DIVERGENT THINKING AND HEMISPHERICITY

by

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I INTRODUCTION

The literature on hemispheric brain specialization has recently been concerned with the study of creativity. It has been suggested that the two hemispheres of the brain operate in functionally different ways (Bogen, 1975; Gazzaniga, 1967; Sperry, 1964). Creativity has been associated with a predominance of right hemisphere thinking (Bogen & Bogen, 1969; Martindale, 1977). This study was designed to examine the relationship between a type of creativity (divergent thinking) and hemisphericity. When variables such as sex, age, hand preference, and verbal ability are controlled, it was expected that a relationship between divergent thinking and right brain dominance, as measured by a dichotic listening task, would be seen in the four, seven, and ten year old subjects. This study also examined the relationship between age and hemisphericity.

Justification

Few empirical studies have focused on the relationship between creativity and hemisphericity despite the need for investigations in this area.

To a large degree, our elementary schools have neglected the measurement of creativity. Much of this neglect may be due to the problems of test construction. Some writers have suggested that creative individuals may be identified according to an established pattern of cerebral dominance. Theorists on creativity have thus asserted that information on cerebral functioning may be used productively in the development of the field of creativity (Bekdal, 1979). Gowan (1979) alluded to the need to examine the mechanics of the creative process. Hemisphericity may be an avenue to this end. The way in which cerebral functioning affects creativity may vary according to the nature of the task (Bogen, 1975; Torrance & Mourad, 1979). The present study lends itself to the examination of divergent thinking tasks. Divergent thinking is logically related to ideational fluency, i.e., "the ability to produce a large number of ideas" (Torrance, 1966, p. 72); and to originality, i.e., the ability to produce ideas that are away from the obvious, commonplace, banal, or established" (Torrance, 1966, p.73). Furthermore, as with all research, there is a need for investigations which utilize a variety of populations and types of creativity tests (Torrance & Mourad, 1979). In general, then, there is a need for any study which contributes to our knowledge of creativity.

Historically, educators have recognized "two ways of knowing" (Languis & Kraft, 1977, p. 5). Paradoxically, the American educational system is skewed toward the left hemisphere modality (Bogen, 1975; Galin, 1976; Garret, 1976; Hunter, 1976; Languis & Kraft, 1977; Rennels, 1976; Sperry, 1975). "Schools have been beaming most of their instruction through a left-brained input (reading and listening) and output (talking and writing) system thereby handicapping all learners" (Turner, 1978, p. 3). McCallum and Glynn (1979) recommended the development of right brain strategies especially in the elementary school. Rather than traditional testing and measuring (a left brain paradigm of our schools), Garret (1976) suggested the construction of a profile to identify creative persons. Information related to hemisphericity would conceivably be included in such a profile. With regard to the need for research in this area, Languis and Kraft (1977) stated that "current directions in brain research provide an opportunity to build a more comprehensive base for facilitating learning in children" (p. 7).

Therefore, in addition to the need for investigations of creativity in general, there is justification for examination of creativity as it is related to hemisphericity in particular. The literature supports the contention that divergent thinking (a form of creative thinking) is associated with right brain thinking. Convergent thinking, on the other hand is associated with left brain thinking (Ornstein, 1977). This study will contribute to our understanding of creativity, hemisphericity, and the processes associated with both.

Theoretical Orientation

The study of hemisphericity has increased in sophistication during the last hundred years: from crude observations made in the 1800s and the landmark evaluations of Roger Sperry's (1964) split-brain patients, to the present electroencephalograms and other techniques. Yet, the experts agree that much more research is needed in the area of cerebral functioning.

There is a paucity of research dealing with hemisphericity and its relationship to creativity. This paucity is due to the nature of hemisphericity, i.e., its dependence on the nature of a task and the recognition of the role of integration of hemispheric functioning, and to the nature of creativity, i.e., the variety of definitions for the term and the difficulty associated with its assessment.

There is , however, a body of literature which suggests a relationship between hemisphericity and creativity. Specifically, the right hemisphere is thought to be the creative hemisphere. Bruner (1965) remarked, "Since childhood, I have been enchanted by the fact and the symbolism of the right hand and the left -- the one the doer, the other the dreamer" (p.2). He goes on to discuss the right hemisphere of the brain as being the source of ideas, hunches, and "lucky" guesses.

Ornstein (1977) referred to right brain thinking as the intuitive mode. Ornstein's intuitive mode can be compared to creativity. In fact, Ornstein made reference to the relationship between creativity and dualistic thinking throughout his writings: "But this other mode [the right hemisphere thinking] ... is important for creativity" (p.36). Ornstein further pointed out that throughout history the duality of consciousness has been recognized. Among those he discussed were the Hopi Indians, noting their distinction of the two hands: one for writing and one for making music. Ornstein also referred to W.I.B. Beveridge's work, The Art of Scientific Investigation, which "stresses the need for development of the intuitive side in scientists. He [Beveridge] defined intuition in science as ' clarifying idea which comes suddenly to mind" (Ornstein, 1977, p.38). The study at hand deals with the dualistic thinking as it may be related to creativity.

Statement of the Problem

This study was designed to investigate the relationship between hemisphericity and divergent thinking. For the purpose of this study, hemisphericity was assessed by a dichotic listening technique and divergent thinking was determined by the Product Improvement Task and the Unusual Uses Task of the *Torrance Tests of Creative Thinking*. It was expected, in congruence with the literature, that hemisphericity would predict the scores on the divergent thinking tests. The sex, age, and hand preference of the child, as they interact with hemisphericity, were also thought to be predictors of the scores on the creativity test. In addition, the development of hemisphericity was reviewed, and the question of age as a predictor of hemisphericity scores was discussed.

Hypotheses to be Investigated

The following hypotheses were investigated:

Right-brain dominant children score higher on divergent thinking tests than do other children, either left-brain dominant, or mixed dominant. The additive effects of hemisphericity, sex, age, hand preference and verbal expression were examined as they accounted for the variance in the divergent thinking tests scores.

II. Each of the following will predict the subjects' divergent thinking test scores: (a) the interaction of the subject's sex and hemisphericity score, (b) the interaction of the subject's age and hemisphericity score, and (c) the interaction of the subject's hand preference and hemisphericity score. There are sex differences between the performance of boys and girls on tasks of hemispheric lateralization of function (Buffery, 1971). Likewise, age influences the extent of hemispheric dominance (Gazzaniga & LeDoux, 1978; Galin, 1976). The nature and extent of the relationship between hand preference and hemisphericity remains unclear (Beaumont, 1974).

In addition, this study examined the research question of whether age will predict hemisphericity scores.

Instrumentation

The methods of measurement of hemisphericity were examined with special emphasis focused on the technique used in the present investigation, dichotic listening. McNeil and Hamre's (1974) review of measures of lateralized cerebral functions included a six-part chronological classification: (a) autopsy studies, (b) handedness correlates, (c) cortico-anatomical techniques, (d) intracarotid sodium amytal techniques, (e) dichotic techniques, and (f) dichoptic techniques. The assessment of hemisphericity through the use of the electroencephalagram (EEG) was also found in the literature.

Autopsy, cortico-anatomical (hemispherectomy and split-brain surgery), and sodium amytal techniques were judged as inappropriate for this study. Likewise, the use of the EEG, although methodologically sound, was ruled out due to technological incapabilities and expense. Saccadic lateral eye-shift as a measure of hemisphericity was found to be surrounded by controversy (McNeil & Hamre, 1974) and dicoptic techniques were judged as not suitable for very young children.

Dichotic listening techiniques have demonstrated consistently and reliably their utility in the assessment of hemisphericity (Kimura, 1973). The dichotic listening technique was developed by Donald E. Broadbent of the British Medical Research Council's Applied Psychology Research Unit (Kimura, 1973). Stimuli presented to one ear was found to be registered more effectively by the contralateral cerebral hemisphere. Research involving many related variables and methodological considerations was reviewed and considered in the selection of the dichotic listening technique chosen for this study.

The assessment of creative thinking has been received with skepticism by those who respect the indubitability of scientific study. The reason for this, in the opinion of many, lies in the absence of a singularly accepted definition of the concept, and in the lack of a set criteria by which instruments can be assessed for validity (Khatena, 1971,1976; Treffinger, Renzulli, & Feldhusen, 1971; Wallach & Kogan,1965).

The Product Improvement Task and the Unusual Uses Task are components of the Torrance Tests of Creative Thinking (TTCT). These tests were chosen because they adequately assess the process of creative thinking as it has been defined by the researcher for this study. If creativity is considered to be a process which may be displayed through freedom of expression and unusual ideas and thoughts, then the Product Improvement Task which asks subjects to think of ways to improve and change an object, and the Unusual Uses Task which asks subjects to think of interesting and unusual uses for an object, may be tapping that process. Adequate data on reliabilty, validity, scoring and norms were also considered in the selection of these tests. Based on the instruments' usability with young children, their availablity, and their satisfactory validity and reliability, the Product Improvement Task and the Unusual Uses Task were chosen for the purpose of assessing creativity.

Assumptions

Two basic assumptions were be considered in the analysis and interpretation of the results of this study: (a) that the Torrance Tests of Creative Thinking (specifically, the Product Improvement Task and the Unusual Uses Task) measure what this study has defined as creativity, and (b) that the dichotic listening technique accurately and sufficiently distinquishes between children for hemisphericity.

Limitations

This study was limited to children from the following age ranges: 3 years, 9 months to 4 years, 3 months; 6 years, 9 months to 7 years, 3 months; and 9 years, 9 months to 10 years, 3 months. The interprettion of the developmental aspect of this study was limited because it was not feasible to conduct a longitudinal study.

Furthermore, because the study deals with subjects of only three ages, it was not be possible to determine changes which may cccur during the ages not assessed.

Definition of Terms

The following terms which are found throughout this study are defined below:

Creativity

Creativity refers to a process possessed by everyone and displayed by children through their freedom of expression, unusual ideas and thoughts and divergent thinking.

Hemisphericity

Hemisphericity refers to the "tendency for a person to rely more on one than other cerebral hemisphere in processing information" (Torrance & Mourad, 1979, p. 44). In agreement with this definition, representative hemisphericity research refers to the "study of the functional organization of the brain according to left or right hemisphere " (Rubenzer, 1979, p.79).

II REVIEW OF THE LITERATURE

Hemisphericity

History

As far back as the nineteenth century, scientists documented the phenomenon that, today, we have named hemisphericity. Broca (1865), Wernicke (1874), and Dejerine (1891) were among those who systematically documented the association between the occurrence of brain damage (usually a brain lesion) and some specific change in an individual's cognitive functioning. Early theories on cerebral dominance generally assumed that no dominace was present for certain functions; for other functions, one hemisphere was consistently dominant. Thus, the left hemisphere was classically related to speech and many other functions, while the right hemisphere was viewed as the minor hemisphere (Geshwind, 1974).

More recent research has dispelled the notion of a minor hemisphere. In addition, a growing body of evidence suggests the notion of interhemispheric communication and the integrated mind (Gazzaniga & LeDoux, 1978).

For many years, the information available about the division of labor between the two cerebral hemispheres came from the split-brain work of Myers and Sperry. Sperry experimentally severed the corpus callosum in laboratory animals. The corpus callosum is the structure connecting the two cerebral hemispheres and through which the two sides of the brain communicate. This procedure allowed Sperry to train the hemispheres independently (Sperry, 1964). In 1960, Sperry's associate, Joseph Bogen, together with Philip Vogel, adopted this surgical technique for human patients with the hopes of controlling severe epilepsy by confining seizures to one hemisphere (Gazzaniga, 1967). Following surgery, these split-brain people exhibited no noticeable change in temperament, personality, or general intelligence. However, a series of subtle tests revealed that "the operation had clearly separated the specialized functions of the two cerebral hemispheres" (Ornstein, 1977, p.24).

The work done by Sperry, Myers, Bogen, Gazzaniga, and Vogel pioneered the field of hemisphericity. Studies were consequently done using normal people as subjects. Nebes (1978) reviewed the research on cognitive functions in the right and left hemispheres including the areas of language, spatial relations, closure factors, nonverbal stimuli, memory, emotion, and consciousness. He pointed out that the synthesis of the research at this point in time can only be viewed as an approach to hemispheric differences rather than a comprehensive statement of the organization of the cerebral functions in man (p. 132). A general overview of the hemispheric dichotomy, as compiled by several authors, is presented in Figure 1.

A cursory perusal of the list presented in Figure 1 is sufficient to establish the wide spectrum of ideas associated with cerebral functioning and hemisphericity. There are, however, several limitations to the bimodal model implied by Figure 1. James Morrow (1978) noted that when evaluating a list such as this, "what the readers do not necessarily know is that this bimodal model is a subjective interpretation of some rather specialized clinical data" (p. 74). He further noted: "A major drawback of dualistic reason is that it takes significantly distinguishable ideas - 'verbal', 'analytic', logical', 'rational', 'scientific', 'Western', - and treats them as if they were all roughly synonomous, practically interchangeable" (p. 75). In order to avoid these pitfalls, it was deemed necessary to critically examine the overall theory of hemispheric specialization and the specific areas of interest within the theory, which are relevant to this study.

