0-315-10950-7

58814

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TITLE OF THESIS/*TITRE DE LA THÈSE* Conjugate Lateral Eye Movements and Performance on the Wechsler Adult Intelligence Scale - Revised

UNIVERSITY/*UNIVERSITÉ* Simon Fraser University

DEGREE FOR WHICH THESIS WAS PRESENTED/ *GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* Master of Arts

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1982

NAME OF SUPERVISOR/*NOM DU DIRECTEUR DE THÈSE* Dr. Paul Bakan

DATED/*DATÉ* Aug. 23/82 SIGNED/*SIGNÉ*

PERMANENT ADDRESS/*RÉSIDENCE FIXÉ*

CONJUGATE LATERAL EYE MOVEMENTS AND PERFORMANCE ON THE WECHSLER ADULT INTELLIGENCE SCALE - REVISED

by

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B.A. (Hons.) Brock University, 1978

THESIS SUBMITTED IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS

in the Department

of

Psychology

SIMON FRASER UNIVERSITY

July 1982

APPROVAL

Name: Marlene Marie Moretti

Degree: Master of Arts

Title of Thesis: Conjugate Lateral Eye Movement Direction and Performance on the Wechsler Adult Intelligence Scale - Revised

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Title of Thesis/Dissertation:

Conjugate Lateral Eye Movements and Performance on the Wechsler Adult Intelligence Scale - Revised

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ABSTRACT

Conjugate lateral eye movements (CLEM) have been proposed as a measure of hemisphericity. Individuals demonstrating consistent movements to the right, "right movers", tend to depend on a left hemisphere mode of processing. In contrast, those demonstrating consistent movements to the left, "left movers", prefer a right hemisphere processing mode. "Bi-movers" are not directionally consistent in the lateral eye movement response.

A review of the literature indicates that individual differences in hemisphericity are associated with differences in verbal and visuospatial task performance. The use of valid clinical measures of neuropsychological functioning would be helpful in clarifying performance differences and in assessing the performance of bi-movers. In addition, the evaluation of sex as a moderating variable in the relationship between CLEM and cognitive ability is necessary.

The performance of 80 male and female left movers, bi-movers and right movers was assessed on measures of verbal comprehension and perceptual organization performance derived from the Wechsler Adult Intelligence Scale -Revised. (WAIS-R). Analysis of variance techniques produced several sex by CLEM group interaction effects. As predicted, male right movers achieved significantly higher Verbal Comprehension scores than male left movers. However the verbal performance of female left and right movers was not found to vary significantly. Two-way

analysis of variance comparing male and female left movers and right movers on measures of Perceptual Organization failed to reveal significant main or interaction effects. Analysis of performance on the Block Design test did indicate that female left movers performed significantly better than female right movers. This is consistent with the CLEM model of hemisphericity. The performance of bi-movers on verbal and visuospatial tasks suggests that the relationship between direction of CLEM response and cognitive ability is not clearly linear.

These results provide support for the CLEM model and point to the importance of examining sex as a moderating variable in future CLEM research. The need for clarification and validation of measures of left and right hemisphere functioning is also indicated.

ACKNOWLEDGEMENTS

I wish first to express my gratitude to Drs. Paul Bakan and Ray Koopman for their patience, encouragement and assistance during the preparation of this thesis. Thanks also to my friends, especially Valerie, Debbie, Steve and Glenn for their support and humour which was at times invaluable. Special thanks to Ian for his patience and understanding and to Dr. Nora Carlsen for her insight and encouragement.

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A. Introduction

The functional asymmetry of the left and right cerebral hemispheres has been traditionally addressed as a verbal/nonverbal capacity distinction. Indeed, the superiority of the left hemisphere for linguistic functions remains the most clearly demonstrated instance of hemispheric specialization. The description of the right hemisphere as nonverbal refers not only to its limited linguistic capacities, but more importantly to its superior ability to process visuo-spatial and other nonverbal materials (Kimura, 1961; Milner, 1971).

More recent investigations have generated additional dichotomies differentiating the functional qualities of the two hemispheres. The left hemisphere has been associated with analytic and sequential processing capacities as noted in sequential component analyses on problem solving tasks. In contrast, holistic and synthetic functional qualities have been ascribed to the right hemisphere as evidenced by its superiority for the perception of component relationships and whole configurations (Nebes, 1978). These dichotomies have been useful in understanding the more fundamental processing differences between the hemispheres which underlie their specialization for verbal and visuospatial functions.

Recent studies have indicated that the model of hemispheric specialization provides a basis for the understanding of individual differences in cognitive abilities. It has been suggested that individuals differ in the degree to which they rely on left hemisphere (propositional) or right hemisphere (appositional) processing strategies (Bogen, 1969). These differences in "hemisphericity" appear to be reflected in differences in performance on tasks defined as measures of left or right hemisphere activity.

Bakan (1969) was the first to identify conjugate lateral eye movements (CLEM) as a measure of hemisphericity. The direction of the CLEM response has been associated with the activation of the contralateral hemisphere (Bakan, 1969; Gur & Reivich, 1980). CLEM direction is typically assessed as a behavioural response following the presentation of a question requiring reflective thought. Most individuals have been found to demonstrate directional consistency -that is, they consistently avert their gaze to the left ("left movers"), or they consistently avert their gaze to the right ("right movers").

The CLEM model predicts that left movers, typically characterized by increased right hemisphere activity, should demonstrate processing strategies consistent with the functional characteristics of the right hemisphere. In contrast, right movers, characterized by increased left hemisphere activity would be expected to employ processing strategies consistent with the functional qualities of the left hemisphere.

Evaluation of the hemispheric specialization of function model and the CLEM model of individual differences in hemisphericity suggests that task performance may represent an interface between these two factors. As a result of these differences in processing strategies it is predicted that left movers should perform differently than right movers on tasks assessing left and right hemisphere functioning. The following sections present a review of the evidence pertaining to the functional asymmetry of the two cerebral hemispheres. In addition, research findings regarding individual differences in hemisphericity will be presented. In this respect, the validity of the CLEM model will be reviewed in detail as this measure has been selected for use in the present study.

The Cerebral Specialization Model

Evidence for the hemispheric specialization model can be drawn from observations of both clinical and normal populations. Documentation of functional deficits in patients with unilateral brain damage due to cerebrovascular accidents, tumors, or penetrating war wounds, has provided considerable information for understanding functional asymmetries. Research with this clinical population typically involves the comparison of specific task performance by patients with unilateral damage to either the left or right cerebral hemisphere. Alternatively, the performance of these two patient groups may be compared to that of a normal, intact control group. In addition, individual case studies are useful in providing information pertaining to the effects of specific localized lesions or hemispherectomy (removal of the entire cerebral cortex of one hemisphere). These latter cases tend to occur so infrequently as to limit the application of more experimental evaluative methods.

Investigation of left and right hemisphere capacities in patients with sectioning of the corpus collosum (split brain patients) has provided a second data source. This operation effectively stops the direct communication between the hemispheres which occurs in the normal intact brain. Lateralized presentation of visual and somesthetic stimuli are therefore successful in assessing of the functional capacities of each hemisphere.

Finally, a significant source of information has been derived from the assessment of funtional asymmetries in normals. Techniques developed for this purpose include both neurophysiological evaluation and performance on tasks of lateralized stimulus presentation. Electrophysiological techniques typically seek to identify asymmetries in EEG measurements, most frequently alpha asymmetries or asymmetries in evoked potential responses as a function of task type. More recently, the measurement of regional cerebral blood flow has provided a more direct assessment of hemispheric activation in response to differential task activity. Lateralized auditory presentations using dichotic techniques, and lateralized visual presentation using tachistoscopic techniques are used for the presentation of stimulus materials to individual hemispheres.

The combined observations from these different samples and diverse assessment procedures provide a convergent data base for the evaluation of the hemispheric specialization model.

Research Findings with Clinical Samples

Clinical Observations

Clinical observations indicate that while unilateral damage to the left hemisphere typically results in the impairment of language functions, unilateral damage to the right hemisphere is rarely associated with damage of this nature. This relationship has been observed since the work of Dax in 1836 (Giannitrapani, 1967) and supported by the identification of Broca's area and Wernicke's area in the left cerebrum. Damage to these two regions has been well documented as central to the occurence of expressive and receptive aphasias (Luria, 1973).

These observations are in marked contrast to findings indicating that removal of the right hemisphere does not usually result in aphasia or gross linguistic deficits (Smith, 1969).

The right hemisphere appears to be able to withstand greater damage without manifesting severe performance impairment perhaps because of its more diffuse organization of function (Semmes, 1968). When impairment does occur, clinical observations indicate that patients demonstrate a variety of visuospatial disorders, disturbance in topographical orientation, and neglect of the left visual field (hemi-inattention syndrome) (DeRenzi, 1978).

Results of Research using the Wechsler Adult Intelligence Scale (WAIS)

Performance on the WAIS is frequently used in clinical and experimental assessments of impairment following brain damage. Studies incorporating this measure generally report deficits in Verbal IQ following unilateral lesions of the left hemisphere, and deficits in Performance IQ following lesions of the right hemisphere (Reitan, 1962; Geurtin, Rabin, Frank and Ladd, 1962). Matarazzo (1972) reached similar conclusions after a review of relevant literature, noting that within-group comparisons of subtest scores are more likely to clearly demonstrate relative Verbal deficits following left hemisphere damage and relative Performance deficits following right hemisphere damage than are between-group comparisons.

Failure to report differential effects of lateralized lesions has been attributed to a verbal component present on some performance subtests (Benton, 1962). Performance on these tests by left hemisphere injured patients would obviously be lowered to the extent that these tests demand verbal-symbolic processes in their completion. Failure to detect comparative

Verbal IQ deficits would therefore be a function of lowered Performance subtest scores. In comparison to the performance of a normal control sample, left hemisphere injured patients may appear to show lowered Verbal and Performance IQ's, while only the Performance IQ of the right hemisphere injured patients would appear lowered.

This pattern of results is identical to that reported by Woods (1980). Lesions of the left hemisphere, regardless of patient age at the time of occurrence, significantly lowered both Verbal and Performance IQs relative to mean scores expected for a normal population. In contrast, right hemisphere lesions incurred after age one resulted in significant decrements on Performance IQ but not Verbal IQ scores. These results were found to be consistent with WAIS score patterns reported by several studies reviewed by Woods (eg. Meier, 1970; Satz, 1966; Vega & Parsons, 1969; Warrington & James, 1967).

The methodological approach of Parsons, Vega, and Burn (1969) illustrates an attempt to improve the specificity of the verbal and nonverbal assessments using the WAIS. Results of previous factor analytic investigation of the WAIS scales were reviewed to identify those subtests which best reflected verbal and "perceptual organization" abilities. The Vocabulary and Block Design subtests were found to have the highest loadings, on the verbal and perceptual organization factors respectively, and thus were selected for performance comparisons of unilateral lesion groups. Results supported the hypothesis that lesions of the left hemisphere are associated with impaired verbal performance, while right hemisphere lesions resulted in impairment of perceptual organization abilities. Moreover, both within-group and between-group performance comparisons were found to be significant in supporting differential lesion effects.

These findings are consistent with the observations of both Smith (1969) and Gott (1973) who report severe impairment of performance on the Block Design subtest following right hemispherectomy. The frequency of impairment on this task has also been reported as higher, although not significantly so, in patients with right hemisphere rather than left hemisphere injuries (Arrigoni & DeRenzi, 1964; Taylor & Warrington, 1973).

In general, studies incorporating the WAIS report performance patterns consistent with a model of hemispheric specialization predicting left hemisphere superiority for linguistic functions and right hemisphere superiority for visuospatial functions. Although differences in performance of unilateral damage groups are not always significant, patterns of deficit in the opposite direction have never been reported. Rather, these performance trends appear to be a function of the verbal overlap in the Verbal and Performance IQ scales. Selection of subtests which best reflect verbal and perceptual organization performance appears to result in increased differentiation between the groups in the predicted direction.

Results of Assessments using other Cognitive Measures

As previously stated, left hemisphere dominance for linguistic functions is well supported by clinical observations of aphasia (Luria, 1973). Research with split brain patients and left hemispherectomy patients consistently indicates left hemisphere superiority for linguistic functions (Gazzaniga & Sperry, 1967; Smith, 1969). While the right hemisphere appears to be capable of comprehending and responding to simple linguistic forms (Zaidel, 1976; 1978), its facility for expressive linguistic functions and its ability to respond to complex linguistic forms is indeed limited (Teng & Sperry, 1973; Zaidel, 1973).

Extensive evaluations of the right hemisphere using a variety of cognitive measures have lead to a more sophisticated understanding of its processes. Specifically, injury to the right hemisphere has been associated with deficits in perceptual closure and in the perception and manipulation of spatial relationships (Benton, 1979). The specialization of the right hemisphere has also been implicated in the recognition of faces and the processing of emotional information.

Tests of perceptual closure usually require the organization or synthesis of limited perceptual information into a meaningful entity. DeRenzi and Spinnler (1966) found the performance of right hemisphere-injured patients to be impaired relative to left-injured patients on the Street Gestalt

Completion Test (Street, 1931). This test requires the identification of fragmented perceptual information. These results are consistent with performance patterns of unilateral lesion groups on the Mooney's Faces Test (Mooney, 1957) which also requires perceptual synthesis of information (Newcombe & Russell, 1969; Lansdell, 1968). Similarly, Warrington and James (1967) found impairment in the recognition of incomplete pictures of objects to be more severe in subjects with right hemisphere lesions than in subjects with left hemisphere damage.

The assessment of split brain patients has lead to similar results substantiating the role of the right hemisphere in the performance of closure tasks. Nebes (1971) had patients haptically examine an arc with their left or right hands and select a circle size from a visual display which best matched the size of the arc. Performance with the left hand was found to be superior to that of the right, demonstrating the specialized capacity of the right hemisphere on this "part-whole" matching task. These results were replicated by Nebes (1972) on a similar task. Again, while the right hand performed at chance level, the left hand demonstrated superior abilities for tactile discrimination of part-whole relations.

