain sex differences in spatial performance, the use of spatial tasks with opposite gender superiorities may provide a more clear and comprehensive test of Levy's theory.

Mental Rotations

The mental rotations test (Vandenberg and Kuse, 1978) contains 20 trials (see Appendix B). Each trial shows a three dimensional block formation followed by 4 block formations, 2 of which are rotations of the first. The subject's task is to identify the 2 correct rotations. The total number of possible correct choices is 40. The subjects were allowed 7 minutes to complete the task. The number of incorrect responses was subtracted from the number of correct responses to control for guessing.

Face Recognition

The subjects were given a free view face recognition task that was originally devised by Milner (1968)(see Appendix C). They were shown a card containing black and white photographs of 6 male and 6 female faces for 45 seconds. Each face was approximately 1.3 by 1.1 inches in size. This was followed immediately with a memory probe card showing 5 rows of 5 faces, 12 male and 13 female. Each face on the memory probe card measured 1 by 1.1 inches. The subjects were required to select 12 of these by filling in 12 squares on a corresponding 5 by 5 grid. They were allowed 3 minutes to record their responses and were told to guess if they were unsure.

Verbal Performance Measure-Similarities Test

The Similarities is a subtest of the WAIS-R(see Appendix D). This is a verbal concept formation task which involves word pairs such as apple-orange or fly-tree. The subject must explain what the words in each pair have in common. As the test progresses the word pairs get more difficult. In accordance with the WAIS scoring manual, subjects were allotted 2 points for a correct abstract solution and 1 point for a correct concrete solution. All 14 test items were presented to each subject allowing for a maximum score of 28. One reason for choosing this test to measure verbal ability is that it has been found to be one of the best discriminators of left versus right hemisphere brain damage (Lezak, 1983).

Music Dichotic Listening Test

The dichotic listening task for melodies used the same auditory equipment and followed the same procedure as that used for the verbal dichotic listening test. The subjects were required to attend to one ear for the first half of the trials and the other ear for the second half. Half of the subjects of each sex attended to their right ear for the first half of the trials while the other half initially attended to their left ear. The music dichotic tape was the same as that used by Kimura (1964). It consisted of 24 trials containing 4 different melodies. The original tape only contained 12 trials. Therefore, in order to get 24 trials, the 12 trials were repeated a second time. This however, could have created a problem. Since the subjects were asked to switch the ear they were attending to and also to reverse their headphones, this would have resulted in their trying to attend to the same target items in the second half as they did in the first. To control for this, when the second set of 12 trials was copied, the channels were reversed. Each trial involved the dichotic presentation of 2 different 4 second melodies followed by the binaural presentation of these 2 melodies plus 2 other melodies. The subject's task was to indicate which one of the binaural melodies occured in the attended ear. The subjects were required to circle the number designating their choice on an answer sheet that was provided. There were 4 possible responses, a correct identification, an intrusion from the other ear or two completely wrong.

The use of a forced attention method also presented one other possible problem. Since the music tape was originally designed for the free report technique, the use of a forced attention method may have resulted in the task being too easy. This in turn, may have obscured any possible asymmetry effects. However, a pilot study with 6 male and 9 female undergraduate students, revealed no ceiling effects.

Music Experience

The subjects background musical experience was also recorded. They were asked to note whether they were presently playing a musical instrument and the number of years they had been playing. Those subjects who were presently playing an instrument and had been playing for 4 or more years were classified as musicians. This criteria has often been used for comparing musicians with nonmusicians in hemispheric asymmetry studies (Pascalis, Marucci, Penna, and Labbrozzi, 1987).

CHAPTER III

RESULTS

Experiment 1-Degree of Lateralization and Cognitive Performance

The mean number of correct responses was 37 percent for the verbal dichotic listening task and 65 percent for the music dichotic listening task.

A 2x2 analysis of variance was performed with sex as a between-subject variable, ear as a within-subject variable and total correct on dichotic listening as the dependent variable. This analysis was performed for each dichotic listening test. As can be seen in Table 4 and 5 respectively, the only significant findings were a main effect for ear on verbal dichotic listening, $F(1,118)=5.30$, $p<.02$, and a main effect for ear on music dichotic listening, $F(1,118)=59.67$, $p<.0000$. There was a right ear advantage for verbal dichotic listening and a left ear advantage for music dichotic listening.

The laterality index that was used in this study to measure dichotic listening was lambda. This index was chosen because it has been shown to be independent of overall accuracy (Bryden and Sprott, 1981). Based on the logs odd ratio method, it requires taking the log of correct right ear scores times the errors for the left ear and divided by the correct left ear scores times the errors for the right ear, $\ln (RC \times LX)/ (LC \times RX)$. To obtain an index of degree of lateralization, regardless of direction,

Table 4

<u>Anova For Ear Advantage For Accuracy Scores On Verbal Dichotic Listening</u>

Source	SS	DF	MS	F	Prob.
Sex (S)	0.08	1	0.08	0.43	.51
Error	22.53	118	0.19		
Ear (E)	0.51	1	0.51	5.30	.02
ES	0.00	1	0.00	0.00	.95
Error	11.32	118	0.10		

Table 5

<u>Anova For Ear Advantage For Accuracy Scores For Music Dichotic Listening</u>

Source	SS	DF	MS	F	Prob.
Sex (S)	0.22	1	0.22	0.20	.65
Error	127.55	118	1.08		
Ear (E)	26.63	1	26.63	59.67	.00
ES	0.07	1	0.07	0.16	.69
Error	52.67	118	0.45		

the absolute value of lambda was used.

Scores on the two dichotic listening tests were not correlated. Therefore, any further analyses were performed separately for each dichotic listening test.

Verbal Dichotic Test

Three 2x2x2 analyses of variance were performed, where sex, degree of lateralization for language and order of ear attended to were between-subject variables and mental rotations face recognition and similarities were dependent variables. For the degree of lateralization variable, those subjects whose scores were below the median were classified as less lateralized and those above the median as more lateralized. The mean mental rotations scores according to group are presented in Table 6. Due to problems with heterogeneity of variance, a square root transformation was applied to the mental rotations scores for all analyses of variance in the present study.

Contrary to prediction, an analysis of variance revealed no significant main effect for degree of language lateralization on mental rotations(See Table 7). A main effect for sex was obtained, with males scoring significantly better on the mental rotations test, $F(1,112)=44.24$, $p<.0000$.

An analysis of variance with face recognition as the dependent variable, revealed significant main effects for sex and degree of lateralization and a two-way interaction for order and degree (See Table 8). As expected, females were superior to

Table 6

Mean Mental Rotation Scores As A Function Of Sex, Order And Degree Of Lateralization On Dichotic Listening For Language

	Male		Female	
	Left First	Right First	Left First	Right First
Less	19.60	18.46	7.57	6.63
	(10.19)	(9.68)	(4.94)	(5.00)
More	14.50	18.71	10.58	8.67
	(8.90)	(10.58)	(6.33)	(5.29)

Note. Standard deviations are in parentheses.

Table 7

Anova For Mental Rotations Scores For Verbal Dichotic Listening

Source	SS	DF	MS	F	Prob.
Order (O)	0.04	1	0.04	0.03	.87
Sex (S)	53.86	1	53.86	29.41	.00
Degree (D)	0.41	1	0.41	0.22	.64
OS	0.16	1	0.16	0.09	.77
OD	4.50	1	4.50	2.46	.12
SD	4.19	1	4.19	2.29	.13
OSD	2.18	1	2.18	1.19	.28
Error	205.12	112	1.83		

males on the face recognition task, $F(1,112)=6.80$, $p<.01$. Contrary to prediction, less lateralized subjects had superior face recognition scores, $F(1,112)=4.42$, $p<.04$. According to the order by degree interaction, $F(1,112)=3.82$, $p=.05$, for subjects who attended to their left ear first, low and high degrees of lateralization resulted in roughly the same face recognition scores. As shown in Table 9, less lateralized subjects recognized 9.8 faces on average while more lateralized subjects recognized 9.91 faces on average. However, for the subjects who attended to their right ear first, less lateralized subjects had superior face recognition scores ($M=10.15$), compared to more lateralized subjects ($M=9.39$).

The mean scores for the similarities test, according to Degree by Sex by Order groupings are presented in Table 10. An analysis of variance revealed no significant main effects or interactions (See Table 11).

As noted earlier, the preceding analyses looked at degree of lateralization regardless of direction. Some authors have questioned whether subjects with reversed-lateralization will perform differently on cognitive tasks. Thus, the preceding analyses were repeated with reversed-lateralization subjects (those showing a left ear advantage) omitted. This resulted in 26 males and 53 females being included in the present analysis.

