# CONJUGATE-LATERAL EYE MOVEMENT BEHAVIOR IN LATER CHILDHOOD

by

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There is no need to run outside

For better seeing

Rather abide

At the center of your being:

For the more you leave it, the

Less you learn.

Search your heart and see.....

The way to do is to be.

Lao-Tzu

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# CHAPTER I

## INTRODUCTION

Students who appear to have average and above average intelligence but seem to have difficulty learning present a perplexing problem in our educational system. Frequently educators have been criticized for not providing experiences which ensure optimal learning environments for these students (Hart, 1975). The problem of how material should be presented to students to enhance optimal learning becomes one of central concern. While various pedagogical methods are based on principles established through developmental, psychological, sociological, and cognitive studies, much of what is practiced needs to be further examined in light of current findings in the neurosciences. Knowledge of the brain and its functions (and possible dysfunctions) becomes important for all who are involved in teaching and making learning possible, because it is with this knowledge and understanding that brain-compatible approaches to learning can be tested and developed (Frostig & Maslow, 1979; Hart, 1978).

Theory emerging from neuropsychological research, which suggests that the brain has specialized areas of function, may provide a basis for understanding the differences in the cognitive functioning characteristics of students who are not succeeding as would normally be expected.

## Hemispheric Specialization Theory

Dimond and Beaumont (1974) stress the importance of understanding cerebral lateralization for the development of human cognition. The two hemispheres of the cerebral cortex are believed to have parallel functions of control over muscular activity. The movements of one side of the body are controlled by the opposite or contralateral brain hemisphere (Kinsbourne, 1978). In addition to this controlling function, each of the hemispheres appears to have other functions which are not parallel. The hemispheres each take on some of these nonparallel functions. In most right-handers (approximately 90% of the human population), the left hemisphere is specialized for semantic, propositional, analytic processing. The right hemisphere is specialized for nonsemantic, holistic, configurational processing (Bogen, 1969; Dimond & Beaumont, 1974; Kinsbourne, 1978). For educators this information means that cognitive functions such as structuring of language, manipulating of consonant and vowel sounds and word meaning, mathematical calculation, and logical thought seem to be processed primarily by the left hemisphere. Functions such as spatial identification and visual imagery, sensory discriminations, recognition of faces, and recognition of musical and environmental sounds seem to be processed by the right hemisphere. Thus, for most right-handers, speech and structured, analytical, logical thinking are considered to be left hemisphere behaviors. Perceptual, intuitive, creative types of thinking are considered to be primarily right hemisphere behaviors.

## Rationale

Statements about knowledge of the brain hemispheres and differing cognitive functions have prompted Kinsbourne and Hiscock (1978) to propose that a goal of education and curriculum should be to provide students with opportunities to use and develop both hemispheres of their brain, rather than using one hemispheric style to the exclusion of the other. Wittrock (1978) has suggested that an implication for educators is that students who seem to favor one mode of processing over the other should receive help in developing learning strategies that employ as many areas of brain potential as possible. Samples (1977) has suggested that curriculum should be changed to place less emphasis on left-hemispheric processing and more emphasis on right-hemispheric processing. While these suggestions seem to be based on neurological theory, they offer little in the way of actual procedures to be used in the classroom. Educators in their consideration of these interesting possibilities need to have a usable, simple measure to determine which of the hemispheres individual students tend to rely on when thinking and learning. This kind of measure becomes most important when trying to assess why a student is not achieving to potential.

Current literature on the complex findings relating to brain processes forms an intricate web which at first glance may not seem to provide direct links to classroom endeavors, and yet these links need to be established in order for appropriate diagnostic and curricular choices eventually to be made. To do this, educators must

try to involve themselves directly in a collaborative effort with neuroscientists in educational research and classroom practices in order to help modify, refine, and confirm brain theories. Figure 1 represents a simplified model of this collaborative process.

From information reported about the brain, notions or theories about behavior and learning are formulated. These theories then direct or influence proposals made for diagnostic and curricular development. The next step, which is perhaps one of the most important in the process, develops ways of verifying the curricular choice or strategy proposed. This calls for educational research and controlled tryout and evaluation of diagnostic and curricular recommendations in schools. Results of these efforts then feed back information through the process either substantiating or suggesting possible revision of curricular proposals, of ideas about behavior and learning, and, maybe, even theories of the brain and its functions. The special responsibility of education, then, is to tryout and report back "real world" findings. It is this function which will help to establish the necessary links that will enable educators to clearly delineate and firmly put the theories of neuroscientific study into practice.

While the present investigation does not propose to prescribe or evaluate trends in curricular development or provide a model of a brain-based curriculum, it does have the potential for laying necessary groundwork in establishing such future developments. By exploring child behavior through notions about adult behavior, this

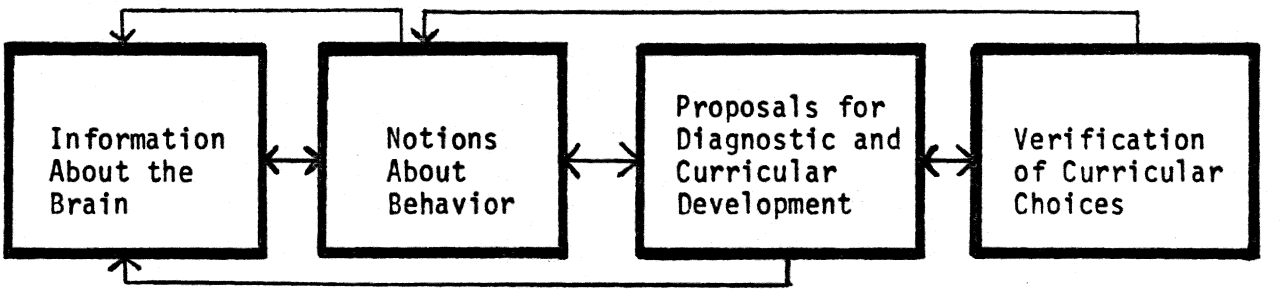



Figure 1

Putting Neuroscientific Theory into Practice

investigation links steps 1 and 2 within the schema of Figure 1 and provides normative data on children in the later childhood years. With this linkage developed, proposals for diagnostic and curricular development and their verification can begin to be legitimated by research in educational settings.

A promising method within the area of hemispheric specialization study offers a technique that proves useful to educators faced with the problems of applying neuroscientific theory and identifying students' hemispheric processing. This area of study, which has been extensively examined in laboratory and experimental situations, involves observations of the joint movement of the eyes to the right or to the left (initial conjugate-lateral eye movement) to determine which hemisphere individuals activate when thinking. The methodology has not been examined extensively with children, but has the possibility of yielding the beginnings of the development of a simple and effective testing instrument that eventually could assist the classroom teacher in diagnosing hemispheric processing tendencies of a student in an attempt to adjust and differentially apply instructional methods or curricular models.

## CLEM as a Means of Assessing Cognitive Functions

Conjugate-lateral eye movement (CLEM) is one of the most frequent motor responses to electrical stimulation of the cerebral cortex (Penfield & Roberts, 1959). When parts of the left hemisphere are stimulated, eyes shift to the right. Conversely, it is found that

when parts of the right hemisphere are stimulated, eyes move to the left. This shift of gaze, or CLEM, has also been noted by researchers who have employed the technique of asking questions requiring adult subjects to reflect before answering orally. Some experimenters who have used the reflective questioning technique have tried to explore characteristic individual differences related to CLEM direction. Others have tried to establish a relationship between CLEM direction and the temporary dominance of one cerebral hemisphere which governs the kind of cognitive processing being done at a given moment. As a result of these investigations, it has been theorized that CLEM direction indicates which hemisphere of the brain is predominantly involved in the thinking process at the time of questioning.

## The Problem

Within basic neuropsychological research there are two competing models of hemispheric processing in relationship to conjugate-lateral eye movement behavior in adult right-handers. One model (Day, 1964, 1967a, 1967b) describes differential activation of the two hemispheres as an individual characteristic. That is, some individuals are believed to gaze predominantly to the right (indicating activation of the left hemisphere) while some gaze predominantly to the left (indicating activation of the right hemisphere) in response to questions which require reflection.

Another model (Kinsbourne, 1972, 1974), more commonly employed in recent studies, describes differential activation

of the hemispheres as a response to characteristics of the stimulus, that is, the type of question used to elicit eye movements. For right-handed adults, questions about verbal propositions (explanation of proverbs) evoke more rightward than leftward CLEMs in the same individual, thus indicating activation of the left hemisphere. Questions of a spatial nature (visualization and identification of spatial relationships) elicit more leftward than rightward CLEMs, indicating activation of the right hemisphere.

Eye gazes or CLEMs used in both of these paradigms have been demonstrated to be easily observable and reliable (Bakan & Strayer, 1973; Day, 1964; Edwards, Antes, Adams, & Trumm, 1971; Gur, 1975; Kinsbourne, 1972). Studies by Daly (1980), Day (1967a), Reynolds and Kaufman (1980), and Schroeder (1976) also have reported that CLEMs are an easily observable behavior in children. Further, CLEMs have been linked to physiological measures of electroencephalographic alpha rhythm recordings of subjects engaged in answering reflective questions (Bakan & Svorad, 1969; Morgan, McDonald, & MacDonald, 1971). There are at present, however, few attempts to test the relative adequacy of either of the two models of adult hemispheric specialization for describing CLEM responses in children. The need exists to determine which of the two adult models is most appropriate and what factors might apply to a child model that are not relevant to adult models. Factors for consideration include such variables as grade level, language, and cognitive development because children are known to mature and change physically more rapidly than adults.

In an attempt to provide additional information on a child model of hemispheric processing, the purpose of this investigation was to examine CLEM direction exhibited by later childhood right-handed female and male children in response to reflective questions of verbal and spatial content. The testing procedure developed for this study, called the Reflective Questions Test (RQT), was developed by the researcher based on techniques used in numerous adult studies. The RQT was examined in terms of grade level differences as well as its relationship to other established cognitive measures of achievement, language, and intelligence in children in order to explore the RQT as a possible assessment instrument for hemispheric processing in children and to gain normative data on children in the later childhood years.

## The Research Questions

This investigation of conjugate-lateral eye movement in children explored four major research questions:

1. When asked a set of reflective questions, will female and male children of fourth, fifth, and sixth grade exhibit initial conjugate-lateral eye movement in a consistent characteristic direction, or will their CLEMs be differentiated in terms of the particular verbal and spatial questions asked?

2. Will question type, grade level, or their interaction account for differences in the number of children's directionally appropriate CLEM responses on the Reflective Questions Test?

3. Will the Reflective Questions Test yield reliable results over time?

4. Will significant positive correlations exist between children's CLEM scores on the Reflective Questions Test and scores on other cognitive measures of achievement, language, and intelligence?

## Implications of the Study

This investigation represents an examination of an application of neuroscientific theory in an educational setting rather than in the confines of a laboratory. It is a controlled attempt to test and relate what is theorized about the functioning of the brain to the behavior of children. The investigation tests the applicability of adult models of hemispheric specialization to children who are in a period of rapid physiological and cognitive development.

The results of this investigation propose a contribution to an understanding of the development of cognitive processing in normal right-handed children. By examining the stimulus characteristics of the reflective questions and the resulting CLEM directions, a clearer picture may be drawn, indicating which of the cerebral hemispheres these children activate when processing verbal and spatial material. The information thus gathered may be used to supplement the information already available on adults. By providing normative data on normal right-handed children, future

research on children of the same age who are learning disabled or who are left- or mixed-handed can be anchored and compared.

Additionally, the present research results have the potential for providing initial steps in the development of an instrument that, when refined, could be appropriate for use by teachers in determining hemispheric processing in a child who is experiencing difficulty in school. If a student's processing tendencies can be identified without highly specialized and technically intricate instruments, the likelihood that teachers will use the information to adjust instructional input becomes greater. A child's responses on the Reflective Questions Test could be used to compare the child's hemispheric processing tendencies with the model examined here to ascertain in which hemisphere the child is initially processing verbal and spatial material. This information becomes useful for teachers who are attempting to match instructional strategies with the unique needs of an individual learner.

## Limitations of the Study

Limitations on the generalizability of this investigation's results are as follows:

1. Students participating in the study were selected from one school in Arlington, Virginia. The school selected, however, had a diverse ethnic and socio-economic student population.

2. In order to conform to the policy of the Arlington Public Schools and to ethics for human subjects, the sample students had

parental permission to be involved in the study. Thus, the data-set analyzed in this investigation was collected from volunteers who elected participation in the study. A random selection of the right-handed volunteers by grade and by sex with replacement was made to choose the final sample of subjects.

3. The sample is representative of a normal population of public school children in the later childhood years rather than a clinical population. Children enrolled in full-time special education classes and those with significant deficits in vision, hearing, and motor ability were not involved in the study.

4. Variables of right-handedness and grade level were selected for examination with reflective question type. No ethnic or home background information on sample students was collected or analyzed in this study because these variables were not considered primary variables in adult studies examining conjugate-lateral eye movement.

## Definition of Terms

For the purposes of this investigation, the following are defined as:

CLEM- conjugate-lateral eye movement or joint movement of the eyes to the left or to the right.

REFLECTIVE QUESTIONS- orally administered questions that require the subject to mentally consider before answering.

VERBAL REFLECTIVE QUESTIONS- orally administered questions that require the subject to mentally consider and explain proverbs.