Disorders in the perception and manipulation of spatial relationships are commonly referred to as constructional apraxias. In general, right hemisphere lesion patients are more frequently and severely impaired on these measures which include: building horizontal or vertical dimensions with blocks, three dimensional block construction, and copying line drawings (Benton, 1979). Arrigoni and DeRenzi (1964) report that impairment in copying designs and block construction is significantly more frequent in right than left-hemisphere injured patients. Similarly, copies of geometric figures produced by patients with right hemisphere damage have been noted to frequently display distortions of shape and orientation, loss of spatial relations and neglect of the left side (Warrington, James & Kinsbourne, 1966; Gainotti & Tiacci, 1970). Smith (1966) and Gott (1973) report consistent observations regarding the performance of right hemispherectomy patients on these tasks.

Research findings with split brain patients are consistent in indicating specialization of the right hemisphere for the perception and construction of visuospatial arrangements. Levy-Agresti and Sperry (1968) noted superior performance of the left hand on a task requiring patients to match a visually displayed two dimensional representation of an object with a solid object form. Left hand performance has also been found superior to right hand performance in copying designs (Bogen, 1969) and in block design construction (Gazzaniga, 1970).

Finally, damage to the right hemisphere has been associated with impairment in the ability to recognize familiar and unfamiliar faces (Benton, 1980). Hecaen and Angelergues (1963) report that of 22 cases of facial agnosia (inability to recognize familiar faces), 72% had right hemisphere damage, 18%

suffered bilateral injuries, and only 9% sustained damage to the left hemisphere. Similarly, impairment in the ability to recognize unfamiliar faces occurs twice as frequently in right hemisphere injured patients than in those with left hemisphere damage (Warrington & James, 1967; DeRenzi, Faglioni & Spinnler, 1968).

It has been suggested that the superiority of the right hemisphere in facial recognition tasks is a function of right hemisphere specialization for the mediation of emotional information (Bradshaw & Nettleton, 1981). The significance of the right hemisphere in emotional processing is evidenced in the differential affective changes associated with right and left hemisphere lesions (Gainotti, 1972) and in the affective responses of split brain patients upon presentation of emotional stimuli to the right hemisphere (Gazzaniga, 1965; Sperry & Gazzaniga, 1967). Related evidence indicates that catastrophic reactions and feelings of guilt and depression are common following anesthetization of the left hemisphere due to a lack of right hemisphere inhibition. In contrast, euphoric and excited states typically follow anesthetization of the right hemisphere (Perria, Rosadini & Rossi, 1961; Terzian, 1964).

Methodological Considerations and Conclusions

Evaluation of the relevance of findings based on clinical samples must include an assessment of methodological problems which frequently occur in these studies. With respect to research on unilateral brain injured patients, it is important to note the infrequency with which patients are matched on variables of age, sex, and handedness. Usually assessments of premorbid intelligence are not available making it difficult to determine individual changes in functioning level. Perhaps more significant is the failure to match subjects on the time elapsed since injury. This seems especially pertinent because of the lack of understanding regarding mechanisms of recovery following damage. Some researchers have interpreted superior left ear performance on dichotic listening demonstrated by recovered aphasics as indicating a shift in hemispheric dominance for language functions (Pettit & Noll, 1979). Others, however, suggest language processes in the aphasic are reorganized in the undamaged areas of the left hemisphere (Penfield, 1971). It must also be noted that because lesions tend to be diffuse and have widespread effects, it is difficult to determine the precise relationship between specific areas of damage and different types of deficit.

Methodological criticisms are also warranted in studies using split-brain patients. Levy and Trevarthen (1977) have pointed out that pre-operative conditions in these patients may have caused reorganization of cerebral functions, such that they do not reflect normal functional capacities. It has also been noted that these patients vary considerably with regard to post-operative impairment (Nebes, 1978). Finally, the possibility of information transfer through midbrain structures or through the development of compensatory cross-cueing behaviours must be acknowledged.

Methodolgical problems in addition to those associated with clinical populations include the selection of tasks as measures of left or right hemisphere functioning primarly on the basis of face validity. This procedure has resulted in the use of a diverse group of assessment materials, some which are of questionable validity.

Clearly, these shortcomings render the interpretation of results based on clinical samples problematic, especially with respect to implications for functional asymmetries in the normal, intact brain. Despite these considerations, it is clear that the general pattern of research results does support the distinctive nature of functioning in the two hemispheres, and that basic conclusions can be drawn in this regard:

1. Research findings consistently support the linguistic superiority of the left hemisphere. It appears that while the right hemisphere has limited verbal abilities, temporal-sequential processes which underlie linguistic functioning are specialized in the left hemisphere (Bradshaw & Nettleton, 1981).

2. Right hemisphere superiority for the synthesis of perceptual information (closure) appears clearly demonstrated, suggesting a holistic, synthetic quality in right hemisphere processing.

3. The right hemisphere appears to be associated with performance on tasks of constructional apraxia, although not all studies have reported differential impairment of unilateral groups on measures of this ability (eg. DeRenzi & Faglioni, 1967). It is important to note that inconsistent research findings may be a function of differing attentional and motor skill demands and varying levels of difficulty in the many tasks used for the assessment of constructional apraxia.

The significance of these task variables is illustrated by DeRenzi's (1978) observation that the superiority of the right hemisphere on spatial tasks " subsides as the task becomes more complex and demands space abilities that go beyond the perceptual level" (p. 82). In addition, the importance of aphasia, apraxia (inability to perform practiced motor abilities) and visual field defects has been acknowledged as significant in task performance, although the specific effects of these factors on performance has yet to be determined.

These disorders are of less significance in the performance of split-brain patients, and research findings with this clinical group support the specialized role of the right hemisphere in the perception and construction of visuospatial arrangements. Thus, while it appears that the right hemisphere is associated with performance on these tasks, the extent to which the symptoms classified as constructional apraxia represent a unitary, basic disorder remains doubtful.

4. There is convincing evidence that the right hemisphere is specialized for the recognition of faces, and for the processing of emotional stimuli. As previously noted, superior facial recognition by the right hemisphere may be a function of its specialization for emotional processing, and/or the synthesis of perceptual information which occurs in the right hemisphere (Carey & Diamond, 1977).

In summary, despite inconsistencies in the literature, there can be little doubt that these results indicate that the cerebral hemispheres are functionally distinct.

Research Findings with Normal Samples

Electrophysiological Measures

Research incorporating EEG and evoked potential measures has indicated asymmetrical patterns of activity are associated with verbal and nonverbal task engagement. Task dependent alpha (8-12 hz.) asymmetries have been demonstrated by Galin and Ornstein (1972) and more recently by Moore and Haynes (1980). In this latter study, alpha asymmetries were observed such that alpha suppression occurred in the left hemisphere during a verbal stimulus tape, and in the right hemisphere during a nonverbal stimulus tape. Similar results have been reported by Morgan, McDonald and McDonald (1971) and by Doyle, Ornstein and Galin (1974).

These results support the specialization model of cerebral functioning since alpha suppression typically occurs over the hemisphere that is engaged in active processing (Galin & Ellis, 1975; Robbins & McAdam, 1974).

With regard to the comparison of average evoked potentials (AEP) in the two hemispheres, Buchsbaum and Fedio (1970) reported that verbal stimuli elicited relatively stronger AEP's in the left hemisphere and spatial stimuli. Similarly, McAdam and Whitaker (1971) reported greater negative potential over the left hemisphere immediately prior to and following a verbal response, again supporting the role of the left hemisphere in linguistic processing.

Not all research findings however, report differential activation of the right and left hemispheres during verbal and nonverbal activities (eg. Mayes & Beaumont, 1977). It is important to note that some variability in research findings is attributable to the inconsistent placement of electrodes and variable recording conditions (eg. eyes closed vs. eyes open). A more significant criticism of this research has been the claim that differences exist in motoric demands in these verbal and nonverbal stimulus conditions (Gevins, Zeitlin, Doyle, Shaffen, Yingling, Callaway, & Yeager, 1979). When these variables are controlled for, EEG asymmetries are still present. Ehrlichman and Weiner (1980) examined asymmetries in subjects instructed to covertly engage in verbal tasks (multiplication, composing a letter or speech etc.) and nonverbal tasks (production of music without words, visual imagery etc.) under eyes closed, resting conditions. Results indicated relatively greater activity of the left hemisphere during verbal tasks, and greater activity of the right hemisphere during nonverbal tasks. Studies of this nature clarify the validity of electrophysiological research findings in supporting the specialization model of hemispheric functioning.

Cerebral Blood Flow

Changes in regional cerebral blood flow (rCBF) have been established as a reliable indicator of the amount of "work" carried out by an area of tissue. Since brain tissue regulates its own blood supply in accordance with its metabolic demands, increases in blood flow are interpreted as reflecting increased cortical activity (Blauenstein, Halsey, Wilson, Wills and Risberg, 1977; Ingvar & Risberg, 1967). Risberg and Ingvar (1973) established a relationship between cognitive activity and increased cerebral blood flow and several studies have reported hemispheric asymmetries in rCBF during verbal and nonverbal tasks.

Risberg, Halsey, Willis and Wilson (1975) noted relatively greater left hemisphere blood flow during a verbal analogies task, and relatively greater right hemisphere blood flow during a picture completion task. A similar pattern of activity was reported by Carmon, Lavy, Gordon and Portnoy (1975) based on three separate injections of Xenon 133, the radioactive isotope commonly used in blood flow studies. The first injection served as a baseline measurement from which subsequent changes in hemispheric blood flow during a verbal auditory task (listening to a verbal passage) and a nonverbal auditory task (listening to melodic music), were evaluated. This silent listening procedure is frequently adopted to avoid the influences of speaking or any other motor activity on results, since focal increases in blood flow have been demonstrated to accompany such activities (Olesen, 1971; Ingvar & Schwartz, 1973). Results of the Carmon et al. study indicated that listening to verbal material was accompanied by increases in left hemisphere blood flow of 4.4 - 20.3% and slight decreases in right hemisphere blood flow. Listening to music was accompanied by an increase in rCBF in both hemispheres, however increases in the right hemisphere were much more evident.

Similarly, Gur and Reivich (1980) found significantly more left to right cerebral blood flow during covert solutions to the Miller's Analogies Test, although predicted differences were not observed for a test of perceptual closure.

These results provide convincing support for the specialization model of hemispheric functioning. Despite criticisms of this method that suggest that it does not reflect rapid variations in cerebral activities, and that it fails to assess blood flow in deeper regions (Springer & Deutsch, 1981), it clearly appears to be the most direct method of assessing asymmetries in cerebral activation.

Lateralized Stimulus Presentation

Two basic techniques have been developed to channel sensory inputs separately to the two cerebral hemispheres. In visual perception, brief tachistoscopic stimulus presentations directed to the left or right visual half fields are channelled primarily to the contralateral hemisphere. Similarly, auditory information presented to the right or left ear is channelled primarly to the contralateral hemisphere. The basis for the latter technique is that, although each ear has both ipsilateral and contralateral connections with the cerebral hemispheres, when both ears receive input simualtaneously, the ipsilateral pathways are inhibited and the contralateral pathways predominate (Kimura, 1967).

In general, studies using these techniques provide some support for the specialization model. For example, McKeever and Huling (1970) report that subjects demonstrate a right visual field (left hemisphere) superiority for processing verbal materials, and a left visual field (right hemisphere) superiority for processing nonverbal materials. Left visual field superiority has been demonstrated on tasks such as dot enumeration and localization (Kimura, 1966; Kimura, 1969) and the identification of block design patterns (Schell & Satz, 1970).

Several issues have been raised regarding the validity of these measures. White (1972; 1973) has criticized lateralized visual presentation methods, pointing out that visual field effects are confounded by subject preference for a left-to-right attentional scan which is established by reading habits. This directional scan preference favours material in the right visual field since scanning proceeds directly from the central fixation point in this condition, while the focus of attention must be shifted to the left-most element of a display presented in the left visual field in order for scanning to proceed. In addition, he has indicated the importance of effectively maintaining subjects' fixation on a central point during stimulus presentation and of placing stimuli at the correct degree from the fixation point to ensure non-foveal vision.

Methodological problems associated with lateralized auditory presentations are illustrated by the research of Teng (1979). First, while left hemisphere dominance for language has been estimated to occur in over 95% of right handed individuals (Wada & Rasmussen, 1960), studies using dichotic techniques report only 65 - 80% of normal subjects show a right ear (left hemisphere) advantage for processing verbal materials. Despite methodological improvements to increase the validity of dichotic assessment, Teng (1979) found only 71% of normal subjects demonstrated the expected right ear advantage for verbal materials. More importantly, test-retest reliabilities for ear difference scores were found to range from .11 to .77. These findings indicate that such measures do not appear to be a reliable indicator of lateralized processing advantages.

Finally, it is important to note that actual visual field or auditory channel performance differences are quite small. In view of these problems it seems reasonable to conclude that, while this body of research generally supports the hemispheric specialization model, at present these results can be seen only as tentative support.

Methodological Considerations and Conclusions

Methodological problems in the examination of hemispheric asymmetries in normals are typically related to the validity of assessment techniques rather than to sample characteristics as is the case in research with clinical populations. For this reason, specific technique-related problems have already been addressed within the context of the research review. It is apparent from this review that each method of assessment presents a unique set of problems for evaluation. In this respect, electrophysiological findings and cerebral blood flow evidence of hemispheric asymmetries in the normal brain appear to be somewhat more conclusive than findings based on lateralized stimulus presentations. These latter studies do, however, reveal a pattern of results consistent with those observed in neurophysiological research.