The mean scores on the mental rotations, face recognition and similarities, according to grouping, are shown in Table's

Table 8

Anova For Face Recognition Scores For Verbal Dichotic Listening

Source	SS	DF	MS	F	Prob.
Order (O)	0.48	1	0.48	0.38	.54
Sex (S)	8.59	1	8.59	6.80	.01
Degree (D)	5.59	1	5.59	4.42	.04
OS	0.02	1	0.02	0.02	.90
OD	4.83	1	4.83	3.82	.05
SD	0.10	1	0.10	0.08	.76
OSD	0.24	1	0.24	0.19	.66
Error	141.59	112	1.26		

Table 9

Mean Face Recognition Scores As A Function Of Sex, Order And Degree Of Lateralization On Dichotic Listening For Language

	Male		Female	
	Left First	Right First	Left First	Right First
Less	9.50	9.92	10.14	10.32
	(.97)	(1.12)	(.95)	(1.16)
More	9.50	8.86	10.08	9.57
	(.97)	(1.07)	(1.23)	(1.21)

Note. Standard deviations are in parentheses.

Table 10

Mean Similarities Scores As A Function Of Sex, Order And Degree Of Lateralization On Dichotic Listening For Language

	Male		Female	
	Left First	Right First	Left First	Right First
Less	21.10	21.00	21.07	21.47
	(2.51)	(2.20)	(3.22)	(1.89)
More	20.50	20.29	20.77	21.33
	(2.01)	(1.38)	(2.34)	(3.18)

Note. Standard deviations are in parentheses.

Table 11

Anova For Similarities Scores For Verbal Dichotic Listening

Source	SS	DF	MS	F	Prob.
Order (O)	0.68	1	0.68	0.11	.74
Sex (S)	4.93	1	4.93	0.79	.38
Degree (D)	4.90	1	4.90	0.78	.38
OS	2.60	1	2.60	0.42	.52
OD	0.00	1	0.00	0.00	.98
SD	1.21	1	1.21	0.19	.66
OSD	0.12	1	0.12	0.02	.89
Error	701.78	112	6.27		

12, 13 and 14 repectively. A two-way analysis of variance on mental rotations revealed a main effect for sex, with males outperforming females, $F(1,75)= 26.08$, $p<.0000$ (See Table 15). No significant effects for degree or interactions were observed. The analysis of variance for face recognition resulted in no main effects or interactions (See Table 16). For the similarities scores, an analysis of variance resulted in a main effect for degree, $F(1,75)=3.69$, $p=.05$ (See Table 17). Less lateralized subjects outperformed more lateralized subjects. No other main effect or interaction was observed.

Music Dichotic Test

Analysis of variance was also computed for the music dichotic listening data, using all subjects. These analyses examined the effect of degree of lateralization for music, sex and order on the three cognitive performance measures. The mean cognitive performance scores for the similarities, mental rotations and face recognition tests are presented in Tables 18, 19, and 20 repectively.

For the similarities data, an analysis of variance revealed no significant main effects or interactions (See Table 21). Thus, the hypothesis that more lateralized subjects on the music dichotic task will have superior similarities scores, was not supported.

An analysis of variance for the mental rotations data, revealed a main effect for sex, $F(1,112)=42.91$, $p<.0000$, and a

Table 12

Mean Mental Rotation Scores As A Function Of Sex And Degree Of Lateralization On Dichotic Listening For Language

	Less	More
Male	16.89	18.75
	(9.13)	(11.71)
Female	7.65.	8.93
	(6.07)	(5.48)

Note. Standard deviations are in parentheses. Subjects with a left-ear advantage are omitted.

Table 13

Mean Face Recognition Scores As A Function Of Sex And Degree Of Lateralization On Dichotic Listening For Language

	Less	More
Male	9.78	9.25
	(.73)	(1.17)
Female	10.15	9.78
	(1.16)	(1.31)

Note. Standard deviations are in parentheses. Subjects with a left-ear advantage are omitted.

Table 14

Mean Similarities Scores As A Function Of Sex And Degree Of Lateralization On Dichotic Listening For Language

	Less	More
Male	21.61	19.88
	(1.94)	(1.46)
Female	21.08	20.82
	(2.67)	(1.52)

Note. Standard deviations are in parentheses. Subjects with a left ear advantage are omitted.

Table 15

Anova For Mental Rotations Scores For Verbal Dichotic Listening With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	31.70	1	31.70	15.95	.00
Degree (D)	1.11	1	1.11	0.56	.46
SD	0.02	1	0.02	0.01	.92
Error	149.05	75	1.99		

Table 16

Anova For Face Recognition Scores For Verbal Dichotic Listening With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	3.19	1	3.19	2.48	.12
Degree (D)	3.19	1	3.19	2.48	.12
SD	0.09	1	0.09	0.07	.79
Error	96.66	75	1.29		

Table 17

Anova For Similarities Scores For Verbal Dichotic Listening With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	0.64	1	0.64	0.15	.70
Degree (D)	15.59	1	15.59	3.69	.06
SD	8.49	1	8.49	2.01	.16
Error	317.07	75	4.23		

Table 18

Mean Similarities Scores As A Function Of Sex, Order And Degree Of Lateralization On Dichotic Listening For Music

	Male		Female	
	Left First	Right First	Left First	Right First
Less	20.78	20.33	21.29	20.18
	(2.44)	(2.02)	(2.34)	(2.91)
More	21.09	21.00	21.22	22.06
	(2.16)	(1.85)	(2.70)	(2.24)

Note. Standard deviations are in parentheses.

Table 19

Mean *Mental Rotation Scores As A Function Of Sex, Order And Degree Of Lateralization On Dichotic Listening For Music*

	Male		Female	
	Left First	Right First	Left First	Right First
Less	15.11	15.92	9.59	9.59
	(9.29)	(12.18)	(4.00)	(6.46)
More	20.18	20.38	7.17	8.28
	(8.13)	(7.46)	(5.65)	(5.94)

Note. Standard deviations are in parentheses.

Table 20

Mean Face Recognition Scores As A Function Of Sex, Order And Degree Of Lateralization On Dichotic Listening For Music

	Male		Female	
	Left First	Right First	Left First	Right First
Less	15.11	15.92	9.59	9.59
	(9.29)	(12.18)	(4.00)	(6.46)
More	20.18	20.38	7.17	8.28
	(8.13)	(7.46)	(5.65)	(5.94)

Note. Standard deviations are in parentheses.

Table 21

Anova For Similarities Scores For Music Dichotic Listening

Source	SS	DF	MS	F	Prob.
Order (O)	1.07	1	1.07	0.18	.67
Sex (S)	3.90	1	3.90	0.65	.42
Degree (D)	12.56	1	12.56	2.09	.15
OS	0.11	1	0.11	0.02	.89
OD	8.65	1	8.65	1.44	.23
SD	1.09	1	1.09	0.18	.67
OSD	4.16	1	4.16	0.69	.41
Error	672.79	112	6.01		

two-way interaction for sex and degree, $F(1,112)=5.52$, $p<.05$ (See Table 22). This latter finding showed that while males outperformed females on the mental rotations task, this advantage was particularly pronounced for the more lateralized subjects (See Figure 1). Of the four subgroups, more lateralized males had the highest mean scores on the rotations task while more lateralized females had the lowest mean scores. When each sex was considered separately however, these differences were not significant (See Tables 23 and 24).

An analysis of variance for face recognition revealed a main effect for sex, with females outperforming males. No other differences were obtained (See Table 25).

As with the verbal dichotic listening data, the music dichotic data was also reanalyzed with reversed-lateralization subjects (those showing a right ear advantage) omitted. This resulted in 32 males and 63 females being included in the following analyses.

The mean scores for the similarities, mental rotations and face recognition, according to Sex by Degree grouping, are shown in Tables 26, 27 and 28 respectively. Two-way analysis of variance for similarities revealed a significant main effect for degree, $F(1,91)=5.53$, $p<.02$ (See Table 29). More lateralized subjects had superior similarities scores. No other main effect or interaction was observed. The analysis of variance for face recognition resulted in no main effects or interaction (See

