

INFORMATION TO USERS

The most advanced technology has been used to photograph and reproduce this manuscript from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

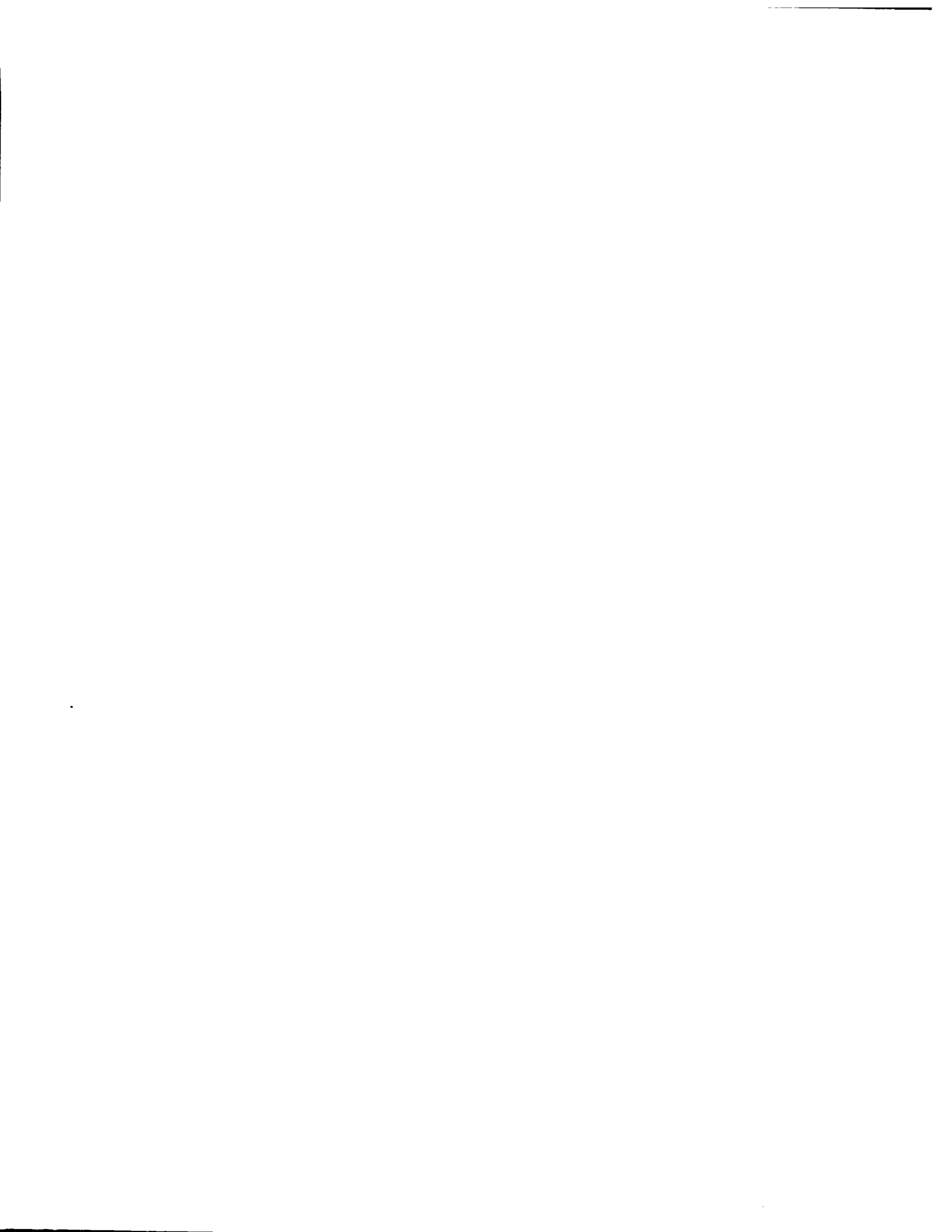
In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

U·M·I

University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346, USA
313 761-4700 800 521-0600



Order Number 9029954

**Development of lateral differences in perceptual versus semantic
matching of line drawings by 4- to 12-year-old children**

Kuslansky, Gail, Ph.D.

City University of New York, 1990

Copyright ©1990 by Kuslansky, Gail. All rights reserved.

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106



A

Development of Lateral Differences
in Perceptual Versus Semantic Matching of Line Drawings
by 4- to 12-Year Old Children

by

Gail Kuslansky

A dissertation submitted to the Graduate Faculty in Psychology
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New York.

1990

© 1990

GAIL KUSLANSKY

All Rights Reserved

ii

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

7/14/90

Date

Jean Moreau

Chair of Examining Committee

Copy 4

Date

Robert C. Santogrossi

Executive Officer

Dr. T. Moreau

Dr. H. Schuckman

Dr. S. Shapiro

Supervisory Committee

The City University of New York

Abstract

DEVELOPMENT OF LATERAL DIFFERENCES IN PERCEPTUAL VERSUS SEMANTIC MATCHING OF LINE DRAWINGS IN 4- TO 12-YEAR OLD CHILDREN

by

Gail Kuslansky

Advisor: Professor Tina Moreau

Sixty right-handed boys (20 in each of three age groups, 4-6, 7-9 and 10-12 years of age) were presented tachistoscopically with line drawings of familiar objects, with a standard stimulus picture presented to the left or right of central fixation for 150 msec, followed by two side-by-side comparison picture stimuli: (1) a perceptual/configurational match; and (2) a semantic/categorical match. The children were instructed to pick the comparison picture that "goes best" with the (standard) picture that preceded and to indicate their preference by moving a manipulandum ("joystick") in the direction (left or right) of the chosen comparison. The two response measures were: 1) matchtype (perceptual/configurational or semantic/categorical) and 2) reaction time. Younger children were expected to make more perceptual matches and fewer semantic matches than the older children. A RVF/LH advantage for semantic matches and a LVF/RH superiority for