Common to all methods of investigation is the use of a diverse set of tasks which are chosen primarily on the basis of their face validity. Inconsistent research findings in several areas have been partially attributed to this problem. For example, Pirozzolo (1977) concludes that disparate research findings in tachistoscopic studies are primarily due to the variety of tasks used, most of which lack validation. The use of such tasks not only reduces the validity of research findings but also precludes the comparison of results across studies. In addition, it is noted that although most studies control for handedness, not all studies control for sex. These two variables have been found to significantly modify cerebral organization of function (Hannay, 1976; McGlone & Davidson, 1973; Piazza, 1979; Witelson, 1976).

Nonetheless, this research does provide substantial support for the hemispheric specialization model. Functional capacities identified for the left and right hemisphere are consistent with those found in research with clinical populations - the left hemisphere is superior for the processing of verbal analytic materials, and the right for the processing of nonverbal, perceptual-spatial stimuli. Conclusions reached with regard to the study of hemispheric asymmetries in clinical populations are equally applicable here - there can be little doubt that these findings indicate the cerebral hemispheres are functionally distinct.

Summary of Evidence for the Cerebral Specialization Model

It is clear from this review that evidence from both clinical and normal populations consistently supports the hemispheric specialization model. Especially apparent is the role of the left hemisphere in linguistic processing. Almost invariably, the left hemisphere is found to process verbal materials more efficiently than the right hemisphere, regardless of the method or stimulus presentation or the type of task used to assess performance.

Specialization of the right hemisphere is somewhat more difficult to summarize succinctly. Evidence has indicated that it is of substantial importance in the ability to organize stimuli into a meaningful gestalt, and in the perception and manipulation of spatial relationships. In addition, the right hemisphere appears to be specialized for facial recognition and for processing of emotional stimuli.

While research may indicate that tasks are performed more efficiently when presented to one or the other hemisphere, it may be misleading to define the functional specialization of each hemisphere simply in terms of these tasks per se. Rather, each hemisphere may be specialized for certain processing strategies which are required for the performance of these seemingly different tasks.

This approach of addressing the functional asymmetries in terms of underlying processing strategies has been proposed by several authors (Bogen, 1969; Nebes, 1978; Semmes, 1968). Bradshaw and Nettleton (1981) suggest that the left hemisphere is specialized for analytic, time dependent and sequential functioning, and that this underlies left hemisphere specialization for language. In contrast, they suggest that right hemisphere superiority for nonverbal tasks occurs not as a function of the distinct specialization of this hemisphere for processing this material, but because specialization of this hemisphere does not occur. These conclusions infer that the hemispheres differ only on one dimension, the extent to which each is specialized for analytic, sequential analysis. Moreover, the two extremes of this continuum are not seen as different types of processing. The processing of the hemispheres are considered to be quantitatively, but not qualitatively, different.

While the specialization of the left hemisphere may be more pronounced and more easily defined, this hardly seems to be an adequate basis for concluding the right hemisphere is "less evolved" and that it lacks specialization for qualitatively different processing strategies. As is apparent in this review, evidence strongly suggests that qualitative differences in functioning mode do exist between the hemispheres and as Wyke (1981) concludes, it is unlikely that the processes of the hemispheres can be distinguished purely on quantitative grounds. The specialization of the right and left hemisphere for for temporal, analytic and sequential processing strategies and of the right hemishpere for holistic, gestalt and synthetic processing strategies seems more consistent with current research findings.

<u>Conjugate Lateral Eye Movements</u>

Presentation of a reflective question to a subject typically elicits an initial conjugate lateral eye movement (CLEM) to the left or right. This behavioural response was first reported by Day (1964) who observed that the direction of the CLEM response was a consistent individual characteristic, and consequently that subjects could be classified as either "right movers" or "left movers". The reliability of CLEM direction has been subsequently established and test-retest values are typically reported in the .70s (Duke, 1968; Bakan & Strayer, 1973).

Bakan (1969) was the first to propose that CLEM direction was associated with increased activation of the contralateral hemisphere. This position is supported by the observation that direct electrical stimulation of one hemisphere triggers eye movements in the contralateral direction (Penfield & Roberts,

1959) and similarly that increased cerebral blood flow in one hemisphere is associated with eye movements in the contralateral direction (Melamed, 1977).

The findings of Wada and Rasmussen (1960) provide additional support for the association of CLEM direction and hemispheric activation. They noted that sodium amytal inactivation of one hemisphere resulted in the extreme reduction of eye movements in the direction contralateral to the anesthetized hemisphere, and consequently to neglect of the contralateral visual field. Similar clinical disorders have been reported in patients with unilateral brain injury. Typically these patients exhibit neglect of the visual field contralateral to the damaged hemisphere, although this syndrome is more frequently observed in patients with right hemisphere damage (Luria, 1973).

Two distinct areas of research have developed incorporating CLEM as a measure of hemispheric activation. One area of investigation focuses on the identification of individual differences in preference for the use of one hemisphere over the other (hemisphericity) and associated differences in personality characteristics and cognitive abilities. A second field of research examines the effects of different types of questions (i.e. verbal vs. nonverbal) in eliciting right or left CLEM responses. These latter investigations are not necessarily in conflict with studies investigating individual differences in hemisphericity. Rather, it is likely that both factors -

individual differences in hemisphericity and task demands - affect CLEM responses. Theoretically, when task demands are ambiguous, or able to be met by alternative processing strategies, individual differences in hemisphericity should determine the CLEM response. In contrast, as task demands become more salient, individual differences should be suppressed and CLEM direction should be largely determined by task demands. Unfortunately, research to date has not investigated the interaction between hemisphericity and question type (task demand). This type of research design would help to clarify this issue. The results of research examining question type effects are not of primary importance to this review, and therefore they are not discussed here. The following section presents a summary of research studies which have examined the personality and cognitive correlates of hemisphericity.

Individual Differences in Hemisphericity

The Validity of CLEM as a Measure of Hemisphericity

The characteristic direction of an individual's CLEM responses has been interpreted as a measure of hemisphericity. Accordingly, subjects who consistently move their eyes to the right have been described as demonstrating relatively greater activity of the left hemisphere, and those who consistently look to the left as demonstrating relatively greater activity of the right hemisphere.

The validity of this distinction in hemispheric activity between left movers and right movers is supported by several sources of evidence. Bakan and Svorad (1969) observations indicated that left movers produce significantly more alpha activity than did right movers. Since alpha is typically more abundant over the right hemipshere (Liske, Hughes & Stowe, 1967) this indirectly suggests that left movers are characterized by increased right hemisphere activity.

Similarly, Meyer (1977) assessed EEG asymmetries in right and left movers while they engaged in problem solving tasks. Left movers were found to exhibit greater activity in the right hemisphere than were right movers.

Shevrin, Smokler and Kooi (1980) present more direct support for the validity of CLEM as a measure of hemispheric activation. They found right movers demonstrated greater event related potentials in the left hemisphere when presented with a standard checkerboard reversal stimulus, while left movers showed greater right hemisphere responses in these conditions. These authors concluded: "that individuals may be characterized by a certain disposition such that lateralization of brain response is correlated with a preferred direction of looking" (Shevrin, Smokler & Kooi, 1980, p. 695). Finally, Gur and Reivich (1980) provide convincing evidence of this relationship with regard to cerebral blood flow patterns. Eleven male left movers were compared to 10 male right movers on three measurements of cerebral blood flow: baseline; verbal task performance condition; and spatial task performance condition. Subjects were instructed to solve problems covertly in order to control for movement associated artifacts, and performance was assessed immediately following blood flow measurements. Results indicated that left movers demonstrated significantly more right than left hemisphere blood flow. In contrast, right movers tended to show more left than right hemisphere blood flow, although this trend was not significant. These results suggest "that a dimension of individual differences in hemispheric activation not only exists, but may also exert significant influence on cognitive performance" (Gur & Reivich, 1980, p. 88-89)

Cumulatively, these studies provide substantial support for the validity of CLEM as a measure of hemispheric activity, and moreover, for the notion of individual differences in hemisphericity. The identification of an unobtrusive behavioural measure of hemisphericity has generated considerable investigation of the personality and cognitive variables which differentiate "right brained" from "left brained" people.

Personality Correlates of Hemisphericity

Right movers and left movers have been found to differ on a number of personality variables. Smokler and Shevrin (1979) noted that right movers presented with an ambiguous stimulus

(Rorschach cards) were more likely to demonstrate responses indicative of an obsessive-compulsive personality type. In contrast, left movers gave responses which were judged as more consistent with hysterical personality type. These results are consistent with previous findings which suggest that left hemisphericity is associated with defense mechanisms characterized by externalization and intellectualization, while right hemisphericity is associated with denial, repression and reaction formation (Gur & Gur, 1975).

Crouch (1976) demonstrated that right movers were more responsive to verbal cues and left movers more responsive to facial cues. Similarly, left movers have been found to display more facial expressivity (Newlin, 1981). Right hemisphericity has also been found to be related to greater hypnotic susceptibility (Bakan, 1969; DeWitt & Averill, 1976; Gur & Reyher, 1973) and creativity as measured by the Remote Associations Test (Harnad, 1972). In addition, differences in hemisphericity have been associated with Jungian personality variables (Prifitera, 1981) and with susceptibility to subliminal perception (Sackeim, Packer & Gur, 1977).

While such findings are interesting, the relationship between personality characteristics and hemispheric activity is not clearly understood. However, it may very well be that these personality characteristics reflect underlying differences in the use of cognitive processing strategies associated with the two cerebral hemispheres.

Cognitive Correlates of Hemisphericity

In general, the cognitive differences found between right and left movers have been consistent with the functional properties of each hemisphere. That is, right movers are typically found to excel on measures of left hemisphere functioning, and left movers are superior on measures of right hemisphere functioning.

Tucker and Suib (1978) compared the performance of left movers and right movers on the Information, Vocabulary, Block Design and Object Assembly subtests of the WAIS. As predicted, right movers had significantly higher verbal relative to nonverbal test performance scores than did left movers. In a related study, Weiten and Etaugh (1973) compared right movers and left movers on a concept identification task which required subjects to identify a single concept relating a set of nouns, and on an inverted alphabet printing task. Again, the performance of right movers was significantly superior to that of left movers on the concept identification task which emphasized verbal and analytic skills. Left movers were found to print more letters on the printing task, but this trend was not significant.

More recently, Packer and Gur (reported in Gur & Reivich, 1980) found left movers demonstrated significantly superior performance on a gestalt completion task, although no significant differences were found in their verbal abilities as measured by the Miller Analogies Test. The superior performance of left movers on perceptual closure tasks has also been reported by Bilsker (1980).

A number of studies have investigated differences in reading speed between the two groups and findings indicate that right movers demonstrate faster reading skill in both oral and silent reading conditions (Bakan & Shotland, 1969; Ogle, 1972). Somewhat related are findings which indicate right and left mover performance differences on the Scholastic Aptitude Test (SAT). Weiten and Etaugh (1973) found right and left movers performed at similar levels on the verbal section. However, on the Quantitative section right movers scored an average 25% higher relative to their verbal scores whereas left movers score only 3% higher on this section. These findings are consistent with previous results reported by Bakan (1969).

Finally, some support for cognitive differences between right and left movers has been provided by findings which indicate that right movers are more likely to major in science/quantitative areas of study, while left movers tend to major in classical/humanist areas (Bakan, 1969; Weiten & Etaugh, 1973; Gur, Gur & Marshalek, 1975; Katz & Salt, 1981).

Some studies have failed to find significant differences between the performance of right and left movers. Croghan (1975) and Ehrlichman (1972) were unable to find significant performance differences on verbal and spatial tests selected from the Reference Kit for Cognitive Factors (French, Ekstrom & Price, 1963). In the latter study, right and left movers were assessed on several of these measures by calculating ipsatized data scores for each subject which reflected performance on any one given task relative to the baseline performance across all tasks. This method of data analysis, however, has been criticized as inappropriate for between-subject comparisons of ability. Bilsker (1980) concluded that due to this problem, the results of Ehrlichman (1972) were uninterpretable.

Fisher (1976) also failed to find performance differences between right and left movers on Bogen's (1969) appositional/propositional ratio measured by the similarities subtest of the WAIS and the Street Gestalt Completion Test. With regard to these findings, it must be noted that the validity of the original Street test, which was used, has been questioned because of its insufficient number of stimuli and its reliance on verbal responses for stimulus identification (Bogen, DeZure, Tenhouten & Marsh, 1972). Finally, Hiscock (1977) examined the performance of male subjects on two verbal measures (Quick Word Test, Verbal scale of Paivio's Individual Differences Questionnaire) and two spatial measures (Spatial Relations Test, and the Imagery scale of Paivio's Individual Differences Questionnaire). Multiple linear regression analyses failed to yield significant relationships between percentage of rightward eye movements and test performance. Subsequently, subjects were divided into right and left mover groups; however, performance comparisons between these groups were also not significant. Hiscock, however, does not report the number of right and left movers in each of these groups, and therefore it is difficult to assess these results in this respect. Also, the use of the Quick Word Test, originally designed as a measure of general intelligence, may not have been an appropriate verbal measure. This test requires subjects to identify pictures which best describe words, and picture-word matches can be made on the basis of a variety of factors. Thus, test performance may reflect several abilities in addition to verbal skills. Similarly, the verbal and imaginal scales of Paivio's Questionnaire are best described as a measure of the extent to which an individual prefers verbal as opposed to imaginal thinking. The validity of these scales as independent measures of verbal ability and capacity to use imagery is questionable.

Summary of Hemisphericity Research

Although some research has failed to identify expected performance differences between right and left movers, several of these studies were quite limited in their methodological sophistication. It should also be noted that significant performance differences in the opposite direction to those predicted have never been reported. As in several other areas of investigation, the selection of right and left hemisphere tasks is primarily based on the face validity of these measures. Tucker and Suib (1978) represent an attempt to incorporate measures which have been extensively validated as sensitive neuropsychological tools. Further research of this nature is required.