Figure 1

Mental Rotation Scores According to

Sex and Degree of Lateralization

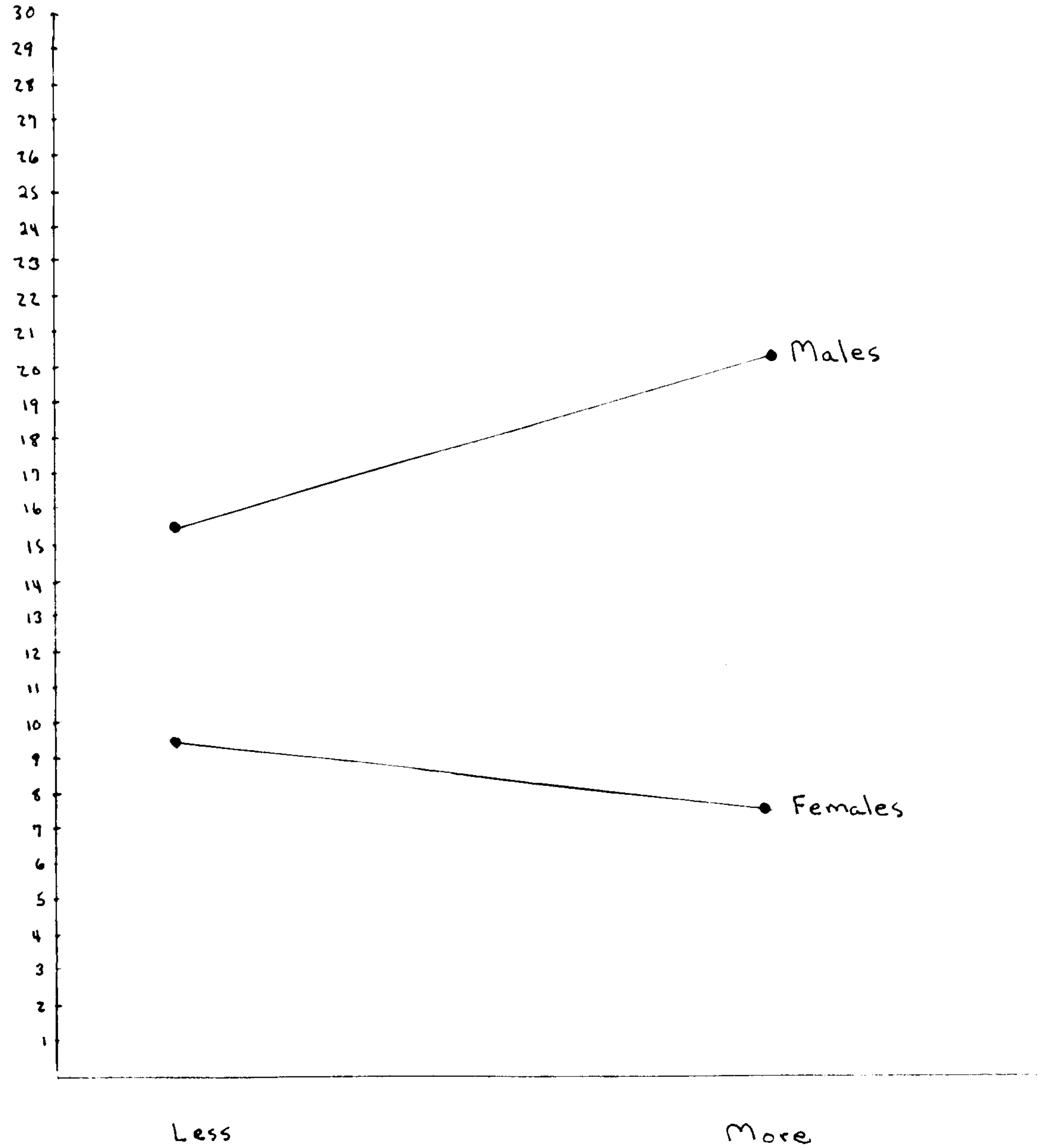

Table 22

Anova For Mental Rotation Scores For Music Dichotic Listening

Source	SS	DF	MS	F	Prob.
Order (O)	0.02	1	0.02	0.01	.93
Sex (S)	48.16	1	48.16	26.30	.00
Degree (D)	0.57	1	0.57	0.31	.58
OS	0.04	1	0.04	0.02	.88
OD	0.58	1	0.58	0.32	.58
SD	10.97	1	10.97	5.99	.02
OSD	0.13	1	0.13	0.07	.79
Error	205.07	112	1.83		

Table 23

Anova For Mental Rotation Scores For Degree Of Lateralization On Music Dichotic Listening For Males

Source	SS	DF	MS	F	Prob.
Degree (D)	6.35	1	6.35	3.57	p>.05
Error	206.17	116	1.78		

Table 24

Anova For Mental Rotation Scores For Degree Of Lateralization On Music Dichotic Listening For Females

Source	SS	DF	MS	F	Prob.
Degree (D)	5.17	1	5.17	2.90	p>.05
Error	206.17	116	1.78		

Table 25

Anova For Face Recognition Scores For Music Dichotic Listening

Source	SS	DF	MS	F	Prob.
Order (O)	0.11	1	0.11	0.08	.77
Sex (S)	6.27	1	6.27	4.74	.03
Degree (D)	0.01	1	0.01	0.01	.92
OS	0.37	1	0.37	0.28	.60
OD	1.70	1	1.70	1.28	.26
SD	2.43	1	2.43	1.84	.18
OSD	0.03	1	0.03	0.02	.89
Error	148.28	112	1.32		

Table 26

Mean Similarities Scores As A Function Of Sex And Degree Of Lateralization On Dichotic Listening For Music

	Less	More
Male	20.00	21.29
	(1.41)	(2.23)
Female	20.44	21.58
	(2.65)	(2.54)

Note. Standard deviations are in parentheses. Subjects with a right-ear advantage are omitted.

Table 27

Mean Mental Rotation Scores As A Function Of Sex And Degree Of Lateralization On Dichotic Listening For Music

	Less	More
Male	16.17	19.79
	(11.68)	(7.72)
Female	9.60	7.66
	(5.42)	(5.76)

Note. Standard deviations are in parentheses. Subjects with a right-ear advantage are omitted.

Table 28

Mean Face Recognition Scores As A Function Of Sex And Degree Of Lateralization On Dichotic Listening For Music

	Less	More
Male	9.28	9.93
	(1.13)	(.99)
Female	10.08	9.84
	(1.08)	(1.37)

Note. Standard deviations are in parentheses. Subjects with a right-ear advantage are omitted.

Table 29

Anova For Similarities Scores For Verbal Dichotic Listening With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	2.78	1	2.78	0.51	.48
Degree (D)	30.41	1	30.41	5.53	.02
SD	0.11	1	0.11	0.02	.89
Error	500.28	91	5.50		

Table 30). The analysis of variance for mental rotations resulted in a main effect for sex, with males obtaining higher scores, $F(1,91)=32.74$, $p<.0000$ (See Table 31). Again, a significant two-way interaction for sex and degree was observed, $F(1,91)=4.00$, $p<.05$. More lateralized males had the highest mean scores on the mental rotations task and more lateralized females had the lowest mean scores. These differences were not significant when males and females were considered separately.

Familial Handedness

In order to test for the possible effects of familial handedness, additional analyses of variance were conducted. The small numbers of subjects in some cells precluded any analysis according to sex. Six two-way analysis of variance with familial handedness, and either degree of lateralization for language or music as independent variables were conducted for the three cognitive performance measures (See Tables 32 to 43). No significant main effects or interactions were obtained.

Experiment 2-CLEM

The number of male and female subjects falling into the 4 possible CLEM groups are presented in Table 44.

Table 30

Anova For Face Recognition Scores For Music Dichotic Listening With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	2.65	1	2.65	1.83	.18
Degree (D)	0.88	1	0.88	.61	.44
SD	4.09	1	4.09	2.83	.10
Error	131.43	91	1.44		

Table 31

Anova For Mental Rotation Scores For Music Dichotic Listening With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	36.95	1	36.95	18.98	.00
Degree (D)	0.25	1	0.25	0.13	.72
SD	7.79	1	7.79	4.00	.05
Error	177.12	91	1.95		

Table 32

Mean Mental Rotation Scores As A Function Of Familial Handedness And Degree Of Lateralization On Dichotic Listening For Language

	Less	More
Familial	21.23	20.74
	(2.22)	(2.09)
Nonfamilial	21.18	20.93
	(2.54)	(2.73)

Note. Standard deviations are in parentheses.

Table 33

Mean Face Recognition Scores As A Function Of Familial Handedness And Degree Of Lateralization On Dichotic Listening For Language

	Less	More
Familial	9.91	9.83
	(1.15)	(1.40)
Nonfamilial	10.12	9.61
	(1.04)	(1.09)

Note. Standard deviations are in parentheses.

Table 34

Mean Similarities Scores As A Function Of Familial Handedness And Degree Of Lateralization On Dichotic Listening For Language

	Less	More
Familial	12.64	11.83
	(8.85)	(9.36)
Nonfamilial	11.44	11.24
	(9.72)	(6.44)

Note. Standard deviations are in parentheses.

Table 35

Mean Mental Rotation Scores As A Function Of Familial Handedness And Degree Of Lateralization On Dichotic Listening For Music

	Less	More
Familial	9.81	9.92
	(1.21)	(1.35)
Nonfamilial	9.92	9.75
	(.98)	(1.20)

Note. Standard deviations are in parentheses.

Table 36

<u>Mean Face Recognition Scores As A Function Of Familial Handedness And Degree Of Lateralization On Dichotic Listening For Music</u>

	Less	More
Familial	11.43	12.92
	(9.00)	(9.17)
Nonfamilial	11.82	10.81
	(7.82)	(8.34)

Note. Standard deviations are in parentheses.

Table 37

Mean Similarities Scores As A Function Of Familial Handedness And Degree Of Lateralization On Dichotic Listening For Music

	Less	More
Familial	21.10	20.88
	(2.17)	(2.17)
Nonfamilial	20.36	21.78
	(2.7)	(2.43)

Note. Standard deviations are in parentheses.