Figure 1

General Hemispheric Dichotomy

Left Hemisphere

verbal	numerical
analytic	linear
abstract	euclidean
rational	logical
temporal	geometric
digital	inductive
objective	convergent
active	parts/segmented
tense	sequential
euphoric	masculine
sympathetic	mathematical
propositional	

Right Hemisphere

preverbal	subjective
synthetic	passive
concrete	relaxed
emotional	depressed
spatial	parasympathetic
analogic	appositional
visual	deductive
perceptual	divergent
intuitive	holistic/Gestalten
imaginative	creative
fantasy	relational
imagery	feminine
metaphoric	artistic
sensory	body image

Theories of Hemispheric Specialization and Integration

The theory of hemispheric specialization appears to be fraught with inconsistencies. Gazzaniga and LeDoux (1978) warn that the facts of lateralization have merged with the inferences. Lateralization has come to imply specialization (p. 47). These authors emphasize the role of interhemispheric duplication which provides for mental unity, as well as the ability to transfer information interhemispherically.

Among the inconsistencies of specialization theory, noted by Gazzaniga and LeDoux (1978) were: (a) both sides of the brain have been shown to be capable of conceptual and logical thought; (b) the right hemisphere can sustain language in the event of early damage to the left hemisphere; and (c) the right hemisphere's advantage on spatial tasks is deflated by methodological changes, i.e., minimizing the use of the hands. Gazzagina and LeDoux (1978) were deliberate in pointing out their belief that:

> what has become uniquely specialized and genetically specified in the course of human neural evolution is a potential for the expression of linquistic function. [Furthermore, they feel] that where linquistic functions ... settle down in the brain during development alters the ... brain plan so that homologous areas in opposite hemispheres come to carry out different functions. Thus, according to this view, lateralized functions do not reflect the genetically specified cognitive styles of the hemispheres but instead represent specific, localized differences in cerebral organization. (p. 72)

Dimond and Beaumont (1974) also referred to the paired organ system of the brain and its advantage in extending the capabilities of man through the two hemispheress working together. Their contention varied slightly from Gazzagina and LeDoux's (1978). Dimond and Beaumont concluded that each hemisphere has its own processing system and acts independently of the other until at a later stage (for instance, following completion of visual analysis) the information from the two hemispheres is integrated.

> There are thus two mechanisms at work ..., each complementing and correcting the answer obtained by the other, each perhaps working to complete the deficiencies of the other. (p. 62)

After a review of experimental studies of hemisphere function, Dimond and Beaumont (1974) concluded that only for more complex abilities does the one side of the brain exceed the other in proficiency. Figure 2 was taken from Dimond and Beaumont (1974). They further noted that different situational demands may reflect specialization.

The formulation of a general statement regarding cerebral specialization must recognize the bilateral nature of the system, with the contributions of one hemisphere playing a more important role than the other hemisphere in certain areas of functioning. At the same time, the interplay between the two hemispheres and the integration of functions must also be kept in mind.

Figure 2

Examples of Hemispheric Functioning

Left Hemisphere Channel	Right Hemisphere Channel
Speech and language	Spatial integration
Complex motor function	Calculation
Vigilance	Creative-associative thinking
Paired-associate thinking	

Both Hemispheres

Simple motor responses

Incidental learning

Fatigue processes

From Dimond & Beaumont, 1974, p. 83

Development of Hemisphericity in Children

There appears of be some question about when and for what functions cerebral dominance develops in children. There is, however, general agreement on several aspects of the development of dominance: (a) physiological, (b) lateralization and plasticity, and (c) environmental factors. The developmental sequence of the establishment of hemisphericity was discussed by Gazzagina (1974). Because the neural fibers connecting the two hemispheres (callosum) are not developed until the age of two, the very young child may be functionally split. Without the ability to extract meaning from language, McCallum and Glynn (1979) hypothesized that it is the right hemisphere which dominates in infancy. Turkewitz, Gardeon, and Birch (1965), and Crowel, Jones, Kappunial, and Nakagawa (1973) supported this hypothesis with the results of their studies with neonates. Galin (1976) reported that the corpus callosum may not be completely developed until age four and possibly as late as age ten.

Gazzaniga and LeDoux (1978) described a model of development based on competition for synaptic space. Briefly explained, they proposed that the human infant uses a predominantly manipulospatial mode of processing. Manipulospatial was defined as the mechanism by which a spatial context is mapped onto the perceptual and motor activities of the hands (p. 55). This predomination was viewed as consistent with McCallum and Glynn's (1979) hypothesized right hemisphere dominance in infancy. At around the age of two years, Gazzagina and LeDoux explained that the child acquires language which starts out bilaterally in development and (in most right handers) becomes largely left lateralized.

Inhelder and Piaget (1956) have shown that various spatial abilities do not develop until the ages of six or seven. Gazzaniga and LeDoux (1978) interpreted this:

> We suggest two developmental models of competition for synaptic space between language and manipulospatial functions. In normal development, language competes by emerging early and tying up space before manipulospatiality sets in. (p.62)

They reiterated:

> The key factor determining functional asymmetry is where language settles both between and within the cerebral hemispheres....To the extent that language uses up space within a hemisphere, nonlanguage functions of that half-brain must sacrifice space. (p.63)

Support for the right hemisphere as dominant for spatial orientation in young children was established by Harris (1973) and Knox and Kimura (1970b). Bogen (1975) attributed the change in this pattern with the acquisition of language to the neglect of the schools in fostering right hemisphere potential. Fadely and Hosler (1979) also agreed that the right hemisphere assumes priority early on. They noted the young child's reliance on concrete sensory information (sight, sound, touch, taste, smell, and kinesthetic awareness).

Developmental trends, as they are seen in specific processing channels, must also be considered. The literature review revealed that trends are evident in language and visual channels.

Investigations on language and hemispheric dominance are addressed here. A comparison of the effects of right and left hemispherectomy in infants was reported by Smith (1976). These findings revealed that there was no difference in subsequent language or nonlanguage functions and were interpreted as suggesting the existence of a biological substrata for language and nonlanguage cognitive functions present and duplicated in each hemisphere at birth. Molfese (1977a) studied infants, children (ages four to eleven years), and adult graduate students with regard to auditory evoked potential. His results indicated that for the infants (less than one year in age), the language stimuli were lateralized to the left hemisphere and the nonlanguage stimuli to the right. These findings were interpreted with regard to the general assumption that language is equally shared between the two hemispheres before the age of five (Lenneberg, 1967) and that cerebral damage to the language dominant hemisphere at an early age (20-36 months) may result in recovery of speech abilities:

> It becomes difficult to accept that the state of lateralization acquired would determine the recovery of language functions.....it appears that some other factor, such as brain plasticity which is thought to decrease with age might be the decisive factor. (p.196)

Entus (1977) concurred with this interpretation, stating that the results of his study of infants led to his conclusion that it is plasticity, rather than lack of specialization, which accounts for the equipotentiality of the infant brain. In a second study, Molfese (1977a, 1977b) examined the characteristics of stimuli which triggered responses in the infant and found acoustic and phonetic dimensions to be related to hemispheric specialization. Molfese cautioned against interpretation of these findings without close examination of assessment techniques and confounding factors.

Moscovitch (1977) reviewed the literature dealing with neurological, electrophysical, behavioral, and anatomical studies for the occurrence of functional and structural differences between the hemispheres in early life. Although evidence did not support the equipotentiality hypothesis, Moscovitch stated that this evidence "does not deny the possibility that some of the differences found in infancy may become more pronounced or that new differences may emerge as the child matures. In short, there may yet be a process of developing lateralization " (p. 196). Moscovitch further suggested that developing lateralization of language is a function of the different strategies adopted by each hemisphere in acquiring language: "that...language...will be represented differently in each hemisphere" (p. 199).

Several writers proposed that environmental experiences play a role in the rate of cerebral lateralization of children. Starck, Genesee, Lambert, and Seitz (1977) studied the effects of linguistically enriched schooling (i.e., English speaking children who were given instruction in French and Hebrew) on lateralized verbal processing with children in kindergarten, grade one, and grade two. A dichotic listening technique was used and social class and I.Q. were controlled. They found that children with multilingual experience demonstrated greater asymmetry, i.e., greater right ear advantage, than monolingual children. A follow-up study one year later led to the conclusion that "diversified language experiences may have strengthened and helped to stabilize the cerebral asymmetry of [the] trilingual subjects earlier than that of their peers" (p. 53) as reflected by ear asymmetry effects. Starck et al. (1970) discussed a study by Bever (1970) conducted with 4.5 year old boys from Harlem. The study involved an intellectual enrichment program which was found to be related to significantly stronger right ear effects and suggested that experimental enrichment does facilitate the development of cerebral asymmetry.

Does socioeconomic status affect ear laterality performance? Knox and Kimura (1970a) found a right ear effect for children ages five to eight years from a low socioeconomic area. No controls for comparison were employed. Geffner and Hochberg (1971) designed a study to compare children, ages four to seven years, from low and middle socioeconomic levels on ear laterality. They found right ear superiority for children from low socioeconomic areas to a lesser degree, however, than for children from middle socioeconomic areas. These findings were discussed in terms of possible factors which might account for the differences such as physical conditions of the home, malnutrition, parental lack of knowledge, family interaction and values, and size of family.

Conflicting evidence was found concerning the developmental trends of cerebral lateralization and the visual channel. Young and Ellis (1976) examined five, seven, and eleven year old children using tachistiscopically presented faces and found no indication of any increase in the degree of lateralization with increasing age. These authors noted, however, that the method employed may not have been sufficiently sensitive to detect an increase in lateralization. Eisert, Kelly, and Tomlinson-Keasey (1979) found that during the preschool years hemispheric specialization for holistic mental set was directed to the right side of the brain and for verbal stimulus to the left side. A tachistoscope was also used in this study. Interestingly, they found that the preschoolers were influenced by the order of stimulus presentation (whether the verbal or holistic stimulus was presented first). This was discussed in terms of a shift in hemispheric differences and the availability of cognitive strategies at this young age. Witelson (1977) summarized her review of right hemisphere specialization during childhood:

> The evidence strongly indicated greater participation of the right hemisphere in both nonlinguistic auditory perception and visual and haptic spatial perception by at least age 6, and possibly in infancy. (p.266)

The information presented above reveals an array of conflicting conclusions about the state of the research with regard to the development of cerebral dominance in childhood. The present state was discussed by Witelson (1977) in her attempt to critically examine 283 related studies. The following is a concise summary of her conclusions.

With regard to the lateralization of speech and language, Witelson (1977) reported:

1. Criticism of methodology must be noted, i.e., insensitive tests, and the increase in accurate responses as a function of age.

2. Most studies have been designed without concern for cognitive processes but rather to demonstrate the existence of lateralization.

3. Left hemisphere specialization does increase but "only as a secondary manifestation of cognitive development" (p.250). With an increase in age, linguistic and sequential processing become a larger part of the child's cognitive repertoire and therefore more cognitive functions can be lateralized to the left hemisphere.

4. The role of the right hemisphere in mediating speech and language is greater in children than in adults but is less than the role of the left hemisphere.

Witelson's remarks were in agreement with several very recent studies which were not included in her review. Hynd and Obrzut (1977) questioned the methodological intricities of the dichotic listening technique and were hesitant to conclude that the magnitude of the right ear effect actually increases as children progress developmentally. Piazza (1977) found that lateralization of left and right functions were present at ages three, four, and five years. She discussed these results, as did Witelson, in light of the early plasticity of hemispheric functioning.

With regard to a possible theoretical explanation of interhemispheric plasticity and the development of cerebral lateralization, Witelson (1977) explained:

1. Functional specialization exists for the left hemisphere before the age of five and possibly at birth. Again, it is noted that an increase with age may be a function of cognitive development.

2. Support is available for the hypothesis that the age of five may be associated with a change in plasticity of hemispheric functions. Age five is a critical age in terms of the development of some cognitive skills (language skills primarily) and therefore it may be the age at which these skills

are lateralized to the left hemisphere. If this is the case, the plasticity evident in the preschool child would be less evident in the child after the acquisition of these skills. Witelson notes that interhemispheric plasticity is still possible after age five, "although perhaps never as completely as before age 5" (Witelson, 1977, p. 270).

3. It is further suggested that puberty or the end of adolescence is associated with the termination of qualitative learning (i.e., Piaget's formal operations) and that this may also be the age at which "neural localization of functions becomes firmly established" (Witelson, 1977, p. 270). This suggestion is in agreement with Lennenberg's (1967) hypothesis that left hemisphere specialization for language increases with age. [This interpretation is adaptable to the theory of development proposed by Gazzaniga and LeDoux (1978) which explained the development of lateralization in terms of competition for synaptic space.]

4. "We have almost no evidence to indicate whether the left hemisphere plays an early role in spatial processing analogous to the right hemisphere's early role for language functions....The potential for the left hemisphere to mediate spatial processing appears to be limited" (Witelson, 1977, p. 273).

5. The right hemisphere may lose plasticity earlier in development than the left (Witelson, 1977, p. 275).

Several areas of agreement seem to be found recurringly in the research on the development of cerebral lateralization or dominance. First, there is a physiological basis for developmental theory. The physical development of the corpus callosum affects the nature of interhemispheric communication. The literature suggested several physiological explanations for cerebral lateralization. Competition for synaptic space was offered by Gazzaniga and LeDoux (1978). Others concurred that a biological substrata for nonlanguage and language functions is present at birth.