SPATIAL REFLECTIVE QUESTIONS- orally administered questions that require the subject to visualize and identify spatial relationships and arrangements of places, objects, and people.

RIGHT-HANDEDNESS- use of the right hand as the hand for writing and performing simple manual tasks of holding a piece of paper, picking up a pencil, holding something up to the eye, selecting a block from a box, and replacing the block back in the box.

CONTRALATERAL HEMISPHERE- hemisphere of the brain acting in conjunction with and affecting the opposite side of the body.

IPSILATERAL HEMISPHERE- hemisphere of the brain acting in conjunction with and affecting the same side of the body.

Research results on the specialized functions of the two cerebral hemispheres of the brain and studies of conjugate-lateral eye movement are reviewed in Chapter II.

The hypotheses, sample, procedures, design, and analysis techniques employed in this investigation are presented in Chapter III.

The results of the study are reported in Chapter IV.

Implications of the investigation's results are discussed in Chapter V.

# CHAPTER II

# REVIEW OF RELATED LITERATURE

This review surveys the literature which provides findings to support a theory of hemispheric specialization of the human brain. Evidence for this theory has come from diverse lines of inquiry flowing from anatomical measurements to behavioral observation. After surveying briefly the findings related to hemispheric specialization, conjugate-lateral eye movement results and issues are presented as an avenue to explore neuroscientific findings and their relationship to educational practice.

## Hemispheric Specialization of Function

### Historical Perspectives

The human brain has two hemispheres which are interconnected by a body of nerve fibers known as the corpus callosum. Until the nineteenth century, the two hemispheres were considered to be mirror images of each other in structure and function. Dax (1830 cited in Von Bonin, 1962) found functional differences between the two hemispheres when he noted that aphasia was generally associated with a lesion of the left hemisphere in right-handed people. He, therefore, concluded that as far as language was concerned, the two cerebral hemispheres were not functionally equal. In 1861, Broca (cited in Nebes, 1978) supported this conclusion by reporting

relationships between motor aphasia and lesions of the left frontal lobe. Later, Wernicke (cited in Geschwind, 1979) studied the left temporal lobe and discovered that this area of the brain had a part not only in speaking but in the comprehension of written and spoken language. Damage to this area was found to be related to speech which seems phonetically normal but semantically deviant (Geschwind, 1979). Both Broca's and Wernicke's findings precipitated numerous other reports of people suffering from loss of language functions associated with damage in the left cerebral hemisphere (Von Bonin, 1962).

In 1874, Hughlings Jackson (cited in Benton, 1972) reported that damage in the right cerebral hemisphere was associated not with loss of language but with loss in visuo-spatial recognition and memory, which resulted in visuo-spatial disorientation, failure to recognize faces, and an inability to dress. Hughlings Jackson's observations were further supported by others who reported people suffering spatial disorders such as loss of geographic memory and inability to locate objects and self in space as a result of right hemisphere lesions (Benton, 1972).

## Morphological Differences

A line of research which followed the early discoveries of Broca attempted to find differences in weight between the two hemispheres (Boyd, 1861; Ogle, 1871; Wagner, 1864; all cited in Von Bonin, 1962). Eberstaller (1884, cited in Von Bonin, 1962) measured fissures in

both cerebral hemispheres and found them to be longer on the left side of the brain. Aresu (1914, cited in Von Bonin, 1962) found the volume of the left hemisphere to be larger than the right. These findings led to a theory that the left hemisphere had a slightly higher specific gravity than the right hemisphere. After summarizing these reports, Von Bonin (1962), however, concluded that these morphological differences were small and could hardly explain the functional differences described by Broca and other earlier researchers.

More recent lines of inquiry have continued to demonstrate that anatomical differences exist between the cerebral hemispheres. Geschwind (1974) in summarizing many research studies, reported that the left Sylvian fissure was usually longer than the right and that the temporal plane was larger in the left hemisphere in a majority of adult as well as infant brains.

Witelson and Pallie (1973) and Geschwind (1974) also reported that structural differences between the two hemispheres were present at birth. Wada, Clark, and Hamon (1975) further reported that asymmetries existed in fetal brains in both frontal and temporal areas as early as the fifth month after conception.

Yakovlev and Lecours (1967) reported that myelination of brain cells takes place throughout life and that different regions of the brain mature at different cycles or stages. The corpus callosum completes myelination during later childhood around the age of 10 or 11 years.

Functional Differences

Functional differences in the left and right hemispheres have also been noted by researchers who have observed persons who have suffered brain injury to one hemisphere (Bogen, 1969; Ettlinger, Warrington, & Zangwill, 1957; Geschwind, 1974, 1979; Goldstein, 1974; Luria, 1966). These contemporary studies have supported, confirmed, and extended the earlier reports of Wernicke, Broca, Hughlings Jackson, and others. Right hemisphere lesions have been seen to result in loss of visuo-spatial abilities and performance such as visual pattern identification, visual closure, spatial orientation, musical recognition , and recognition of faces and familiar places. Left hemisphere lesions have been reported to result in the loss of speech, reading, and writing abilities; the inability to understand spoken words; the inability to perform difficult arithmetic calculations; and the loss of reasoning ability.

The impetus for much of the most recent studies of hemispheric functions has grown out of work with epileptic patients who have undergone surgery to disconnect the two cerebral hemispheres in order to prevent continued severe epileptic seizures. Based on the findings of these studies, the significance of the functional differences or asymmetries of the brain has become most obvious.

Sperry (1964, 1969, 1975) reported that the two hemispheres of split-brained patients were independently and frequently conscious at the same time, yet each hemisphere was oblivious of the experiences of the opposite hemisphere as well as of its own incompleteness. Levy,

Trevarthen, and Sperry (1972) in studies of the perception of chimeric figures (composites formed of the right half of one stimulus and the left half of another) following hemispheric deconnection further supported this description of split-brain patients.

Studies by Bogen and Gazzaniga (1965); Gazzaniga (1970); and Geschwind (1974), have reported that the right hemisphere of split-brained patients had little or no verbal ability, but had no impairment in visual discrimination tasks and spatial orientation. The left hemisphere had little or no visuo-spatial abilities, but could produce speech and perform arithmetic calculation and reasoning tasks.

To summarize, theory growing from split brain studies indicate that when the corpus callosum was severed, the human brain had two states of consciousness, each associated with a particular hemisphere. Each had its own cognitive mode and system of processing sensory information. The role of the corpus callosum was not only to connect but to unify the two hemispheres into a single processing entity. When the corpus callosum was severed, the two hemispheres each functioned separately and quite differently.

The studies of split-brain persons further stimulated study of people who have an intact corpus callosum and do not necessarily have a history of neurosurgery or of brain damage. Investigations into hemispheric brain processes with these subjects are presented in the following sections.

A less used but seemingly effective method for investigating hemispheric specialization consists of injecting sodium amytal into the carotid artery and temporarily anesthetizing one hemisphere while leaving the other hemisphere alert (Wada & Rasmussen, 1960). Studies using this procedure have consistently presented evidence which indicates that the left hemisphere controls most speech functions. Branch, Milner, and Rasmussen (1964) and Wada and Rasmussen (1960) found that after anesthetization of the left hemisphere, right-handed subjects were usually completely incapable of producing speech. Other studies also have demonstrated the left hemisphere's lack of expressive speech when injected with sodium amytal; however, Terzain (cited in Nebes, 1978) also confirming this, further demonstrated that during a period of left hemisphere anesthetization, subjects can understand and carry out very simple verbal commands.

Bogen and Gordon (1971) used the sodium amytal technique to test subjects on singing familiar songs. When the right hemisphere was anesthetized, tonal and pitch singing ability was disturbed but speech was preserved. When the left hemisphere was anesthetized, tones could be reproduced but singing of words was grossly disturbed. These findings show a dissociation between speech and at least some aspects of musical production in the two hemispheres.

Specialization of cortical functioning has also been examined using an electroencephalograph (EEG) to measure electrical activity of the cerebral hemispheres. It has been possible to ascertain which

of the two hemispheres is most active while a subject is engaged in a task by measuring the alpha wave band component. A lower proportion of the alpha component in the EEG signal indicates greater brain activity. The ratio of the alpha components of the signals of the two hemispheres serves as a reliable reflection of their activity (Doyle, Ornstein, & Galin, 1974).

Using EEG recordings, the left hemisphere has been found to have less alpha activity than the right hemisphere when processing verbal material, mathematical computation, and logical reasoning (Galin & Ornstein, 1972; Morgan, MacDonald, & Hilgard, 1974). The right hemisphere has been found to exhibit less alpha activity than the left hemisphere during visuo-spatial tasks, musical listening, and imagining scenes (Doyle et al., 1974; Galin & Ellis, 1975; Galin & Ornstein, 1972; Morgan et al., 1974). These findings further substantiate the separate and specialized modes of processing of the two hemispheres.

Asymmetrical electrical activity of the hemispheres to verbal and nonverbal stimuli also has been reported in infants as early as one week old (Gardiner & Walter, 1977; Molfese, 1973). Both studies have demonstrated that infants can categorically perceive speech sounds and differentiate them from musical sounds. Through monitoring the alpha wave component, the left hemisphere was found most actively involved in the processing of speech sounds, while the right hemisphere was found to be involved in the processing of musical sounds.

The development of the dichotic listening technique has yielded considerable supportive information on the differing functions of the two hemispheres. The technique involves presenting subjects with simultaneous auditory stimuli, one in each ear, and then measuring performance differences. Based on the theory that each hemisphere receives information primarily from the contralateral ear, better left ear perception is believed to indicate right hemisphere involvement and better right ear perception is believed to indicate left hemisphere involvement. Dichotic listening studies have revealed for right-handed subjects a general right ear (left hemisphere) advantage for verbal material such as words, digits, and linguistic stimuli (Berlin, Hughes, Lowe-Belle, & Berlin, 1973; Geffner & Hachberg, 1971; Ingram, 1975; Knox & Kimura, 1970). Left ear (right hemisphere) has shown superiority in recognition of non-verbal environmental sounds, melodies, and pitch perception (Curry, 1967; Kimura, 1967a; Knox & Kimura, 1970).

In keeping with the information obtained through tests of dichotic listening, studies of tachistoscopic presentation of visual stimuli to one hemisphere at a time have also supported the theory of specialized functions of the cerebral hemispheres. Through the use of a tachistoscope, visual images presented to the nasal half of the retina are sensed by the contralateral brain hemisphere. Images presented to the outer portion of the retina are sensed by the ipsilateral hemisphere. The right visual hemifield (left hemisphere) has been found to be superior in recognizing words, letters and

digits (Marcel, Katz, & Smith, 1974; McKeever & Huling, 1971; Yeni-Homshain, Isenberg, & Goldberg, 1975). The left visual hemifield (right hemisphere) has been found to be superior in recognizing faces, dot configurations, and binocular depth perception (Kimura, 1967b; McGlone & Davidson, 1973; Rizzolatti, Umilta, & Berlucchi, 1971).

The collective results of these studies involving measurement of brain activity and performance data have led investigators (Dimond & Beaumont, 1974; Harnad, Doty, Goldstein, Jaynes, & Krauthamer, 1977; Kinsbourne, 1978) to conclude that in right-handers, the left hemisphere is specialized for verbal, rational, analytical types of functions while the right hemisphere is specialized for spatial, holistic, configurational types of processing. However, females and left-handers are considered to have cerebral functioning which is less well lateralized than male right-handers. Both groups have been reported to have more problems in performing spatial tasks than male right-handers (Knox & Kimura, 1970; Nebes, 1971). Further, the performance of females and left-handers in other verbal and reasoning tasks has not been as easily predictable as that of male right-handers (Hécaen & Sauget, 1971; Levy & Gur, 1980; Levy & Reid, 1978; McKeever & Hoff, 1979).

Similarly, a clear picture has not yet been drawn for the exact nature of hemispheric functioning in children. Asymmetrical electrical activity of the hemispheres to verbal and nonverbal stimuli has been reported in infants (Kinsbourne, 1978a, 1978b;

Molfese, 1973; Witelson & Pallie, 1973) and structural differences between the two hemispheres are observable at birth (Geschwind, 1974). In summarizing many studies on cerebral lateralization, Kinsbourne and Hiscock (1978) conclude "that brain function is lateralized from birth, if not earlier, and that language does not become increasingly lateralized as the child matures". (p. 220) Case studies of individuals recovering language facilities following left hemisphere damage, however, have led Hécaen (1976) to postulate that full lateralization of hemispheric function does not occur until later childhood (9 to 12 years).

In further support of later childhood lateralization, Denckla (1978) and Rudel (1978) have brought to the attention of the educational community evidence that suggests young children's brains have the capacity to recover from the effects of many forms of injury. This capacity has been called neuroplasticity. Rudel (1978) accounts for the absence or disappearance of the effects of early insults by establishment of new pathways by the existing neurons, by synaptic connections with undamaged areas, and/or by one area of the brain taking over the function for another. Evidence also suggests that as the age of an individual increases, full recovery from insults becomes less predictable and occurs less often. The explanation offered is that the neurons may not be able to find new pathways over which to reroute themselves, because with age the brain becomes more fully developed and specialized.

Epstein (1978) proposes a theory of brain development involving stages, which he believes coincide with Piagetian stages of cognitive development. These stages, or brain growth spurts, occur between the ages of 3 and 10 months, and from 2 to 4, 6 to 8, 10 to 12, and 14 to 16 years. During these spurt stages, the brain's neural networks increase in extent and complexity.