Nevertheless, the general pattern of results found in studies which incorporate CLEM as a measure of hemisphericity have been consistent with the hemispheric specialization model, and moreover they have indicated that individuals differ with respect to their reliance on one or the other hemisphere. Several conclusions are suggested from this research:

1. CLEM is a valid, unobtrusive behavioural measure of hemispheric activity. More specifically, activation of the right hemisphere is reflected in leftward visual scans, and activation of the left hemisphere in rightward visual scans.
2. The direction which characterizes an individual's CLEM responses is indicative of their preference for the use of one rather than the other hemisphere. Right movers are "left brained" and left movers are "right brained".
3. Individual differences in hemisphericity are reflected in differences in cognitive ability. Right movers are typically superior on tasks which require left hemisphere processing, and left movers are superior on tasks involving right hemisphere processing strategies. Although personality correlates have also been established in conjunction with differences in hemisphericity, the relationship of these variables to hemispheric functioning is not clearly

established.

4. Relatively little is known with regard to the performance of individuals who do not demonstrate directional consistency in CLEM responses. Weiten and Etaugh (1974) examined the SAT performance of these subjects and found them to score significantly lower than subjects demonstrating directional consistency. This was regarded as evidence for the hypothesis that incomplete lateralization is related to intellectual deficit. Bakan (1975) however, was unable to replicate these findings and his results indicated that inconsistent subjects, bi-movers, demonstrated slightly higher performance on the SAT. Katz and Salt (1981) did not find the performance of consistent and inconsistent movers significantly different. It is apparent that further research is necessary to clarify the nature of cognitive abilities in this group.

5. Few studies have investigated the interaction between hemisphericity and sex with regard to performance on verbal and nonverbal tasks. This interaction has been found to be significant in studies investigating the relationship between hemisphericity and personality variables (Gur & Gur, 1974; Woods, 1977). Investigation of this interaction would be helpful in understanding sex differences in functional organization and cognitive abilities.

Handedness and Sex : Moderating Variables in Cerebral Organization of Function

There is substantial evidence to suggest that the organization of hemispheric functions is different in left handers and females. Representation of speech almost always occurs in the left hemisphere for right handers, while this is less predictable for left handers. By using sodium amytal to temporarily anaesthetize each hemisphere, Rasmussen and Milner (1975) found that in 96% of 140 right handers, speech was specialized in the left hemisphere. In contrast, speech was specialized in the left hemisphere for only 70% of left handers. Following a review of the literature regarding handedness and hemispheric organization, Hicks and Kinsbourne (1978) concluded "virtually any lateralized dimension in right handers appears more symmetrical in left handers; the mean relative asymmetry score is closer to zero in left handers" (p. 539).

Hemispheric organization of function may also vary according to sex (Lansdell, 1961; McGlone & Kertesz, 1973). Males and females have been found to differ with respect to cognitive abilities. Generally, males are found to demonstrate superior performance on visuospatial tasks, while females show superior performance on certain linguistic tasks such as speed of articulation, verbal fluency and grammar (McGlone, 1980). Almost every conceivable hypothesis has been posited to explain sex differences in these abilities and their relationship to differences in the functional organization of the brain. The female brain has been hypothesized as more lateralized for both verbal and spatial functions than the male brain (Buffrey & Gray, 1972); as less lateralized organized for verbal functions only (McGlone, 1977); as less lateralized organized for spatial functions only (Harris, 1978; Witelson, 1977; Kail & Siegel, 1978); and as less lateralized organized for both verbal and nonverbal functions (Bryden, 1979; McGlone, 1978; Trotman & Hammond, 1979).

While little support has accrued for the first hypothesis of more lateralized organization of function in females, substantial evidence supports the less lateralized organization of verbal functions in females. Left hemisphere damage almost invariably leads to more severe linguistic deficits in males than in females (McGlone & Kertesz, 1973; McGlone, 1978). Relatively less is known with regard to differences in the representation of nonverbal, spatial processes, however McGlone (1980) concludes from a review of the literature that these processes may also be less asymmetrically represented in females.

The implications of these organizational differences for task performance have yet to be resolved. Witelson (1978) suggests that bilateral representation of function results in the activation of both hemispheres during task performance and that consequently there will be conflict between the processes of the two hemispheres and lowered task performance. In contrast, McGuinness and Pribram (1977) point out that females are superior on tasks of both right and left hemisphere functioning (i.e. verbal abilities, facial recognition, imagery, drawing) and that processing conflicts do not appear to be evident.

Needless to say, sex differences in hemispheric lateralization of function are not clearly understood, nor are the implications of such differences. While there can be little doubt that they do occur, how they develop and how they affect cognitive abilities still remains to be addressed.

Rationale for the Present Study

This review has presented evidence which substantiates the hemispheric specialization model. Each hemisphere is characterized by a distinct processing mode which underlies its superior performance for different functions. Moreover, individuals differ with respect to the extent to which they rely on the processes of one or the other hemisphere.

Methodological problems have been identified specific to each area of research which has investigated hemispheric asymmetries, and it is noted that almost all methods of investigation with both clinical and normal populations have failed to consistently select validated measures of right and left hemisphere functioning. As previously mentioned, this problem is also evident in research studies examining the cognitive correlates of hemisphericity. Further research is required not only to validate earlier findings, but to define, more precisely, the cognitive correlates of individual differences in hemisphericity.

The Wechsler Adult Intelligence Scale is commonly utilized as a clinical and research instrument for the assessment of deficits resulting from brain injury. Considerable research evidence has accrued supporting the validity of this test as a measure of left and right hemisphere functioning. The research of Parsons et al. (1969), presented earlier, suggests that the ability of the WAIS to discriminate between brain injured groups improves when performance is compared on selected subtests which best reflect verbal and nonverbal functioning.

This approach in using the WAIS is incorporated in the present study for the investigation of cognitive correlates of hemisphericity. Not only will it serve to validate previous research findings by Tucker and Suib (1978), but the interaction between sex and hemisphericity will also be examined, as will the performance of subjects with inconsistent CLEM responses. These latter issues have largely been ignored by previous investigations in this area. The WAIS-R (Wechsler Adult Intelligence Scale-Revised) rather than the WAIS will be used since the former test will be more frequently used in future research. This will also provide an opportunity to examine the factor structure of the WAIS-R which has yet to be investigated, in order to determine the similarity of this test to its predecessor.

Specifically, the following hypotheses will be addressed. It is predicted that:

1. Right movers (left hemisphericity) will achieve significantly higher test scores than left movers on WAIS-R tests identified as the best measures of verbal ability.
2. Left movers (right hemisphericity) will achieve significantly higher test scores than right movers on WAIS-R tests identified as the best measures of visuospatial ability.

In addition, this study will explore possible sex differences in the relationship between CLEM and cognitive ability. Finally, the performance of individuals who fail to demonstrate directional consistency in CLEM respones will be evaluated.

I. Method

Subjects

Forty two male and 43 female Simon Fraser University students participated in the study. Subjects were informed when recruited that test results were strictly confidential and that individual IQ scores would not be made available to participants. Initial subject selection criteria included self reported right handedness, and minimum residency in Canada or United States of 10 years.

Data for 40 males and 40 females met criteria for inclusion in the study based on CLEM assessement results as described in the measures section. This final pool consisted of 55 arts students, 17 science students and 8 business administration students. All subjects were citizens of Canada or United States. Subject ages ranged from 18 to 43 years, with a mean age of 24.8 for the total group. The mean age for males and females was 24.7 and 25.3 respectively. Degree of right hand preference was assessed on a modified version of Annett's (1967) handedness questionnaire as described below.

Measures

Handedness Questionnaire

A modified version of Annett's (1967) handedness questionnaire was used to assess degree of right hand preference (Briggs & Nebes, 1975). This scale consists of twelve items scored for strength of preference on a 5-point scale as follows: "always right", 2 points; "usually right", 1 point; "no preference", 0 points; "usually left", -1 point; "always left", -2 points. This scoring system yields a range of scores from -24, indicative of extreme left handedness, to 24, indicative of extreme right handedness. This modification of Annett's (1967) questionnaire has been found to be a reliable and valid test of handedness (Loo & Schneider, 1979).

In the present study subjects were classified as right handed on the basis of right hand preference for writing and strength of right handedness was verified by questionnaire responses. Familial handedness was also assessed on this scale with specific test items evaluating handedness of father, mother, and siblings.

CLEM

A set of 20 reflective questions were used to assess CLEM (Appendix A). Previous research suggested that these neutral questions maximize individual CLEM responses rather than question type induced effects (Bakan, Coupland, Glackman & Putnam, 1974).

Direction of CLEM was scored on the basis of the subject's initial eye movement response following each question. CLEM responses were defined with reference to a clock face (experimenter facing clock) such that responses within the 1 o'clock to 5 o'clock positions were scored as left movements, and responses within the 7 o'clock to 11 o'clock positions range were scored as right movements. Movements to the 6 or 12 positions were considered invalid trials as were no movement stares, closed eyes or looking away before the end of the question.

In order to meet the criterion for inclusion in the study, subjects were required to demonstrate valid responses on 75% or 15 of the 20 question trials. Left-movers were defined as subjects demonstrating 0-30% valid CLEM responses to the right, and right-movers were defined as subjects demonstrating 70-100% valid CLEM responses to the right. Subjects with valid right CLEM responses in the 31-69% range were considered bi-movers.

<u>Wechsler Adult Intelligence Scale-Revised</u>

The Wechsler Adult Intelligence Scale-Revised (WAIS-R) is similar in content and organization to its predecessor. Like the 1955 Wechsler Adult Intelligence Scale (WAIS), it consists of 6 verbal tests - Information, Digit Span, Vocabulary, Arithmetic, Comprehension and Similarities, and 5 nonverbal tests - Picture Completion, Picture Arrangement, Block Design, Object Assembly and Digit Symbol. A Verbal IQ is calculated on the basis of performance on the 6 verbal tests and a Performance IQ is calculated on the basis of performance on the 5 nonverbal tests. All 11 tests together yield a Full Scale IQ.

General revisions on the WAIS-R entail updating of and modification of test items to ensure more equal representation of both sexes and different racial groups. The significant alteration with reference to the verbal tests appears to be a modified scoring procedure on the Digit Span test. On the 1955 edition, total score was the sum of the longest forward series repeated plus the longest backward series repeated. The revised scoring system allots 2 points if the series is repeated correctly on the first trial, 1 point if the series is repeated correctly on the second trial, and 0 points if both trials are failed. This procedure effectively increases the range of test scores.

On the performance tests, significant modifications appear in the scoring system for both Picture Arrangement and Block Design. On the 1955 scale, bonus points were given for quick perfect performance on the last two Picture Arrangement items, while no bonus points are alloted in the revised test. Bonus points on the Block Design test have been modified from the addition of up to 2 time bonus points on the WAIS to the addition of up to 3 time bonus points on the WAIS-R. Additional changes to the test are specified in the WAIS-R manual (Wechsler, 1981).

Reliability coeffients for the eleven tests and IQ scales of the WAIS-R are quite similar to those obtained for the WAIS, with the exception of generally higher coefficients obtained on the WAIS-R Digits Span test. This was considered to reflect the revised scoring system for the test and the increased raw score range.

Correlation coefficients of test scores and IQ scale scores on the WAIS-R with test scores and IQ scale scores on the WAIS range form .39 to .89 for a 16 yr. group, and from .50 to .91 for a 35-44 yr. group. These values are somewhat lower, but similar to test-retest coefficients of the WAIS-R suggesting that the WAIS and the WAIS-R measure the same abilities.

The validity of the WAIS is supported by extensive rational and empirical evidence (Guertin, Ladd, Frank, Rabin & Hiester, 1977; Guertin, Ladd, Frank, Rabin & Hiester, 1971; Guertin, Rabin, Frank & Ladd, 1962; Zimmerman & Woo-Sam, 1973). To the extent that the WAIS-R measures the same abilities as the WAIS, it can also be considered a valid instrument.

Factor analytic research examining the WAIS has generated results which are generally consistent with Cohen's (1957) findings (Guertin, et al., 1962, 1966, 1971; Zimmerman & Woo-Sam, 1973). Cohen's analysis yielded three major factors which were consistent over an age range from 18-75+ years-verbal -comprehension, perceptual-spatial and freedom from distractability or memory. A similar factor structure is expected to emerge in analysis of the WAIS-R.

Procedure

Subjects were informed that the purpose of the study was to aid in the validation of a revised edition of the WAIS and that it was important that they direct their full attention to the experimenter throughout the testing session. Subjects were tested individually in a 4 x 6 ft. experimental room where they sat directly opposite the experimenter at a small two and one-half foot wide table. With the exception of the experimenter, the subject faced a homogeneous field of vision.

Subjects were directed to complete the handedness questionnaire and following this a complete WAIS-R was administered according to directions specified in the manual. CLEM assessment questions were administered immediately following completion of the last WAIS-R test in a manner which suggested that they were also a test on the WAIS-R.

An attempt was made to establish rapport with the subject in order to ease anxiety associated with taking an IQ test, and thus, to increase the validity of the assessment. Eye contact was established early during the testing session so that observation of eye movements on the CLEM questions would not be suspect. Few subjects reported suspicion of the experimenter watching eye movements, and of these, no subjects could correctly identify the questions on which CLEM was assessed. All subjects were debriefed following completion of the tests, and thanked for their cooperation.

2.4 Analysis of Results

Factor analysis of the WAIS-R was necessary to identify those tests which were the most reliable indicators of verbal and nonverbal performance. These results were used to generate a verbal composite score, calculated for each subject by summing the scores for those tests which were considered verbal measures and dividing this sum by the number of contributing tests. A visuospatial composite score was calculated in the same manner. A difference score was calculated by subtracting the spatial-perceptual composite score from the verbal-comprehension score. Thus, in addition to WAIS-R test and scale scores, verbal, visuospatial and difference scores were avaialable for each subject.

Analysis of variance techniques were appropriate to test research hypotheses. Since research predictions are specified for left-movers and right-movers only, two-way analyses of variance were calculated comparing males and females in these two CLEM groups. In addition, two-way analyses of variance were calculated comparing left-movers, bi-movers, and right-movers of each sex. These analyses were performed initially for verbal and visuospatial composite measures, and subsequently for each WAIS-R test and IQ scale. Appropriate calculation of simple main effects and planned comparisons were then completed.