The equipotentiality hypothesis was applied to language development, i.e., language capacity may be shared equally by both hemispheres at birth. However, language was found to be lateralized to the left hemisphere and to become more pronounced with development. This was explained in terms of an increase in cerebral lateralization or a decrease in cerebral plasticity. On the other hand, the right hemisphere was found to have greater participation in nonlinguistic auditory channels, visual and haptic spatial perception early on. Specialization in some channels, then, was seen as operative in infancy with an increase in lateralization or decrease in plasticity occurring with development, and with the right hemisphere losing its plasticity earlier than the left.

The developmental increase in functional specialization was explained in relation to increased cognitive development. Because age five is associated with the development of cognitive skills, it was discussed as a critical age in the development of cerebral dominance for specific cognitive processes.

Other factors affecting the development of cerebral dominace may be found in the environment. Specifically, experience and socioeconomic level were shown to influence the results of dichotic listening tasks.

Perhaps the most obvious conclusion to be reached here concerns the research methodologies from which our results and conclusions were derived. The field has progressed significantly since the early days of research, however, our conclusions must always be viewed in terms of the methodologies employed and caution must be exerted in comparing studies which employed different instrumentation.

Sex

In a discussion of the issues relevant to hemisphericity or brain lateralization, the sex of the child is a variable which warrants consideration. In general, there exists significant differences between the performance of boys and girls on tasks which measure hemispheric function. These differences have been incorporated into the general theory of sex differences (Buffery, 1971). Research on the effects of lesions in epileptic children are further evidence in support of sex differences in the development of lateralized cerebral function (Buffery & Gray, 1972).

The sex differences in lateralized functions, as seen in the research, were multifarious and too numerous to detail here. Restak (1979) discussed sex differences in sound sensitivity, motor performance, performance as dependent on social context, curiosity, and verbal and spatial abilities.

Harris (1978) reviewed the scope of sex differences related to lateralization and included: recall and detection of shapes, mental rotation and identification, geometrical and mathematical skills, chess, sense of direction, certain Piagetian tests, and auditory perception. In addition, he discussed the roles of experience (socialization theory), genetic factors, neurological models, and the effects of sex hormones on brain specialization and nervous system activity.

Some experts agreed that boys specialize earlier than girls with regard to visuospatial tasks (Kail & Siegal, 1977; Witelson, 1976), while others simply acknowledged that boys are generally superior to girls on spatial skills (Berlin, 1979; Maccoby & Jacklin, 1974). On the other hand, in study of speech lateralization using an auditory test, Kimura (1963) found evidence that boys lag behind girls in perception of speech sounds at age four; this trend reached significance at age five and six, and then disappeared at ages seven through nine. She concluded that for the lateralization of speech girls develop more rapidly than boys. Eisert, et al. (1979) found that school age males exhibit a right hemisphere superiority for processing holistic materials. Witelson (1977), in an endeavor to analyze and summarize a complex compilation of research, stated that the nature of sex differences for nonlinguistic auditory processes is not clear. However, she affirmed the idea that there does seem to be a marked sex differences in neural representation of nonlinguistic, spatial, holistic processing.

Witelson (1977) agreed that there are sex differences in right hemisphere specialization,in contrast to a relative nonexistent sex difference for left hemisphere specialization. One theory which proposed to account for this sex differentiation dealt with the idea of competition between verbal and nonverbal functions served by the same hemisphere. McGlone and Davidson (1973) studied adolescents and found that females had a higher incidence of right visual field superiority on spatial tasks and suggested that the females' poorer performance on spatial tasks was due to the fact that the same hemisphere was serving the verbal and nonverbal function. Kimura (1969) commented on this. After affirming that differentiation of right and left hemispheres with respect to visuospatial ability may be greater in males than females, she explained: "Where a task can be performed with either left- or right-hemisphere mechanisms, males will employ right-hemisphere systems but females will not" (p. 457).

The research presented here reflected the nature and scope of the sex differences which have been associated with lateralized functions. Because of the difficulty in accurately assessing precisely what cognitive process and which hemisphere is being utilized by a subject in a research situation, it seemed appropriate to include the sex of the subject as a controlled variable in any research endeavor dealing with hemisphericity.

Handedness

The relationship between handedness and cerebral organization was found to be a topic of current research. In general, there were three areas of investigation of this topic: a) the electrophysiological and somatosensory correlates of handedness; b) the relationship between handedness and educational and developmental disturbances; and c) the relationship between handedness and speech and language (Beaumont, 1974). Beaumont (1974), based on laboratory studies by Dimond and Beaumont (1974), offered a model of cerebral organization and handedness which explained interhemispheric differences in terms of the complexity and integration of the task employed. From this limited representation of theories it can be seen that the role of handedness in cerebral dominance is unclear.

Commenting on the relationship between handedness and cerebral organization, Beaumont (1974) stated:

> It can be seen ... that there is no uniformity about the concept of cerebral dominance and its relation to handedness, but that there is a general concensus which accepts the presence of dominance relationships. It is the nature and degree of these which are in dispute. (p. 98)

Creativity

In looking at the information available on the relationship between hemispheric dominance and creativity, researchers appear to recognize that, although creative thought may be associated with the right hemisphere, the consideration of the role of both hemispheres must be made. This line of thinking is in agreement with the general conclusions reviewed in the section on hemispheric specialization. However, before a close examination of this topic can ensue, the term creativity must be clarified.

Definition of Creativity

The review of the literature revealed myriad definitions of the term creativity. Because it involves several behaviors, it was difficult to formulate any definition which was all inclusive. Two characteristics were agreed upon by most authorities: an aspect of newness, and the idea that it is a property possessed by everyone. The quality of newness was discussed in regard to whom the creative experience must be novel. Torrance (1965) contended that newness is relevant to the individual while a conflicting opinion by Stein (1953) asserted that creativity must be defined with regard to the culture in which it appears. That all humanity possesses a creative potential was an assumption supported in the literature (Guilford, 1965; Marksberry, 1963; Smith, 1966; Torrance, 1965).

The various attempts to establish a logical framework of meaning for the definitions of creativity have resulted in a diverse perspective on the topic. Within this diversity, an inbrication of ideas and theories was observed. Common theories of creative thinking included: traditional logic, classical associationism, Gestalt formulation of productive thinking, psychoanalytic conceptions, and the dynamic-perception theory of creativity. These theories were explained by Getzels and Jackson (1962, chap. 3). The theory of the transliminal chamber was also noted by Rugg (1963). Taylor (1963) looked at creativity as varying in depth rather than type, from expressive creativity (simple observation) to emergentive creativity in which a "new principle or assumption emerges at a most fundamental and abstract level" (Taylor, 1968, p. 25).

Many authorities presented explanations of creativity which focused on the creative product (MacKinnon, 1962, 1963; Rogers, 1959; Smith, 1966). MacKinnon (1962, 1963) referred to the product of a creative endeavor as fulfilling at least three conditions: (a) originality, (b) adaptiveness, and (c) realization or sustaining evaluation. Rogers (1959) saw the creative product as "growing out of the uniqueness of the individual on the one hand, and the materials, events, people, or circumstances of his life on the other" (p. 71). In terms of product, some authorities have viewed creativity as developing in stages. MacKinnon (1963) and Marksberry (1963) reviewed these stages: (a) period of preparation, (b) period of concentrated effort, (c) period of withdrawl (giving the creator time and freedom of growth), (d) period of insight, illumination or inspiration, and (e) period of verification.

The process orientation to creativity was evidenced in the writings of Anderson (1965), Barchielon (1961), Guilford (1965), Marksberry (1963), Sinnott (1959), and Starkweather (1971). Marksberry (1963) defined simple creativity as measured not by the product but "rather by the way an individual approaches the problems and incidents of life" (p.6). She further acknowledged that production necessitated certain psychomotor skills which may not be fully developed in young children.

Guilford (1965) reported his analysis of test scores and other measures from a large sample. His analysis revealed that a creative person possesses fluency and flexibility of thought, and originality. Guilford also listed the traits of sensitivity to problems, redefinition and elaboration. From his findings, he deduced that most aptitude factors which are associated with creativity belong to the class of divergent thinking abilities.

Several theories concerning the terms of creativity and intelligence were found in the literature. It was generally agreed that a certain level of intelligence is necessary for creativity; however, the antithesis was not true. Getzels and Jackson (1962) substantiated this statement when they found a positive but low correlation between the two. Torrance (1967) compiled the results of 178 coefficients of correlation between intelligence and composite creativity scores and found the median to be .20. Marksberry (1963) stated that creative thinking is "both a type of thinking and an aspect of critical or problem-solving thinking" (p. 8). Bloom (1956), in his taxonomy, viewed creativity as part of the synthesis process involved in evaluation. He saw creativity as an integral part of reflective, critical, and problem-solving thinking.

The literature suggested that every child has a potential for creativity. The definition adopted for this study was modified to insure legitimacy for the young child. It was concluded that creativity is a process (similar to the incubation and illumination stage described earlier) which may be displayed through a child's freedom of expression and his unusual ideas and thoughts. In concurrence with Guilford (1965), creativity was viewed as closely related to divergent thinking.

Creativity and Hemisphericity

Theorists such as Bruner (1965), in his work On Knowing: Essays for the Left Hand, have alluded to the belief that the left hand is perhaps responsible for the genesis of artistic and creative production. Likewise, Bogen and Bogen (1969) discussed the right hemisphere's role in the ontogeny of problem-solving with regard to neurologic evidence and nonneurologic explanations in their publication, "The Other Side of The Brain III: The Corpus Callosum and Creativity". Others restate or qualify the assertion that a relationship between the right hemisphere and creativity exists. West (1975) acknowledges the role of both hemispheres and the possibility of an altered state of awareness for creativity. He continues, "Creativity in many extraordinarily gifted individuals depends in part upon temporary dominance of the right cerebral hemisphere" (p. 221).

Rubenzer (1979) related two stages of the creative process to the receptive mode as explained by Deikman (1971). 9 when an individual is "instructed to produce as many solutions to the given problem without any evaluation as to their merit or practicality" (p. 88), and the illumination stage is described as "the appearance of the 'happy idea' together with the psychological events which immediately precede it" (p.86). The relationship of these two stages of creativity to the receptive mode (Deikman, 1971) was evidenced in experiments employing the electroencephalogram. Rubenzer (1979) stated:

> EEG pattern...the subjects reported shifts in cognitive styles and affective It has been discovered that when subjects succeeded in producing the alpha EEG pattern...the subjects reported shifts in cognitive styles and affective states. These states appeared to be closely related to insight states reported by creatively productive individuals. (p. 86)

Martindale (1977) investigated the relationship between the level of cortical arousal and creativity. He reported alpha blocking on all cognitive tasks for uncreative subjects, but differential reactions for creative subjects. In addition, he found that highly creative subjects exhibited high alpha activity and no difference between hemispheres, while medium creatives showed much more right alpha activity (low creatives showed low alpha activity and no hemispheric differences). He attributed these findings to the fact that speech was used in the testing procedure, that is, "highly creative subjects do indeed show comparatively more right hemisphere EEG activity during speech at least when they are compared with subjects of medium creativity" (p. 82).

The EEG studies supply perhaps the best documentation available on the nature of hemispheric specialization. Investigations of hemisphericity and creativity are also reviewed here.

Harnard (1972) tested graduate students and professors of mathematics and found a positive relationship between the nondominant, right hemisphere and creativity. Harnard employed a rating scale to measure creativity and saccadic eye-movements to measure the predominance of activity in the contralateral hemisphere. Criticism of his methodology was found (McNeil & Hamre, 1974), although Harnard's findings supported the idea that eye-movements are an index of hemispheric dominance with "inferences made from other sources such as unilateral cortical lesions, split-brain and dichotic listening experiments" (p. 654).

Williams (1976) found support for the assumption that divergent cognitive thought has a positive relationship to left lateral dominance. Using the Harris Test of Lateral Dominance and the Torrance Tests of Creative Thinking she found that for 9 to 12 year old subjects there existed a significant difference between lateral dominance and creativity. Specifically, she reported a one-way analysis of variance of main effects which indicated that the left lateral dominant group performed significantly better on the tests of verbal originality and figural elaboration. She related these two subtests to divergent cognitive thought and suggested that these findings be viewed as "evidence of the specialization of the right cerebral hemisphere in the ability to produce unique or statistically different responses" (p. 9).

Similarly, Dusewicz (1968), in a study using a creativity rating scale and test of lateral dominance, found no support for the hypothesis of a negative relationship between creativity and lateral dominance. The sample used in this study was 109 children from grades two through six. The use of a teacher rating scale, however, may be viewed in a critical light when evaluatng the results of this study.