While total agreement does not exist on the exact age/stage for the brain to cease its major growth, most neuroscientists agree that brain growth and development of functions can be considered as a continuous phenomenon. Because of the enormous complexity of the human brain, further study in all areas of child brain development and processing is warranted (Chall & Mirsky, 1978; Knights & Bakker, 1976).

## Conjugate-Lateral Eye Movement Observation

The review of literature previously presented has revealed evidence which indicates that the two cerebral hemispheres of the human brain serve different functions. This evidence has been obtained through the use of a variety of highly specialized and often costly techniques. Recently another and seemingly simpler technique for studying cerebral specialization has been introduced. This technique is based upon evidence that the direction of orientation of the eyes (conjugate-lateral eye movement) indicates an activation of the cerebral hemisphere contralateral to the direction of eye movement (Kinsbourne, 1972). That is, rightward eye movements have

been postulated to indicate activation of the left hemisphere and leftward eye movements have been postulated to indicate activation of the right hemisphere.

Conjugate-lateral eye movement (CLEM) has been investigated by many researchers who have employed the technique of asking questions requiring subjects to reflect before answering orally. Two lines of inquiry have grown from this technique. Studies designed to explore individual differences have suggested that among right-handed subjects, CLEM direction can be a characteristic response and therefore, indicates a characteristic tendency for one hemisphere to be activated more quickly than the other. Other studies have explored the stimulus characteristics of the reflective questions themselves and suggest that CLEM direction can be dependent upon the type of reflective question asked.

The following sections report findings from both these avenues of theoretical inquiry.

## CLEM as an Individual Characteristic Tendency

Much research on conjugate-lateral eye movement has been limited to adults. In early studies, Day (1964, 1967a, 1967b) reported that in situations where the examiner faces an adult subject and asks questions which require reflection before answering orally, the direction in which the subject's eyes move is usually consistent (75% or more of the time). Therefore, a subject can be classified as a right- or left-mover.

Duke (1968) confirmed Day's observations that CLEMs occurred more often in response to reflective than to factual questions. Duke also reported that while subjects tended to individually turn their eyes consistently (86% of the trials for all subjects on reflective questions), there was no tendency for the group to prefer one direction over the other (N = 53).

In a study of 34 adults by Bakan and Strayer (1973), CLEMs were found to be consistent for individuals over time. A reflective test-retest reliability coefficient of .78 for left movements over 12 trials was reported.

Individual differences also have been related to a subject's being a consistent right- or left-mover. Bakan and Shotland (1969), using a criterion of 80% of CLEMs in the same direction over 5 questions (N = 42), found that right-movers tended to perform better than left-movers on tasks which require visual attention while left-movers were found to report clearer visual images. In another study using the 80% criterion, Bakan (1969) found left-movers to be more susceptible to hypnosis than right-movers. Morgan et al. (1971) found similar characteristics for adult right-handed subjects (N = 20). In choice of classroom seating, right-movers were found to prefer sitting on the left side of a classroom, while left-movers preferred to sit on the right (Gur, Gur, & Marshalek, 1975).

It has also been suggested that CLEM direction has correlates at the psychological level. In studies of anxiety states, left-

movers were found to be more internally anxious than right-movers (Day, 1970; Gerdes & Kinsbourne, 1974). Left-movers tended to describe anxiety as a problem coming from within themselves, while right-movers saw anxiety as having an external cause (Day, 1970). Bakan (1969) also described left-movers as having a tendency to focus attention on internal subjective experiences while right-movers showed a greater tendency to external focus of attention.

Bakan (1969, 1971) explained the differences between left-movers and right-movers by theorizing CLEM as an indication of the relative processing dominance of one cerebral hemisphere over the other. Because eye movements are controlled contralaterally in the frontal eye fields, left-CLEMs are caused by right hemisphere activation and right-CLEMs are caused by left hemispheric activation. Thus as an individual begins to process sensory input, s/he relies upon a characteristic processing mode which becomes activated regardless of the content of the reflective questions asked.

It is important to note that the reflective questions used in many of the studies mentioned minimized the type of cognitive processing the subject might utilize while answering. The questions were not usually categorized into verbal-analytic or visuo-spatial types and were more typical of daily experience such as "How many letters are in the word school?", "What color shirt did you wear yesterday?", or "How much is 18 times 5?". Therefore it becomes difficult to know whether these results and interpretations could

differ if the questions used were systematically varied by verbal and spatial type.

CLEM as a Characteristic of Question Type

Several studies have suggested that rather than being an individual tendency displayed across all situations, cerebral activation can be modified by the cognitive demands of the reflective questions asked. Galin and Ornstein (1974), Katz and Salt (1981), Kinsbourne (1972), and Kocel et al. (1972), suggest that when questions are designed specifically to differentiate between specialized modes such as verbal (explanation of proverbs) and spatial (visualization and identification of spatial relationships), questions with a verbal content evoke more right CLEMs in the same individual, thus indicating activation of the left hemisphere. Questions with a spatial content evoke more left CLEMs, indicating activation of the right hemisphere. This relationship seems to occur predominantly with adult right-handers, especially males, though not always with left-handers whose specialization of cerebral function is considered to be variable and not as easily predictable (Hécaen & Sauget, 1971; Levy & Gur, 1980; Levy & Reid, 1978; McKeever & Hoff, 1979).

In at least one investigation, however, results contrary to the preceding studies have been obtained. Ehrlichman, Weiner, and Baker (1974) have found eye movement direction to be opposite to the eye movement direction of the previous studies; that is, they have found more rightward movements for verbal than spatial questions

and more leftward movements for spatial than verbal questions. This study's methodology has been criticized and may have accounted for the differences in results. Ehrlichman et al. had subjects fixate their eyes on the video recording aparatus employed in the investigation and had the subjects respond into a microphone which was hung around their necks. It has been suggested that either or both of these conditions could have provided a stimulating focal point which could have contaminated the resulting CLEMs (Kinsbourne, 1974). Studies conducted after the report of Ehrlichman et al., seem to have removed these methodological variables and have demonstrated CLEMs to be dependent on question type (Gur, 1975; Hiscock; 1977; Katz & Salt, 1981).

Another variable related to task-specific CLEM behavior, experimenter position in relation to the subject being tested, has been examined. Gur (1975), Hiscock (1977), and Kinsbourne (1972) have suggested that examiner location in front of a subject tends to elicit more characteristic CLEMs in each subject, while examiner position behind the subject enhances the stimulus characteristics of the reflective questions asked. This effect has been explained by Gur and Gur (1980):

> To account for this effect of experimenter location, we hypothesized that when the experimenter is behind the subject the problem itself is the most salient stimulus and the subject, more nearly free to attend exclusively to it, can use the hemisphere that more nearly serves the cognitive strategies needed for solving the problem. Furthermore, the experimenter-facing-subject condition is more personal and, therefore, more likely to produce interpersonal

> anxiety that would tend to elicit stereotypic or habitual modes of responding in the subject, thereby enhancing stylistic effects. (p. 218)

Studies by Katz and Salt (1981) and Meskin and Singer (1974), however, have demonstrated that the experimenter-facing-subject paradigm can be used successfully to examine CLEMs in response to verbal and spatial questions, and, therefore, experimenter position need not be a significant main variable in the resulting direction of conjugate-lateral eye movement. Both paradigms (experimenter-facing- and experimenter-behind-subject) have demonstrated support for the theory that CLEMs can be influenced by the types of reflective questions asked and that the CLEM phenomenon is a sensitive and useful index of cerebral lateralization and cognitive function.

## CLEM in Children

The preceding research studies on the relationship between eye movement and brain function have centered on adult subjects. Little is clearly known about the nature of hemispheric specialization and its relationship to conjugate-lateral eye movement in children.

Day (1964, 1967a) reported that children seemed to exhibit CLEMs from about the age of 4 years. He theorized that CLEMs were related to verbal fluency of the individual and maturation of the frontal lobes (Day, 1967a). Schroeder (1976), in a study of preschoolers, also reported CLEMs in children as young as 4 years, but found no clearcut evidence of characteristic CLEMs. A criterion

of 70% or more CLEMs in the same direction was employed in an experimenter-facing-subject paradigm. Out of a sample of 45 boys and girls (43 right-handers and 2 left-handers), 31% of the children were classified as having predominantly right CLEMs and 42% as having predominantly left CLEMs on questions which dealt with daily experiences and asked such things as "What is your favorite ice cream?". Twenty-seven percent of the children were classified as having inconsistent eye shifts and were dropped from the study. No attempt was made to describe this group or to analyze CLEMs by questions. Further, no relationship was found between sex and eye shift.

Daly (1980), also using the experimenter-facing-subject method, studied CLEMs in 65 right-handed children in kindergarten and grades one, two, four, and six (N = 13 for each grade; ages 5 to 12 years). In tests asking 10 verbal reflective questions (explanations of proverbs), CLEMs were observable in all children tested. It was hypothesized that the verbal questions would elicit 75% or more right-CLEMs in a majority of the children (75% or 49 children). Findings indicated that children in kindergarten and grades one and two as a group exhibited inconsistent right CLEM tendencies (N = 39, 46% showed inconsistent CLEMs, 54% showed consistent right CLEMs). Fourth and sixth graders, however, showed trends in exhibiting a consistent right CLEM direction (N = 26, 12% inconsistent CLEMs, 88% right CLEMs). Only 44 of the children (68% of the total) exhibited consistent right CLEM tendencies

for verbal reflective questions. No children exhibited consistent left CLEM tendencies. Questions of spatial relationships were not included in the study. The relationship of sex to CLEM direction was also not examined.

Shortly after Daly's study was completed, Reynolds and Kaufman (1980), using a criterion of 70% or more CLEMs in the same direction, reported CLEMs observable in 50 of 52 children (ages 2.8 to 9.11) studied with an experimenter-facing-subject paradigm. CLEMs were also reported to be well established by age 3.6. Thirty percent of the children were classified as left-movers, 22% as right-movers, and 48% as bidirectionals on questions of analytical and spatial nature (analytical questions were taken from various IQ tests traditionally used with children; spatial questions were constructed by the first author). Item content of the questions did not approach significance in influencing eye movement. Sex was not found to be a significant variable in eye shift.

## Unresolved Issues in the Study of Children's CLEM Responses

The results of these studies seem to indicate that conjugate-lateral eye movement direction is an easily observable phenomenon in children. However, younger children's CLEMs seem to be less consistent while older children's CLEMs seem to be more consistent and more dependent on question type. The differences in reflective questions used and ages of samples studied leave many questions

unanswered and call for more extensive examination with clearly specified methodological techniques and careful varying of question type.

While these few child studies and the numerous adult studies of CLEM serve as excellent starting points for further investigation, there is a need to continue to try to formulate and refine an appropriate model for children. Because the issue of the relative influence of an individual's characteristic CLEM tendencies versus the stimulus characteristics of question type is yet unresolved, further testing of the two competing models found in adult studies must be carried out to determine which model is best supported by the data on children.

There is also need to study age-related changes in hemispheric specialization as indexed by conjugate-lateral eye movements. The later childhood years (9 to 12) are of particular interest because they have not yet been thoroughly investigated in CLEM studies, and fall within the theorized time of nearly full development of lateralization of hemispheric functions (Hécaen, 1976). The later childhood years also encompass the end of the concrete operational stage and onset of the stage of formal logical reasoning (Piaget, 1970), as well as a time of reported brain growth spurt (Epstein, 1978).

Within the age span of the upper elementary grades, several different models for age/grade trends are possible. Some of these might include models briefly described in the section that follows.

1. A gradual change model in which scores on a measure such as the Reflective Questions Test should increase gradually across the grades, as do other measures of cognition and school performance. Failure to find gradual change would not rule out the possibility of developmental change at least in some grade ranges, but would indicate that developmental change in hemispheric differentiation would not be apparent during the period of fourth to sixth grades.

2. A no-change model in which scores on a measure such as the RQT should not differ significantly across the grades. A pattern of no-change with low means would indicate that neuropsychological development has not yet fully matured even by sixth grade; while a pattern of no-change with high means would indicate that neuropsychological development is established even by fourth grade.

3. A grade-by-question type model in which Verbal subtest scores may, for example, be higher than Spatial subtest scores, or in which hemispheric differentiation as measured by the RQT might be present for verbal questions by fourth grade but for spatial questions by sixth grade.

4. A spurts and plateaus model in which scores on a measure of neuropsychological functioning such as the RQT would jump from fourth to fifth grade and then remain about the same for sixth grade. This model would support Epstein's (1978) contention that both neurological form and function increase in alternating two year spurts and plateaus.

By highlighting just a few of the many possibilities, it becomes apparent how important it is to determine which of these grade-related models best describes the CLEM responses of children in the upper elementary grades. Further, an examination of scores on the RQT with scores on other measures of language and cognitive development and classroom learning would also be useful in determining if neuropsychological development covaries with other aspects of children's development.

In order to examine more closely a later childhood model of hemispheric processing and its relationship to conjugate-lateral eye movements, the study to be described in Chapter III was initiated.

Chapter III presents the hypotheses, sample, procedures, design, and analysis techniques employed in this investigation.