II. Results

Subject Variables

Conjugate Lateral Eye Movements

Forty male and 40 female subjects with 75% valid CLEM responses were divided into 6 CLEM groups according to percentage of right CLEM responses as described in the method section. This procedure identified the following groups: 18 male left-movers, 16 female left-movers; 12 male bi-movers, 15 female bi-movers; 10 male right-movers, and 9 female right-movers.

These results suggest a preponderance of left movers which would be expected given the considerable proportion of Arts students present in this sample. Previous research indicates that left-movers are more prevalent in Arts faculties (Bakan, 1969; Weiten & Etaugh, 1973).

Handedness

All subjects were classified as right-handed on the basis of self-reported hand preference for writing. Degree of right hand preference scores ranged from +6 to +24, with a mean score of 19.44 for all subjects. Mean handedness scores were calculated for left-movers, bi-movers and right-movers of each sex (Table 1). Two-way analysis of variance (Table 2) produced a significant main effect for sex, $F(1,74)=5.31$, $p \leq .02$, indicating males were more sinistral than females. This is consistent with previous research evaluating sex differences in the distribution of handedness scores (Loo & Schneider, 1979; Annett, 1972). Neither the main effect for CLEM group, nor the sex by CLEM group interaction effect were found to be significant.

Wechsler Adult Intelligence Scale-Revised

The mean Full Scale IQ for all subjects was 115.04, with a mean Verbal IQ of 114.64 and a Performance IQ of 111.68. These measures will be discussed in detail below.

Factor Analysis of the Wechsler Adult Intelligence Scale-Revised

In order to identify those tests which were the most reliable and consistent measures of verbal and nonverbal functioning, an analysis of the correlation matrices of the WAIS-R tests reported in the manual (Wechsler, 1981) was conducted. This data was subjected to principal factor analysis, maximum likelihood factor analysis, and principal components analysis comparing oblique and varimax rotations in each case. Factors were extracted sequentially until maximum separation and clarity of the first two factors was achieved. Results indicated that a 5 factor solution using prinicipal components analysis yielded the most interpretable and consistent results for the first two factors. These results are strikingly similar to those observed by Cohen (1957) for the WAIS. Factor loadings for WAIS-R tests on Factor 1 and Factor 2 are presented in Table 3 and Table 4 respectively.

Factor 1

Information, Vocabulary, Comprehension and Similarities load on Factor 1 for all age groups and this factor appears identical to Cohen's (1957) Verbal-Comprehension factor of the WAIS. Factor loadings for Vocabulary, Comprehension and Similarities tests are generally strong and consistent across all age groups, however factor loadings for the Information test gradually decline with increasing age. Although factor loadings are observed for the Arithmetic test on Factor 1 in the 18-19 year age group and the 25-34 year age group, Arithmetic does not load on Factor 1 in the remaining two age groups. It is therefore not considered a consistent measure of Factor 1 or verbal-comprehension abilities.

Factor 2

Block Design and Object Assembly consistently load on this factor in all four age groups. This factor is clearly the same factor identified as Perceptual Organization on the WAIS (Cohen, 1957). While loadings on this factor are noted for Digit Symbol in the 18-19 year age group, for Picture Completion in the 20-24 year and 25-34 year age groups and for Arithmetic in the 35-44 year age group, these loadings are relatively weak and inconsistent across all age groups. Thus, these tests are not considered valid measures of Factor 2 or Perceptual Organization abilities.

The consistency of Information, Vocabulary, Comprehension and Similarities test loadings on Factor 1, and of Block Design and Object Assembly test loadings on Factor 2, indicated that a composite test score could efficiently assess subject performance on these two variables. A Verbal-Comprehension composite score was calculated for each subject by summing Information, Vocabulary, Comprehension and Similarities test scores and dividing this sum by 4. Similarly, a Perceptual Organization composite score was calculated by summing Block Design and Object Assembly test scores for each subject and dividing this sum by 2.

Verbal Comprehension

Mean Verbal Comprehension scores are displayed separately for left movers, bi-movers and right movers of each sex in Table 5. Male right movers appear to demonstrate higher Verbal Comprehension scores than do male left movers. This is consistent with the predicted tendency of right movers to excel on verbal tasks. Mean Verbal Comprehension scores for females, however, suggest that female left movers perform somewhat better than female right movers.

Two-way analysis of variance comparing the performance of left and right movers of each sex (Table 6) failed to yield significant main effects for both sex and CLEM group, however a significant sex by CLEM group interaction effect was found, $F(1,49)=4.77$, $p \leq .03$. Simple main effect analysis confirmed the predicted superiority of verbal abilities in male right movers relative to male left movers, $F(1,49)=5.68$, $p \leq .05$, although the performance of female left and right movers was not found to vary significantly. In addition, the performance of male and female left movers was not significantly different. However, there was a trend for male right movers to achieve higher scores than female right movers, $F(1,49)=3.32$, $p \leq .10$.

To investigate the performance of bi-movers, a two-way analysis of variance comparing left movers, bi-movers and right movers of both sexes (Table 7) was completed. Although main effects for sex and CLEM group were not significant, a significant sex by CLEM group interaction effect was found, $\underline{F}(2,74)=3.22$, $p \leq .05$. Analysis of simple main effects indicated that male CLEM groups were significantly different at a marginal level, $\underline{F}(2,74)=3.00$, $p \leq .06$. Male bi-movers performed at an intermediate level compared to male right movers and left movers, but planned comparison analyses revealed that their performance was not significantly different from either group. Female CLEM groups were not found to vary significantly. Finally, there was a trend for male bi-movers to demonstrate better verbal abilities than female bi-movers, $\underline{F}(1,74)=3.04$, $p \leq .10$.

Perceptual Organization

Table 8 displays mean Perceptual Organization scores for left movers , bi-movers and right movers. Two-way analysis of variance comparing the performance of male and female left and right movers (Table 9) failed to produce significant main effects for both sex and CLEM group. The sex by CLEM group interaction effect was also not significant.

To investigate the performance of bi-movers, an additional two-way analysis of variance comparing male and female left movers, bi-movers and right movers (Table 10) was computed. This analysis also failed to show significant main effects for sex and CLEM group. The sex by CLEM group interaction effect was also not significant.

These results indicate the importance of sex as a moderating variable in the relationship between CLEM and cognitive ability. The predicted superiority of right mover verbal abilities was supported for males only. Nonverbal visuospatial abilities did not appear to differentiate left movers from right movers for both males and females.

As previously noted, Tucker and Suib (1978) found CLEM direction to be associated with the ratio of verbal to nonverbal test performance as measured by the WAIS. Right movers demonstrated relatively higher scores on verbal tests, while left movers performed relatively better on nonverbal, visuospatial tests. In order to compare the results of the present study with those of Tucker and Suib (1978), a difference score was calculated by subtracting the Perceptual Organization score from the Verbal Comprehension score for each subject.

Table 11 presents mean difference scores for male and female left movers, bi-movers and right movers. Two-way analysis of variance comparing difference scores for left movers and right movers of each sex (Table 12) failed to produce significant main effects for sex and CLEM group, nor was the interaction effect significant. Two-way analysis of variance (Table 13) comparing male and female left movers, bi-movers and right movers also failed to show significant main or interaction effects.

These results are not consistent with those of Tucker and Suib (1978). Unfortunately, Tucker and Suib do not present test score information in their report and therefore it is difficult to evaluate these discrepant findings.

Other Findings

WAIS-R Verbal Tests

Information Test

Mean Information test scores were computed separately for male and female left movers, bi-movers and right movers (Table 14). Two-way analysis of variance comparing left and right movers of each sex (Table 15) revealed a significant main effect for sex, $F(1,49) = 6.41$, $p \leq .01$, indicating males scored higher on this test than did females. The main effect for CLEM group was not significant, however the sex by CLEM group interaction effect was significant, $F(1,49) = 7.54$, $p \leq .01$. Analysis of simple main effects indicated a trend for male right movers to achieve higher test scores than male left movers, $F(1,49) = 3.18$, $p \leq .10$. In contrast, female left movers scored significantly higher than female right movers on this test, $F(1,49) = 4.38$, $p \leq .05$. Test performance was not significantly different for male and female left movers, however male right movers scored significantly higher than female right movers, $F(1,49) = 10.85$, $p \leq .01$.

To investigate the performance of bi-movers, a two-way analysis of variance comparing male and female left movers, bi-movers and right movers (Table 16) was computed. This analysis also yielded a significant main effect for sex, $\underline{F}(1,74)=12.12$, $p\leq.001$, and a significant sex by CLEM group interaction effect, $\underline{F}(2,74)=4.30$, $p\leq.02$. The main effect for CLEM group was not significant. Analysis of simple main effects indicated that male CLEM groups did not vary significantly in their test performance. Similarly, the performance of female CLEM groups was not significantly different. Finally, male bi-movers scored significantly higher than female bi-movers on this test, $\underline{F}(1,74)=5.78$, $p\leq.03$.

Vocabulary Test

Table 17 displays mean Vocabulary test scores for male and female left movers, bi-movers and right movers. Two-way analysis of variance comparing left and right movers of each sex (Table 18) produced a marginally significant main effect for CLEM group, $\underline{F}(1,49)=3.09$, $p\leq.09$, indicating a trend for right movers to achieve higher Vocabulary test scores than left movers. These results are consistent with predictions generated from the CLEM model of hemisphericity. The main effect for sex was not significant, nor was the sex by CLEM group interaction effect.

An additional two-way (sex by CLEM group) analysis of variance (Table 19) was calculated to investigate the performance of bi-movers. This analysis failed to yield significant main effects for sex and CLEM group. The sex by CLEM group interaction effect was also not significant.

Comprehension Test

Mean Comprehension test scores for male and female left movers, bi-movers and right movers are summarized in Table 20. Two-way analysis of variance comparing the scores of male and female left and right movers (Table 21) produced a marginally significant main effect for CLEM group, $\underline{F}(1,49)=3.20$, $p\leq.08$, indicating superior performance of right movers on this verbal task. These results are consistent with predictions generated from the CLEM model of hemisphericity. The main effect for sex was not found to be significant, nor was the sex by CLEM group interaction effect.

To investigate the performance of bi-movers, a two-way analysis of variance comparing the scores of male and female left movers, bi-movers and right movers (Table 22) was computed. This analysis did not produce significant main effects for sex and CLEM group, nor was the sex by CLEM group interaction effect significant.

Similarities Test

Mean Similarities test scores for male and female left movers, bi-movers and right movers are presented in Table 23. Neither main effect for sex nor CLEM group was found to be significant in a two-way analysis of variance comparing left and right movers of each sex (Table 24). The sex by CLEM group interaction effect was also not significant.

Similar results were found in a two-way (sex by CLEM group) analysis of variance (Table 25) computed to investigate the performance of bi-movers. Both main effects for sex and CLEM group were not significant, nor was the sex by CLEM group interaction effect.

Digit Span

Mean Digit Span test scores were calculated separately for left movers, bi-movers and right movers of each sex (Table 26). Two-way analysis of variance comparing left and right movers of each sex (Table 27) did not produce significant main effects for sex and CLEM group. However, a marginally significant sex by CLEM group interaction effect was found, $\underline{F}(1,49)=3.02$, $p \leq .09$.

To investigate the performance of bi-movers, a two-way analysis of variance comparing male and female left movers, bi-movers and right movers (Table 28) was computed. This analysis also failed to yield significant main effects for sex and CLEM group; nor was the sex by CLEM group interaction effect significant.

Previous research has indicated that different skills are required for the digits forward and digits backward components of the Digit Span test. Rudel and Denckla (1974) suggested that the digits forward task requires the retrieval of a temporal sequence while the digits backward task requires the translation of a given sequence in space. Cremonini, DeRenzi and Faglioni (1980) reported that patients with damage to the left hemisphere perform poorly on the digits forward task while those with damage to the right hemisphere perform poorly on the digits backward task. Thus, visualization or use of spatial imagery appears to be a necessary component of performance on the digits backward task, although it is not a significant aspect in performance on the digits forward task.

Raw mean digits forward and digits backward scores for male and female left movers, bi-movers and right movers are presented in Tables 29 and 30, respectively. Two-way analysis of variance comparing digits forward scores for right movers of each sex (Table 31) produced a significant main effect for sex, $\underline{F}(1,49)=6.28$, $p \leq .02$, indicating females achieve higher scores on this task. Neither the main effect for CLEM group nor the sex by CLEM group interaction effect were significant. Two-way analysis of variance comparing digits backward scores for left movers and right movers of each sex (Table 32) yielded a marginally significant main effect for CLEM group, $\underline{F}(1,49)=3.68$, $p \leq .06$, indicating a trend for left movers to perform better on this task.

In order to investigate the performance of bi-movers, two-way analysis of variance comparing digits forward scores for male and female left movers, bi-movers and right movers (Table 33) was computed. This analysis also yielded a significant main effect for sex, $\underline{F}(1,74)=6.11$, $p\leq.02$, indicating females achieve higher test scores. The main effect for sex and the sex by CLEM group interaction effect were not significant. Two-way analysis of variance comparing digits backward scores for males and females in all CLEM groups (Table 34) yielded a significant main effect for CLEM group, $\underline{F}(2,74)=3.96$, $p\leq.02$. Both the main effect for sex and the sex by CLEM group interaction effect were not found to be significant.

These results are consistent with Rudel and Denckla's (1974) observations that the digits forward and digits backward components of this test are distinct. More importantly, they suggest that performance differences may be related to individual differences in hemisphericity. Individuals with a preference for right hemisphere processing strategies appear to be at an advantage for performance on such tasks which require the use of visualization or spatial imagery techniques.