The self-report method of assessing dominance was employed by Torrance and Mourad (1979). Torrance and Mourad examined the relationship between style of learning and thinking defined as "tendency for a person to rely more on one than the other cerebral hemisphere in processing information" (p. 44), as measured by Your Style of Learning and Thinking (Torrance, Reynolds, & Riegel, 1976), and the scores on a varied battery of creativity tests. Using a sample of graduate students, Torrance and Mourad (1979) concluded that creative behavior involves both hemispheres, however he stated that:

> the evidence produced by this study indicates rather clearly that persons classified as having a left hemisphere style of processing information attained lower scores than the other two groups on the measures of creative thinking ability and on the personality measures associated with creative behavior. (p. 53)

They further remarked that the nature of the task is related to the extent to which hemisphericity affects creativity and that:

> Superior adults having a style of information processing associated with right cerebral hemisphere functions and those having an integrated style of information processing appeared to be generally more effective than those with a left style and to have the motivations and personality characteristics usually associated with creative achievement. (p. 53)

The area of cerebral dominance as it is related to personality and learning was the topic of a book by Fadly and Hosler (1979). These authors provided a checklist for use by classroom teachers. The checklist was developed to aid in identifying the socialized mode of the Theta Child (left brain dominant) and the naturalized mode of the Alpha Child (right brain dominant). The following items on the checklist described the lateral thinking of the Alpha Child::

> Lateral thought - creative
>
> 1. Tends to be imaginative and fantasy oriented.
> 2. Develops unusual responses and solutions.
> 3. Tends to develop a variety of thoughts surrounding one stimulus.
> 4. Tends to automatically elaborate on ideas.
> 5. Can visualize and create unusual "things". (p. 151)

The right dominant child was seen by Fadley and Hosler (1979) as displaying traits usually associated with creativity.

Instruments

Dichotic Listening Technique

In congruence with the physiology of the human nervous system, each cerebral hemisphere receiving information primarily contralateraly, the human auditory system was found to receive stimuli from both ears with the stronger reception associated with the crossed connection (Kimura, 1973). Dichotic listening techniques were thus regarded as a means of determining hemispheric superiority (McCallum & Glynn, 1979). However, current investigations have revealed that various dimensions of acoustic stimuli must be considered when this technique is used (McNeil & Hamre, 1974). The acoustic stimulus is presented to both ears simultaneously. The hemisphere which receives the stimulus is dependent to some extent on the nature of the stimulus. Taking such variables into consideration, this method, has been employed as a means of assessing hemisphericity. Kimura (1973) reported evidence that "superior performance of one ear on dichotic listening tasks did in fact reflect a hemispheric specialization of function" (p. 70).

The dimensions relevant to hemispheric processing included linguistic and semantic characteristics of the stimuli, the type of presentation, differences in types of subjects, the administration variables as well as other stimulus variables (McNeil & Hamre, 1974). Those relevant to the present study were critically examined. Of specific concern were the linguistic status of the stimuli (verbal or nonverbal), subject variables (especially with regard to age and sex), and the syntactic quality and order of presentation of stimuli.

Kimura (1961) pioneered the area of dichotic auditory testing for hemispheric processing. Using an epileptic sample of 120 patients at the Montreal Neurological Institute, she concluded that "the crossed auditory pathways are stronger than the uncrossed" (p. 171). The left hemisphere was found to be dominant for reception of digits and the right hemisphere for melodies (Kimura, 1964); and further, voice quality was found not to "independently engage right or left hemisphere mechanisms since verbal and non-verbal vocal stimuli may be processed in differnt hemispheres" (King & Kimura, 1972), as determined in a study using hummed melodic patterns and vocal non-speech sounds (laughing, crying, sighing, etc.). McNeil and Hamre (1974) reviewed the literature and outlined the following division: the right ear more accurately perceives verbal or linguistic stimuli and the left ear transmission is greater for nonverbal or nonlinguistic stimuli.

Age and sex were reported to be related to dichotic listening performance. Curcio, Rosen, and Mackavey (1976) reported that dichotic right ear advantage was obtainable in normal reading children as young as five years of age.

Using digits as stimuli, Kimura (1963) reported that a right ear effect was achieved as early as age four. She noted, however, that these findings do not rule out the "participation of the right hemisphere" (p. 901) for speech function and that speech representation may be less rigidly established in children than in adults. In addition, Kimura (1963) found that although some research indicates that boys lag behind girls in speech development, there was no sex difference in the four to nine year olds tested. She stated:

> However, at the age of four, boys are significantly better on the right ear than on the left, and there is no trend for this to disappear at the early ages for boys or girls....There is...no evidence from these data that speech becomes represented in the left hemisphere any later in boys than in girls, though the possibility cannot be ruled out.

The issue of sex differences was more thoroughly addressed at another point in this review.

Age, as it is associated with the development of dichotic listening performance, was found to be an issue surrounded by controversy. The research which reports an increase or decrease of right ear advantage with age was fraught with discrepancies in procedures, materials, and subjects. Curcio, et al. (1976) criticized these developmental studies on the basis of their lack of controlled order of report patterns and their inability to address stability of dichotic listening performance (use of cross sectional samples). Curcio, et al. (1976) designed a study which corrected these two shortcomings and determined that controlled order of report was a more appropriate procedure in dichotic experiments.

The syntactic organization of the stimuli was also addressed. Curcio, et al. (1976) found that both sentence and digit materials were effective in tapping right ear advantage, although it was more likely for sentence material. This was related to maturity. Scholes (1969) found that for three year old children all types of stimuli are treated alike with the ability to use grammatical features acquired during the fourth year. Curcio et al. (1976) concurred with this finding. The kindergarten children in their sample processed "words-in-a-sentence in a way that does not take full advantage of their syntactic organization. To a degree they...[were]...processed as isolated word units" (p. 36).

A synthesis of the literature just reviewed and its application to this investigator's purpose resulted in the following conclusions:

1. Dichotic listening performance reflects hemispheric specialization of function.

2. Voice quality is not a relevant variable.

3. The ages and the sex of the subjects tested must be controlled.

4. The order of report of the stimuli must be controlled.

5. The syntactic quality of the stimuli must attempt to insure similar processing for all subjects and is therefore of a single word nature.

<u>The Product Improvement Task and The Unusual Uses Task</u>

Since creativity has been defined in terms of process, an evaluative measure developed by a sympathetic theorist was selected. The effectiveness of this measure with young children was another criteria of selection. The developer of the test stated a respect for the process interpretation of creativity and has designed an instrument suitable for use with young children (Torrance,1965). The instructions for the administration of the Product Improvement Task were thought to be clear and simple and therefore easily understood by children. For example: "Try to think of the cleverest, most interesting, and most unusual ways you can for changing this toy dog so that boys and girls will have more fun playing with it" (Torrance, 1976, p. 233). Likewise, the instructions for the Unusual Uses Task are: "Most people throw their empty cardboard boxes away, but they have thousands of interesting and unusual uses....[tell me] as many of these ...uses as you can think of" (Torrance, 1966b, p.7).

The issue of dimensionality was discussed with regard to the assessment of creativity. The problem of dimensionality was concerned with the differentiation between evaluative tools for creativity and other measures of a more cognitive nature such as achievement or intelligence tests. The latter's emphasis on conforming behavior, traditional academic values, and the need for creativity measures which are independent of conventional cognitive measures was commented on by Torrance (1976) and Treffinger, Renzulli, and Feldhusen (1971). The Torrance instrument was equated with divergent thinking (Torrance, 1966a).

The reliability of the _Torrance Tests of Creative Thinking_ (TTCT) was discussed by many researchers. The interscorer reliablilty of the TTCT was reported to exceed .85 (Torrance, 1966a; Halpin & Halpin, 1974). The factor most evident in lower interscorer reliability was the scorer's inadequacy in reading the scoring guide (Torrance, 1966a). Neither Torrance nor Halpin and Halpin reported results for the Product Improvement Task or the Unusual Uses Task specifically. With regard to the test-retest reliability of the TCTT, Torrance (1966a) cautioned that emotional, physical, motivational, and mental health factors influence creative functioning and therefore may be reflected in a lowering of reliability. Test-retest reliability for Forms A and B of the TTCT, (with 118 fourth, fifth, and sixth grade children) ranged from .50 to .93; 30% of which were above .71 (Torrance, 1966a, p. 21). Other studies reported reliabilities for the Product Improvement Task from .61 to .85 (Rouse, 1965; Torrance, 1966a). No reliability data related to the Product Improvement Task or the Unusual Uses Task for children under the age of six was found.

The need for more evidence in all areas of validation of the TTCT was acknowledged by its developer: "It is hoped that several studies now underway will provide more adequate evidence" (Torrance, 1976, p. 64). The available relevant information was reported here. In terms of content validity, Torrance (1966a) indicated that the tests are based on the "best theory and research now available" (p. 24). He noted that such areas as personality traits of creative people, properties of creative actions, and "research and theory concerning the functioning of the human mind" (p. 24) have all been considered under content validity. Construct validity was established by Torrance (1966a, 1967, & 1976) through a review of studies which dealt with the qualities the tests measured [characteristic personality traits: high self-image; humor; playfulness, relaxation, and originality as exhibited through their productions; wild or "silly" ideas; withstanding the "uncertainty of an undecided state" (Torrance, 1966a, p. 27); and a lack of rigidity]. Buros (1972) in _The Seventh Mental Measurements Yearbook_ reported Baird's conclusion that from the 50 studies on validity which were reviewed, it may be suggested "that the test does measure behaviors consistent with the literature on creative behavior" (p. 837). Criticism included the mention of the "extreme groups" (p. 837) utilized by some studies which compared "creatives" with an "unselected sample" (p. 837). Torrance (1966a) and his associates reported that they have been unable to find a "generally acceptable criteria of concurrent validity" (p.42). However, investigations into the relationship between creativity and intelligence, school achievement, teacher grades, teacher identification, peer identification, and sales productivity were included in reviewing this aspect of validity (Torrance, 1966a, & 1967).

Ogletree (1971) concluded from findings of his international study that "creativity measures exhibit a significant degree of concurrent validity in countries other than the United States" (p. 130). The limited information concerning predictive validity was favorable (Torrance, 1966a, 1972; Witt, 1971).

Torrance (1966b) employed a conventional method of scoring for originality, i.e., statistical infrequency. Included in the test manual was an "originality index" which was developed from "actual tabulations of responses given by subjects covering a broad educational span" (Torrance, 1965, p. 270). The Product Improvement Task was also scored for fluency and flexibility. The fluency score was obtained by tabulating the number of relevant or appropriate responses given. The flexibility score was determined by using the list of categories in the scoring guide. The responses were classified into these categories and the score was obtained by counting the number of different categories (Torrance, 1965, p. 269-70).

Limited normative data were available on the TTCT. For the Verbal Form A of the TTCT normative data were available for selected groups: The California school system, grades four through twelve; fourth and fifth grade students from a rural area in St. Croix, Wisconsin; and fifth grade students in suburban St. Paul, Minnesota. Other comparison group norms for high school and college subjects were presented. For Verbal Form B of the TTCT data was available for nine comparison groups: first through sixth grade, rural, small town Wisconsin; fifth grade, suburban, St. Paul, Minnesota; seventh grade, small town New Jersey; and college seniors at a Catholic Liberal Arts institution (Torrance, 1966a).

Verbal Expression Test

A subtest of the revised Illinois Test of Psycholinguistic Abilities (ITPA) was chosen to assess the expressive (vocal encoding) abilities of the subjects (Kirk, McCarthy, & Kirk, 1968). The ITPA was developed as a diagnostic tool to "deliniate specific abilities and disabilities in children (Kirk, et al., 1968). The examiner's manual which describes the verbal expression subtest stated as its purpose the assessment of the child's ability to "express his own concepts vocally" (p.11). This test was reported to evaluate the child's ability to use verbal symbols to transmit an idea.

The standardized administration and scoring of this test were found to be adequately detailed. In addition to the manual's explicit general directions, the developers included self-instructional practice exercises for the verbal expression subtest.

Waugh (1975) discussed the reliability of the ITPA. He found the subtests to have good internal consistency and the composite score to be reliable. Paraskevopoulos and Kirk (1969) also found internal consistency, with the median for the subtests to be .78, and the range to be from .48 to.96.

The construct validity of the ITPA was examined in several studies (Hare, Hammil, & Bartel, 1973; Newcomer, Hare, Hammill, & McGettigan, 1974, 1975). These studies factor analyzed the subtests with 20 criterion tests in order to determine their utility in assessing separate abilities. The verbal expression subtest was found to cluster with the criterion test which was designed to parallel it (Hare, et al., 1973; Newcomer, et al., 1974, 1975). Newcomer, et al. (1975) reported that the verbal expression subtest loaded (.72) on the factor titled "oral language usage" (p. 36). Newcomer, et al. (1975) remarked that "educators and clinical personnel who administer the ITPA may feel relatively secure in interpreting specific subtest results" (p.42).

Schmitt (1976) examined the use of the verbal expression subtest with articulation-defective children. The results of this study revealed significant differences between the articulation-defective and the control groups. In addition, Schmitt reported a "nearly 20-point mean raw score difference between the performance of the controls and both experimental groups on the verbal expression subtest" (p. 184).

The short form of the ITPA was chosen for use in this study in order to help minimize the amount of testing time needed. Newcomer and Hammill (1974), based on their investigation, reported that the short form of the ITPA can be justified in its use for the purposes of research and screening. Specifically, they found correlations of raw scores on the full and short form of the ITPA to be .89 for the verbal expression subtest.