Table 38

Anova For Similarities Scores For Verbal Dichotic Listening

Source	SS	DF	MS	F	Prob.
Hand (H)	0.13	1	0.13	0.02	.88
Degree (D)	3.81	1	3.81	0.62	.43
HD	0.40	1	0.40	0.06	.80
Error	712.02	116	6.14		

Table 39

<u>Anova For Face Recognition Scores For Verbal Dichotic Listening</u>

Source	SS	DF	MS	F	Prob.
Hand (H)	0.00	1	0.00	0.00	.98
Degree (D)	2.45	1	2.45	1.84	.18
HD	1.26	1	1.26	0.95	.33
Error	154.41	116	1.33		

Table 40

<u>Anova For Mental Rotation Scores For Verbal Dichotic Listening</u>

Source	SS	DF	MS	F	Prob.
Hand (H)	0.65	1	0.65	0.29	.59
Degree (D)	0.04	1	0.04	0.02	.90
HD	0.79	1	0.79	0.35	.56
Error	264.98	116	2.28		

Table 41

Anova For Similarities Scores For Music Dichotic Listening

Source	SS	DF	MS	F	Prob.
Hand (H)	0.19	1	0.19	0.03	.86
Degree (D)	10.07	1	10.07	1.72	.19
HD	18.83	1	18.83	3.22	.08
Error	677.63	116	5.84		

Table 42

Anova For Face Recognition Scores For Music Dichotic Listening

Source	SS	DF	MS	F	Prob.
Hand (H)	0.02	1	0.02	0.01	.90
Degree (D)	0.03	1	0.03	0.02	.88
HD	0.55	1	0.55	0.40	.53
Error	158.59	116	1.37		

Table 43

Anova For Mental Rotation Scores For Music Dichotic Listening

Source	SS	DF	MS	F	Prob.
Hand (H)	0.57	1	0.57	0.25	.62
Degree (D)	0.16	1	0.16	0.07	.79
HD	1.15	1	1.15	0.50	.48
Error	264.33	116	2.28		

Table 44

Distribution Of Male And Female Subjects According To CLEM

	Left Movers	Nondiscriminators	Discriminators	Right Movers
Male	18	8	2	12
Female	31	20	12	17
	—	—	—	—
	49	28	14	29

CLEM and Degree of Lateralization

The hypothesis that discriminating bimovers are more lateralized on dichotic listening than nondiscriminating bimovers was not confirmed. Due to the small number of males who were discriminating bimovers (See Table 44), sex was not included in any analyses comparing the discriminating versus non-discriminating bimover groups. Two one-way analyses of variance were conducted with CLEM as a between-subject variable and degree of lateralization for each dichotic task the dependent variables (See Tables 45 and 46). Contrary to prediction, no significant differences between discriminating and nondiscriminating bimovers was observed for degree of lateralization on verbal or music dichotic listening.

CLEM and Cognitive Performance

The mean scores on the three cognitive performance measures, according to sex and CLEM classification, are presented in Tables 47, 48 and 49.

The hypothesis that left movers would perform better than right movers on the spatial measures was, at best, only partially confirmed. A 2x3 analysis of variance was performed, with sex and CLEM as between subject variables and mental rotations the dependent variable (See Table 50). This revealed a main effect for sex, $F(1,114)=31.43$, $p<.0000$, with males performing significantly better than females on the mental rotations test. A sex by CLEM interaction was also obtained,

Table 45

Anova For Degree Of Lateralization On Verbal Dichotic Listening For Bimovers

Source	SS	DF	MS	F	Prob.
Bimovers	0.01	1	0.01	0.12	.73
Error	3.67	40	0.09		

Table 46

Anova For Degree Of Lateralization On Music Dichotic Listening For Bimovers

Source	SS	DF	MS	F	Prob.
Bimovers	0.00	1	0.00	0.00	.97
Error	15.77	40	0.39		

Table 47

Mean Mental Rotation Scores As A Function Of Sex And CLEM

	Right Movers	Bimovers	Left Movers
Male	20.83	21.60	13.67
	(7.31)	(10.99)	(8.94)
Female	8.12	7.84	9.50
	(6.24)	(5.51)	(5.51)

Note. Standard deviations are in parentheses.

Table 48

Mean Face Recognition Scores As A Function Of Sex And CLEM

	Right Movers	Bimovers	Left Movers
Male	20.75	20.70	20.83
	(2.30)	(1.77)	(2.18)
Female	20.94	20.59	21.81
	(2.86)	(2.34)	(2.71)

Note. Standard deviations are in parentheses.

Table 49

Mean Similarities Scores As A Function Of Sex And CLEM

	Right Movers	Bimovers	Left Movers
Male	9.42	9.70	9.5
	(.90)	(1.49)	(.92)
Female	10.29	10.13	9.74
	(.99)	(1.21)	(1.21)

Note. Standard deviations are in parentheses.

Table 50

Anova For Mental Rotation Scores For CLEM

Source	SS	DF	MS	F	Prob.
Sex (S)	55.74	1	55.74	31.43	.00
CLEM (C)	2.50	2	1.25	0.70	.50
SC	14.88	2	7.44	4.19	.02
Error	202.16	114	1.77		

$F(2,114)=4.19$, $p<.01$. As can be seen in Figure 2, for males, right movers scored higher than left movers on the mental rotations test. However, for females, left movers scored higher than right movers. A closer examination of this relationship revealed significant differences between male left and right movers, $F(1,28)=5.16$, $p<.03$ (See Table 51). A comparison of female left and right movers revealed no significant differences (See Table 52).

A 2x3 analysis of variance was also conducted for the face recognition data (See Table 53). This revealed a main effect for sex, $F(1,114)=5.07$, $p<.03$, with females scoring significantly higher than males. No main effect for CLEM or interaction was observed.

The hypothesis that right movers would perform better than left movers on the similarities test was not confirmed. A 2x3 analysis of variance revealed no main effects or interaction (See Table 54).

The hemisphericity approach to CLEM assumes that individuals have typical lateralization patterns, that is, left hemisphere specialization for language and right hemisphere specialization for nonverbal functions. To control for the possibility that the inclusion of subjects with reversed lateralization may have affected the results, the preceding analyses were repeated with reversed-lateralization subjects omitted. The subjects demonstrating a right hemisphere advantage on the verbal