# CHAPTER III

## DESIGN OF THE STUDY

This investigation of conjugate-lateral eye movement in children was designed to: examine differing hemispheric processing (as indexed by direction of conjugate-lateral eye movement) in response to two types of reflective questions (verbal and spatial) in fourth, fifth, and sixth grade children; test for differences in responses to the reflective questions used as a function of question type, grade level, and their interaction; establish reliability information on the reflective questions measure; and assess the relationship of the reflective questions measure to other established measures of achievement, language, and intelligence in children.

### Hypotheses

The main research hypotheses which were examined are:

1. The number of conjugate-lateral eye movement responses in a given direction is a function of the type of reflective question asked.

2. There are significant differences across question type, grade level, and their interaction for the number of directionally appropriate CLEM responses on the Reflective Questions Test.

3. Reflective Questions Test scores on the first and second administrations of the test are significantly positively correlated.

4. Correlations between the Reflective Questions Test, the Peabody Picture Vocabulary Test, the Raven's Progressive Matrices, and the SRA Short Test of Educational Ability are positive and differ significantly from zero.

## Research Design

This investigation employed three grade levels of subjects from fourth, fifth, and sixth grades. Equal numbers of males and females at each grade level were administered the two subtests of Verbal and Spatial questions of the Reflective Questions Test. A chi-square test was employed to determine if the distribution of observed left and right CLEM responses for verbal and spatial questions differed significantly from the expected distribution.

An analysis of variance was done to determine the effects of question type (verbal and spatial) and grade level (4, 5, and 6) on the dependent variable conjugate-lateral eye movement direction. A second testing of a subsample of the original subjects was conducted for purposes of comparison of scores.

In addition, all subjects were administered the Peabody Picture Vocabulary Test, the Raven's Progressive Matrices, and the Short Test of Educational Ability in order to examine the relationships of these measures with the Reflective Questions Test across all grade levels. Correlations between measures were computed and the significance of the difference of these correlations from zero was assessed.

Sample

The children of the Arlington Public School System in Northern Virginia served as the population for this study. A sample of fourth, fifth, and sixth graders was selected from Barcroft Elementary School.

The sample consisted of 20 right-handed children from each grade level (10 boys and 10 girls) randomly selected by grade and by sex from the pool of volunteers who had parental permission to be involved in the study.

Handedness was determined initially by information supplied by teachers on the writing hand of each of the sample subjects. The researcher also had each of the subjects perform a short series of manual tasks to confirm the information supplied by teachers.

Children in the ESOL (English for Speakers of Other Languages), HILT (High Intensity Language Training for fourth-, fifth-, and sixth-grade ESOL students), and Resource (Identified Special Education) Programs were eliminated from the study. It was the opinion of this researcher and the Arlington Public Schools that these children would not have the language ability necessary to attempt to explain the proverbial questions that were used in the study. No children with significant deficits in vision, hearing, or motor ability volunteered for the study.

## Procedures

### Determining Handedness

Prior to the administration of the Reflective Questions Test, each sample subject was asked to perform a short series of manual tasks to determine handedness. Each subject was instructed to pick up a pencil from a midline position on a paper and asked to write his/her name, homeroom teacher, and grade level. Then the subject was directed to put down the pencil and hand the paper to the examiner. Next, the subject was given a box and asked to reach in it and pick out one of the objects inside, and describe it to the examiner. After putting the object back into the box, the subject was directed to pick up a set of transparent yellow- and blue-colored paddles and look through both of them at the same time to determine the new color made by their combination. Hand preference behavior for each of these activities was recorded to substantiate the writing hand information supplied by teachers. The use of the right hand in four or more of the tasks was the criterion for classification as right-handed. Only one subject performed less than four of these tasks with the right hand and was dropped from the sample. She was replaced by a randomly selected volunteer from the same sex and grade level pool.

### Determining Conjugate-Lateral Eye Movement (CLEM)

Conjugate-lateral eye movement, as defined in Chapter I, is the joint movement of the eyes to the right or to the left. This

movement can be detected by observing a person's eyes while s/he is reflecting or thinking about something. In studies where subjects are given a question that requires consideration before answering, the subject usually moves both eyes to the right or to the left before answering. The initial eye movements of the subject are considered to be the most reliable measure of directional eye preference (Combs, Hoblick, Czarnecki, & Komler, 1977; Edwards et al., 1971), and these movements are usually "gross and unequivocal" (Kinsbourne, 1972, p. 540). Even in studies where a criterion of movement has been set at a minimum of an arc of $5^{o}$, CLEMs have exceeded the minimal movement constraint and have been reported as easily observable (Ahern & Schwartz, 1979; Hiscock, 1977; Kinsbourne, 1972). As reported in previous chapters of this study, the direction of the CLEM has been postulated to be an overt indicator of which of the hemispheres of the brain an individual tends to activate when thinking. For right handers, left CLEMs are believed to indicate activation of the right hemisphere and right CLEMs are believed to indicate activation of the left hemisphere.

The Reflective Questions Test

In discussions of items to be used to elicit eye movement, studies of conjugate-lateral eye movement have suggested that specific types of reflective questions, such as those of verbal and spatial content, seem to influence eye movement direction more than do simple questions that require the subject to recall familiar

information (Bakan & Shotland, 1969; Bakan & Strayer, 1973; Kinsbourne, 1972; Kocel et al., 1972). Hiscock (1977) further reports that questions asking subjects to explain proverbs produce the highest percent of CLEMs. Therefore, the Reflective Questions Test, employed in this study, includes questions of both verbal and spatial nature. Ten verbal questions (explanation of proverbs) and 10 spatial questions (visualization and identification of spatial relationships and arrangements of places, objects, and people) have been constructed by the researcher and used to elicit eye movements.

Drawing from adult studies which used explanation of proverbs (Hiscock, 1977; Gur, 1975; Kinsbourne, 1972), the verbal sections incorporated in the RQT were selected on the basis of ease of vocabulary and familiarity to children. The spatial sections of the RQT were devised by this researcher to parallel the content of the verbal questions. This was done to provide a control on the stimulus characteristics of the questions. These specific spatial questions do not appear in other studies of conjugate-lateral eye movement.

The verbal questions of the RQT were randomly assigned to position slots in each of two blocks of five verbal questions (Verbal I and Verbal II). The spatial questions were randomly assigned to position slots in each of two blocks of five spatial questions (Spatial I and Spatial II). The blocks of verbal and spatial questions were randomly assigned to forms of the test for orders of blocks of questions, with the constraint that the two

types of question blocks be alternated. Four forms of the test were developed following this procedure. Subjects were then randomly assigned to one of these four orders for testing. Each form of the test was given to 15 of the sample group. Appendix A contains the four forms of the test used.

The Reflective Questions Test was administered to all subjects in a one-to-one setting. Each subject was seated directly across a table from the examiner at a distance of 1.3 meters to allow for direct eye contact. Each subject was asked to perform the sequence of manual tasks mentioned above and hand-preference behavior was recorded. These introductory activities were intended to check the writing-hand information on the subject, to establish rapport, and to fix initial eye contact before questioning began.

The following directions were given to each subject at the onset of testing. "You will be asked 20 brief questions. Please listen carefully to each one. You may take your time to think and answer when you are ready."

The examiner read the directions to each block of verbal and spatial questions and recorded the subject's direction of initial CLEM as right or left (R or L) after each question was presented. No category for scoring lack of CLEM was incorporated because all children exhibited eye movement after each question was presented. Eye movements in the predicted direction (to the right for verbal and to the left for spatial questions) were considered correct and given a score of 1. Eye movements opposite to the predicted

direction were given a score of 0. Scores for the total test had a possible range of 0 to 20. Verbal and Spatial subtests each had a possible range of 0 to 10. Testing time was approximately 20 minutes.

## The Peabody Picture Vocabulary Test

The Peabody Picture Vocabulary Test (PPVT) is an individually administered test of oral receptive language and is designed to provide an estimate of a subject's understanding of spoken words (Dunn, 1965, p. 25). Form B of the PPVT was used for all subjects in this study.

The PPVT consists of 150 numbered plates of four pictures each in hierarchical order of difficulty. The examiner presented a set of four pictures and said a word. The subject then had to point to a picture which represented the word spoken. Starting points, basal, and ceiling levels on the PPVT varied from subject to subject. Testing time was approximately 15 minutes, although no time limit was specified. Raw scores and standardized scores were used in the correlation analyses of this investigation.

Validity and Reliability information on the PPVT appears in Appendix B.

## The Raven's Progressive Matrices

The Raven's Progressive Matrices Test (RPM) is a nonverbal test of rational, analytical reasoning. The Standard Form of this test was used for all subjects in this study. The test consists of 60

problems divided into five sets (matrices) of 12 problems each. The test requires a subject to study figures or pictures presented for observation, "to see relations between them, conceive the nature of the figure completing each system of relations presented," and choose one of a number of possible solutions given (Raven, Court, & Raven, 1978, p. 2). All subjects started at the same point on the test and worked through the five matrices at their own speed. The test was administered to small groups of subjects (N = 6). Testing time was approximately 25 minutes. Raw scores and standardized scores were used in the correlation analyses of this investigation.

Validity and reliability information on the RPM appears in Appendix B.

The Short Test of Educational Ability

The Short Test of Educational Ability (STEA) is designed to provide an estimate of general educational ability and present academic aptitude. Level 3 of this test was used for all subjects in the study. The test consists of 40 verbal meaning items and 15 arithmetic reasoning items. Each item is multiple choice, with four or five responses from which to choose. All subjects started with the verbal meaning items and worked through to the arithmetic reasoning items. The test was administered as a group test and was timed at 20 minutes. Raw scores and derived quotients (standardized scores having an arbitrary mean and standard deviation

at each grade level) were used in the correlational analyses of this investigation.

The STEA was administered to the fifth-grade sample by the researcher in early November, 1980, to coincide with the Arlington Public School's fourth- and sixth-grade testing time. The fifth-grade tests were scored by the researcher. The fourth- and sixth-graders were tested by their classroom teachers as a regular part of the Virginia State testing program. Information on the scores for the fourth- and sixth-graders was obtained from school records.

Validity and reliability information on the STEA appears in Appendix B.

## Data Collection

Data collected for this study included: handedness for each subject; individual subject CLEM scores on the Reflective Questions Test; individual subject scores on the Peabody Picture Vocabulary Test; individual subject scores on the Raven's Progressive Matrices; individual subject scores on the Short Test of Educational Ability; and personal subject characteristics consisting of grade level and sex.

Each of the tests (excluding the STEA) was administered to subjects over a four-week period during the winter of 1981. The RQT retesting of a subsample of 24 took place approximately eight weeks after initial testing. Standardized tests were administered and scored in accordance with the manual directions accompanying

them. Anonymity of each subject was guaranteed in accordance with the policy of the Arlington Public Schools.

## Analysis of Data

Equal numbers of male and female subjects in fourth, fifth, and sixth grade responded to the RQT, PPVT, RPM and STEA. Although sex differences were not considered to be a central question in this investigation, these were assessed for all the tests before proceeding with other analyses. T-tests for independent samples were used to test for significant differences in means of correct responses for males and females.

The four forms of the RQT were used in this study as a control rather than a factor in the design itself. The potential effect of test form was assessed by means of a one-way analysis of variance of mean scores of subjects on each of the four forms of the RQT.

A chi-square test was employed to determine if the distribution of observed left and right CLEM responses differed from the distribution that would be expected by chance.

An analysis of variance for the effects of types of questions (2) and grade level (3) was computed on the number of directionally appropriate CLEMs observed in response to the reflective questions.

Reliability estimates of the RQT were obtained through test-retest score correlations. Cronbach's alpha coefficient of internal consistency was also computed and inter-rater reliability was

assessed by correlating a subsample of 20 administrations of the RQT given by the researcher and an independent observer.

To examine the relationship of the RQT to other linguistic, cognitive and achievement measures, Pearson product-moment correlations for RQT raw scores and PPVT, RPM, and STEA raw and standardized scores were obtained.

The results of these analyses are reported in Chapter IV.

# CHAPTER IV

# RESULTS

The statistical techniques used for testing the hypotheses of this investigation, as described in Chapter III, included preliminary testing for sex differences and for order effects by form of the Reflective Questions Test; a chi-square for testing the relationship of type of question and direction of resulting CLEMs; analysis of variance for question type, grade level, and their interaction; calculation of reliability coefficients for the Reflective Questions Test; and correlational analysis of the relationship of the Reflective Questions Test with other measures of achievement, language, and intelligence in children.

## Sample Distribution

As can be seen from Figures 2 and 3, the distribution of correct responses of the Reflective Questions Test (RQT) total score across all three grade levels was somewhat skewed to the left, indicating scores clustering to the right of the mean. The distributions of the Verbal (RQV) and Spatial (RQS) subtests were also skewed to the left and were more sharply peaked than the distribution for the total score of the RQT.