III METHOD

In order to accomplish the objectives of this study, the methodology outlined here was employed. Subjects of three age groups were assessed on divergent thinking (Product Improvement Task and Unusual Uses Task) and hemisphericity (dichotic listening technique) . A test of v was also given to insure that the subjects' verbal abilities did not interfere with their verbal responses on the test of divergent thinking. In addition, the sex, age, and hand preference of the subjects were noted and included in the analyses.

Subjects

The subjects were selected at three age levels. These levels were chosen in agreement with the literature on the development of hemisphericity, i.e., an increase in hemispheric dominance with age may be a function of cognitive development (Witelson, 1977). The youngest subjects (age 3 years, 9 months to 4 years, 3 months) theoretically represented a lower level of cognitive development. If the age of five years is critical in the development of some cognitive skills, then these children represented the period before or possibly the beginning of this critical period in cognitive growth. The second age group (age 6 years, 9 months to 7 years, 3 months) represented the period between the cognitive growth spurt and the onset of puberty. The third group (age 9 years, 9 months to 10 years, 3 months) represented the age at which the development of hemisphericity is thought to be completely or nearly completely established. The literature made reference to puberty as the time during which "neural localization of functions becomes firmly established" (Witelson,1977, p. 270).

The subjects were selected from several sources. The four year old subjects were from two private nursery schools and the University Laboratory School in Blacksburg, Virginia. The seven year old subjects and the ten year old subjects were selected from the Giles County, Virginia, school district. The total number of subjects was to be 90, with 30 in each age group and 10 in each of the dominance groups (left, right, and mixed). The selection of subjects was limited to middle class children from southwestern Virginia. Because of the expected difficulty in finding right dominant subjects, the dichotic listening test was used for initial screening. The left dominant subjects were then to be selected randomly from all of the subjects who tested as left dominant. Only subjects who passed a hearing screening were retained as subjects. The hearing screening was administered by either a speech pathologist or audiologist and was completed within six weeks of data collection.

Instruments

Product Improvement Task and Unusual Uses Task

The subjects were administered the Product Improvement Task and the Unusual Uses Task (Form A) of the Torrance Tests of Creative Thinking. As was stated previously, the tests were chosen to assess divergent thinking because of their utility with young children and their adequate reliability and validity. The tests were administered and scored in accordance with the directions manual (Torrance, 1966b). Each subject was tested individually and scored on fluency, flexibility, and originality.

As explained in Chapter II, the child was shown a small stuffed toy elephant and ask to think of the "cleverest, most interesting and unusual ways...for changing this toy elephant so that children will have more fun playing with it" (p. 7). The child was then ask to think of as many interesting and unusual uses for empty cardboard boxes as he could. The responses were recorded and scored later by the examiner.

Dichotic Listening Technique

Because a shift in synaptic processing seems to occur in the early years and because of the developmental nature of this study, the use of single word material was used for the dichotic listening phase of this investigation to insure that the processing mechanism for all aged subjects would be similar. A controlled order of report was utilized to add a further control to the technique. The audio tapes used were constructed by Sawyers (1979). She reported the selection of task words from Palermo and Jenkins' (1964) established word association norms as matched for number of syllables and letters and as having the "same primary association for both sexes and ... no associative connection to any other word in the same four-pair group" (p. 47). (See Appendix A for word lists.)

A Wollensak stereo cassette tape recorder and stereo earphones were used. Volume imbalance was controlled by counterbalancing the headset.

Twelve groups of four pairs of dichotically presented words were heard by each subject. After each group of words, the subject was asked to report, in any order, all of the words remembered. An initial practice trial was done to insure that the subject understood the instructions. Trial twelve was a reinteration of trial six. Trials one and twelve were not scored and therefore, ten trials were scored. A maximum score for each ear was 40.

The pilot testing of this procedure revealed that the youngest subjects had difficulty remembering any of the four word pairs presented. When the words were presented two pairs at a time, the four year old subjects did not have difficulty responding. Therefore, this procedure was adopted and used with subjects in all three age groups.

Verbal Expression Test

The subjects were administered the short form of a subtest of the Illinois Test of Psycholinguistic Abilities (Kirk, et al., 1968), verbal expression. This test was administered and scored individually according to the procedure outlined in the examiner's manual.

The verbal expression test was given to insure that the divergent thinking tasks scores would not be affected by the child's inability to express his ideas. The subject's verbal expression score was viewed as a source of variance of the child's divergent thinking task score and therefore, the verbal expression score served as a necessary control.

The materials for the test consisted of three objects: a nail, a block, and an envelope. The subject was asked to verbally describe each object. Standardized eliciting responses for the examiner were outlined. The first object was designated for demonstration and the next two objects were used for actual testing. The examiner's manual suggested that response time be limited to about one minute and five encouragements be given if needed. The subject's responses were recorded and scored later by the examiner.

Handedness

The hand preference of the seven and ten year old subjects was assessed by handing the child a pencil at his/her midline and asking the subject to write his/her name. The hand(s) with which the subject grasped the pencil and wrote his /her name was noted. The four year old subjects were asked to draw a line between two points and the hand used was noted.

Analysis

The data collected with regard to hypotheses I and II of this study were analyzed by multiple regression procedures. Multiple regression was used to determine (a) the relationship between divergent thinking and hemisphericity (with verbal ability, sex, age, and handedness controlled); and the relationship between divergent thinking and hemisphericity (with verbal ability, sex, age, handedness, and interaction terms controlled). The data relating to the research question were also examined using frequencies and correlational statistics to examine the relationship between hemisphericity and age.

IV RESULTS, DISCUSSION, AND CONCLUSIONS

This study was conducted to examine the relationship between hemisphericity and divergent thinking and the relationship between age and hemisphericity. Hemisphericity, the tendency for a person to rely more on one cerebral hemisphere than the other in processing information, was assessed for language function by a dichotic listening task. Divergent thinking was assessed by two subtests of the Torrance Tests of Creative Thinking (1974): the Product Improvement test and the Unusual Uses test. Subjects were selected at ages four, seven, and ten years. The development of hemisphericity was studied in relation to age. This chapter is organized as follows: description of subjects, explanation of variables, reliability of dichotic listening task, analyses and discussion of hypotheses and research question, conclusions, and implications.

Description of Subjects

Three groups of subjects comprised the total sample of 92. Each subject's age, hand preference, sex, hemispheric dominance, verbal expression, and IQ were used in the analyses. Each subject was assigned to one of three groups according to age. Group I was four-year-olds. Group II was seven-year-olds. Group III was ten-year-olds. The mean age of the 27 subjects in group I w as 4 years, 8.5 months (range = 4 years, 0 months to 5 years, 6 months). For group II (N=30), the mean age was 7 years, 6 months (range = 7 years, 0 months to 8 years, 0 months); and for group III (N=35), it was 10 years, 6 months (range = 10 years, 2 months to 11 years, 4 months). Of the 92 total subjects, 39 were male and 53 were female. By group, the sexes were represented as follows: group I, 11 males and 16 females; group II, 11 males and 19 females; and group III, 17 males and 18 females.

An attempt was made to secure approximately equal numbers of subjects in each of three hemispheric dominance classifications of left, right, and mixed dominance. As was expected, more left dominant subjects were tested. Subjects were not arbitrarily assigned to hemispheric dominance groups as originally planned. Instead, the subjects' scores were calculated by subtracting the right ear score from the left ear score and then dividing by the total number of correct responses for both ears. The scores ranged from -1.0 to +1.0 (-1.0 = right dominance and +1.0 = left dominance), with 0.0 representing mixed dominance. The means and standard deviations of these scores are presented in Table 1.

Variables

Dependent Variables

The variables used in testing the hypotheses are described in this section. The dependent variable was divergent thinking. The two divergent thinking tasks, Product Improvement Task (PI) and Unusual Uses Task (UU), were each scored for fluency, flexibility, and originality. Several new variables were computed: Product Improvement total (PI total), Unusual Uses total (UU total), and divergent thinking total (DT total). Total scores for fluency, flexibility, and originality were computed by combining the appropriate subscore on PI and UU tasks. For example, the total fluency score was created by adding PI fluency and UU fluency. The total number of dependent variables was 12 (the three scores for each of two divergent thinking tasks and the six computed scores just explained).

Independent Variables

The independent variables for this study were hemispheric dominance (HD), verbal expression, sex, age, hand

Table 1

Means, Standard Deviations, and Range

of Hemispheric Dominance Scores

Group	n	Means	SD	Range
I	27	.18	.54	-.19 to +.93
II	30	.23	.36	-.47 to +.83
III	35	.09	.44	-.85 to +.93

preference, and interaction terms. The interaction terms were developed by multiplying HD by each of the other independent variables. Hemispheric dominance scores were created from the right and left ear scores on the dichotic listening task by subtracting the number of correct responses for the right ear from the number of correct respnses for the left ear and dividing this difference by the total number of correct responses. The absolute value of HD (AbHD) was also computed. Table 2 is a summary of the computation of new variables.

Reliability of Dichotic Listening Task

The dichotic listening task, consisting of 12 trials, was used to assess hemispheric dominance. Each subject was to listen to the 12 trials of four word pairs. (See Appendix A for word list.) Each word pair was presented through stereo headphones, one word to the right ear and another word to the left ear simultaneously. Because the youngest subjects had difficulty remembering four word pairs at one presentation, only two word pairs were presented at a time. After hearing the two word pairs, each subject reported the word(s) heard and these responses were recorded.

The dichotic listening task was designed with two identical trials (trial 6 and trial 12) in order to assess

Table 2

Computation of New Variables

New Variable	Computation
Product Improvement Total (PI Total)	Fluency + flexibility + originality on Product Improvement Task
Unusual Uses Total (UU Total)	Fluency + flexibility + originality on Unusual Uses Task
Divergent Thinking Total (DT Total)	PI total + UU total
Fluency Total	PI fluency + UU fluency
Flexibility Total	PI flexibility + UU flexibility
Originality Total	PI originality + UU Originality
Hemispheric Dominance (HD)	(left ear-right ear)/left ear + right ear) values from -1.0 to 0.0
Absolute value of HD (AbHD)	values from 0.0 to +1.0
Interaction Terms	Verbal expression x HD
	Sex x HD
	Age x HD
	Hand preference x HD

the reliability of the instrument. Each subject was scored for the number of identical responses given on these two trials, regardless of whether the response was correct. A consistency score was computed by dividing the number of identical responses by the total number of responses. These results are presented in Table 3. For the total group, the consistency score was 68%. Consistency scores of 70.7%, 60.2%, and 73.1% were reported for groups I, II, and III respectively.

Analysis and Discussion

The means and standard deviations of the divergent thinking total (DT total), Unusual Uses total (UU total), and Product Improvement total (PI total) are presented in Table 4. In Table 5 are presented the means and standard deviations for the verbal expression measure. The mean IQ score for group I was 24.2 with a standard deviation of 4.58. IQ scores were available only for group I. IQ was assessed using the Information and Picture Completion subtests of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI), a verbal and spatial task, respectively (Wechsler, 1949).

The Pearson Correlation Coefficient procedure was used in obtaining the correlation matrices for selected variables.

Table 3

Consistency Score for Dichotic Listening Task

Group	$\overline{X}$ Consistency Score	n	Missing Data
I	70.70	23	4
II	60.21	24	6
III	73.09	34	1
Total	68.00	81	11

Table 4

Means and Standard Deviations for Total Scores on Divergent Thinking, Unusual Uses,

Product Improvement, Fluency, Flexibility, and Originality Measures

Group	n	DT Total		UU Total		PI Total		Fluency Total		Flexibility Total		Originality Total	
		$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
I	27	20.42	8.07	6.11	4.66	13.52	7.26	11.39	4.67	5.54	1.56	5.96	3.24
II	30	51.63	27.93	27.20	17.70	24.23	14.18	32.03	17.87	10.27	5.30	9.33	8.11
III	35	88.09	73.55	48.86	40.43	41.23	39.60	48.60	41.93	15.26	6.08	24.08	28.25
Total Group	92	57.44	55.09	29.59	31.04	27.62	28.26	32.51	31.67	10.84	6.28	14.10	19.80

Table 5

Means and Standard Deviations

for Verbal Expression

Group	$\underline{n}$	Verbal Expression $\bar{X}$	Verbal Expression SD
I	27	8.96	3.16
II	30	16.70	4.75
III	35	16.80	3.63

These matrices are included in Appendix B and only those correlations of special interest are discussed in this chapter.

Correlation coefficients representing the relationship between sex, IQ, and verbal expression for group I are presented in Table 6. IQ was made up of a verbal and a spatial component based on the Information and Picture Completion subtests of the WPPSI. (Males were coded as 1, and females were coded as 2.) The correlation coefficient ($\underline{r}$ = -.35) between sex and verbal expression indicated that males scored higher than females on verbal expression. This finding was contrary to the literature on sex differences which reports males as less verbally competent than females (Hutt, 1972).