Arithmetic Test

Table 35 presents mean Arithmetic test scores separately for left movers, bi-movers and right movers of each sex. Two-way analysis of variance comparing left and right movers of each sex (Table 36) did not produce significant main effects for sex and CLEM group, however a significant sex by CLEM group interaction effect was found, $\underline{F}(1,49)=6.66$, $p \leq .01$. Analysis of simple main effects indicated the scores of male left and right movers were not significantly different, while female left movers scored significantly higher than female right movers, $\underline{F}(1,49)=6.73$, $p \leq .025$. In addition, male and female left movers did not demonstrate significantly different performance, although male right movers performed significantly better than female right movers, $\underline{F}(1,49)=6.09$, $p \leq .03$.

To investigate the performance of bi-movers, a two-way analysis of variance comparing right movers, bi-movers and left movers of each sex (Table 37) was computed. This analysis produced a significant main effect for sex, $\underline{F}(1,74)= 5.78$, $p \leq .02$, indicating males achieved significantly higher Arithmetic test scores. A significant sex by CLEM group interaction effect was also found, $\underline{F}(2,74)=4.43$, $p \leq .02$. Analysis of simple main effects revealed that male CLEM groups were significantly different at a marginal level, $\underline{F}(2,74)=2.60$, $p \leq .09$. Planned comparisons indicated that male bi-movers scored significantly higher than male left movers, $\underline{F}(1,74)=5.16$, $p \leq .05$. Male bi-movers were not significantly different from male right movers in their test performance.

Female CLEM groups were also found to vary significantly, $F(2,74)=3.41$, $p\leq.04$, and planned comparisons indicated a trend for female bi-movers to achieve higher test scores than female right movers, $F(1,74)=2.85$, $p\leq.10$. Female bi-movers were not significantly different from female left movers in their test performance. Finally, test scores for male and female bi-movers were not significantly different.

WAIS-R Performance Tests

Block Design

Mean Block Design test scores for left movers, bi-movers and right movers of each sex are displayed in Table 38. Two-way analysis of variance comparing male and female left and right movers (Table 39) produced a significant main effect for sex, $F(1,49)=7.29$, $p\leq.01$. This is consistent with previous research indicating males demonstrate superior performance on this test (Shaw, 1965). The main effect for CLEM group was not significant, however a significant sex by CLEM group interaction effect was found, $F(1,49)=6.03$, $p\leq.02$. Analysis of simple main effects indicated that performance of male left and right movers was not significantly different, however female left movers achieved significantly higher test scores than female right movers, $F(1,49)=5.14$, $p\leq.05$. In addition, the performance of male and female left movers does not vary significantly, while male right movers score significantly higher than female right movers, $F(1,49)=10.37$, $p\leq.01$.

To investigate the performance of bi-movers, a two-way analysis of variance comparing right movers, bi-movers and left movers (Table 40) was computed. This analysis yielded a significant main effect for sex, $F(1,74)= 10.42$, $p\leq.002$, and a significant main effect for CLEM group, $F(2,74)=3.34$, $p\leq.04$. A marginally significant sex by CLEM group interaction effect was also found, $F(2,74)=2.85$, $p\leq.06$.

Planned comparisons between CLEM groups indicated that bi-movers achieved significantly higher Block Design scores than right movers, $F(1,74)= 4.74$, $p\leq.05$, and that there was also a trend for bi-movers to achieve higher test scores than left movers, $F(1,74)=3.12$, $p\leq.10$. Simple main effects analysis failed to reveal significant differences between male CLEM groups, however female CLEM groups were found to differ in their performance at a marginal level of significance, $F(2,74)=3.45$, $p\leq.10$. Planned comparisons indicated that female bi-movers and left movers were not significantly different in their performance, however female bi-movers achieved significantly higher scores than female right movers, $F(1,74)=6.37$, $p\leq.02$. Finally, the performance of male and female bi-movers was not found to vary significantly.

Object Assembly

Mean Object Assembly scores for male and female left movers, bi-movers and right movers are presented in Table 41. Two-way analysis of variance comparing left and right movers of each sex (Table 42) did not produce significant main effects for sex and CLEM group, nor was the sex by CLEM group interaction effect significant.

To investigate the performance of bi-movers, a two-way analysis of variance comparing test scores for male and female left movers, bi-movers and right movers was computed (Table 43). This analysis also failed to yield significant main effects for sex and CLEM group, nor was the sex by CLEM group interaction effect significant.

Picture Arrangement and Picture Completion

Mean Picture Arrangement and Picture Completion scores for male and female left movers, bi-movers and right movers are presented in Tables 44 and 45, respectively. Two-way analysis of variance comparing Picture Arrangement scores for left and right movers of each sex (Table 46) failed to produce main effects for sex and CLEM group, and the sex by CLEM group interaction effect was also not significant. Similar results were found in a two-way analysis of variance comparing Picture Arrangement scores for male and female left movers, bi-movers and right movers (Table 47).

Two-way analysis of variance comparing Picture Completion scores for left and right movers of each sex (Table 48) also failed to produce significant main effects for sex and CLEM group, nor was the sex by CLEM group interaction effect significant. Similar results were found in a two-way analysis of variance comparing Picture Completion test scores for male and female left movers, bi-movers and right movers (Table 49).

Digit Symbol

Mean Digit Symbol test scores calculated for male and female left movers, bi-movers and right movers are presented in Table 50. Two-way analysis of variance comparing left and right movers of each sex (Table 51) yielded a significant main effect for sex, $F(1,49)=7.68$, $p \leq .01$, indicating females achieved higher scores on this test. Left movers tended to demonstrate better performance than right movers on this test, $F(1,49)=2.79$, $p \leq .10$; however the sex by CLEM group interaction effect was not significant.

To investigate the performance of bi-movers, a two-way analysis of variance comparing left movers, bi-movers and right movers of each sex was computed (Table 52). This analysis also produced a significant main effect for sex, $F(1,74)=9.71$, $p \leq .003$, however neither the main effect for CLEM group, nor the sex by CLEM group interaction effect were significant.

WAIS-R Scales

Verbal IQ

Mean Verbal IQs for male and female left movers, bi-movers and right movers are presented in Table 53. Two-way analysis of variance comparing left and right movers of each sex (Table 54) failed to produce significant main effects for sex and CLEM group. A marginally significant sex by CLEM group interaction effect was found, $\underline{F}(1,49)=3.79$, $p \leq .06$, however analysis of simple main effects failed to reveal any significant group differences.

To investigate the performance of bi-movers, a two-way analysis of variance comparing male and female left movers, bi-movers and right movers was computed (Table 55). This analysis also failed to produce significant main effects for sex and CLEM group, although a marginally significant interaction effect was found, $\underline{F}(2,74)=2.52$, $p \leq .09$.

Performance IQ

Table 56 displays mean Performance IQs for male and female left movers, bi-movers and right movers. Two-way analysis of variance comparing left and right movers of each sex (Table 57) did not produce significant main effects for sex and CLEM group, and the interaction effect was also not significant. A two-way analysis of variance comparing male and female left movers, bi-movers and right movers was also computed (Table 58). This analysis also failed to yield significant main or interaction effects.

Full Scale IQ

Mean Full Scale IQs of male and female left movers, bi-movers and right movers are presented in Table 59. Two-way analysis of variance comparing left and right movers of each sex (Table 60) did not produce significant main effects for sex or CLEM group, although a marginally significant interaction effect was found, F (1,49)=3.65, p≤.06. Analysis of simple main effects indicated that male left and right movers achieved similar scores, however there was a trend for female left movers to achieve higher Full Scale IQs than female right movers, F(1,49)= 3.15, p≤.10.

To investigate the performance of bi-movers, a two-way analysis of variance comparing the scores for male and female left movers, bi-movers and right movers was computed (Table 61). This analysis failed to produce significant main effects for sex and CLEM group, nor was the interaction effect significant.

Table 1

Mean Handedness Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	17.83	17.50	18.60
SD	5.92	5.05	5.78
Females	21.13	20.67	21.11
SD	3.07	5.45	3.72

Table 2

ANOVA of Handedness Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	132.55	1	132.55	5.31	$p \leq .02$
Clem Group	20.55	2	10.28	.41	n.s.
Interaction	5.01	2	2.51	.10	n.s.
Error	1845.87	74	24.94		

Table 3
Factor 1 Loadings on WAIS-R Tests
for Four Age Groups

Test	18-19	20-24	25-34	35-44
Information	.89	.85	.79	.60
Digit Span	.02	.10	.03	.12
Vocabulary	.91	.83	.83	.81
Arithmetic	.41	.12	.48	.29
Comprehension	.88	.82	.80	.93
Similarities	.84	.83	.80	.89
Picture Completion	.14	.31	.18	.29
Picture Arrangement	.03	.07	.07	.03
Block Design	.01	-.15	.02	.04
Object Assembly	.05	.11	-.04	-.05
Digit Symbol	.10	.00	-.01	-.03

Table 4
Factor 2 Loadings on WAIS-R Tests
for Four Age Groups

Test	18-19	20-24	25-34	35-44
Information	-.05	-.06	.01	.02
Digit Span	-.11	.03	.03	.07
Vocabulary	-.03	-.03	-.02	-.02
Arithmetic	.37	.13	.19	.49
Comprehension	-.01	.05	-.09	.01
Similarities	.06	.08	.18	.05
Picture Completion	.05	.52	.60	.22
Picture Arrangement	.09	-.01	.10	.06
Block Design	.89	.77	.68	.85
Object Assembly	.72	.90	.98	.95
Digit Symbol	.44	.03	-.02	-.03

Table 5

Mean Verbal Comprehension Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.78	12.73	13.30
SD	1.44	1.80	2.30
Females	12.45	11.62	11.94
SD	1.03	1.62	1.94

Table 6

ANOVA of Verbal Comprehension Scores for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	1.41	1	1.41	.54	n.s.
CLEM Group	3.12	1	3.12	1.19	n.s.
Interaction	12.53	1	12.53	4.77	$p \leq .03$
Error	128.59	49	2.62		

Table 7

ANOVA of Verbal Comprehension Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	6.71	1	6.71	2.47	n.s.
CLEM Group	3.39	2	1.70	.63	n.s.
Interaction	17.50	2	8.75	3.22	$p \leq .05$
Error	200.88	74	2.71		

Table 8

Mean Perceptual Organization Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.33	12.13	11.95
SD	1.50	1.43	2.65
Females	11.31	11.77	10.33
SD	1.58	1.85	1.50

Table 9

ANOVA of Perceptual Organization Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	8.15	1	8.15	2.55	n.s.
CLEM Group	.40	1	.40	.12	n.s.
Interaction	7.74	1	7.74	2.42	n.s.
Error	156.66	49	3.20		

Table 10

ANOVA of Perceptual Organization Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	8.31	1	8.31	2.71	n.s.
CLEM Group	8.79	2	4.39	1.43	n.s.
Interaction	7.98	2	3.99	1.30	n.s.
Error	227.16	74	3.07		

Table 11

Mean Difference Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	.44	.60	1.35
SD	1.90	2.21	3.06
Females	1.14	-.15	1.61
SD	1.61	1.60	2.21

Table 12

ANOVA of Difference Scores for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	2.78	1	2.78	.61	n.s.
CLEM Group	5.75	1	5.75	1.26	n.s.
Interaction	.57	1	.57	.13	n.s.
Error	223.48	49	4.56		

Table 13

ANOVA of Difference Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	.09	1	.09	.02	n.s.
CLEM Group	17.44	2	8.72	2.06	n.s.
Interaction	8.00	2	4.00	.95	n.s.
Error	312.64	74	4.22		

Table 14

Mean Information Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	12.61	13.67	14.20
SD	2.03	2.19	2.86
Females	12.75	11.6	10.78
SD	1.84	2.10	2.64

Table 15

ANOVA of Information Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	32.75	1	32.75	6.41	$p \leq .01$
CLEM Group	.45	1	.45	.09	n.s.
Interaction	38.53	1	38.53	7.54	$p \leq .01$
Error	250.43	49	5.11		

Table 16

ANOVA of Information Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	59.73	1	59.73	12.12	$p \leq .001$
CLEM Group	.45	2	.23	.05	n.s.
Interaction	32.34	2	21.17	4.30	$p \leq .02$
Error	364.70	74	4.93		

Table 17

Mean Vocabulary Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.83	12.92	13.80
SD	1.89	1.68	2.82
Females	12.13	11.80	12.33
SD	1.67	2.21	2.60

Table 18

ANOVA of Vocabulary Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	4.19	1	4.19	.90	n.s.
CLEM Group	14.37	1	14.37	3.09	p≤.09
Interaction	9.39	1	9.39	2.02	n.s.
Error	227.85	49	4.65		

Table 19

ANOVA of Vocabulary Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	10.96	1	10.96	2.48	n.s.
CLEM Group	14.37	2	7.19	1.63	n.s.
Interaction	12.07	2	6.04	1.37	n.s.
Error	327.17	74	4.42		

Table 20

Mean Comprehension Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.50	12.33	13.10
SD	1.86	2.61	2.51
Females	12.88	11.87	13.33
SD	1.46	1.85	2.50

Table 21

ANOVA of Comprehension Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	7.86	1	7.86	1.95	n.s.
CLEM Group	12.87	1	12.87	3.20	p≤.08
Interaction	3.96	1	3.96	.98	n.s.
Error	197.15	49	4.02		

Table 22

ANOVA of Comprehension Test Scores for Male and Female

Left, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	2.72	1	2.72	.63	n.s.
CLEM Group	16.57	2	8.28	1.92	n.s.
Interaction	13.05	2	6.52	1.51	n.s.
Error	319.55	74	4.32		

Table 23

Mean Similarities Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.17	12.00	12.10
SD	2.01	1.91	2.89
Females	12.06	11.20	11.33
SD	1.39	2.11	1.23

Table 24

ANOVA of Similarities Test Scores for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	.05	1	.05	.01	n.s.
CLEM Group	.13	1	.13	.03	n.s.
Interaction	8.40	1	8.40	2.23	n.s.
Error	184.34	49	3.76		