Figure 2

Mental Rotation Scores According to

Sex and CLEM

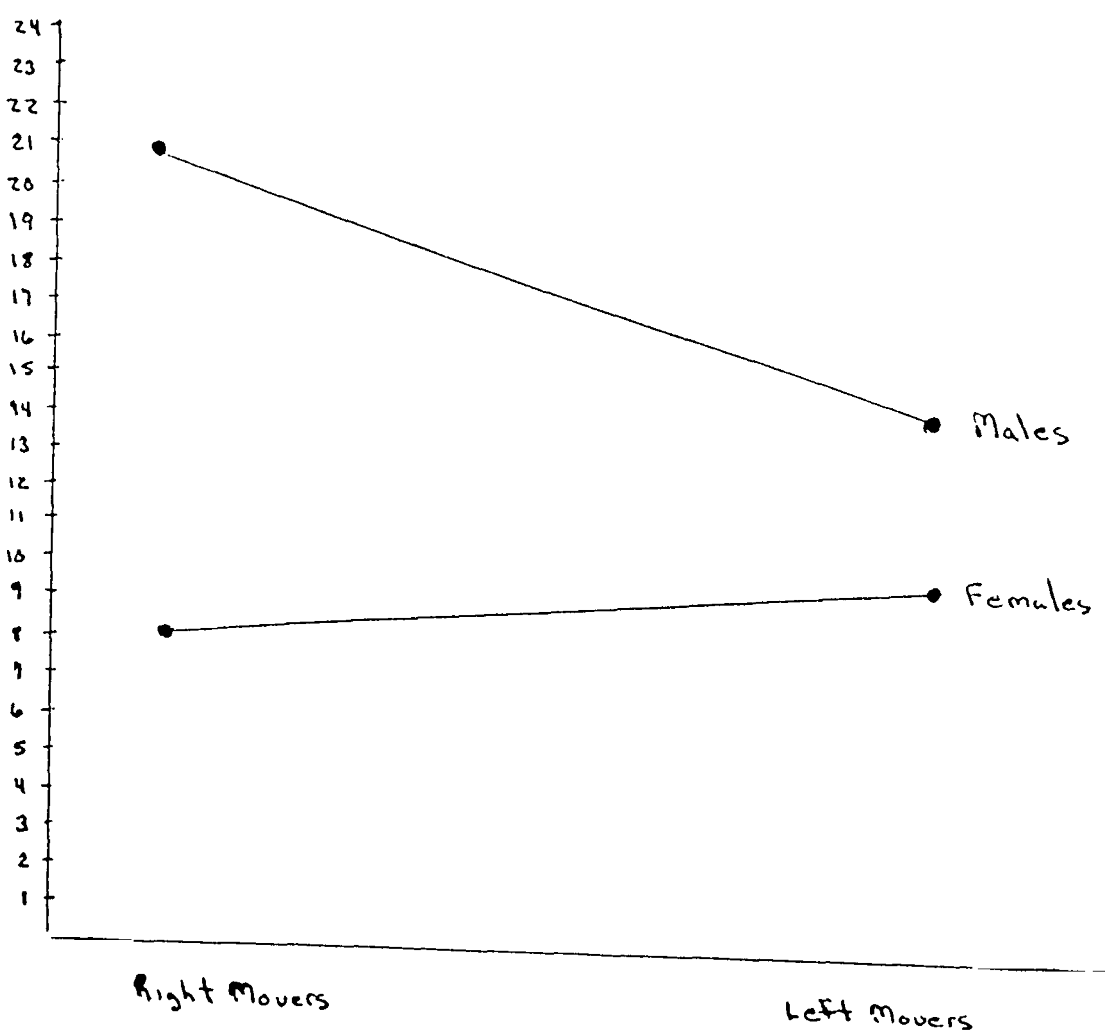

Table 51

Anova For Mental Rotation Scores For Male Right Versus Left Movers

Source	SS	DF	MS	F	Prob.
CLEM (C)	8.82	1	8.82	4.98	$p<.05$
Error	202.16	114	1.77		

Table 52

Anova For Mental Rotation Scores For Female Right Versus Left Movers

Source	SS	DF	MS	F	Prob.
CLEM (C)	1.98	1	1.98	1.12	$p>.05$
Error	202.16	114	1.77		

Table 53

Anova For Face Recognition Scores For CLEM

Source	SS	DF	MS	F	Prob.
Sex (S)	6.60	1	6.60	5.07	.03
CLEM (C)	1.84	2	0.92	0.70	.50
SC	1.78	2	0.89	0.68	.51
Error	148.48	114	1.30		

Table 54

Anova For Similarities Scores For CLEM

Source	SS	DF	MS	F	Prob.
Sex (S)	3.10	1	3.10	0.51	.48
CLEM (C)	9.13	2	4.56	0.76	.47
SC	5.94	2	2.97	0.49	.61
Error	688.35	114	6.04		

dichotic test were excluded from the similarities analysis. Alternatively, subjects demonstrating a left hemisphere advantage on the music dichotic test were excluded from the mental rotations and face recognition analyses. Analyses of variance were performed with sex and CLEM as between subject variables for each cognitive performance measure (See Tables 55 to 57). The results of these analyses were almost identical to those with all subjects included. A main effect for sex, $F(1,89)=22.77$, $p<.0000$, and an interaction between sex and CLEM, $F(1,89)=3.55$, $p<.03$, was observed for the mental rotations data. Again, a square root transformation was applied to the mental rotations scores. However, the main effect for sex on face recognition was not observed. No other significant results were obtained.

In order to test for the possible effects of familial handedness, additional analyses of variance were conducted (See Tables 58 to 60). Familial handedness and CLEM were between subject variables and cognitive performance measures were the dependent variables. No significant differences were observed.

Secondary Results

Question-type

Overall, 43% of the scorable responses resulted in eye movements to the right. The mean proportion of rightward eye movements was 46% for the verbal questions and 41% for the

Table 55

<u>Anova For Similarities Scores For CLEM With Reversed-Lateralization Subjects Omitted</u>

Source	SS	DF	MS	F	Prob.
Sex (S)	0.06	1	0.06	0.01	.90
CLEM (C)	5.27	2	2.63	0.61	.55
SC	5.21	2	2.60	0.60	.55
Error	316.60	73	4.34		

Table 56

<u>Anova For Mental Rotation Scores For CLEM With Reversed-Lateralization Subjects Omitted</u>

Source	SS	DF	MS	F	Prob.
Sex (S)	43.38	1	43.38	22.77	.00
CLEM (C)	4.07	2	2.03	1.07	.35
SC	13.54	2	6.77	3.55	.03
Error	169.55	89	1.90		

Table 57

Anova For Face Recognition Scores For CLEM With Reversed-Lateralization Subjects Omitted

Source	SS	DF	MS	F	Prob.
Sex (S)	3.33	1	3.33	2.24	.14
CLEM (C)	1.81	2	0.91	0.61	.55
SC	1.07	2	0.54	0.36	.70
Error	132.23	89	1.49		

Table 58

Anova For Face Recognition Scores For CLEM And Handedness

Source	SS	DF	MS	F	Prob.
Hand (H)	0.55	1	0.55	0.42	.52
CLEM (C)	2.58	2	1.29	0.99	.38
HC	6.71	2	3.36	2.56	.08
Error	149.23	114	1.31		

Table 59

Anova For Mental Rotation Scores For CLEM And Handedness

Source	SS	DF	MS	F	Prob.
Hand (H)	1.22	1	1.22	0.54	.46
CLEM (C)	3.19	2	1.59	0.71	.49
HC	5.97	2	2.98	1.33	.27
Error	256.56	114	2.25		

Table 60

Anova For Similarities Scores For Clem And Handedness

Source	SS	DF	MS	F	Prob.
Hand (H)	0.01	1	0.01	0.00	.98
CLEM (C)	14.06	2	7.03	1.15	.32
HC	2.01	2	1.01	0.16	.85
Error	697.46	114	6.12		

spatial questions. A matched pairs t test was used to determine whether there was a question-type effect for the CLEM data. This revealed a significant difference in the number of left and rightward eye movements elicited by the spatial versus verbal questions, $t(119)=2.85, p<.005$. Although there was a greater number of left movements overall, spatial questions resulted in a greater proportion of leftward eye movements than verbal questions.

The finding of a significant question-type effect may undermine the earlier individual differences analyses with CLEM groups. To check on the robustness of the CLEM groupings despite a question-type effect, a Pearson product-moment correlation was conducted on the proportion of rightward eye movements for spatial questions with the proportion of rightward eye movements for verbal questions. This revealed a significant positive correlation, $r(119)=.81$, $p < .001$, indicating that an individual's preferred direction of gaze was consistent regardless of the type of question.

Musical Experience

A two-way analysis of variance was also performed to determine whether sex or music experience had any influence on music laterality scores. No significant main effects or interaction were observed for degree of lateralization of music (See Table 61). For direction of lateralization however, a two-way interaction was obtained, $F(1,116)=5.36$, $p<.05$ (See

Table 62). All four sex by music experience subgroups demonstrated a left-ear advantage for melodies (See Tables 63 and 64). However, for males, nonmusicians showed a significantly greater left-ear advantage while for females, musicians showed a greater left-ear advantage, although not significant (See Figure 3).

Figure 3

Direction of Lateralization on Music Dichotic Listening According to Sex and Music Experience