This difference could be related to the nature of this particular verbal expression test. Overall, verbal expression was not found to be highly correlated with the information component of IQ ($\underline{r}$ = .13). For males, verbal expression and information correlated ($\underline{r}$ = .41) which indicated a moderate relationship; however for females, the correlation was much lower ($\underline{r}$ =.13). One possible explanation of this difference may be a function of the scoring dimensions of the verbal expression test. The

Table 6

Pearson Correlation Coefficients for Group I:

Sex, IQ, and Verbal Expression

	Verbal Expression	IQ[a]	Information	Picture Completion
Total Group $\underline{n}$ = 27				
Sex[b]	-.35*	.40	.42**	.38*
Verbal Expression		.10	.13	-.07
Males $\underline{n}$ = 11				
Verbal Expression		.37	.41	.01
Females $\underline{n}$ = 16				
Verbal Expression		.22	.13	.20

[a]IQ = Information + Picture Completion

[b]Males = 1, Females = 2

*$p < .05$

**$p < .01$

subjects' responses on the verbal expression test were scored in several classifications. The classifications were: (a) label or classification, (b) color, (c) shape, (d) composition, (e) function or action, (f) major parts, (g) numerosity, (h) other physical characteristics, (i) comparison, and (j) person, place, or thing commonly associated with the object or with some action of that object. The classification by function or action of the object may be biased in favor of the males. For example, in response to the block, points were given for answers such as: "build with it", "stack them", "carve it", "saw it", or "it floats" (Kirk, et al., 1969, p. 64). Males might be likely to respond more proficiently in this action mode (McGuiness & Pribram, 1978). Thus, the higher scores of the males on the verbal expression test may be a result of accumulating more points in this scoring classification.

Hypotheses I and II

Multiple regression with listwise deletion of missing data was used to examine the effect of the independent variables on divergent thinking. For group I, IQ was also included in the list of independent variables. Divergent thinking was broken down into its component subscores and each of these subscores were entered into the regression as dependent variables (see Table 2 for component subscores).

Hypothesis I: Right-brain dominant children score higher on divergent thinking tests than do other children, either left-brain dominant, or mixed dominant. The regression equations and R^2 values for group I are presented in Table 7. Only those regressions in which the effects of hemisphericity on divergent thinking that reached levels of significance ($p < .05$) are shown in Table 7. Additional regression information may be found in Appendix C. The R^2 value of .536 for the total regression indicated that about 54% of the variance in PI total can be attributed to the linear combination of the independent variables. Likewise, the regression involving PI fluency (47%), PI flexibility (51%), and UU flexibility (32%) as dependent variables indicated that the variance in each of these variables may be attributed to the linear combination of the predictor variables. The use of standardized regression coefficients enables one to see the relative influence of each of the independent variables on the dependent variable, divergent thinking.

The standardized regression coefficients and correlations which represent the relationship between HD an the dependent variables, PI fluency, PI flexibility, UU flexibility, and PI total are reported in Table 8. The dependent variables associated with the Product Improvement task were found to be negatively related to HD. This seemed

Table 7

Regression Coefficients for Dependent Variables

Where HD Reached Significance for Group I

Dependent Variables	Independent Variables						
	HD	Verbal Expression	Sex	Age	Hand Preference	IQ	R^2
	Standardized Coefficients						
PI fluency	-.443	.497	-.209	.154	-.207	-.293	.471
PI flexibility	-.441	-.006	-.177	.352	-.110	-.484	.580
UU flexibility	.631	-.311	-.135	.162	.224	.263	.319
PI total	-.480	.448	-.157	.221	-.230	-.475	.536
	Regression Coefficients[a]						
PI fluency	-3.574 (1.682)	.633 (.301)	-1.918 (1.958)	.126 (.160)	-1.808 (1.915)	-3.13 (.225)	
PI flexibility	-1.037 (.474)	-.212 (.085)	-.476 (.552)	.842 (.045)	-.281 (.540)	-.151 (.063)	
UU flexibility	1.393 (.574)	-.106 (.097)	-.338 (.623)	.389 (.056)	.530 (.619)	.883 (.085)	
PI total	-6.708 (2.760)	.988 (.494)	-2.497 (3.212)	.314 (.262)	-3.487 (3.142)	-.879 (.369)	

[a]standard errors in parentheses

Table 8

Correlations Between and Standardized Regression Coefficients for Hemispheric Dominance and Selected Dependent Variables

Dependent Variables	r	B (Beta)
PI Flu	-.09	-.443
PI Flex	-.31	-.441
UU Flex	.37	+.631
PI Total	-.18	-.480

to indicate that right HD was associated with high scores on this divergent thinking measure. Diametrically, the Unusual Uses score, which was also significantly related to HD, was found to be associated in the opposite direction; that is, high scores on UU flexibility correlated with left dominance (*r* = .37).

The intercorrelation matrix of Product Improvement and Unusual Uses scores (Table 9) reflects the relationship between the two tests. Theoretically, if these two tests of divergent thinking were measuring the same construct, they should be highly intercorrelated. PI total and UU total were not highly correlated (*r* = -.14). Similarly, the correlations between the PI subtests and the UU subtests ranged from -.28 to .15; the correlation between the PI subtests and UU total ranged from -.18 to .01; and the correlation between the UU subtests and PI total ranged from -.24 to -.05. This suggested that the two tests were not measuring the same construct and indicated a need for further examination and comparison of these tasks.

In the four year old age group, more subjects scored higher on PI flexibility than on UU flexibility (Table 10). For PI flexibility, 37% of the subjects scored in the upper range of scores (4 - 6 points), while for UU flexibility,

Table 9

Intercorrelation of Product Improvement and

Unusual Uses Scores for Group 1

		2	3	4	5	6	7	8
1	PI Flu	.51*	.58**	-.12	-.19	-.17	.91**	-.18
2	PI Flex		.59**	.15	-.28	.01	.72**	.01
3	PI Orig			.01	-.18	-.10	.85**	-.09
4	UU Flu				.48*	.58**	-.05	.88**
5	UU Flex					.56*	-.24	.74**
6	UU Orig						-.14	.85**
7	PI Total							-.14
8	UU Total							

*$p < .01$

**$p < .001$

Table 10

Flexibility Scores on Product Improvement and Unusual Tasks

Score	PI flexibility	%	UU flexibility	%
Group I				
1	4	14.8	6	23.1
2	8	29.6	7	26.9
3	5	18.5	9	34.6
4	6	22.2	3	11.5
5	3	11.1	0	0.0
6	1	3.7	1	3.8
n	27		26	
range of scores	1-3 4-6	62.9 37.1	1-3 4-6	84.6 15.4
$\overline{X}$	2.96		2.50	
Group II				
n	30		30	
range of scores	0-6 7-12	60.0 40.0	0-6 7-12	70.0 30.0
$\overline{X}$	5.30		4.96	
Group III				
n	35		34	
range of scores	3-8 9-15	62.0 38.0	1-9 10-17	65.7 34.3
$\overline{X}$	7.57		7.74	

only 15.3% of the subjects fell in this range. This suggested that the four-year-old subjects were able to think of more categories of responses for the Product Improvement task than for the Unusual Uses task. This trend was not evidenced with group III where the ten-year-old subjects received similar scores on the flexibility measures for both the Product Improvement and Unusual Uses tasks. In group III, when the scores were separated into upper and lower ranges, PI flexibility and UU flexibility were separated in about the same proportions (PI flexibility - 62:38 proportion, UU flexibility - 66:34 proportion).

Torrance (1974) reported the mean verbal subtest scores for a sample of fifth graders (N=112). He reported lower mean scores for PI flexibility (mean score = 4.28) than for UU flexibility (mean score = 6.71). No intercorrelations were reported by Torrance.

This information may be interpreted as suggesting that for the preschool child, the Unusual Uses and Product Improvement tasks were not measuring the same construct, specifically with respect to the number of different categories into which responses fall. One possible explanation for this may be related to the properties of the tasks. The Unusual Uses task required a subject to think of "interesting and unusual uses" (Torrance, 1974, p.7) for empty cardboard boxes. This task confined the subject to utility-bound responses. On the other hand, the Product Improvement task asked the subject to think of "interesting and unusual ways...for changing this toy elephant" (p.6). For the Product Improvement task, a utility based response was but one way of changing the toy.

There is a paucity of research on creativity tests which are suitable for use with young children. Uses tasks have been found to be problematic with young children (Busse, Blum, Gutride, 1972). Four creativity tests were used by Busse in a study involving four year old subjects. One of these tests, a variation of Unusual Uses, was dropped from the study after pretesting because "it appeared that the children were not relating to it; few of the 40 pretest children gave meaningful responses to the items" (p. 289). In Busse's study, the subjects were asked to think of uses for an object (such as a toy dog or a toy monkey) a procedure similar to the one used in the present study. The difference between the tasks in the two studies was that in the Busse study, the child was presented with the object; while in the present study, the child had to imagine or to form a mental image of the empty cardboard box. If the preschool age subjects in Busse's study had difficulty giving meaningful responses to a question of uses when they were permitted to handle an object, it seemed reasonable to assume that preschool children would have more difficulty with a uses task which did not include a concrete object.

Another possible explanation could be based on the cognitive ability of the preschool child. The Product Improvement task afforded the subject the opportunity to look at, touch, and handle the toy elephant. The Unusual Uses task required a child to talk about the uses for imaginary boxes. Thus, a higher level of mental representation is required on the Unusual Uses task. The ability to consider several aspects of a mental representation is a thought pattern that most preoperational four-year-olds have not developed (Ginsburg & Opper, 1978). In responding to the Uses task, the group I subjects may have focused on only one type or size of box. The Product Improvement task provided the preschool age child with a concrete object about which he was asked to respond. The data seemed to support this explanation in that higher flexibility scores were reported for the Product Improvement task than for the Unusual Uses task . The data for groups II and III showed flexibility scores were closer for the two tasks. This may further support the explanation based on developmental cognitive limitations as responsible for the relationship between HD and UU flexibility.

For groups II and III, HD did not reach levels of significance for any of the dependent variables. The reason for the lack of significant findings in groups II and III may be related to the distribution of HD scores. These two groups had more cases of mixed dominance and fewer cases of right or left dominance. A more sensitive test may have been able to pick up more variation in the HD scores and thereby have contributed to significant findings. On the other hand, the development of interhemispheric communication or mixed dominance (Kraft, 1976) may have obscured the differences which the assessment of brain lateralization attempts to find. More elaboration on this idea is found in the discussion of the research question which deals with the development of hemispheric dominance. Thus, the nonsignificant results for groups II and III may be the combined result of an insensitive test and of brain laterality development, not to mention the obvious small sample size.

Furthermore, when evaluating the results presented here, individual differences in the rate of development and the types of previous experiences of the subjects were not assessed. Therefore these factors became part of the error term.

Hypothesis II: <u>Divergent thinking will be predicted by the independent variables and the interaction terms: sex x hemisphericity, age x hemisphericity, and hand preference x hemisphericity</u>. The interaction between verbal ability and hemisphericity was also included in the regression. To test this hypothesis, the R^2 change was calculated between the regressions which included and excluded the interaction terms. The R^2 change for the total group was not significant. For the total group, the R^2 values for divergent thinking total score without interactions was .361 and with interactions it was .366. (The zero-order correlations for this analysis are shown in Appendix B.)

Divergent thinking was hypothesized to be predicted by the independent variables and the interaction terms. The theory and prior research upon which this hypothesis was based suggested the existence of these interactions; however, because the research in this field is new, the nature and extent of these relationships remain unclear. This study has failed to find any significant interaction terms.

Research Question

Will age predict hemisphericity? Hemispheric dominance scores were computed for each subject by dividing the difference between the correct left and right ear responses by the total number of correct responses (HD = left ear - right ear / left ear + right ear). The means, standard deviations, and range of scores for each group are presented in Table 1. Figures 3 and 4 show the frequency of HD scores for each group. These scores fall between -1.0 and +1.0. Figures 3 and 4 show higher right ear scores across all three groups. This right ear superiority was consistent with the findings reported in the literature (Witelson, 1977) and was not necessarily due to the verbal nature of the response. Broadbent and Gregory (1964) found right ear superiority with a verbal stimulus and recognition responses. Furthermore, right ear superiority for processing language was found as early as three years of age and possibly in infancy (Witelson, 1977). These data, then, were in agreement with the findings of other researchers who have utilized the dichotic listening technique.