Table 25

ANOVA of Similarities Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	.94	1	.93	.24	n.s.
CLEM Group	.17	2	.09	.02	n.s.
Interaction	13.75	2	6.88	1.77	n.s.
Error	286.74	74	3.87		

Table 26

Mean Digit Span Test Scores of Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.67	12.92	10.20
SD	2.47	2.88	3.74
Females	12.44	12.60	12.00
SD	2.19	2.20	1.73

Table 27

ANOVA of Digit Span Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	20.08	1	20.08	3.02	p≤.09
CLEM Group	11.01	1	11.01	1.66	n.s.
Interaction	3.22	1	3.22	.48	n.s.
Error	325.54	49	6.64		

Table 28

ANOVA of Digit Span Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	10.60	1	10.60	1.62	n.s.
CLEM Group	30.47	2	15.23	2.33	p≤n.s.
Interaction	12.62	2	6.31	.96	n.s.
Error	484.05	74	6.54		

Table 29

Mean Digit Forward Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	9.78	10.08	8.60
SD	2.07	2.91	2.88
Females	10.44	10.87	11.11
SD	2.28	2.13	1.27

Table 30

Mean Digit Backward Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	8.78	10.08	7.10
SD	2.39	1.88	3.25
Females	8.88	8.93	7.78
SD	2.31	2.66	2.22

Table 31

ANOVA of Digit Forward Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	30.54	1	30.54	6.28	p≤.02
CLEM Group	.77	1	.77	.16	n.s.
Interaction	10.41	1	10.41	2.14	n.s.
Error	238.34	49	4.86		

Table 32

ANOVA of Digit Backward Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	1.82	1	1.82	.29	n.s.
CLEM Group	23.39	1	23.39	3.68	p≤.06
Interaction	1.02	1	1.02	.16	n.s.
Error	311.31	49	6.35		

Table 33

ANOVA of Digit Forward Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	32.63	1	32.63	6.11	p≤.02
CLEM Group	4.49	2	2.24	.42	n.s.
Interaction	11.71	2	5.85	1.10	n.s.
Error	394.99	74	5.34		

Table 34

ANOVA of Digit Backward Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	.29	1	.29	.05	n.s.
CLEM Group	48.05	2	24.03	3.96	p≤.02
Interaction	10.41	2	5.20	.86	n.s.
Error	449.16	74	6.07		

Table 35

Mean Arithmetic Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.67	13.83	12.70
SD	2.83	1.85	3.37
Females	12.56	11.60	9.78
SD	1.75	2.95	2.28

Table 36

ANOVA of Arithmetic Test Scores for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	12.47	1	12.47	1.88	n.s.
CLEM Group	9.32	1	9.32	1.40	n.s.
Interaction	44.29	1	44.29	6.66	$p \leq .01$
Error	325.59	49	6.64		

Table 37

ANOVA of Arithmetic Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	37.87	1	37.87	5.78	p≤.02
CLEM Group	24.19	2	12.09	1.85	n.s.
Interaction	58.01	2	29.00	4.43	p≤.02
Error	484.86	74	6.55		

Table 38

Mean Block Design Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	12.33	14.17	13.30
SD	1.88	2.44	2.41
Females	12.19	12.53	10.22
SD	2.34	2.26	1.48

Table 39

ANOVA of Block Design Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	31.60	1	31.60	7.29	p≤.01
CLEM Group	3.03	1	3.03	.70	n.s.
Interaction	26.11	1	26.11	6.03	p≤.02
Error	212.09	49	4.33		

Table 40

ANOVA of Block Design Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	49.23	1	49.23	10.42	p≤.002
CLEM Group	31.55	2	15.78	3.34	p≤.04
Interaction	26.96	2	13.48	2.85	p≤.06
Error	349.49	74	4.72		

Table 41

Mean Object Assembly Test Scores for Male and Female

Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	10.33	10.08	10.60
SD	1.94	1.62	3.06
Females	10.44	11.00	10.44
SD	1.55	2.00	1.81

Table 42

ANOVA of Object Assembly Test Scores for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	.01	1	.01	.00	n.s.
CLEM Group	.23	1	.23	.05	n.s.
Interaction	.20	1	.20	.05	n.s.
Error	210.56	49	4.30		

Table 43

ANOVA of Object Assembly Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	1.56	1	1.56	.39	n.s.
CLEM Group	.43	2	.22	.05	n.s.
Interaction	3.84	2	1.92	.48	n.s.
Error	295.48	74	3.99		

Table 44

Mean Picture Arrangement Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	13.00	13.08	13.80
SD	2.91	2.58	3.46
Females	12.44	12.27	12.22
SD	2.71	3.08	3.42

Table 45

Mean Picture Completion Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	10.50	12.58	11.20
SD	2.85	2.28	2.20
Females	11.69	10.80	10.33
SD	2.70	2.60	4.18

Table 46

ANOVA of Picture Arrangement Test Scores for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	13.91	1	13.91	1.50	n.s.
CLEM Group	1.04	1	1.04	.11	n.s.
Interaction	3.13	1	3.13	.34	n.s.
Error	455.09	49	9.29		

Table 47

ANOVA of Picture Arrangement Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	18.25	1	18.25	2.04	n.s.
CLEM Group	1.43	2	.72	.08	n.s.
Interaction	3.19	2	1.59	.18	n.s.
Error	660.94	74	8.93		

Table 48

ANOVA of Picture Completion Test Scores for Male and Female Left and Right Movers*

Source	SS	DF	MS	F	Prob.
Sex	.31	1	.31	.04	n.s.
CLEM Group	1.30	1	1.30	.15	n.s.
Interaction	12.82	1	12.82	1.46	n.s.
Error	431.54	49	8.81		

Table 49

ANOVA of Picture Completion Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	4.46	1	4.46	.57	n.s.
CLEM Group	10.37	2	5.18	.66	n.s.
Interaction	34.93	2	17.47	2.22	n.s.
Error	582.85	74	7.88		

Table 50

Mean Digit Symbol Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	11.39	10.50	10.10
SD	2.20	2.43	1.29
Females	12.56	11.93	12.00
SD	1.67	2.31	2.35

Table 51

ANOVA of Digit Symbol Test Scores for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	28.70	1	28.70	7.68	$p \leq .01$
CLEM Group	10.41	1	10.41	2.79	$p \leq .10$
Interaction	1.60	1	1.60	.43	n.s.
Error	183.12	49	3.73		

Table 52

ANOVA of Digit Symbol Test Scores for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	42.39	1	42.39	9.71	$p \leq .003$
CLEM Group	13.64	2	6.82	1.56	n.s.
Interaction	1.60	2	.80	.18	n.s.
Error	323.05	74	4.37		

Table 53

Mean Verbal IQs for Male and Female

Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	112.83	119.75	117.90
SD	9.40	11.28	16.55
Females	117.13	114.20	110.00
SD	8.45	9.82	10.01

Table 54

ANOVA of Verbal IQs for

Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	39.55	1	39.55	.33	n.s.
CLEM Group	12.87	1	12.87	.11	n.s.
Interaction	451.55	1	451.55	3.79	p≤.06
Error	5839.15	49	119.17		

Table 55

ANOVA of Verbal IQs for Male and Female
Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	175.04	1	175.04	1.51	n.s.
CLEM Group	111.98	2	55.99	.48	n.s.
Interaction	584.07	2	292.04	2.52	p≤.09
Error	8589.79	74	116.08		

Table 56

Mean Performance IQs for Male and Female
Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	111.17	115.92	112.40
SD	9.31	11.36	12.45
Females	114.31	113.33	107.22
SD	8.81	14.89	15.34

Table 57

ANOVA of Performance IQs for

Male and Female Left Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	12.54	1	12.54	.10	n.s.
CLEM Group	104.21	1	104.21	.86	n.s.
Interaction	210.48	1	210.48	1.74	n.s.
Error	5911.89	49	120.65		

Table 58

ANOVA of Performance IQs for Male and Female

Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	44.45	1	44.45	.32	n.s.
CLEM Group	256.94	2	128.47	.91	n.s.
Interaction	243.83	2	121.92	.86	n.s.
Error	10436.13	74	141.03		

Table 59

Mean Full Scale IQs for Male and Female Left Movers, Bi-Movers and Right Movers

	Left Movers	Bi-Movers	Right Movers
Males	113.61	120.08	117.40
SD	8.74	11.42	14.67
Females	117.94	116.00	110.11
SD	8.19	11.79	12.52

Table 60

ANOVA of Full Scale IQs for Male and Female Left and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	26.66	1	26.66	.24	n.s.
CLEM Group	49.52	1	49.52	.44	n.s.
Interaction	409.87	1	409.87	3.65	$p \leq .06$
Error	5496.50	49	112.17		

Table 61

ANOVA of Full Scale IQs for Male and Female Left Movers, Bi-Movers and Right Movers

Source	SS	DF	MS	F	Prob.
Sex	103.60	1	103.60	.86	n.s.
CLEM Group	208.10	2	104.05	.87	n.s.
Interaction	489.66	2	244.83	2.04	n.s.
Error	8877.41	74	119.97		

III. Discussion

The results of this study indicate the importance of sex as a moderating variable in the relationship between CLEM and cognitive ability. Several CLEM by sex interaction effects were identified. With reference to CLEM and verbal ability, the predicted superiority of right movers on tests selected as measures of verbal comprehension (Information, Vocabulary, Comprehension, Similarities) was found only for males. Male right movers achieved significantly higher scores than male left movers and this clearly supports the CLEM model of hemisphericity. For female subjects, right and left movers were not significantly differentiated by their performance on these tests.

Similarly, with reference to CLEM and nonverbal ability, the predicted superiority of left movers on tests selected as measures of perceptual organization (Block Design, Object Assembly) was found only for females on the Block Design subtest. Female left movers scored significantly higher than female right movers on this test and this is consistent with the findings of Galin and Ornstein (1972). These results indicating female left movers excel on tests of visuospatial ability provide support for the CLEM model. Nonverbal test performance failed to significantly differentiate male left movers from right movers.

These sex differences in the relationship between CLEM and cognitive ability complicate the CLEM model. Bakan (1969) proposed that movements of the eyes to the right are indicative of increased left hemisphere activity while movements to the left indicate increased right hemisphere activity. The sex differences observed in this study suggest that because hemispheric organization of function is different in males and females, the relationship between CLEM and cognitive ability is also different for males and females.

A substantial amount of evidence has accrued indicating that sex differences in cognitive ability are related to underlying differences in lateralized brain organization. Side of lesion by sex interaction effects are frequently found in clinical studies investigating the results of unilateral brain injury (Lansdell & Urbach, 1965; Lansdell, 1968; McGlone, 1978). As McGlone (1980) notes, this literature consistently supports the notion of greater left hemisphere lateralization of verbal functions in males than in females. Similar results have been found in studies using dichotic listening and tachistoscopic techniques (McGlone, 1980). Conclusions regarding sex differences in hemispheric specialization for visuospatial functions are more tentative, although some researchers have suggested that males demonstrate increased right hemisphere specialization for these functions as well (Lansdell, 1968; McGee, 1979; Harris, 1978).

The results of this study are consistent with sex difference models which describe the male brain as more lateralized for verbal functions. Such theories would predict that male right movers should demonstrate better verbal abilities than male left movers. In contrast, because of bilateral representation of verbal functions in females, left and right movers should not show significantly different performance on such measures. This is precisely the pattern of results noted in this study.

It is somewhat more difficult to interpret the present results regarding the relationship between CLEM and nonverbal ability. Sex difference models postulating greater right hemisphere specialization of spatial functions in males (McGlone, 1978; Bryden, 1979) would predict superior spatial abilities in male left movers relative to male right movers while female left and right movers should not vary in the performance on these tasks. As previously stated, this study found no significant differences in spatial ability between male left and right movers while female left movers achieved significantly higher Block Design scores than did female right movers. These results suggest that females, rather than males, demonstrate more right hemisphere specialization for nonverbal functions. As noted in McGlone's (1980) review of the sex difference research, little support is available for this interpretation.

An alternative explanation for these results may be that female right movers, demonstrating a preference for left hemisphere functioning, tend to employ verbal mediation in solving spatial problems. In contrast, female left movers, utilizing right hemisphere problem solving strategies, are more successful on these tasks. This interpretation has also been suggested by Hannay (1976) who noted that females demonstrating left visual-field superiority for recognition of spatial information scored significantly higher on the WAIS Block Design subtest than females showing right-visual field superiority. Visual field superiority was not related to Block Design test performance in males. Similar explanations have been proposed by Kimball (1982), however empirical support for these interpretations is questionable. For example, McGlone (1982) reported that female subjects in both brain-injured and control samples failed to report the use of verbal strategies more frequently than male subjects. She concluded that her results indicating sex differences in lateralization for visuospatial functions could not be attributed to sex differences in the use of verbal strategies on such tasks. It appears that the interpretation of the current results awaits a more sophisticated understanding of sex differences in hemispheric lateralization of spatial functions.

These results stress the importance of examining sex as a moderating variable in future CLEM research. Several studies incorporating CLEM as a measure of hemispheric activation have failed to report sex of subjects (Ogle, 1971), or have selected only right handed males for their samples (Gur & Rehyer, 1973; Gur & Reivich, 1980). Others have controlled for sex by including both males and females in the subject pool, yet have failed to examine CLEM by sex interaction effects (Bakan & Shotland, 1969; Tucker & Suib, 1969). The few studies which have evaluated CLEM by sex interaction effects report a different pattern of results for male and female subjects. For example, Strayer (1968) found rightward eye movements were associated with increased alpha production for males although this relationship was not significant for females. Similarly, Gur and Gur (1974) observed that hypnotic susceptibility was negatively related to the number of eye movements to the right for males, while the correlation between these variables was not significant for females. These results, in conjunction with the findings of the present study, emphasize the importance of evaluating sex by CLEM interaction effects in future research.