The distribution of scores for the Peabody Picture Vocabulary Test (PPVT), the Raven's Progressive Matrices (RPM), and the Short

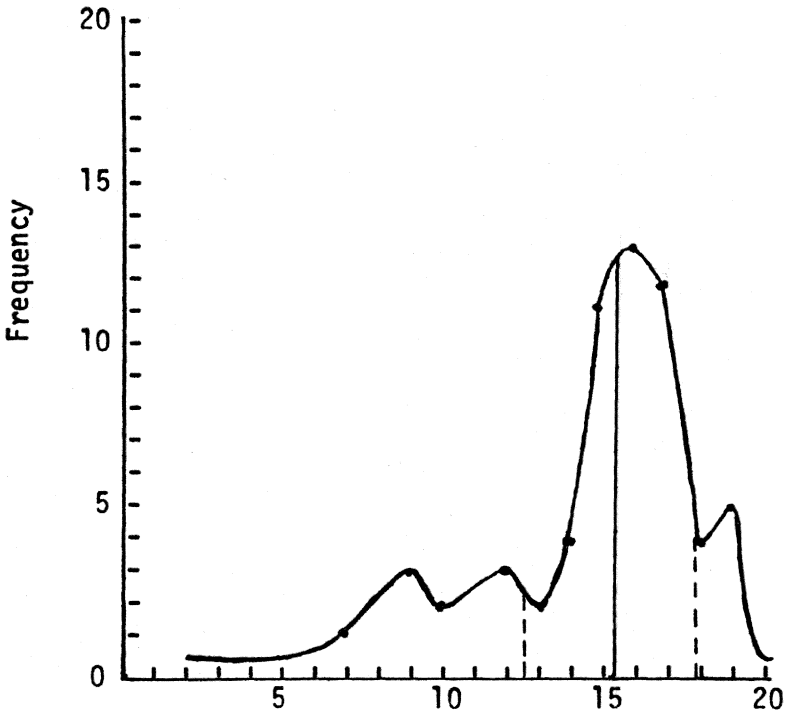
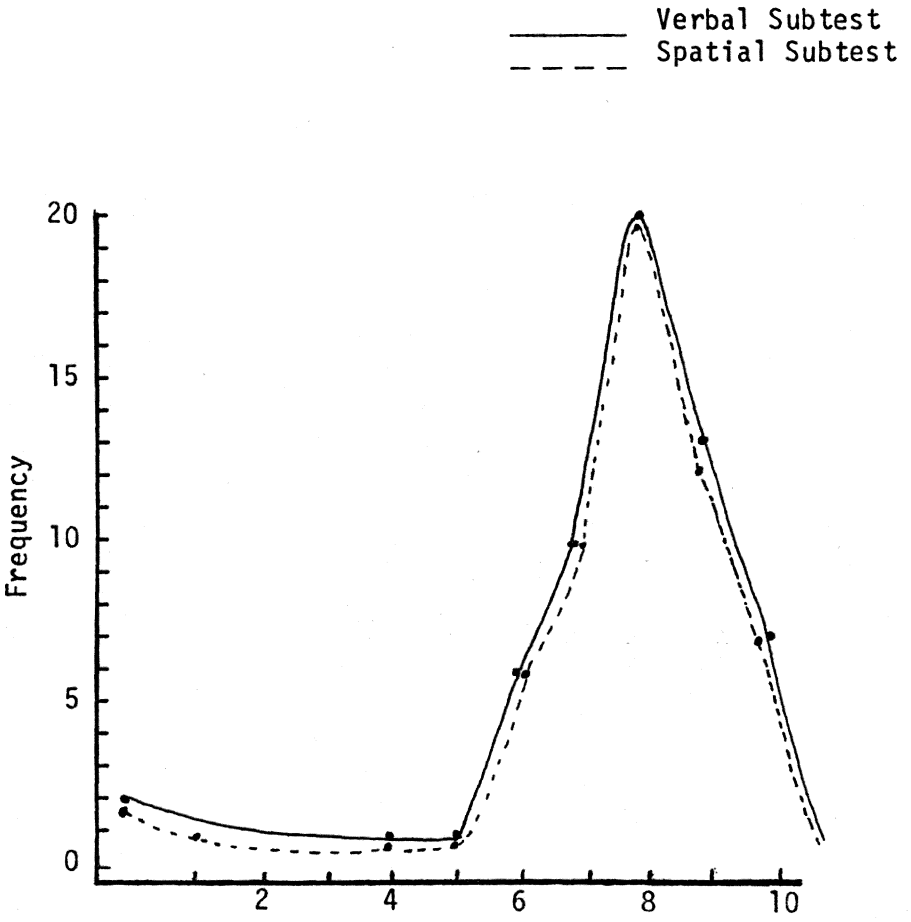



Figure 2

Reflective Questions Test Total Scores




$\overline{X}_V = 7.70$ $SD_V = 1.94$

$\overline{X}_S = 7.56$ $SD_S = 2.11$

Figure 3

Frequency of Correct Responses on the Verbal and Spatial Subtests of the Reflective Questions Test

Test of Educational Ability (STEA) all closely resemble a normal distribution at each grade level. Table 1 displays the raw score means and standard deviations of each of these tests by grade level.

Preliminary Analyses

In this investigation, the variables of sex and form of the RQT were not entered as variables of theoretical interest but were used as variables to control for possible extraneous sources of variance. As a preliminary exploratory procedure, differences between males and females in mean scores on all tests employed in this investigation were analyzed through the use of the *t*-test for independent samples. Pooled variance estimates for each test indicated no significant sex differences on the Reflective Questions Test, its Verbal and Spatial subtests, the Peabody Picture Vocabulary Test, the Raven's Progressive Matrices, and the Short Test of Educational Ability. These results appear in Table 2. On the basis of these results, the data-set for males and females was pooled for the remaining analyses in this investigation.

Four forms of the Reflective Questions Test (N = 15 for each form) were used in this study. Table 3 presents the means and standard deviations of each of these test forms. A one-way analysis of variance of mean total scores across all forms of the test was performed to determine if order of questions had any effect on test score. The results of the ANOVA revealed that no significant differences appear in the mean scores of the four forms of the RQT

Table 1

Means and Standard Deviations for the PPVT, RPM, and STEA

| Test | Grade | $\bar{X}$ | SD |
|---|---|---|---|
| PPVT | 4 | 75.70 | 8.00 |
| | 5 | 98.20 | 16.05 |
| | 6 | 98.55 | 13.72 |
| RPM | 4 | 29.25 | 7.34 |
| | 5 | 37.20 | 6.39 |
| | 6 | 37.30 | 5.34 |
| STEA | 4 | 21.35 | 10.70 |
| | 5 | 38.95 | 11.27 |
| | 6 | 42.25 | 7.84 |

Table 2

T-Tests for Sex Differences*

| Test | Males (N = 30) | | Females (N = 30) | | t |
|---|---|---|---|---|---|
| | $\bar{X}$ | SD | $\bar{X}$ | SD | |
| RQT | 15.07 | 2.56 | 15.47 | 2.87 | .57 |
| RQV | 7.73 | 1.72 | 7.67 | 2.17 | .13 |
| RQS | 7.33 | 2.22 | 7.80 | 2.02 | .85 |
| PPVT | 91.20 | 16.97 | 90.43 | 16.80 | .18 |
| RPM | 35.20 | 7.01 | 33.97 | 7.76 | .65 |
| STEA | 34.27 | 13.11 | 34.10 | 14.18 | .05 |

*With 58 degrees of freedom, no contrasts are significant at .05 level.

Table 3

Means and Standard Deviations for
Forms of the Reflective Questions Test

| Form | $\overline{X}$ | SD |
|---|---|---|
| 1 | 15.46 | 3.11 |
| 2 | 15.33 | 2.60 |
| 3 | 15.20 | 2.78 |
| 4 | 15.06 | 2.57 |

at the .05 level ($F$ = .058, df = 3, 56). Therefore, data for all forms of the test were pooled for the remaining analyses.

Direction of CLEM Responses

It was first hypothesized that the number of initial conjugate-lateral eye movement responses in a given direction is a function of the type of reflective question asked. That is, verbal questions would tend to elicit more rightward CLEMs than spatial questions, and spatial questions would tend to elicit more leftward CLEMs than verbal questions. This hypothesis was supported. Figure 4 shows that for verbal questions, 77% of the CLEMs were to the right (the predicted direction); while for spatial questions, 76% of the CLEMs were to the left (also the predicted direction). For each type of question, less than 25% of the CLEM responses were in a direction opposite to the predicted direction.

A 2 x 2 chi-square analysis of question type by direction of CLEM was computed for the 60 subjects of the sample. The obtained chi-square of 333.06 was found to be significant at the .001 level with one degree of freedom. For verbal questions, 462 CLEM responses were to the right and 138 to the left. For spatial questions, only 146 CLEM responses were to the right while 454 were to the left. Direction of CLEM was not found to be independent of question type.

Five subjects, or approximately 8% of the sample, were classified as unidirectional (only moving their eyes in one direction). The criterion for this classification was based on these individuals

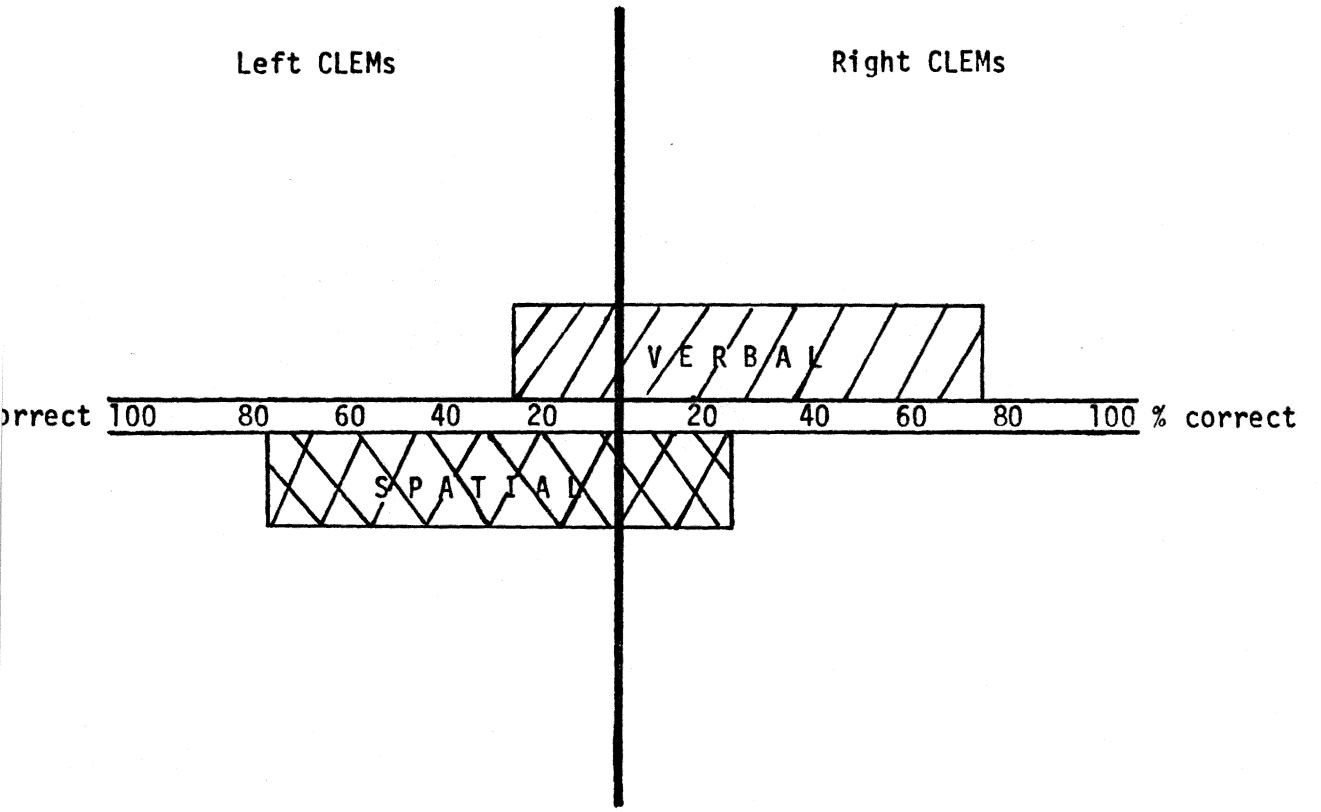



Figure 4

Percentages of CLEMs for Verbal and
Spatial Subtests of the RQT

displaying CLEMs in one direction more than 75% of the time regardless of question type. One fourth-grade male exhibited left CLEMs 85% of the time. Two fifth-grade children (one male, one female) exhibited right CLEMs 95% of the time. Two sixth-grade children also exhibited consistent unidirectional CLEMs; a male exhibited 90% right CLEMs and a female exhibited 95% left CLEMs. No children exhibited CLEMs which were totally the opposite of the theoretically expected direction, that is, left for verbal and right for spatial questions.

Scores from the five unidirectional subjects as well as the 55 bidirectional subjects were included in the primary data analysis. If only the 55 bidirectional subjects were analyzed, however, an even sharper picture of CLEM differentiation emerges. The percentages for CLEMs in this case were 79% to the right for verbal questions and 79.5% to the left for spatial questions.

Effects for Question Type and Grade Level

It was hypothesized that the number of directionally appropriate CLEMs would vary as a function of question type, grade level, and their interaction. In order to examine these effects, a two-way analysis of variance with equal cells was conducted. Table 4 summarizes the results of this analysis.

No significant effect for question type was found. The mean number of directionally appropriate CLEM responses for each of the two subtests was almost identical and was relatively high (although,

Table 4

Two-Way ANOVA Summary Table for
Question Type and Grade

| Source | df | SS | MS | F* |
|---|---|---|---|---|
| Question type | 1 | .533 | .533 | .127 |
| Grade | 2 | .217 | .108 | .026 |
| Interaction | 2 | 9.817 | 4.908 | 1.172 |
| Within | 114 | 477.293 | 4.187 | |
| Total | 119 | 487.860 | | |

*All effects are nonsignificant at the .05 level.