This discussion of dominance should also consider the chance that right-left differences may have been obscured by the level of processing required by the dichotic listening task or by attentional factors. If the memory component of

Figure 3

Frequency of Hemispheric Dominance Scores by Group

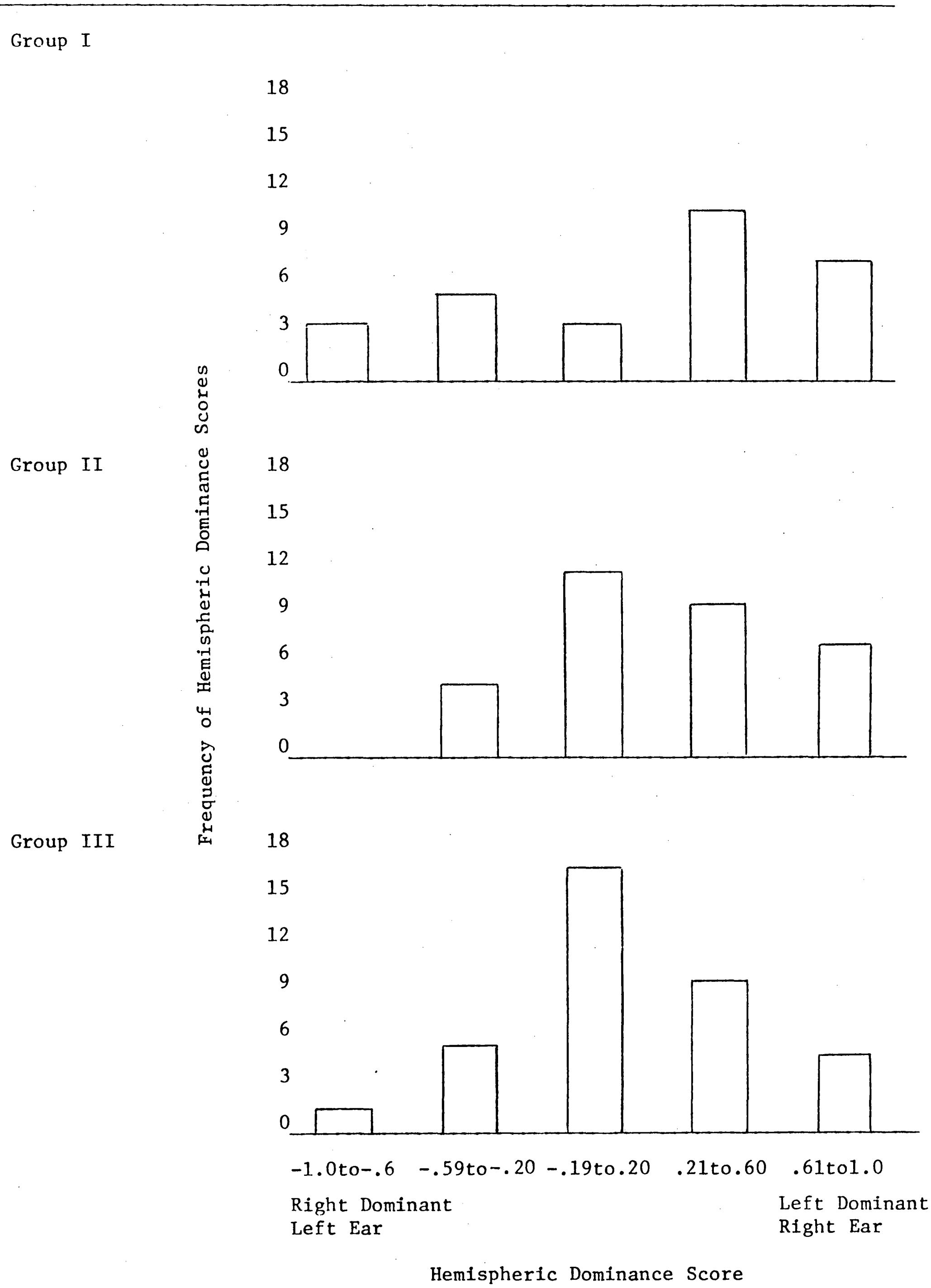
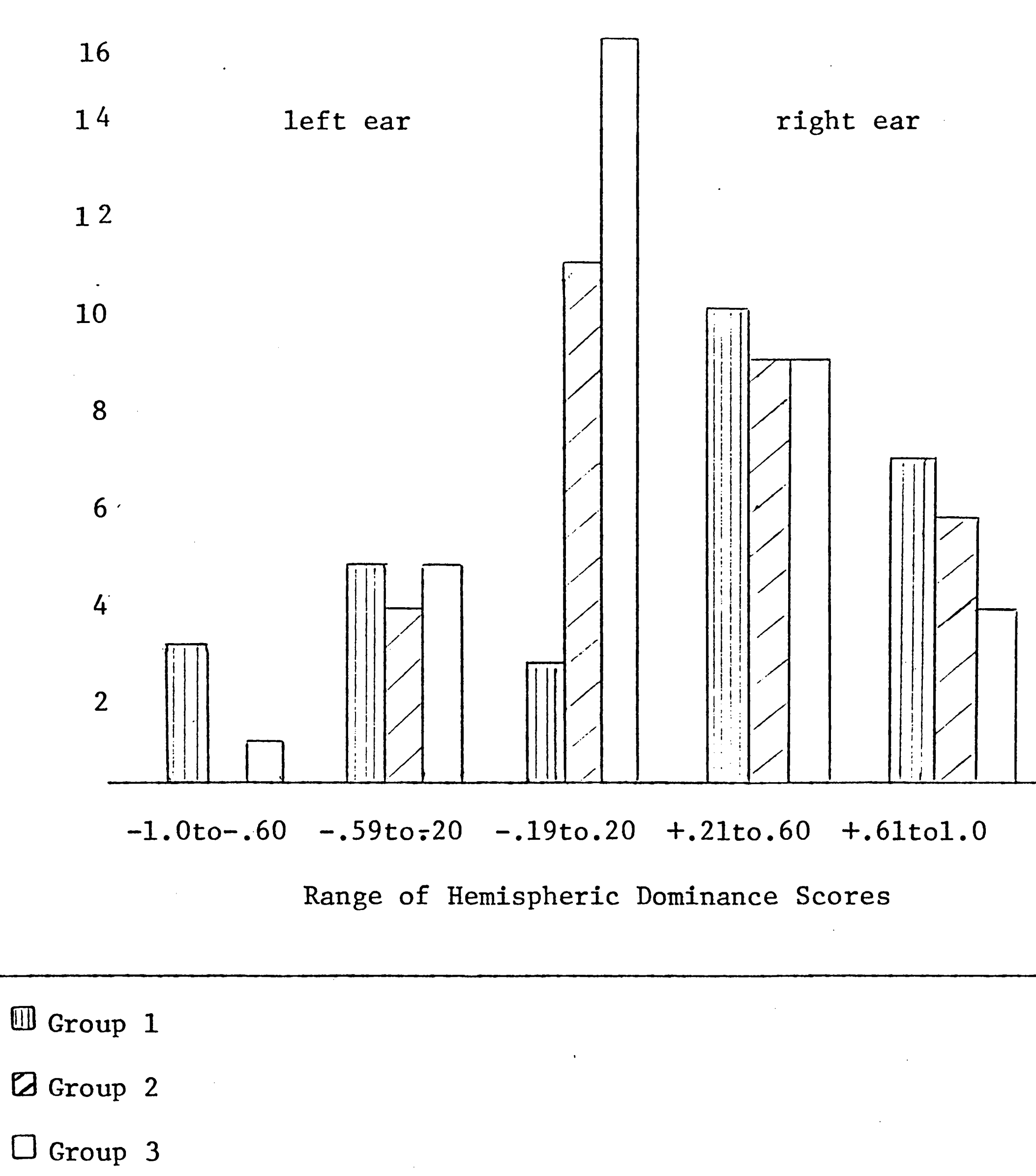


Figure 4

Frequency of Hemispheric Dominance Scores



the task were too difficult for the four-year-olds, a floor effect may have operated (Witelson, 1977). However, adjustments in the dichotic listening task procedure were made for this in the pilot testing phase of this study. Attentional factors which could have caused possible problems with group I subjects were recognized. The dichotic listening test was terminated for several of the preschoolers before concluding the twelveth trial and several others had to be encouraged to continue the task to its end. Thus attentional factors must be taken into account before further discussion can ensue.

The technical aspects of the dichotic listening task warrant mention here. The original reel-to-reel tapes were produced in a sound studio with meticulous controls for quality. Some of that quality was lost when the tapes were transferred to cassette form. Furthermore, the Wollensak stereo recorder which was used for testing in this study could also have some technical limitations.

In discussing these findings, several areas of controversy were considered. There is still a question about whether the dichotic listening technique is "sufficiently sensitive that the magnitude of ear difference is an index of the degree of hemispheric lateralization of function" (Witelson, 1977, p. 231). However, this study made the assumption that the dichotic listening technique would accurately and sufficiently distinquish between children for hemisphericity (Kimura, 1973; McCallum & Glynn, 1979). The question of magnitude of ear difference must be recognized. Some authors would agree that dichotic listening is at least a "correlate of laterality for speech and language functions" (Berlin, 1977, p. 303).

Another analytic problem addressed by Witelson (1977) was the claim that the magnitude of ear asymmetry is related to age, without consideration for the natural increase in overall accuracy which occurs with age. This study attempted to adjust for this problem by using the (left-right)/(left+right) formula. Moreover, the use of the dichotic listening technique for research in brain functioning is in its infancy and the theory upon which this study was based has seen little substantiating research. Therefore, it is possible that divergent thinking may be an aspect of cognition, considered specific to left or right hemispheres, which cannot be confidently investigated using the dichotic listening technique.

When the data were examined by sex, it was found that group I girls had a higher percentage of left dominance than

Table 11

Percentage of Subjects: Hemispheric Dominance by Sex

Group	Sex	n	Hemispheric Dominance Score[a]					Total
			Right Dominant Left Ear				Left Dominant Right Ear	
			-1.0 to -.60	-.59 to -.20	-.19 to +.20	+.21 to +.60	+.61 to +1.0	
I	Male	11	0.0	11.6	0.0	19.2	11.6	42.4
	Female	15	11.6	3.7	7.7	19.2	15.4	57.6
	Total	26[b]	11.6	15.3	7.7	38.4	27.0	100.00
II	Male	11	0.0	6.7	10.0	6.7	13.3	36.7
	Female	19	0.0	6.7	26.6	23.3	6.7	63.3
	Total	30	0.0	13.4	36.6	30.0	20.0	100.00
III	Male	17	2.9	2.9	25.6	8.6	8.6	48.6
	Female	18	5.7	5.7	20.0	17.1	2.9	51.4
	Total	35	8.6	8.6	45.6	25.7	11.5	100.0
Total	Male	39	1.1	6.6	13.2	11.0	11.0	42.9
	Female	52	5.5	5.5	18.7	19.7	7.7	57.1
	Total	91	6.6	12.1	31.9	30.7	18.7	100.00

[a]Scores by range

[b]Missing data = 1

boys (Table 11). Group I boys had greater left dominance than right dominance but the difference was not as pronounced as it was for girls. Witelson (1977) cautioned against any overinterpretation of these findings, noting Kimura's (1963) study in which early ear asymmetry was reported for both girls and boys. Sex differences may be in overall accuracy, a reflection of "the earlier development of language skills in females. But this does not necessarily mean greater lateralization" (Witelson, 1977, p.232). The sex differences in dominance scores were not as pronounced in groups II and III. As previously stated, when sex differences were ignored, the the number of subjects in the mixed dominance area increased with age. This same trend was seen for both girls and boys separately, but especially among the boys. The percentage of total subjects per group by sex along the HD continuum is presented in Table 11. In group I 0.0%, in group II 10.0%, and in group III 25.7 % of the male subjects were in the center of the continuum (more highly mixed dominance). This was representative of the overall pattern which was found when sex was not considered.

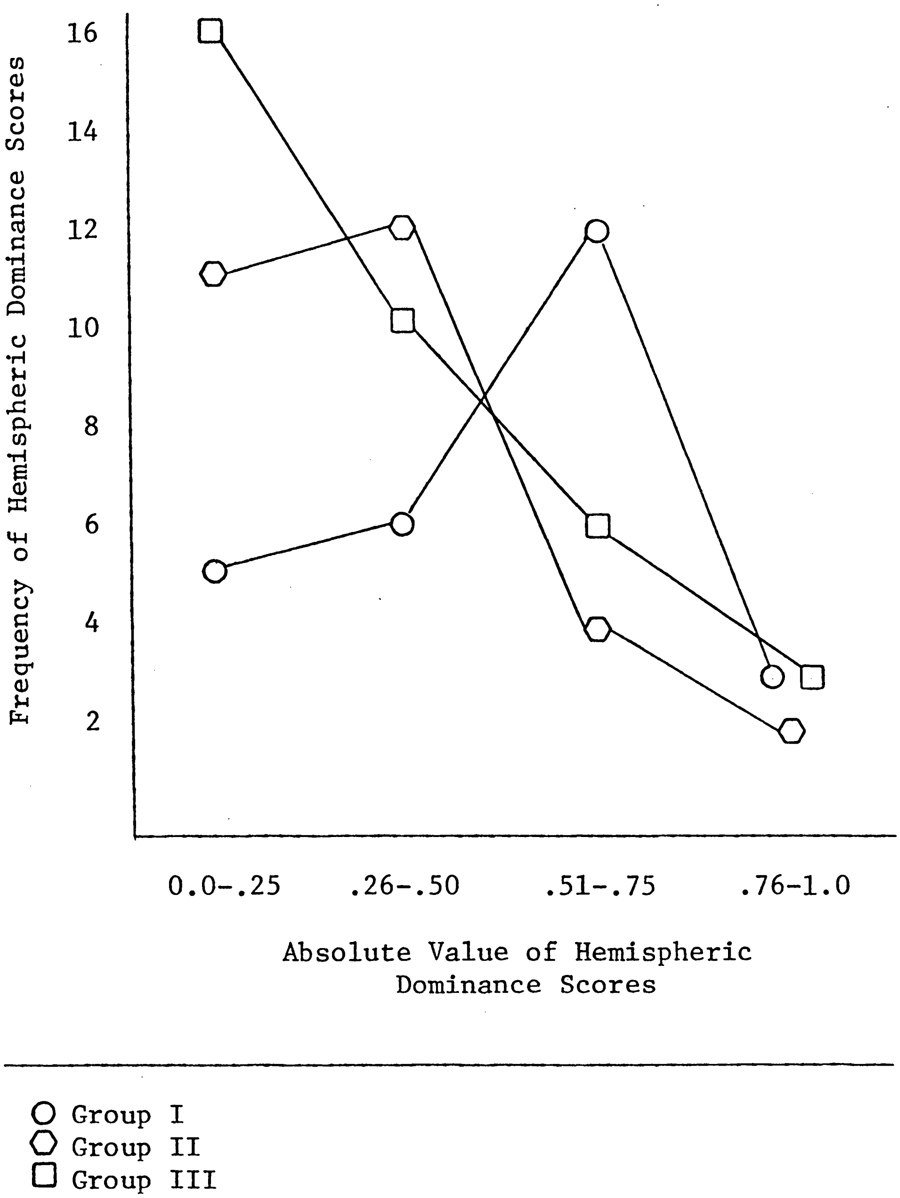
The next step in the analysis was to assign an absolute value to the HD scores (AbHD). A low absolute value for any HD score represented a subject with mixed or undifferentiated dominance. A higher absolute value, approaching 1.0, represented a subject with more highly differentiated hemispheric dominance. These frequencies are presented in Figure 5. The results seemed to indicate that cases of mixed hemispheric dominance increase with age. There were more cases of highly mixed dominance in group II than in group I and in group III than in group II. The correlation coefficient between age and AbHD was significant, $\underline{r} = -.19$, $p < .03$.