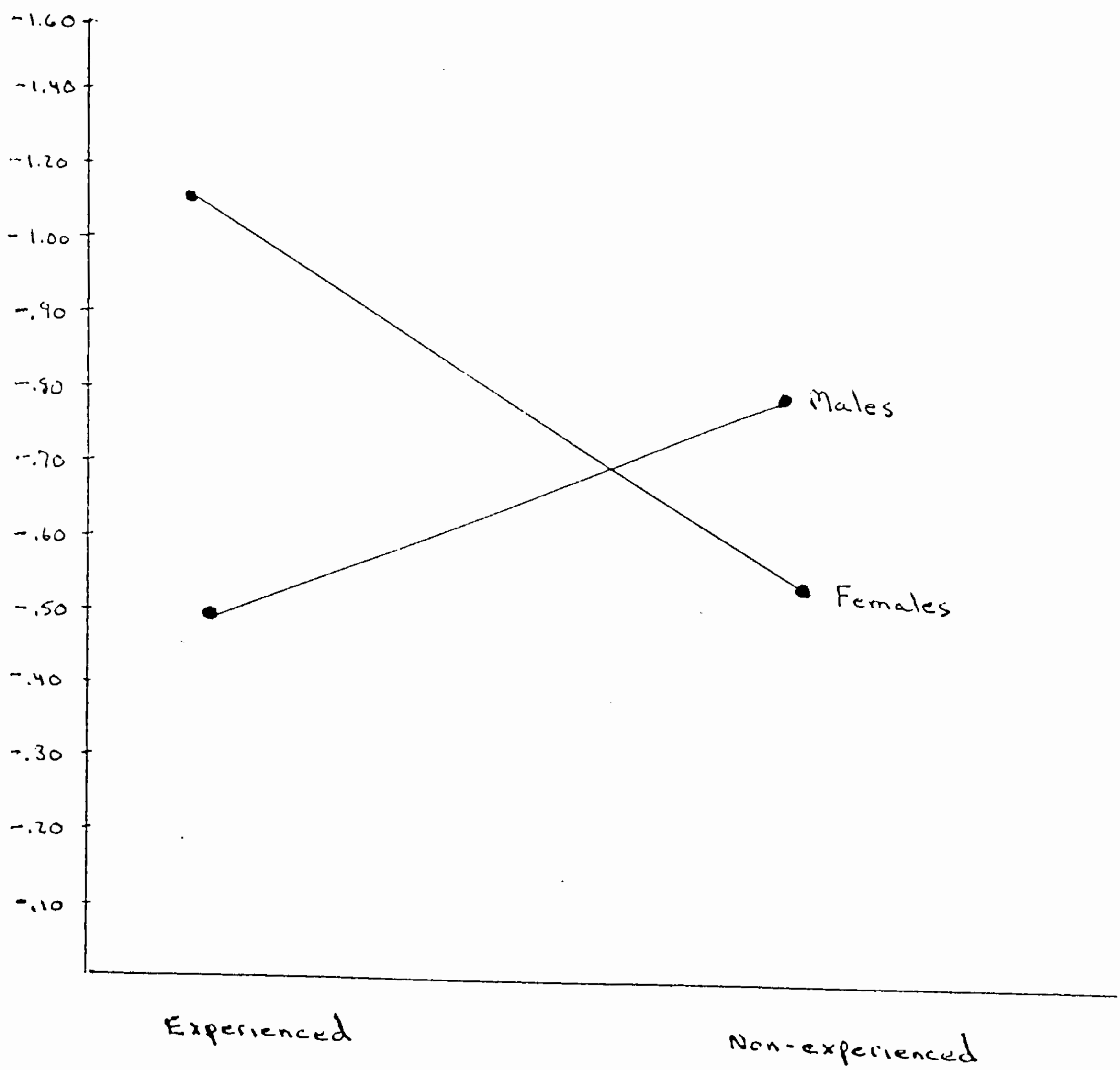

Table 61

Anova For Degree Of Lateralization On Music Dichotic Listening For Music Experience

Source	SS	DF	MS	F	Prob.
Sex (S)	0.66	1	0.66	1.47	.23
Music (M)	0.07	1	0.07	0.15	.70
SM	1.30	1	1.30	2.86	.09
Error	52.62	116	0.45		

Table 62

Anova For Direction Of Laterality On Music Dichotic Listening For Music Experience

Source	SS	DF	MS	F	Prob.
Sex (S)	0.89	1	0.89	1.04	.31
Music (M)	0.50	1	0.50	0.59	.44
SM	4.56	1	4.56	5.36	.02
Error	98.71	116	0.85		

Table 63

Anova For Direction Of Laterality For Music Experience For Males

Source	SS	DF	MS	F	Prob.
Music (M)	0.78	1	0.78	0.91	p>.05
Error	98.71	116	0.85		

Table 64

Anova For Direction Of Laterality For Music Experience For Females

Source	SS	DF	MS	F	Prob.
Music (M)	5.85	1	5.85	6.88	p<.01
Error	98.71	116	0.85		

CHAPTER IV

DISCUSSION

Experiment 1

Degree of Lateralization and Cognitive Performance

The hypothesis that less lateralization of verbal functions will result in a decrement in spatial ability was not supported. Indeed, just the opposite was observed for the face recognition test. Subjects who were less lateralized on the verbal dichotic listening task performed significantly better on the face recognition test. In addition, for the mental rotations test, no differences were observed for degree of lateralization. Thus, there appears to be no support for Levy's (1969;1974) primary contention, that less lateralization for verbal functions results in a crowding of the right hemisphere and a subsequent reduction in spatial ability. If anything, less lateralization for verbal functions may result in enhanced spatial ability.

The hypothesis that less lateralization for verbal functions will result in enhanced verbal ability was partially supported. When all subjects were included in the analysis, no relationship was observed between degree of language lateralization and performance on the similarities test. However, when subjects with reversed lateralization (right hemisphere advantage) were omitted, less lateralized subjects were significantly better on the similarities test. This latter finding supports Levy's

(1974) suggestion that less lateralization for verbal functions results in enhanced verbal ability because both hemispheres display language processing capacities. As such, more neural space is devoted to the execution of verbal functions.

The data from the music dichotic listening task also yielded conflicting evidence. Contrary to Levy's theory, no differences were obtained between less and more lateralized subjects on face recognition. Also, a two-way interaction for sex by degree was observed for the mental rotations test. In line with the crowding theory, less lateralized females had higher mental rotations scores than more lateralized females. However, these differences were not significant. Contrary to the crowding theory, less lateralized males had poorer mental rotations scores than more lateralized males. This latter finding is particularly important in that the difference between the less and more lateralized males was significant.

The hypothesis that less lateralization on the music dichotic listening task would be associated with lower verbal ability was only partially supported. Just as with the verbal dichotic data, when all subjects were included, no relationship was observed between degree of lateralization and performance on the similarities test. However, when reversed-lateralization (left hemisphere advantage) subjects were omitted, less lateralization was associated with lower similarities scores, a finding consistent with Levy's theory.

Thus overall, there appears to be, at best, only marginal support for the crowding theory. For the most part, spatial abilities appeared to have little association with degree of lateralization for either verbal or music functions. The exceptions to this were opposite to Levy's prediction. The aspect of the crowding hypothesis which has received the most empirical and theoretical attention, is that less lateralization of verbal functions results in a decrement in spatial ability. The present study found just the opposite for face recognition.

In contrast, the results for verbal ability partially confirmed the crowding theory. No relationship was observed between degree of lateralization for verbal or music functions and verbal ability. However, when reversed-lateralization subjects were excluded from the analysis, less lateralization of verbal functions was associated with enhanced verbal ability while less lateralization of music functions was associated with reduced verbal ability.

In summary, the conflicting findings of the present study, when viewed in conjunction with the few past studies which have examined this relationship, offer little support for a crowding interpretation. As noted earlier, Kraft (1983) found no relationship between verbal and nonverbal degree of lateralization and verbal and nonverbal cognitive performance. Similarly, Waber (1977) reported no relationship between verbal degree of lateralization and verbal and nonverbal cognitive performance. Birkett (1980), on the other hand, found that less lateralization on a form recognition test was associated with lower spatial scores on only 1 of 3 different spatial tests. Furthermore, this relationship was only found for left handed males. No relationship was found for the other 3 handedness by sex groups. Therefore, in all, Birkett's study provides little evidence of a crowding influence.

Indeed, it is surprising how popular and commonplace Levy's crowding theory is, given the paucity of studies in this area and their failure to support her theory. Most of the evidence which has usually been put forth to support her theory has been studies comparing left and right handers on cognitive abilities. However, a thorough review of this literature revealed little evidence of a deficit for left handers. Of the 52 studies testing this theory, only 8 clearly supported the theory and 3 found opposite results.

Furthermore, as noted earlier, using handedness as the lone index of cerebral lateralization may be problematic. Only a small percentage of left handers actually have bilateral representation of language. At the least, this may be a very insensitive measure. However, given that a possibly equal number of left handers have reversed specialization of function, it would be difficult to determine whether any deficit, should it exist, is due to less lateralization or reversed lateralization.

Although the evidence to date has been unsupportive, more direct research in this area is needed before any definite conclusions can be reached. Of the three past studies that have directly examined this issue, two of them used children. Given that both degree of lateralization and cognitive abilities may vary with age (Halpern, 1986; Kahn, 1985), one has to be particularly cautious in the conclusions they draw from such samples.

Lewis and Harris (1988), in a recent review of the laterality and cognition area, suggest other methodological factors which must be addressed. One of these is the choice of the cognitive ability test. The cognitive test should have sufficient variability in order to allow for an adequate test of the laterality-cognition relationship. In studies where sex differences are of importance, a cognitive test which has been shown to yield considerable sex differences would be desirable. As they note, a test such as the mental rotations may be preferable to the block design. Thus, with regard to spatial ability, the present study satisfies this condition.

The present investigation used two distinct measures of spatial ability, a mental rotations test and a face recognition test. One interesting difference between the present study and the three preceding it (Birkett, 1980; Kraft, 1983; Waber, 1977) is the use of tests that are thought to have opposite gender superiorities. The findings from the present study support this contention. Males were significantly better at mental rotations while females were significantly better at face recognition. The use of tests which have opposite gender superiorities may be particularly helpful in allowing us to gain a better understanding of any relationship, should it exist. If a theory such as the crowding hypothesis is invoked to explain sex differences in spatial ability then it must also be capable of explaining any opposite gender superiorities.

A second consideration which Lewis and Harris (1988) address is the compatability of the laterality and cognitive performance tests. To some extent, this problem has plagued all of the earlier studies. As they point out, degree of lateralization may vary for different types of spatial or verbal functions since neither are necessarily unitary constructs. Therefore, if one is interested in examining the relationship between, say spatial lateralization and spatial ability, it may be more appropriate to have both come from the same spatial category. Unfortunately, this particular criterion is especially difficult to apply with dichotic listening studies. Furthermore, this situation becomes even more complex when you consider lateralization for other cognitive functions, such as music. One possible drawback with the present experiment was the use of dichotic listening for melodies as a nonverbal lateralization measure with spatial tests as nonverbal cognitive performance measures. Whether music and spatial functions involve the same neural space or pattern of coding, as a crowding theory would imply, is unclear with our present state of knowledge.