Cell Means

| Question Type \ Grade | 4 | 5 | 6 | |
|---|---|---|---|---|
| V | 7.35 | 8.00 | 7.75 | $\bar{X}_V$ = 7.70 |
| S | 8.00 | 7.30 | 7.40 | $\bar{X}_S$ = 7.57 |
| | $\bar{X}_4$ = 7.67 | $\bar{X}_5$ = 7.65 | $\bar{X}_6$ = 7.57 | $\bar{X}$ = 7.63 |

as noted earlier, the direction of the responses was sharply differentiated for verbal and spatial questions).

Grade level differences in the mean number of directionally appropriate CLEM responses were found to be nonsignificant. The interaction of question type and grade level was also nonsignificant.

The findings of this analysis do not support hypothesis 2. They do suggest that a no-change model is appropriate for this grade range and that a good portion of hemispheric specialization has occurred prior to fourth grade.

## Reliability of the RQT

Hypothesis 3 states that the correlations of the first and second administrations of the RQT are positive and significantly different from zero. In order to examine the stability of RQT results over time, the test was readministered to a subsample (N = 24) of the original sample approximately eight weeks after the first testing. The stratified subsample was randomly selected by sex, grade, and RQT form first administered. The subsample consisted of four boys and four girls from each grade. One boy and one girl at each grade level took one of the four forms of the test. For the second administration of the RQT, each child was given the same form s/he took the first time.

First and second administration test scores were correlated using the Pearson product-moment procedure. A high positive stability

coefficient of .78 was found to be significant at the .05 level. Results of this analysis support the acceptance of hypothesis 3.

Using one-way analyses of variance, mean scores of the second administration of the RQT were not found to differ significantly by form ($F$ = .328, df = 3, 20) or sex ($F$ = .000, df = 1, 22) at the .05 level. Additionally, a two-way analysis of variance yielded no significant main or interaction effects for question type and grade. The summary table for this analysis appears in Appendix C. These results complement first administration findings and lend further support to the stable nature of RQT results. Means and standard deviations of the second administration of the RQT are presented in Table 5.

In addition to assessing temporal stability, it also seemed desirable to assess inter-rater reliability and internal consistency. An estimate of inter-rater reliability was obtained for the RQT by matching ratings for observations made over 20 administrations of the test by the examiner with those made by an independent observer. Inter-rater reliability using the Pearson product-moment procedure was found to be .94, which is significant at the .01 level. This coefficient represents a very high positive correlation between observations.

To estimate RQT reliability on the basis of consistency of subject performance from item to item within the test, Cronbach's alpha coefficient was computed for the RQT (.54) and its Verbal (.59) and Spatial (.65) subtests using the SPSS computer subprogram

Table 5

Means and Standard Deviations of the
Second Administration of the RQT

| FORM | $\bar{X}$ | SD | SEX | $\bar{X}$ | SD |
|---|---|---|---|---|---|
| 1 | 16.17 | .98 | M | 15.83 | 1.03 |
| 2 | 15.67 | 1.03 | F | 15.83 | .94 |
| 3 | 15.67 | 1.21 | | | |
| 4 | 15.83 | .75 | | | |

RELIABILITY: Alpha (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). Each of the measures of internal consistency was moderate and positive.

Correlations of Measures

Hypothesis 4 postulates that correlations between the RQT and other measures used in this investigation will be positive and significantly different from zero. The results of the correlational analysis of raw scores are presented in Table 6. As can be seen, the Verbal and Spatial subtests each had significant positive correlations with the Total Reflective Questions Test scores. The correlations between these two subtests were not, however, significantly different from zero. As will be discussed more fully later, the subtests seem to measure not opposite but different aspects of brain-related behavior.

The Peabody Picture Vocabulary Test, Raven's Progressive Matrices, and Short Test of Educational Ability were found to be significantly, positively correlated with one another. Scores on the PPVT, RPM, and STEA, however, were not found to be significantly correlated with scores on the Reflective Questions Test or its Verbal and Spatial subtests.

The correlations discussed above were based on raw scores. It was also possible that the pattern of correlations for standardized scores, which are adjusted for grade level, would be different. For this reason, correlations of the standardized scores of the PPVT,

Table 6

Correlations Between Raw Scores of the RQT, PPVT, RPM, and STEA

| | RQT | RQV | RQS | PPVT | RPM | STEA |
|---|---|---|---|---|---|---|
| RQT | 1.00 | .63* | .70* | - .06 | - .10 | - .02 |
| RQV | | 1.00 | - .11 | .14 | .04 | .04 |
| RQS | | | 1.00 | - .21 | - .17 | - .07 |
| PPVT | | | | 1.00 | .69* | .81* |
| RPM | | | | | 1.00 | .69* |
| STEA | | | | | | 1.00 |

*Correlations significant at the .01 level.

RPM, and STEA with the raw scores of the RQT (Total, Verbal, and Spatial) were computed. As depicted in Table 7, similar patterns were observed; that is, the linguistic/cognitive measures were significantly, positively correlated with one another, but they were not significantly correlated with the RQT measure of neuropsychological functioning.

The results of the correlational analyses do not support hypothesis 4. They do suggest that the RQT has discriminant validity in that it seems to be tapping a phenomenon different from the linguistic/cognitive constructs being tapped by the PPVT, RPM, and STEA.

Implications of the results of the analyses reported in this chapter are discussed in Chapter V.

Table 7

Correlations Between Raw Scores of the
RQT and Standardized Scores of the PPVT, RPM, and STEA

| | RQT | RQV | RQS | PPVT | RPM | STEA |
|---|---|---|---|---|---|---|
| RQT | 1.00 | .63* | .70* | - .09 | - .05 | .09 |
| RQV | | 1.00 | - .11 | .09 | - .06 | .05 |
| RQS | | | 1.00 | - .19 | - .07 | .03 |
| PPVT | | | | 1.00 | .50* | .51* |
| RPM | | | | | 1.00 | .52* |
| STEA | | | | | | 1.00 |

*Correlations significant at the .01 level.

# CHAPTER V

# DISCUSSION

After summarizing the results of this investigation, Chapter V explores some of the possible measurement issues which have grown from the analysis of the data set. Subsequent sections discuss implications of findings for theory, research, and curriculum.

## Summary

The major findings of this investigation of conjugate-lateral eye movement in children were that: the CLEM responses of children in grades four, five, and six were clearly differentiated by question type (77% of the gazes were to the right while considering verbal questions and 76% were to the left while considering spatial questions); the degree of hemispheric differentiation did not vary by question type or grade level, nor was there a significant grade-by-question type interaction, suggesting that the rate or pattern of growth observed for CLEM responses to verbal questions was not different from the rate or pattern for spatial questions across grade levels; the Reflective Questions Test was found to yield reliable results over time; and the correlations of scores on the RQT with scores on the Peabody Picture Vocabulary Test, Raven's

Progressive Matrices, and Short Test of Educational Ability were not significantly different from zero.

## Measurement Issues

### Within-Subjects Variance

The second hypothesis of this investigation was concerned with question type, grade level and their interaction. While no main or interaction effects were significant, the mean square within subjects was 447.293, which reduced to 4.187 when adjusted for degrees of freedom. This could be interpreted as a large error term relative to the explained variance and deserves some discussion.

A first step in examining possible sources for this within subjects error term included exploring whether the introduction of other individual difference variables would account for some of the variance. In a stepwise multiple regression analysis, raw scores on the Peabody Picture Vocabulary Test, Raven's Progressive Matrices, and Short Test of Educational Ability were entered as possible predictor variables for scores on the RQT. Although using measures which have multicolinearity violates a basic assumption of multiple regression analysis, this procedure was carried out for exploratory purposes only. Collectively the measures were found to contribute less than 4% of the total variance.

A second possibility was that the outlier subjects contributed heavily to the error term. As mentioned in Chapter IV, 55 of the 60 children studied could be classified as bidirectionals (moving

their eyes in one direction for verbal and in the other direction for spatial questions), while only 5 children or 8% were unidirectionals who moved their eyes more than 75% of the time in one direction regardless of question type. In order to check more probingly for the cause of the error term, a post hoc two-way analysis of variance by question type and grade, with outliers eliminated, was performed. The within-subjects term was reduced to 1.827, but main and interaction effects remained nonsignificant. This is consistent with the analysis for the second administration of the RQT with a stratified subsample of 24, which by chance included no outliers and yielded a within subjects term of .899. This information is useful because it confirms that it is inclusion of subjects with a different (but not necessarily wrong) pattern of response, rather than other unexplained sources, which accounts for much of the variance within RQT scores.

Internal Consistency of the RQT

An exploration of the internal consistency of the RQT on the basis of subject performance from item to item within the test showed moderate positive correlations. When the alpha coefficient is used with tests from the same sample, as in this study, the approach is considered to yield a conservative estimate of the test's true internal consistency (Feldt, 1980).

Appendix D contains each of the items of the RQT Verbal and Spatial subtests in order of difficulty based on number of

directionally appropriate CLEM responses. The Spatial subtest seems to have more variability of responses from item to item than the Verbal subtest. This may account for some of the difference in reliability coefficients for each subtest.

Another element affecting the internal consistency of the RQT results may be the rather homogeneous scores on each of the subtests and the total test. Children's mean scores were quite high and most ranged within two points of the mean for each subtest resulting in a somewhat skewed and peaked distribution.

To further explore the differences in coefficients, the two most frequently missed items, V3 and S8, were pulled out to see what effect their absence would have on the internal consistency. The effect of their removal was to decrease rather than to increase the internal consistency coefficient. Removal of these items reduced the already low variability as well as shortened the test.

Although not within the scope of this study, factor analysis of items may be useful to determine dimensions of differences in items. The most frequently missed questions can also be examined to determine if they may be eliciting or calling out different hemispheric activation than was thought to be the case in the test. For example, item S8, "People laughing at something," may have led some children to analyze what people could be laughing at rather than picture how the people looked. Item V3, "Great bodies move slowly," may have led some children to picture a "great body" first before attempting to explain the proverb.

On the whole, the RQT and its subtests have provided a good starting place from which to examine CLEMs. The test does seem to be tapping hemispheric differentiation as indexed by the large numbers of CLEMs appropriate to question type, consistent with adult studies of CLEM differentiation by question type. The test-retest correlation coefficient of .78 also suggests that each of the four forms is equivalent. Inter-rater reliability of .94 indicates the easily observable nature of CLEMs. Explorations of individual factors affecting question items seems the next appropriate step in the refinement process of the RQT for future use in research.

Correlations of Verbal and Spatial Subtests

As discussed in Chapters I and II, the two hemispheres of the brain function differently and seem to mediate verbal and spatial material in opposite hemispheres. These separate functions are not necessarily opposite functions, therefore, there is no strong reason to expect that measures tapping their functions should be either highly positively or highly negatively correlated with one another. The actual results of the correlational analysis support this notion. The Verbal and Spatial subtests were found to be significantly positively correlated with the RQT, but correlations between these two subtests were not found to be significantly different from zero. While the somewhat restricted range of RQT scores and a consequently relatively low degree of variability could also tend to reduce correlations, it appears that as each

subtest taps an aspect of neuropsychological functioning (either verbal or spatial processing), it is not necessarily tapping an opposite function, or doing it in exactly the same way.

## Implications for Theory and Research

### The Effect of Question Type

The main phase of this investigation corroborated studies which found CLEMs to be dependent upon question type. A great number of the children (55 of 60) differentiated their CLEMs by question type. Only 5 of the 60 children tested (approximately 8%) showed unidirectional or characteristic CLEM direction for more than 75% of the questions asked. Subjects within this minority group varied in sex, grade level, ability, and preferred CLEM direction, and could not be labeled as all right-gazers or left-gazers.

For these few children a model of characteristic CLEM is appropriate, while for the great majority a stimulus differentiation model is appropriate. This supports the neuropsychological principle of left hemisphere mediation of verbal tasks and right hemisphere mediation of spatial tasks.

While the results of this investigation on the whole support a model of CLEM differentiation by question type rather than by individual characteristic, they do not rule out the possibilities that a characteristic mode may predominate in early childhood, that characteristic CLEM tendencies are displayed on questions which are less cognitively demanding, or that a few individuals have a marked

tendency to respond in the same direction regardless of stimulus question type. As reported earlier, the kinds of questions asked may explain CLEM results in various studies. Many of the studies supporting the model of characteristic CLEM response (e.g., Bakan, 1969; Duke, 1968; Schroeder, 1976) tended to ask questions requiring recall of familiar and daily experiences rather than analysis, while the present study, supporting the model of Gur (1975) and Kinsbourne (1972), differentiated the questions by verbal (analytic) and spatial modes. An interesting future study would be the examination of both kinds of reflective questioning (familiar experiences versus more abstract specialized verbal and spatial) with the same subjects and comparison of resulting CLEMs.

Unlike the studies with adults by Gur (1975), Hiscock (1977), and Kinsbourne (1972), an experimenter-facing-subjects paradigm in this study did not seem to lessen the stimulus characteristics of the questions. The present results support the findings of studies by Katz and Salt (1981) and Meskin and Singer (1974) which also used the experimenter-facing-subjects paradigm. Perhaps school children are more used to face-to-face types of activity and are not as anxious in an interview situation as adults are reported to be (Gur & Gur, 1980). It seems feasible to suggest that in future studies with normal right-handed children and children with left- and mixed-handedness, this experimenter-facing-subjects technique be employed in order to provide comparability of data collection methods across studies.