Some prior research indicated that there is an increase in the degree of lateralization with increasing age (Witelson, 1977). This research was explained with regard to increased lateralization as a function of cognitive development. Other research, such as that by Young and Ellis (1976), found no increase in lateralization with age. In the Young and Ellis study, lateralization was measured by the dicoptic technique, and the authors remarked that the method used may not have been sufficiently sensitive to detect an increase in lateralization. The findings of the present study were not in agreement with the research reviewed by Witelson (1977) and it is difficult to compare the findings of this study to the results of Young and Ellis because different methods were used to assess lateralization.

Figure 5

Frequency of Absolute Value of Hemispheric

Dominance Scores by Group



The frequencies in Figure 5 indicated that the patterns for groups II and III are similar while for group I the pattern deviates. The frequency of the highest AbHD score (.76 - 1.0) was low; and so ignoring this datum point for a moment, the differences between group I and groups II and III were more obvious. Were these patterns the result of physical neurological maturation? Galin, et al., (1979) provided evidence for a hypothesis proposed by Kraft (1976) which stated that during the preschool years, interhemispheric communication is established by the myelination of the fibers of the corpus callosum. From his study of preschool age children, Galin reasoned that interhemispheric communication was greatly improved between the ages of three and five years. Kraft's original premise suggested improved interhemispheric communication as a possible explanation for Piagetian conservation and reversability. Using an EEG, she monitered the brain wave activity of her subjects while engaging in conservation of substance tasks. She found more balanced hemispheric activity for subjects who had achieved conservation, thus making a case for the relationship between conservation in Piagetian tasks and interhemispheric communication.

These findings by Galin and Kraft may be used in understanding the data presented in Figure 5. What happened to the subjects between the ages of four and five, and the ages of seven and ten, which is related to the larger number of undifferentiated dominance scores? Kraft's hypothesis of interhemispheric communication associated with the maturation of the corpus callosum was one possible explanation.

Related to this explanation, was the idea that with the increase in age and in cognitive growth comes the ability to better use both hemispheres. The data showed more correct responses and a trend toward mixed dominance as age increased.

Conclusions

The findings of this study indicated that for the preschool age subjects, there was a positive relationship between right hemispheric dominance for language and divergent thinking as measured by the Product Improvement task (Torrance, 1974). The two divergent thinking tasks (Torrance, 1974) used in the study appeared to be measuring different constructs for the preschool age subjects, i.e., the intercorrelations between the Product Improvement task and the Unusual Uses task were low. For the Unusual Uses task, the subjects had to form a mental image of a box(es) and this suggested that the uses task required a higher level of mental operations than is available to the four-year-old child. Because the responses on the Unusual Uses task are confined to the utility of an object, it was possible that the number of relavent responses was further reduced. Thus, the Unusual Uses task may not be appropriate for use with preschool age children.

There was no relationship between hemisphericity and divergent thinking for the two older groups. This may be a function of the insensitivity of the dichotic listening technique, in that it may not have picked up the total variation in ear differences. It could also be a result of the development of interhemispheric communication, or of both. The interactions of sex, age, hand preference, and verbal expression with hemisphericity were hypothesized to contribute to the variance in divergent thinking. No meaningful interactions were found for any group.

With regard to the development of hemisphericity, there appeared to be a trend toward greater mixed dominance with age. This finding was discussed as a function of physical cerebral maturation. Galin, et al. (1979) and Kraft (1976) theorized that as the corpus callosum matures, more interhemispheric communication occurs. This development of interhemispheric communication and advance in the ablility to better use both hemispheres was associated with an increase in age and with cognitive growth.

Implications for Further Study

Many of the problems usually associated with research on cerebral hemispheric dominance were recognized and incorporated into the discussion of the findings of this study. These problems were predominantly methodological in nature and need to be investigated in future research.

First, there is a need to examine the reliability and validity of the dichotic listening technique in assessing hemispheric dominance. Although the listening task in this study showed fair consistency of responses, there is a need for reliability measures based on performance over time, i.e., over periods of weeks and/or months. Second, validation of this technique for differentiation of functional dominance (perhaps through the use of an EEG) is another area that needs further investigation. The measurement of response time in investigations of hemispheric dominance which use the dichotic listening technique has been theorized as a possible link in the assessment of interhemispheric communication or interference (Springer, 1977) and warrants attention in future investigations.

Third, there is a need for more longitudinal studies which would assess the changes in hemispheric dominance over time. The findings of this study showed that cases of mixed dominance increased with age, particularly between the ages of four and seven years. A longitudinal study would provide better quality information about individual changes or patterns.

Fourth, investigations of patterns of hemispheric dominance is another arena for testing Piagetian theory. Although Piaget did not specifically attribute cognitive advances to patterns of cerebral hemispheric dominance, his theory of the development of intelligence may prove to be a productive base for testing theories of brain development. Specific to this study and the finding of increased mixed dominance between ages four and seven years, is the relationship of increased mixed dominance to Piagetian explanations of cognitive growth. More investigations of the application of Piagetian theory of the development of hemisphericity are needed.

The possible association between cognitive growth and hemispheric dominance suggests that the relevance of brain dominance research to educational practices and outcomes may also prove to be a productive line of inquiry. "The level of maturation of the brain determines the rate at which an individual is able to learn a given material and whether, at whatever rate, he is capable of learning that material, (a) by the usual methods; and/or (b) by specially designed methods" (Kinsbourne, 1980, p. 339). Rekdal (1979) suggested that information about patterns of hemispheric dominance may be useful in identifying creative individuals. More investigations dealing with the nature of the association between creativity and hemispheric dominance are needed. Such investigations might assist the classroom teacher by creating an awareness of right-brain strategies.

The search for the connection between hemisphericity and creativity may require more precise measurement of both functional hemispheric dominance and creativity. This investigation revealed that the Product Improvement and Unusual Uses tasks apparently did not measure the same construct with a preschool sample. Findings such as this point up the need for more research employing various tests of creativity, especially with young children.

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Appendix A

DICHOTIC LISTENING TASK WORD LIST

Dichotic Listening Task Word List

Practical Trial

anger	eagle
become	doctor
swift	stove
whisky	fingers

Trial 2

dark	stem
man	joy
soft	tell
at	am

Trial 3

cry	get
house	stand
sell	this
thinner	running

Trial 4

girl	jump
street	where
chair	swift
on	an

Trial 5

baby	over
is	me
quiet	heavy
rough	fruit

Trial 6

younger	working
only	river
spider	carpet
lamp	salt

Trial 7

always	butter
from	moon
how	sit
faster	doctor

Trial 8

slow	come
eating	needle
justice	blossom
cold	guns

Trial 9

dream	speak
square	priest
boy	now
earth	stove

Trial 10

trouble	command
bath	king
hungry	window
numbers	because

Trial 11

high	they
sour	loud
sleep	white
fingers	thirsty

Trial 12

younger	working
only	river
spider	carpet
lamp	salt

Appendix B

CORRELATION MATRICES

Table A

Correlation Matrices of Independent Variables by Group

	Hand Preference	Sex	Hemispheric Dominance	Verbal Expression	IQ
Group I					
Age	.38**	-.06	-.06	.15	.17
Hand Preference			-.15	-.21	-.11
Sex			-.10	-.35*	.35*
Hemispheric Dominance				.36*	.09
Verbal Expression					.16
Group II					
Age	.29	.03	.19	.13	
Hand Preference			-.02	.13	
Sex			.09	-.33*	
Hemispheric Dominance				.20	
Group III					
Age	.40	-.32**	-.09	-.09	
Hand Preference		.03	-.05	.17	
Sex			-.14	.03	
Hemispheric Dominance				-.07	
Total Group					
Age	.01	-.11	-.12	-.58	
Hand Preference		-.01	-.05	.06	
Sex			-.10	-.16	
Hemispheric Dominance				-.04	

*$p \leq .04$
**$p \leq .03$

Sex: male = 1, female = 2

Hand Preference: right = 1, left = 2

Table B

Pearson Correlation Coefficients:

Interaction Terms

	HP x HD	Sex x HD	Verbal Expression x HD
Group I			
Age x HD	.98	.95	.93
HP x HD		.95	.91
Sex x HD			.84
Group II			
Age x HD	.98	.93	.95
HP x HD		.91	.94
Sex x HD			.87
Group III			
Age x HD	.95	.95	.98
HP x HD		.88	.91
Sex x HD			.96
Total Group			
Age x HD	.93	.87	.94
HP x HD		.90	.90
Sex x HD			.86

HP (Hand Preference)

HD (Hemispheric Dominance)

All significant *p* .001

Appendix C

R^2 VALUES FOR REGRESSIONS BY GROUP AND DEPENDENT VARIABLE

Table C

Hypothesis I: R^2 Values for Regressions[a]

by Group and Dependent Variable

Dependent Variable	Group			
	I	II	III	Total Group
PI Fluency	.47	.29	.43*	.28*
PI Flex	.51	.24	.42	.39**
Orig	.43	.19	.38	.15
UU Fluency	.61	.11	.46*	.37**
Flex	.32	.12	.20	.38**
Orig	.61	.20	.40	.29*
PI Total	.53	.29	.45*	.28*
UU Total	.56	.16	.43*	.37**
Fluency Total	.41	.20	.48*	.37**
Flexibility Total	.35	.14	.24	.46**
Originality Total	.27	.25	.40	.24*
DT Total	.40	.23	.46*	.36**

[a]independent variables: hemisphericity, verbal expression, sex, age, hand preference (IQ included for group I only)

*$p < .05$

**$p < .01$

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DIVERGENT THINKING AND HEMISPHERICITY

by

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(ABSTRACT)

This study investigated the relationship between divergent thinking, assessed by the Product Improvement and Unusual Uses tests of the Torrance Tests of Creative Thinking (1974), and hemisphericity. Hemisphericity, cerebral hemispheric dominance for language function, was assessed by a dichotic listening technique. Sex, age, hand preference, and verbal expression (assessed by a subtest of the Illinois Test of Psycholinguistic Abilities) were controlled. Subjects were selected at three age levels: four years, seven years, and ten years. For the four-year-old group, the findings indicated that a significant positive relationship existed between the fluency and flexibility scores on the Product Improvement task and right dominant subjects; while a significant negative relationship existed between the flexibility scores on the Unusual Uses test and right dominant subjects. In an effort to explain these contradictory findings, the low correlation between the flexibility scores on the Product Improvement and Unusual Uses tasks was noted and discussed in terms of the possibility that these two tests were not measuring the same construct.

The effect of hemisphericity on divergent thinking did not reach significance for any other age group. No meaningful interactions were found when the following independent variables were analyzed: sex x hemisphericity, age x hemisphricity, hand preference x hemisphericity,

and verbal expression x hemisphericity.

When cerebral dominance was examined across the three age groups, there was an increase in mixed dominance with increasing age. This finding was discussed with regard to the physiological maturation of the corpus callosum which may contribute to interhemispheric communication. Further discusssion acknowledged that with an increase in age and cognitive growth comes the ability to better use both cerebral hemispheres.

Several limitations were considered in the discussion of the results of this study. These included: insensitivity of tests, attentional factors, the role of memory in the dichotic listening task, technical limitations associated with equipment, and the paucity of previous research on which to build in the area of hemisphericity and its relationship to creativity.

It was concluded from the findings of this study that for preschool age subjects, there is a positive relationship between right hemispheric dominance for language and the fluency and flexibility scores on the Product Improvement Task. With regard to the development of hemisphericity, the findings of this study indicated a trend toward greater mixed dominance with increasing age.