A related consideration here, is whether the laterality measure and cognitive test are in the same sensory modality. In the past, there has been some debate over how related laterality measures such as the visual-half field and dichotic listening tasks are (Hines and Satz, 1974; Fennell et al., 1977). It is conceivable that an individual may be more lateralized for verbal or nonverbal processes on one laterality measure than another (eg.,visual versus auditory). This may arise from changes in the cognitive demands of the laterality task associated with different sensory modalities. Indeed, past research has shown that a number of stimulus and subject characteristics may influence the degree and direction of hemispheric advantage on a perceptual laterality test. Some of the factors that may influence the outcome are complexity of and familiarity with the task (Mathieson, Sainsbury and Fitzgerald, 1990; Dee and Hannay, 1981) attention (Bryden, 1980; Graves, Morley and Marcopulos, 1987) hemisphericity or characteristic arousal (Levy, 1983; Neilson and Sorensen, 1976) and subject strategies (Bryden, 1978, 1980).

Another consideration is whether the chosen laterality measure yields enough variation in degree of lateralization. According to Lewis and Harris (1988), dichotic listening and visual-half field tasks may offer the greatest variation, a condition satisfied by both the present study and its three predecessors.

A final factor which should be dealt with is the confounding of degree of lateralization with direction. That is, most studies which have examined a laterality-cognition relationship have failed to clearly differentiate between degree and direction. It is for this reason that only the three aforementioned studies (Birkett, 1980; Kraft, 1983; Waber, 1977) were considered appropriate to include in this literature review.

While it is debatable whether there is any "perfect" method for examining degree of lateralization, some methods may be more problematic than others. The common problem with most studies which have examined degree of lateralization is how they measure degree. They typically average the laterality scores of the subjects within each group (eg., sex) irrespective of the direction of hemispheric advantage. As such, the group with the smaller hemispheric advantage (eg., a small right ear advantage), is deemed less lateralized. The problem with this method is that direction may make a significant contribution to the average laterality score. Hypothetically, it would be possible to have a group of subjects, half strongly lateralized to the right and the other half strongly lateralized to the left. In this instance, their average score would indicate no hemispheric advantage, although in reality, all of the subjects are strongly lateralized. Given that a greater proportion of subjects are classified as reversed or less lateralized on perceptual laterality tasks, compared to the Wada (Springer and Deutsch, 1989), this could pose a serious problem for an averaging method of this sort.

In conclusion, the concept of degree of lateralization is a far more complex issue than it is usually treated in the general literature. Degree and direction of lateralization may be influenced by a number of different stimulus and subject characteristics which cloud any interpretation about the "true" underlying cerebral organization. Most of the studies which have examined this area have failed to differentiate between degree and direction of lateralization. Thus, only a paucity of studies directly examine the crowding theory. The present study, although generally unsupportive, did find some positive evidence with regard to verbal ability.

Experiment 2

CLEM and Degree of Lateralization

The hypothesis that nondiscriminating bimovers are less lateralized on dichotic listening than discriminating bimovers was not supported. Contrary to Gur et al.'s (1975) theory, no differences were observed for either the verbal or music dichotic listening tasks. In their original study, Gur et al. (1975), believed nondiscriminating bimovers were less lateralized, on the basis of two different lines of evidence. First, the nondiscriminating bimovers are those subjects whose failure to show a characteristic hemispheric preference does not appear to be due to the influence of the type of CLEM questions. Secondly, they found a significantly greater proportion of nondiscriminators among left handers and discriminators among right handers. As noted earlier, past research has suggested that left handers may be less well lateralized.

One of the drawbacks to the present investigation was the small number of discriminating bimovers, particularly males. This precluded any analysis involving sex, a variable which has been shown to be an important moderating variable in many cerebral lateralization studies (Bryden, 1980; Segalowitz, 1983). This is in stark contrast to Gur et al.'s (1975) study. They had 28 right handed bimovers in their study, 18 of whom were discriminators. The present study, on the other hand, had 10 male and 32 female bimovers. Of these, there were 2 male and 12 female discriminators.

One possible explanation for why the present study failed to support Gur et al.'s theory is the differences between subject samples. The present study used a primarily female sample while Gur et al.'s used all males. It may be that degree of lateralization and bidirectionality are only related in males. Certainly, before we can come to any conclusions regarding this theory future research must account for any possible sex differences.

Another factor which should be taken into account in future research is the type of laterality task and stimuli. As mentioned earlier, degree of lateralization is not a unitary construct, but rather it may vary for different functions. Future studies might examine this issue using both visual-half field and dichotic listening measures for various types of stimuli (eg., stop consonants versus digits). If nondiscriminating bimovers do not respond to question-type because they are less lateralized, then this may be due to less lateralization for a specific function or multiple functions. For instance, if an individual is less lateralized for spatial functions this may be sufficient enough for them to fail to show a question-type effect.

Related to this issue, is the match between the functions assessed by the lateralization task and the type of questions asked. Although some researchers have attempted to create valid spatial and verbal questions for the CLEM test (Ehrlichman and Weinberger, 1978), to date, this still remains a problematic issue. In addition to developing reasonably "pure" spatial or verbal questions, it may also be valuable to look at the specific subtype of question. Many CLEM studies that look at question-type use a variety of different types of verbal or spatial questions on the same test. For example, a verbal set may contain questions on spelling, vocabulary and proverbs. It may be better to use only the one subtype of question which appears to be as close a match as possible to the function assessed by the laterality test.

CLEM and Cognitive Ability

The hypothesis that left movers would demonstrate better spatial performance than right movers, was for the most part, not supported. An analysis of the mental rotation data revealed a sex by CLEM interaction. For females, left movers were superior to right movers, however for males, just the opposite was true. Two past studies which have examined this relationship have also failed to show differences in the predicted direction.

In a study of male undergraduate university students, Glackman (1977) found evidence consistent with the present investigation, with right movers superior to left movers. However, Herman and Bruce (1983) found no differences for either young or elderly adults of both sex.

One possible reason for these discrepant results is individual differences in problem solving strategies. The importance of subject strategies has often been cited in studies dealing with sex differences in both cerebral lateralization and cognitive performance. A number of researchers (Bryden, 1980; Segalowitz, 1983) have argued that the apparent direction and extent of lateralization may be influenced by the strategy the subject uses. For example, females may appear to be less lateralized or show a reversed asymmetry on laterality tasks because they are using a problem solving strategy which better suits the opposite hemisphere. A more verbal strategy on a spatial laterality task may result in a left hemisphere advantage. Similarly, an individual's performance on a cognitive task may vary according to the strategy they use. Some researchers (Caplan, MacPherson and Tobin, 1985; Cochran and Wheatley, 1983; Sherman, 1978) have attempted to explain the supposed inferiority of females on spatial tasks by suggesting that they use an inappropriate strategy.

Research with the mental rotations test suggests that this task may be particulary open to individual strategies. In fact, when the mental rotations test was first developed, researchers (Shepard and Metzler, 1971) argued that this task required a holistic, gestalt strategy. That is, the subject rotates a mental image of the whole set of blocks simultaneously, a process thought to favor the right hemisphere. Soon after, another group of researchers (Yuille and Steiger, 1982) tried to argue that mental rotation performance involved analytic strategies (more suited to the left hemisphere).

Subsequent studies (Kimball, 1987) have shown that strategy use may be determined by both subject preferences and task demands. A lack of practice or the use of unfamiliar stimuli in this task may lead to more analytic strategies because the subject has less integrated internal representations (Shepard and Cooper, 1982; Bethell-Fox and Shepard, 1988). Thus, the Vandenberg and Kuse (1978) version, that was used in the present study, may lend itself to both types of strategies (Kimball, 1987).

While an individual strategies approach is an appealing explanation for the results of the present study, it has its problems as well. Past studies have suggested that an holistic approach is associated with superior performance on this task (Kimball, 1987). This is also consistent with studies showing that males use this strategy more often (Tapley and Bryden, 1977; Went and Kimball, 1986) and are superior at this task (Linn and Petersen, 1985). However, one problem with regard to this study, is that better performance for males was associated with the left hemisphere while better performance for females was associated with the right hemisphere. One would expect just the opposite since the left hemisphere is usually associated with analytic processing and the right hemisphere with holistic processing (Bradshaw and Nettleton, 1981).

Contrary to prediction, no differences were observed between left and right movers on face recognition. To date, very few studies have examined the relationship between CLEM and face recognition. Consistent with the present study, Jean (1982) found no relationship between CLEM and Milner's face recognition test. Similar findings were reported by Bakan (1980) and Davies (1982). However, Jean also found that left movers were significantly faster than right movers at recognizing faces briefly presented at a central position on a tachistoscope. According to Jean, the failure to find hemispheric differences on Milner's free view face recognition test is predictable. Again, subject strategies may be playing a role.