Another variable which may interact is the point in the task at which hemispheric activation is assessed. While CLEM studies have been concerned with initial hemispheric activation, Kraft, Mitchell, Languis, and Wheatly (1980), using EEG tracings, have indicated that the same tasks may activate one hemisphere at first and the other a little later.

Task directions for each set of questions rather than the content of the questions themselves may have elicited CLEMs. As has been suggested by Cohen (1975), cuing may create an attentional set that shifts hemispheric asymmetry in tasks. The present investigation used tasks similar to those used in previous studies in this domain, though it attempted to reduce extraneous differences by having the verbal and spatial questions parallel each other in general topic. The results of this study cannot clearly separate the effects of question type from the effects of directions, but the effect of form (four orders of four blocks of explain-verbal and visualize-spatial questions) was found to be nonsignificant. These four forms reflected differences in order of task directions (cuing conditions). If a significant effect had been observed for form, that might have suggested that the effect of cuing conditions was large relative to the effect of question type, though that would have been a less than direct test. A more direct test would be to cross directions with content, so that some children are asked to explain the verbal propositions, some to explain the spatial items, some to visualize the verbal propositions, and some to visualize

the spatial descriptions. Future studies may wish to attempt to vary task and content, building these two factors into a new design.

The RQT provides a first approximation of visual and spatial differences but the differences between the hemispheres are not as simple as verbal versus spatial or analytic versus holistic. While the Verbal and Spatial subtests of the RQT appear to be adequate measures of hemispheric differentiation and a reasonable way to operationalize this construct, the neuropsychological mechanisms underlying this phenomenon are complex and not yet adequately conceptualized by the field.

The most obvious need in the field of hemispheric specialization is for clarification of the nature of the neuropsychological processes involved. The first step is to pose the questions: Is the critical feature in activation of the left hemisphere verbal content or analytic processing? Is the critical feature in activation of the right hemisphere spatial content or holistic processing? Is the relative difficulty of an item for a given individual an influence in determining which hemisphere is activated in processing such an item?

Though other variables may be involved, these seem to be the three central dimensions that need to be disentangled. Such questions suggest research strategies in which there is a conscious attempt to construct both analytic and holistic tasks for verbal and for spatial content of varying difficulty levels. Other variables such as cuing conditions or point of measurement

(Kraft et al., 1980) may also be included in the design, but the central purpose of such studies would be to define more carefully the relative roles of verbal versus spatial content and analytic versus holistic processing (for items of varying difficulty) in hemispheric differentiation. Clarification of the roles of these factors will make it possible to examine more finely the life-long developmental patterns.

Age/Grade Tendencies

Several possible models describing age/grade differences were discussed in Chapter II. These included a gradual change in mean scores over the grades; no-change in mean scores over the grades, accompanied either by high or by low means; an interaction model where, for example, means of the Verbal or Spatial subtests could increase at different rates across grades; and a spurts-and-plateaus model which would predict that mean scores would jump from fourth to fifth grade and remain about the same for sixth grade. The results of this investigation indicated no significant differences across grade levels. Furthermore, the means for each of the subtests were relatively high. These results do not support a gradual change model. The interaction of grade by question type was also nonsignificant. This finding would seem to rule out an interaction model and also a spurts and plateaus model.

The results clearly support a no-change model. However, two versions of this model are possible. If the data had yielded low

means, one could assume that hemispheric specialization had not emerged even by sixth grade. Since the data yielded relatively high means, it suggests that hemispheric functioning as indexed by the RQT is well established by fourth grade and does not change significantly by sixth grade. These grade level results support those who have reported that specialization of hemispheric functioning is well developed and established by later childhood (Bryden & Allard, 1978), but it is still not clear whether this phenomenon is an instance of developmental invariance, or is acquired at some time prior to the fourth grade.

The fact that the aspect of hemispheric differentiation tapped by the RQT is for most children well established at least by fourth grade does not rule out the possibility that some aspects of hemispheric differentiation have developed earlier, some aspects are in flux, and some are still to emerge. Because of the vast complexity of the brain, the picture that ultimately emerges in this field is likely to be one of a topography of response. There may still be more developmental interactions which emerge during early childhood or adolescence involving physiological, maturational, or cognitive processes not examined here. Perhaps adults may have preferences more easily drawn out by tasks or more easily shown through reliance on an acquired learning strategy which has not yet developed in children.

In this section there has been discussion of possible age trends in differentiation. In the previous section there was

discussion of the relative merits of the stimulus differentiation model and the individual characteristic model. There is, however, a further matter which includes aspects of both of these issues: What is the relative power of bidirectional versus unidirectional processing at various points in the life span? Is it necessary that one of these models be proven "right", and the other "wrong" (as some have tried to do)? Is it enough to try to determine whether one of these types of processing precedes the other? Is it instead possible that both potentials are present early and remain available throughout the course of development?

If this last possibility should gain support, that would imply the need for research strategies that explore the conditions needed to elicit bidirectional or unidirectional processing at various ages. Because the RQT allows subjects to express either bidirectional or unidirectional processing tendencies, it can serve as a starting point for studying both potentials in children of the later childhood years.

The results of this study clearly indicated that for hemispheric differentiation as indexed by CLEMs, little change was seen in the upper elementary grades. It is possible, though, that the "growing edge" will differ at various ages, and that a test sensitive to important individual differences at one age will be insensitive earlier or later. If that turns out to be true, it will be necessary in the future to construct a battery of items reflecting the same

general trait but including subtests sensitive to critical differences at various ages or for various subgroups.

Sex Differences

A preliminary stage of this investigation using sex as a form of control variable found no significant differences in the means of correct responses for males and females on any of the cognitive measures or on the Total, Verbal and Spatial scores for the RQT used in this study. This is of particular interest because it supports the findings of two earlier child studies (Reynolds & Kaufman, 1980; Schroeder, 1976), but does not seem consistent with some of the findings of adult studies (Duke, 1968; Schweitzer & Chacko, 1980) which suggest that males are more fully lateralized than females. The CLEM phenomenon seems to be similar for both sexes at this fourth- to sixth-grade level and, in fact, none of the child studies reviewed showed sex differences before age 12. Several explanations may account for this finding.

Hiscock and Kinsbourne (1978), studying other means of assessing speech lateralization, support this finding and suggest that no sex differences exist from early childhood, through adolescence, to adulthood. Harris (1975, 1978), studying means of assessing spatial skills, reported that in studies where sex differences appear, the results may be a factor of certain testing situations or individually learned and/or culturally imparted strategies for responding to tasks. Fairweather (1976), in studying both spatial and linguistic areas,

found that few convincing sex differences exist. Still another explanation may be that sex differences in hemispheric specialization have not developed yet in this part of the age span. The differences between findings in this study and those observed in adult studies may also be related, in part, to recent culturally less strict role definition and learning in current school conditions which stress nondiscriminatory practices and open curricular choices for males and females, thus allowing the development of visuo-spatial and logico-linguistic skills in both sexes. With the nature versus nurture factor in the development of brain lateralization still to be determined, it is premature to speculate on whether sex differences in brain lateralization as indexed by the RQT would be displayed in earlier childhood or in adolescence. Because the question of sex differences is still an open one, further examination with other age groups is warranted.

## Implications for Curriculum

A key assumption underlying proposals for brain-based curricula is the expectation that neurological development is correlated with ability to learn in classrooms. Scores on the Reflective Questions Test, however, were not significantly positively correlated with any of the measures of achievement, language, and intelligence studied. Total number of appropriate CLEM responses on the RQT was not significantly correlated with scores on the Peabody Picture Vocabulary Test, the Raven's Progressive Matrices, or the Short Test

of Educational Ability. The results were similar both for total score and for the separate Verbal and Spatial subtests of the RQT. While these results do not rule out the possibility that some aspects of neurological or neuropsychological maturation are related to some aspects of cognitive/linguistic measures of current functioning in school learning, they provide no support for the assumption of such relationships, at least during the later elementary years. These findings point to the possibility that neuropsychological development, or more specifically, hemispheric differentiation as indexed by the RQT, is largely independent of established measures of language development, achievement, and intelligence traditionally related to school performance, at least during the later elementary years. This raises the question of whether it is always reasonable to assume that neurological development, apart from gross deviations from normal, has strong correspondence with cognitive development.

The results also have implications for the spurts and plateaus brain-based curriculum model of Epstein (1978). The spurts and plateaus model is based upon a strong assumption that there are brain weight spurts in neurological processes and plateaus of almost no growth which are said to set limits on advances in cognitive development and classroom learning. According to this model, brain growth stages alternating every two years would predict a plateau from 8 years to about 10 years and a spurt from 10 to 12 years. If the development of neurological function followed the same pattern as those reported by Epstein for brain weight, it would be expected

that neurological function as indexed by scores on the RQT would show a significant increase from fourth grade to fifth, with sixth grade scores approximately the same as fifth. As discussed earlier this pattern was not observed. Results of correlational analyses also bring into question the notion that measures of neurological function are correlated with measures of cognitive development, language development, and classroom learning.

In a second approach to the development of brain-based curricula, Samples (1977), for example, assumes that education is directed almost entirely to the development of left hemispheric processing and proposes that the curriculum should be changed to place more emphasis on right-hemispheric processing. The observed differentiation in CLEM behaviors, however, clearly demonstrated children's ability to activate both hemispheres in considering verbal and spatial questions (except in the minority of unidirectionals). The proposals advanced by Samples may have merit, but do not seem to be justified in terms of the results of this study.

Neuropsychological studies have frequently demonstrated a less than one-to-one correspondence between the structural and functional development of the brain (Dimond & Beaumont, 1974; Kinsbourne, 1978; Von Bonin, 1962). Because of this, there continues to be reason for caution in designing and promoting curriculum which relies upon results based solely on structural differences (i.e., Epstein, 1978).

Caution should also be exercised in implementing a curriculum which is predicated upon the assumption that hemispheric

specialization or other indices of neurological maturation are correlated with linguistic/logical development. Very careful evaluation of such assumptions and the resulting curriculum must be made until neuropsychological functions can be accurately assessed and these correlations strongly represented. To suggest that some "brain-based" curricula are premature and inadequately linked to research is not to suggest that neurological processes are irrelevant to education. It is necessary, however, that there be clarification of the nature and development of neurological form and function and that the links between neurology and classroom learning be tested rather than assumed.

## Conclusions

The findings of this study indicate that conjugate-lateral eye movement is an appropriate unit of measurement for children in later childhood and justify continued exploration of CLEM responses in children. The study should be viewed as an effort to explore the relevance of findings from the neurosciences in an educational setting. The results provide basal normative data on right-handed children in the later childhood years. By supplying this information, the investigation also provides a background for future studies to determine if similar patterns exist for children in kindergarten through grade three (when the acquisition of a learning style is developing) and in adolescence. The information is also useful as background for studies of learning disabled children and left- and

mixed-handers of the later childhood years to ascertain if these subjects demonstrate similar patterns of behavior.

With continued controlled experimentation, the RQT has the possibility of refining conjugate-lateral eye movement as an easily administered index to children's hemispheric specialization. Subsequent studies with other children can only add to and clarify our understanding of this process and how it relates to ease of learning with different teaching techniques and strategies. The Reflective Questions Test seems to be a tool worthy of consideration for use in the slow and careful research cycle needed to build a neuroscientific base for educational practice.

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# APPENDIX A

## REFLECTIVE QUESTIONS TEST

The verbal sections (explanation of proverbs) incorporated in the Reflective Questions Test (RQT) were selected on the basis of ease of vocabulary and familiarity to children. Proverbs were also used in a number of adult studies.

The spatial sections (visualization and identification of spatial relationships and arrangements of places, objects, and people) were devised by this researcher to parallel the content of the verbal questions. This was done to provide a check on the stimulus characteristics of the questions. These questions do not appear in other studies of conjugate-lateral eye movement.