The current research also provides some interesting observations regarding the performance of individuals who fail to demonstrate directional consistency in the CLEM response. This group comprised approximately 34% of the study sample suggesting bi-movers represent a substantial portion of the general population. A simple prediction of the CLEM model would be that, compared to left and right movers, these individuals should show an intermediate level of performance on verbal and nonverbal tasks. This pattern of results would be consistent with the greater development of verbal skills by right movers because of their preference for left hemisphere processing and the greater development of visuospatial skills by left movers because of their preference for right hemisphere processing. In contrast, bi-movers should demonstrate more equally developed verbal and visuospatial skills due to their lack of preference for left or right hemisphere functioning.

Scanning performance means for left movers, bi-movers and right movers across all WAIS-R subtests selected as measures of verbal and nonverbal ability suggests that the relationship between direction of CLEM response and cognitive ability is not clearly linear. The results of this study indicated that left movers, bi-movers and right movers did not differ in verbal ability although bi-movers achieved higher Block Design subtest scores than both left and right movers indicating that individuals who fail to demonstrate directional consistency may excel on tasks of visuospatial ability. These findings are not consistent with the research of Hoffman and Kagan (1977) who reported bi-movers performed significantly poorer than both left and right movers on the Block Design test. However, both the current results and the findings of Hoffman and Kagan (1977) suggest bi-movers do not consistently demonstrate levels of performance which are intermediate to those noted for left and right movers. Perhaps the performance of bi-movers is not completely attributable to their lack of preference for left or right hemisphere processing. It may be that both verbal and nonverbal functions are more bilaterally represented in bi-movers. These speculations await further research evaluating the cognitive abilities and neurophysiological responses of bi-movers. At present, it is clear that these individuals represent a substantial population about which little is known.

Two additional conclusions were noted from this research. First, available tasks for evaluating spatial ability tend to be more varied and less well validated than those assessing verbal abilities. As McGlone and Kertesz (1973) have pointed out, spatial processing may be influenced by both verbal and nonverbal systems and consequently it is difficult to identify measures which assess only spatial skills. There can be little doubt that research in this area would be clarified by the refinement and validation of tasks for assessing right hemisphere functioning. Second, in a normal population, it is apparent that differences in cognitive ability associated with individual differences in hemisphericity or sex-related differences are typically small. For this reason, these differences may only become apparent in studies using large samples. More importantly, while such investigations contribute to a more sophisticated understanding of hemispheric specialization of function, generalizations with reference to individual differences in cognitive abilities are clearly limited.

In summary, this research provides support for Bakan's (1969) CLEM model of hemisphericity and emphasizes the importance of sex as a moderating variable in this research. Further research is necessary to establish an understanding of sex-related differences in hemisphericity, as are investigations evaluating the cognitive abilities of individuals who fail to demonstrate directional consistency in the CLEM response.

Appendices

Appendix A : CLEM Assessment Questions

1. What is the meaning of the proverb: a watched pot never boils.
2. What is the meaning of the proverb: it is an ill wind that blows no one good fortune.
3. Make up a sentence using two forms of the same verb.
4. Tell me two verbs beginning with "N".
5. What is the meaning of the proverb: a poor worker blames his tools.
6. Spell "therapeutic".
7. What is the meaning of the proverb: Call no man happy 'til he's dead.
8. List two adverbs.
9. What is the meaning of the proverb: lend your money and lose your friends.
10. What is the meaning of the proverb: more than enough is too much.
11. List two prepositions.
12. What is the meaning of the proverb: words should be weighed, not counted.
13. What is the meaning of the proverb: he is rich who has few

wants.

14. Define inflation.

15. What is the meaning of the proverb: a rolling stone gathers no moss.

16. Make up a sentence using two adverbs.

17. Tell me two verbs beginning with "R".

18. What is the meaning of the proverb: the hardest work is to go idle.

19. What is the meaning of the proverb: what saddens a wise man, gladdens a fool.

20. Define the word "economics".

Appendix B : Factor 3 Loadings on WAIS-R Tests for Four Age Groups

Test	18-19	20-24	25-34	35-44
Information	.05	.10	.13	.08
Digit Span	.91	.87	.88	.19
Vocabulary	.02	.12	-.11	-.02
Arithmetic	.22	.58	.44	.14
Comprehension	-.11	-.05	.02	-.08
Similarities	.04	.00	-.17	.10
Picture Completion	.13	-.21	-.05	.26
Picture Arrangement	.06	.01	-.03	.03
Block Design	.04	.18	.23	-.03
Object Assembly	-.12	.02	-.03	.01
Digit Symbol	.54	.02	.05	1.01

Appendix C : Factor 4 Loadings
on the WAIS-R Tests for Four Age Groups

Test	18-19	20-24	25-34	35-44
Information	.03	-.04	-.06	.27
Digit Span	.12	.03	.10	.21
Vocabulary	.06	-.03	-.04	.17
Arithmetic	.24	.11	-.01	-.09
Comprehension	.01	.11	.06	.00
Similarities	-.11	.01	.14	-.12
Picture Completion	.17	.06	.18	.36
Picture Arrangement	.88	-.01	.04	.87
Block Design	.11	.07	.09	.04
Object Assembly	.03	-.01	-.08	.04
Digit Symbol	-.23	1.01	.98	-.01

Appendix D : Factor 5 Loadings on the WAIS-R Tests for Four Age Groups

Test	18-19	20-24	25-34	35-44
Information	-.04	.05	.12	.09
Digit Span	.04	-.06	.03	.68
Vocabulary	-.01	.09	.13	.08
Arithmetic	-.27	.24	-.08	.33
Comprehension	.12	.00	.10	.02
Similarities	.01	-.04	-.12	-.07
Picture Completion	.11	.93	.90	.08
Block Design	-.13	.18	.11	.16
Object Assembly	.33	-.15	.02	-.15
Digit Symbol	.11	-.03	.03	.04

Appendix E : Raw Data

Coding Key :

Columns 1-3: Subject identification

Columns 5-6: Sex (01 Male; 02 Female)

Columns 8-9: Age

Columns 11-12: Handedness Score

Columns 14-15: Information Test score

Columns 17-18: Digit Span Test score

Columns 20-21: Vocabulary Test score

Columns 23-24: Arithmetic Test score

Columns 26-27: Comprehension Test score

Columns 29-30: Similarities Test score

Columns 32-33: Picture Completion Test score

Columns 35-36: Picture Arrangement Test score

Columns 38-39: Block Design Test score

Columns 41-42: Object Assembly Test score

Columns 44-45: Digit Symbol Test score

Columns 47-49: Verbal IQ

Columns 51-53: Performance IQ

Columns 55-57: Full Scale IQ

Columns 59-61: Percentage of rightward CLEM

101	01	18	24	09	13	09	10	09	06	08	09	12	13	15	102	114	108	06
102	01	19	19	16	15	13	17	15	12	11	13	19	09	11	129	124	132	40
103	01	18	07	11	10	11	11	10	09	07	13	10	12	11	110	106	109	26
104	01	19	24	09	10	11	14	14	11	14	15	14	10	12	119	128	126	00
105	01	19	17	13	08	12	14	11	10	12	10	08	10	13	118	106	114	00
106	01	18	18	15	12	14	15	12	14	17	[illegible]	14	10	11	133	124	134	37
107	02	19	18	07	10	09	10	13	11	06	[illegible]	10	09	13	107	96	103	79
108	02	18	23	10	11	10	11	11	10	11	[illegible]	14	11	15	111	132	123	53
109	02	19	18	13	13	16	17	14	13	10	11	16	12	15	139	126	136	06
110	02	18	21	11	11	09	11	11	10	09	10	14	11	13	111	114	113	00
111	02	18	24	12	12	12	11	15	11	11	11	12	11	12	124	114	122	56
201	01	22	21	10	10	12	07	14	14	10	17	11	09	08	109	106	107	81
202	01	21	10	13	15	14	15	11	15	11	11	11	09	06	128	94	115	65
203	01	22	24	13	10	12	15	12	13	14	11	10	10	10	119	106	114	39
204	01	21	14	15	14	13	11	14	10	10	10	12	10	12	121	104	115	10
205	01	23	24	11	08	09	11	09	08	08	17	12	10	10	96	109	101	75
206	01	24	21	12	13	13	11	12	12	11	13	12	08	15	116	112	116	06
207	01	22	23	13	10	15	12	13	08	10	17	12	12	10	113	115	116	93
208	01	23	22	15	08	16	13	14	12	10	08	11	06	10	122	89	108	100
209	01	22	14	10	08	11	11	09	09	12	13	12	12	08	98	109	102	67
210	01	22	21	16	13	15	11	16	12	12	17	14	12	12	128	125	131	40
211	01	24	21	15	14	14	13	12	10	09	17	15	15	10	122	123	128	13
212	01	22	06	15	11	10	07	09	12	06	11	12	08	09	105	90	99	06
213	01	20	24	13	14	10	11	10	10	11	11	15	10	11	110	111	111	25
214	01	22	22	13	14	13	17	11	13	10	11	13	11	11	126	108	121	18
215	01	22	16	15	14	15	15	11	14	14	11	19	18	11	129	136	135	72
216	02	22	23	10	14	10	11	13	12	08	11	14	09	11	112	102	108	47
217	02	23	14	13	14	13	11	12	14	10	15	12	11	13	121	115	122	29
218	02	24	16	11	13	10	07	13	11	08	10	10	10	08	106	90	100	39
219	02	22	22	10	12	09	12	14	10	14	11	11	10	12	109	111	110	18
220	02	23	24	09	13	10	06	10	10	11	13	08	10	10	98	100	99	89
221	02	21	23	12	09	12	10	11	12	14	13	09	10	12	107	111	109	19
222	02	20	24	10	14	10	10	11	11	06	12	10	10	08	107	90	101	76
223	02	24	15	11	10	12	10	12	10	11	12	11	13	14	106	115	111	73
224	02	21	16	12	14	12	11	12	12	12	13	12	12	12	124	122	126	32
225	02	22	23	15	14	12	17	13	12	11	11	15	09	15	128	115	128	47
226	02	22	23	16	10	17	11	11	11	12	08	14	13	10	124	109	120	53
227	02	21	20	12	12	12	11	11	16	09	17	14	13	13	118	123	124	41
228	02	23	14	10	17	12	14	12	10	11	12	14	12	15	119	120	123	47
229	02	21	13	12	10	09	08	11	10	10	12	10	07	10	101	96	99	61
230	02	22	24	13	13	12	13	15	14	11	11	17	10	11	125	114	124	10
231	02	22	23	12	10	12	11	14	12	09	13	11	08	11	113	100	108	00
232	02	21	20	14	14	14	13	11	14	11	11	12	10	12	125	108	120	29
233	02	23	24	07	15	08	09	07	06	10	07	07	09	13	92	90	91	44
301	01	26	18	11	16	16	13	12	13	10	12	10	10	10	122	102	114	29
302	01	26	20	11	06	10	08	12	09	09	15	12	09	10	93	106	98	100
303	01	27	16	12	10	12	13	13	12	14	17	10	10	10	110	116	114	11
304	01	25	18	15	07	12	11	10	11	09	17	13	10	15	103	121	111	00
305	01	33	10	16	09	13	17	14	13	14	17	14	11	09	123	122	127	71
306	01	25	18	12	14	11	11	10	13	10	13	13	07	12	109	106	108	22
307	01	30	07	18	19	16	17	18	16	14	10	15	11	13	150	119	142	89
308	01	33	22	18	08	18	14	15	12	12	15	14	10	10	126	116	126	88
309	01	32	13	15	11	14	15	17	14	17	13	15	13	16	128	138	135	53

310	01	25	14	16	12	13	11	14	14	14	17	14	11	08	121	121	124	11
311	01	26	21	15	10	14	13	11	15	11	11	13	10	10	118	106	114	87
312	01	28	24	11	09	08	07	10	09	07	11	12	08	13	91	101	95	00
313	01	31	22	13	10	11	15	11	10	12	11	15	10	10	108	112	109	47
314	01	25	18	12	14	12	13	09	10	11	10	15	10	12	108	112	109	33
315	01	26	09	10	18	10	12	11	10	10	13	16	10	10	109	113	111	47
316	01	28	24	15	16	14	14	14	13	12	17	13	07	09	128	112	124	35
317	01	26	24	13	10	12	08	11	13	10	17	13	11	10	104	116	109	06
318	01	31	18	16	13	15	13	11	12	12	17	16	09	11	121	122	125	33
319	01	30	09	12	11	13	17	15	13	17	10	14	12	08	122	116	123	00
320	02	30	22	12	12	14	11	11	13	11	12	14	11	12	111	114	114	40
321	02	30	16	18	12	12	13	13	13	14	08	14	09	13	122	112	120	05
322	02	25	24	11	15	13	15	11	10	19	15	15	15	14	113	145	131	44
323	02	28	24	12	15	13	13	11	13	11	15	12	11	13	116	118	120	20
324	02	34	24	11	12	11	11	14	12	18	15	11	11	15	109	132	122	06
325	02	28	23	10	12	12	10	12	12	09	17	13	13	16	105	128	117	82
326	02	26	22	16	12	17	11	18	12	17	13	11	12	13	128	124	130	100
327	02	32	16	13	15	15	14	14	13	17	17	11	09	12	125	124	129	94
328	02	32	23	15	12	12	14	13	11	09	17	09	08	08	116	101	109	20
329	02	30	19	12	18	13	14	14	11	14	17	12	11	13	123	126	129	00
330	02	26	24	12	10	13	10	14	12	10	17	11	11	11	109	114	112	50
331	02	27	24	09	11	14	10	16	13	08	11	09	08	11	111	95	103	73
332	02	28	20	13	13	12	14	14	12	11	11	14	14	14	118	121	123	18
333	02	31	24	12	11	12	07	14	10	08	07	09	10	11	103	93	98	82
334	02	33	24	13	11	12	13	11	12	14	12	12	09	13	110	114	113	00
401	02	37	23	12	10	12	11	14	10	08	09	09	12	13	110	106	109	06
402	02	43	21	12	10	13	17	13	12	09	11	12	12	08	121	114	119	50

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