Numerous unilateral brain damage (De Renzi, Faglioni and Spinnler, 1968; Milner, 1968; Newcombe, De Haan, Ross and Young, 1989) and tachistoscopic studies (Ellis, 1983; Rhodes, 1985) have demonstrated a right hemispheric advantage for face recognition. Although faces may be primarily processed by the right hemisphere, different task conditions may allow for left versus right hemisphere strategies. Facial stimuli which are unfamiliar (opposite of the mental rotations test) and briefly presented, may favor global, holistic processing and result in a right hemisphere advantage (Sergent and Bindra, 1981). Although both tasks utilized unfamiliar faces, the free view face recognition test involved a far longer exposure time. This longer exposure time may have allowed for alternative coding strategies.

The hypothesis that right movers would perform better than left movers on the similarities test was not confirmed. These results are consistent with the only other study that has examined this relationship (Moretti, 1982).

On the surface, the similarities test would appear to be an excellent test for the purposes of this study. Of all the verbal subtests of the WAIS, the similarities is the least affected by experience and educational background and is considered one of the best predictors of left hemisphere damage (Lezak, 1983). However, just because this test is sensitive to the effects of brain injury (Lezak, 1983), does not guarantee that this will apply to conventional laterality tests with normals. In fact, of the major verbal subtests of the WAIS, Moretti (1982) found the least relationship between CLEM and the similarities test.

A more appropriate approach in future studies may be to use a composite verbal score comprising several verbal tests. For example, when Moretti (1982) used a verbal comprehension factor, based on several WAIS verbal subtests, right movers scored significantly higher than left movers. Similar findings have been reported using ratios of composite verbal and spatial scores (Stern and Baldinger, 1983; Tucker and Suib, 1978). As discussed earlier, verbal and spatial abilities are not unitary constructs. Therefore, any one test by itself, may not be a sufficient index of an individuals verbal or spatial ability.

Secondary Analyses

Another finding worth noting, is the differences in laterality for musicians and nonmusicians according to sex. Although overall, the subjects exhibited a left-ear advantage for music, for males, musicians showed a smaller left-ear advantage. This is somewhat consistent with past research suggesting that musicians process music with their left hemisphere (Bever and Chiarello, 1974). Females, on the other hand, showed a reversed pattern. Musicians showed a much stronger left-ear advantage. One possible qualification with respect to the present study (and a number of studies preceding it), is the way the classification for musician and nonmusician was determined. The present study's criterion for being classified a musician was 4 years of playing an instrument and the subject had to be currently playing. Such a criterion may be lacking in that it fails to account for those musically inclined subjects who sing. Also, it fails to differentiate on the basis of factors such as formal versus informal training, expertise in classical music (given the melodies were classical passages), and the type of instruments played. In addition, university samples often involve subjects recently graduated from high school. These subjects could easily have participated in music as part of their high school curriculum and therefore would be classified as musicians. Should a subject with the same training but out of high school for a few years and no longer playing be classified as a nonmusician? The use of more extreme groups may be more valuable for future research.

Another pertinent finding, in the present study, is a question-type effect. As noted earlier, a review of the literature revealed some support for this idea. Approximately half of the studies examining this issue have reported a question-type effect. One possible problem, which may arise with studies examining either question-type or hemisphericity is they may negate each other. The failure to find differences for different types of questions in a number of past studies may be due to characteristic activation or hemisphericity overriding any question-type effect. A concern with the present study may have been that the finding of a question-type effect would result in diminished individual differences in hemisphericity. However, a correlation between the proportion of right eye movements for verbal and spatial questions demonstrated that individuals are consistent in their direction of gaze, regardless of the type of question. This implies that even in studies where the type of question influences the direction of gaze, individual differences in hemisphericity appear to be the more important determinant.

Conclusion

The present study examined the relationship between degree of lateralization, cognitive performance and CLEM. Although degree of lateralization is a popular concept in the cerebral lateralization area, it has historically been misunderstood. The literature is replete with examples of problems with the definition and assessment of this concept. Degree of lateralization has often been assessed by insensitive measures such as handedness or it has been confounded with direction of laterality. Furthermore, it was noted that an individual's degree of lateralization score may be affected by a number of stimulus and subject characteristics. The present study attempted to control for two of the most important of these factors, attention and accuracy on the laterality task. A forced attention method on dichotic listening was used to control for the former and Bryden and Sprott's (1981) accuracy-free laterality ratio was used to control for the latter.

One area where degree of lateralization has been thought to play a central role is its relationship with cognitive performance. Experiment 1, of the present study, examined this relationship. Another area where degree of lateralization may prove to be of interest is with regard to CLEM. Experiment 2, of the present study, looked at the relationship between bimoving on the CLEM test and degree of lateralization. In addition, Experiment 2 also looked at the relationship between CLEM and cognitive performance. Many of the methodological and theoretical considerations discussed above are applicable to both experiments.

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APPENDIX A

1) Briefly describe the face of Ronald Regan

2) What does the following word mean? Anthropology

3) On a quarter, which way does the queen face?

4) Name a synonym for the word-elaborate

5) Where is your student # in relation to your picture on your student card?

6) Spell the word - ludicrous

7) In lecture, which side of the room do you usually sit on?

8) Name a synonym for the word- penetrating

9) Briefly describe the outside of your parents home

10) What does the following saying mean? He who hesitates is lost.

11) Which direction would you be facing if east was on your left?

12) What does the following word mean? vivacious

13) Briefly describe the face of Brian Mulrony

14) Name an antonym for the word-crowded

15) On a nickel, which way does the beaver face?

16) Spell the word - parallel

17) Which is closer to downtown? South Burnaby or Richmond

18) Name an english word that starts with a "t" and ends with a "t".

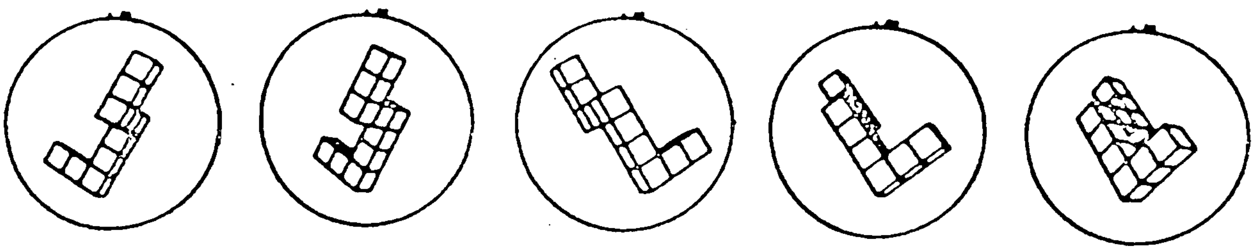
19) On a dartboard, where is the number 3?

20) What is an antonym for the word - unusual

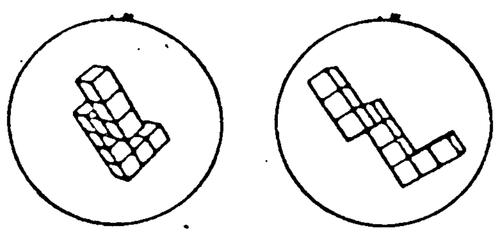
APPENDIX B

MENTAL ROTATION TEST

INSTRUCTIONS



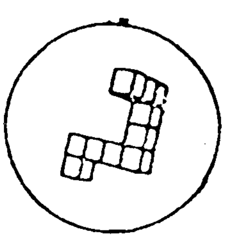
Note that these drawings show an object made from 10 blocks shown from different angles. Try to imagine moving the object (or yourself with respect to the object), as you look from one drawing to the next.

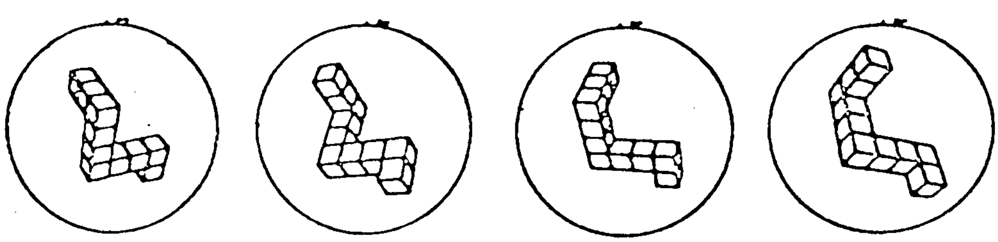


Next, satisfy yourself that these two drawings are different from the above object, in which the 10 blocks are arranged a little differently so that you can not "rotate" them to be identical with the object shown in the first 5 drawings.

Now look at this object:

Two of these four drawings show the same object. Can you find those two? Circle the number below those two:





1 2 3 4

PLEASE CONTINUE ON THE NEXT PAGE.

APPENDIX C

APPENDIX D

11. SIMILARITIES Discontinue after 4 consecutive failures.	Score 2, 1, or 0
1. Orange—banana	
2. Dog—lion	
3. Coat—suit	
4. Boat—automobile	
5. Eye—ear	
6. Button—zipper	
7. North—west	
8. Egg—seed	
9. Table—chair	
10. Air—water	
11. Poem—statue	
12. Work—play	
13. Fly—tree	
14. Praise—punishment	
Total	Max=28