# REFLECTIVE QUESTIONS TEST FORM 1

You will be asked twenty brief questions. Please listen carefully to each one. You may take your time to think and answer when you are ready.

| | R | L |
|---|---|---|
| VERBAL I | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. All that glitters is not gold. | | |
| 2. Don't count your chickens before they are hatched. | | |
| 3. Great bodies move slowly. | | |
| 4. He who laughs last laughs best. | | |
| 5. A bird in the hand is worth two in the bush. | | |
| SPATIAL I | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. A nest filled with bird eggs. | | |
| 2. Golden rocks scattered in a stream. | | |
| 3. A pot cooking on a stove. | | |
| 4. Books on a shelf in the library. | | |
| 5. Someone sewing by hand. | | |
| VERBAL II | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. A rolling stone gathers no moss. | | |
| 2. The weakest spoke of a wheel breaks first. | | |
| 3. A watched pot never boils. | | |
| 4. A stitch in time saves nine. | | |
| 5. Don't judge a book by its cover. | | |
| SPATIAL II | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. Elephants walking in the jungle. | | |
| 2. Wagon wheels on a covered wagon. | | |
| 3. People laughing at something. | | |
| 4. Rocks in a landslide. | | |
| 5. Someone hunting for ducks. | | |

# REFLECTIVE QUESTIONS TEST FORM 2

You will be asked twenty brief questions. Please listen carefully to each one. You may take your time to think and answer when you are ready.

| | R | L |
|---|---|---|
| SPATIAL I | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. A nest filled with bird eggs. | | |
| 2. Golden rocks scattered in a stream. | | |
| 3. A pot cooking on a stove. | | |
| 4. Books on a shelf in the library. | | |
| 5. Someone sewing by hand. | | |
| VERBAL I | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. All that glitters is not gold. | | |
| 2. Don't count your chickens before they are hatched. | | |
| 3. Great bodies move slowly. | | |
| 4. He who laughs last laughs best. | | |
| 5. A bird in the hand is worth two in the bush. | | |
| SPATIAL II | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. Elephants walking in the jungle. | | |
| 2. Wagon wheels on a covered wagon. | | |
| 3. People laughing at something. | | |
| 4. Rocks in a landslide. | | |
| 5. Someone hunting for ducks. | | |
| VERBAL II | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. A rolling stone gathers no moss. | | |
| 2. The weakest spoke of a wheel breaks first. | | |
| 3. A watched pot never boils. | | |
| 4. A stitch in time saves nine. | | |
| 5. Don't judge a book by its cover. | | |

# REFLECTIVE QUESTIONS TEST FORM 3

You will be asked twenty brief questions. Please listen carefully to each one. You may take your time to think and answer when you are ready.

| | R | L |
|---|---|---|
| VERBAL II | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. A rolling stone gathers no moss. | | |
| 2. The weakest spoke of a wheel breaks first. | | |
| 3. A watched pot never boils. | | |
| 4. A stitch in time saves nine. | | |
| 5. Don't judge a book by its cover. | | |
| SPATIAL II | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. Elephants walking in the jungle. | | |
| 2. Wagon wheels on a covered wagon. | | |
| 3. People laughing at something. | | |
| 4. Rocks in a landslide. | | |
| 5. Someone hunting for ducks. | | |
| VERBAL I | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. All that glitters is not gold. | | |
| 2. Don't count your chickens before they are hatched. | | |
| 3. Great bodies move slowly. | | |
| 4. He who laughs last laughs best. | | |
| 5. A bird in the hand is worth two in the bush. | | |
| SPATIAL I | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. A nest filled with bird eggs. | | |
| 2. Golden rocks scattered in a stream. | | |
| 3. A pot cooking on a stove. | | |
| 4. Books on a shelf in the library. | | |
| 5. Someone sewing by hand. | | |

# REFLECTIVE QUESTIONS TEST FORM 4

You will be asked twenty brief questions. Please listen carefully to each one. You may take your time to think and answer when you are ready.

| | R | L |
|---|---|---|
| SPATIAL II | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. Elephants walking in the jungle. | | |
| 2. Wagon wheels on a covered wagon. | | |
| 3. People laughing at something. | | |
| 4. Rocks in a landslide. | | |
| 5. Someone hunting for ducks. | | |
| VERBAL I | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. All that glitters is not gold. | | |
| 2. Don't count your chickens before they are hatched. | | |
| 3. Great bodies move slowly. | | |
| 4. He who laughs last laughs best. | | |
| 5. A bird in the hand is worth two in the bush. | | |
| SPATIAL I | | |
| Can you visualize or picture in your mind each of the things I am going to say to you? Tell me how each looks to you. | | |
| 1. A nest filled with bird eggs. | | |
| 2. Golden rocks scattered in a stream. | | |
| 3. A pot cooking on a stove. | | |
| 4. Books on a shelf in the library. | | |
| 5. Someone sewing by hand. | | |
| VERBAL II | | |
| Can you explain in your own words each of the sentences I am going to say to you? | | |
| 1. A rolling stone gathers no moss. | | |
| 2. The weakest spoke of a wheel breaks first. | | |
| 3. A watched pot never boils. | | |
| 4. A stitch in time saves nine. | | |
| 5. Don't judge a book by its cover. | | |

# APPENDIX B

## PEABODY PICTURE VOCABULARY TEST

Validity. Content validity of the PPVT has been established by selecting words from the Webster's New Collegiate Dictionary, the meanings of which could be depicted by a picture (Dunn, 1965).

"Item" validity has been established by selecting individual words "where the percent of subjects passing increased from one age group to the next. Only items demonstrating linear, steep growth curves were retained." (Dunn, 1965, p. 33.)

Construct validity has been established from several sources on IQ measurements, which have demonstrated that vocabulary subtest scores correlate more highly with full-scale IQ scores than any other IQ subtest scores (Dunn, 1965, p. 32).

Concurrent validity, the extent to which the PPVT scores compare with scores on other vocabulary and intelligence tests, has been computed for the Stanford-Binet and the Verbal Scale of the Wechsler Intelligence Scales for Children. PPVT correlations with the Stanford-Binet are .71 and with the WISC-V .67. Highest correlations tended to be with the Ammons Vocabulary Test (.84) and the Van Alstyne Picture Vocabulary Test (.87), which are instruments most readily comparable to the PPVT (Dunn, 1965, pp. 33-41).

Reliability. The original PPVT (Forms A and B) was standardized on 4,012 subjects in Tennessee. Alternate form reliability coefficients were obtained by calculating Pearson product-moment

correlations on the raw scores of the standardization subjects. Correlations ranged from a low of .67 for 6-year olds, to a high of .84 for 17- and 18-year olds. The median correlation was .77 (Dunn, 1965, p. 30).

## RAVEN'S PROGRESSIVE MATRICES

Validity. Content validity of the RPM has been established by examining the internal consistency of the test. Biserial correlations between items of the Raven's Progressive Matrices have shown a range of .45 to .80 (Raven et al., 1972, p. 9).

Item order has been established to insure that the sequence of items has a "teaching function so that later items are solved successfully due to the experience provided by earlier items in any one set" (Raven et al., 1978, p. 9). Test items have been said to appear to assess the basic ability to reason "in a form of presentation which is not obviously culturally biased" (MacArthur in Raven et al., 1978, p. 9).

Congruent or concurrent validity has been computed for the Raven's Progressive Matrices Test and the Stanford-Binet and Wechsler Intelligence Scales for Children with English speaking children and adolescents. Correlations ranged from .54 to .86.

Reliability. The original Raven's Progressive Matrices Test was standardized on "representative samples of British people, 6 to 65 years of age and for Irish children aged 6 to 12 years of age" (Raven et al., 1978, p. 4). Split-half measures of reliability have yielded correlations of at least .90, with a high of .98 with 12-year-old subjects (Raven et al., 1978, p. 5). Test-retest reliability for short-term intervals have yielded .90 correlations,

which reduce to about .80 at intervals up to one year (Raven et al., 1978, p. 6).

## SHORT TEST OF EDUCATIONAL ABILITY

Validity. Content validity of the STEA has been established by "authorities", teachers, educators, and curriculum specialists who considered the questions as adequately covering levels of mental reasoning and factors of intellect necessary for school success (Science Research Associates, 1972, pp. 3-5).

Concurrent validity has been computed in terms of correlation coefficients between STEA levels 3 - 5 and subtests of the Science Research Associates Assessment Survey. Data are listed below for Level 3 (Science Research Associates, 1972, p. 10):

| Assessment Survey Sub-tests | STEA Level 3 Grades 4 | 5 | 6 |
|---|---|---|---|
| Composite | .81 | .85 | .84 |
| Reading Comprehension | .76 | .80 | .80 |
| Reading Vocabulary | .82 | .87 | .86 |
| Reading Total | .82 | .85 | .86 |
| Math Concepts | .69 | .79 | .74 |
| Math Computations | .60 | .60 | .56 |
| Math Total | .70 | .75 | .69 |
| Language Usage | .70 | .76 | .72 |
| Language Spelling | .63 | .71 | .73 |
| Language Total | .71 | .78 | .76 |

Reliability. The STEA has been standardized via 156,000 students in grades 1 through 9 in a stratified random sample across the United States. From subsamples randomly drawn from the standardization group

to match the distribution of the national sample, Kuder-Richardson-20 reliabilities were calculated by level and grade. Test-retest correlations were .90 for grade 4, .93 for grade 5, and .93 for grade 6 on the Level 3 test (Science Research Associates, 1972, p. 9).

# APPENDIX C

Two-Way ANOVA Summary Table for
Question Type and Grade of the
Second Administration of the RQT

| Source | df | SS | MS | F* |
|---|---|---|---|---|
| Question Type | 1 | 2.083 | 2.083 | 2.318 |
| Grade | 2 | 1.792 | .896 | .997 |
| Interaction | 2 | 4.042 | 2.021 | 2.248 |
| Within | 42 | 37.750 | .899 | |
| Total | 47 | 45.666 | | |

*All effects are nonsignificant at the .05 level.

Cell Means

Grade

| Question Type | 4 | 5 | 6 | |
|---|---|---|---|---|
| V | 8.13 | 8.25 | 8.00 | $\bar{X}_V = 8.13$ |
| S | 7.50 | 7.25 | 8.38 | $\bar{X}_S = 7.71$ |
| | $\bar{X}_4 = 7.81$ | $\bar{X}_5 = 7.75$ | $\bar{X}_6 = 8.19$ | $\bar{X} = 7.92$ |

# APPENDIX D

REFLECTIVE QUESTIONS TEST ITEM DIFFICULTY

| | Subtest Item | Number Correct | Number Incorrect | Percentage Correct |
|---|---|---|---|---|
| V3 | Great bodies .... | 41 | 19 | 68 |
| V4 | He who laughs .... | 44 | 16 | 73 |
| V9 | A stitch .... | 45 | 15 | 75 |
| V8 | A watched pot .... | 45 | 15 | 75 |
| V7 | The weakest spoke .... | 45 | 15 | 75 |
| V6 | A rolling stone .... | 46 | 14 | 77 |
| V5 | A bird .... | 46 | 14 | 77 |
| V1 | All that glitters .... | 49 | 11 | 82 |
| V10 | Don't judge a book .... | 50 | 10 | 83 |
| V2 | Don't count your .... | 51 | 9 | 85 |
| S8 | People laughing .... | 39 | 21 | 65 |
| S7 | Wagon wheels .... | 43 | 17 | 72 |
| S4 | Books .... | 43 | 17 | 72 |
| S2 | Golden rocks .... | 44 | 16 | 73 |
| S6 | Elephants .... | 45 | 15 | 75 |
| S3 | A pot .... | 45 | 15 | 75 |
| S10 | Someone hunting .... | 48 | 12 | 80 |
| S5 | Someone sewing .... | 48 | 12 | 80 |
| S1 | A nest .... | 49 | 11 | 82 |
| S9 | Rocks .... | 50 | 10 | 83 |

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# CONJUGATE-LATERAL EYE MOVEMENT BEHAVIOR IN LATER CHILDHOOD*

by

Jo Ann Elizabeth Daly

(ABSTRACT)

There are currently many statements about the effects of hemispheric specialization of the brain upon children's cognitive processing and therefore, upon content or modes of instruction. Before educators can accept or even test these statements, it is important to devise easy-to-use measures of hemispheric functioning and to study their relationship to established measures of achievement and linguistic and cognitive development.

Current research in brain functioning has indicated that conjugate-lateral eye movement direction (the direction in which a person looks while thinking) can be a sensitive indicator of which cerebral hemisphere is initially activated. The central purpose of this investigation was to analyze the effects of the stimulus characteristics of reflective questions of verbal and spatial nature on the conjugate-

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lateral eye movement (CLEM) behavior of right-handed children from fourth, fifth, and sixth grades. A major objective was to determine whether data on children's CLEM responses would better support a model of characteristic individual differences or a model of differentiation by question type. The testing instrument devised for this purpose was the Reflective Questions Test (RQT) which included both Verbal and Spatial subtests. In an experimenter-facing-subject paradigm with a sample of 60 (30 boys, 30 girls), conjugate-lateral eye movement was found to be easily observable and question type was found to influence the direction of eye movement, thus supporting a differentiation by question type model. Verbal questions elicited significantly more rightward CLEMs than spatial questions and spatial questions elicited significantly more leftward CLEMs than verbal questions in the sample studied. No significant sex differences were found. These results seem to be consistent with the neuropsychological theory that once hemispheric specialization has occurred with normal right-handed children, the left hemisphere mediates language functions and the right hemisphere mediates spatial functions.

Examining the number of directionally appropriate CLEM responses, a two-way analysis of variance (verbal and spatial question type by grade level) yielded no main or interaction effects. The results suggest that although children in grades four, five, and six tended to gaze in different directions while responding to verbal than while responding to spatial questions, the rate of responses appropriate to the question (gazing in the direction predicted) was

no greater for verbal than for spatial questions. Further, the means for question types were almost identical across grade levels for CLEM responses to verbal and to spatial questions, supporting a no-change model of neuropsychological function, which contends that within the later childhood years, hemispheric specialization is well developed.

The Reflective Questions Test was found to have high inter-rater reliability (.94) and temporal stability (.78). These results indicate that the RQT produced reliable and stable results for the sample studied and support the appropriateness of the RQT for future refinement and use in educational research of this type.

Correlations of the RQT with other measures of linguistic and cognitive development, and educational ability were found to be nonsignificant. These results suggest that hemispheric activation as indexed by the RQT at this age range may be largely independent of measures traditionally associated with school performance.

The results of this investigation have provided normative data on normal right-handed children, thereby providing a comparative basis for future research with children of the same age from other populations such as the learning disabled.