perceptual matches was hypothesized, with an age-related shift from a preference for perceptual matching (LVF/RH) to a preference for semantic matching (RVF/LH). Although all the boys made more semantic than perceptual matches, the youngest group made significantly more perceptual matches than the older children, a finding consistent with Piaget and other developmental theorists. Whereas no visual hemified asymmetry in reaction time was shown for perceptual matching, an unexpected "laterality shift" was demonstrated for semantic matching, with a progression from a LVF/RH advantage in the 4-6 year olds, to no visual hemified asymmetry in the 7-9 year olds, to the typical adult-like RVF/LH superiority in the 10-12 year olds. The results are consistent with Goldberg and Costa's (1981) theory of laterality regarding acquisition of descriptive codes, and the role of the right hemisphere in the acquisition of language in children (Dennis, 1980; Schneiderman, 1988). Findings are discussed with respect to the developmental literature regarding the emergence of matching and categorizing skills in children, and to the laterality literature with special consideration of the differing views concerning the development of lateralized functions, including Lenneberg's (1967) theory of progressive lateralization and Kinsbourne's (1975, 1981) theory of developmental invariance.

ACKNOWLEDGEMENTS

My heartfelt thanks and endless gratitude to:

my dissertation committee--

Dr. Tina Moreau, for her wisdom, guidance, editorial expertise, emotional support, and cherished friendship....

Dr. Harold Schuckman, for being there from the first tentative steps in undergraduate "physio" to the dissertation research and defense....

Dr. Sandra Shapiro...first, for suggesting a return to school...second, for cheering me on when the going got rough...third, for filling in at the last minute...and always, for friendship....

Dr. Mitchell Kietzman, for introducing me to the pleasures and pitfalls of psychological research....

My outside readers, Drs. Gerald Turkewitz and Jeffrey Halperin, for their insightful commentary and thought-provoking questions.

I am so thankful to have had the opportunity to make new and lasting friendships - David J. Scarisbrick, Alison Pratt, Roxanne Hughes-Wheatland, and Bill Matos, who sweated, moaned and cheered along with me. Extra thanks to Dave who spent countless hours patiently wrestling with the statistics. Special thanks to Stan Shamm and Mark Cullen who provided hardware, software, laughter, tears,

friendship and more. And to my friends in the "front office" - Norma, Jean, Cynthia, Laura, Dolores, and Anita - thanks for all the helpful shoulders and emergency assistance.

Loving thanks to my husband Phil who grew along with me...and to my family and friends who assured me that they knew I could do it. Special thanks to C.N.K. for helping me find the strength.

But this must end where it began - with Tina - who nurtured the budding researcher in me with endless encouragement and boundless enthusiasm. Without you, Tina, this would not be.

Table of Contents

	Page
Abstract.....	iv
Acknowledgements.....	vi
List of Tables.....	xii
List of Figures.....	xiv
Introduction.....	1
I. Matching, Grouping, Classifying, and Categorizing in Children.....	3
A. Infant Studies.....	5
B. Matching and Categorizing in Preschoolers.....	20
C. Matching, Classifying, and Categorization in School-Age Children.....	33
D. Issues in Acquisition of Categorizing Skills....	54
II. The Development of Functional Hemispheric Asymmetries in Children.....	66
A. Historical Background of Hemispheric Specialization of Function.....	66
B. Functional Hemispheric Asymmetries in Adults....	68
C. Development of Lateralization of Function in Children.....	73
1. Development of Neuroanatomical Asymmetries...79	
2. Development of Electrocortical Asymmetries...83	
3. Development of Behavioral Asymmetries.....94	
a. Auditory Asymmetries.....	94
b. Tactile and Haptic Asymmetries.....	102

c. Visual Hemifield Asymmetries.....	107
(i) Non-verbal stimuli: dots, lines, colors.....	107
(ii) Non-verbal stimuli: faces/figures..	108
(iii) Non-verbal stimuli: shapes/line drawings.....	111
(iv) Linguistic stimuli.....	114
4. Laterality in Atypical Children.....	124
5. Conceptual Issues in Development of a Laterality "Shift".....	126
Method.....	134
Subjects.....	134
Stimuli.....	135
Apparatus.....	140
Procedure.....	141
Data Analysis.....	148
Methodological Considerations.....	153
Results.....	158
Stimuli.....	158
Experimental Task.....	158
I. Type of Match: Semantic versus Perceptual.....	158
II. Reaction Time.....	168
A. Semantic and Perceptual Matches combined...	169
B. Semantic Matches (n=60).....	178
C. Perceptual Matches (n=38).....	179
Follow-up Tasks: Shape Matching and Identity Matching.....	180

A. Frequency of Correct Responses.....	180
B. Reaction Time.....	181
Variability in Reaction Times.....	184
A. Variability in Experimental Task.....	184
B. Variability in Follow-up Tasks.....	196
Summary of Results.....	196
Discussion.....	202
I. Age Differences in Perceptual and Semantic/ Categorical Matching.....	202
Perceptual Matching in 7-9 and 10-12 year olds.....	216
II. Hemispheric Asymmetries.....	218
A. Lateralization of Semantic/Cateogrical Matching.....	219
B. Lateralization of Perceptual Matching.....	223
III. The development of hemispheric asymmetries.....	223
Appendices	
Appendix A: Consent Form.....	248
Appendix B: Harris Tests of Lateral Dominance.....	250
Appendix C: Picture Stimuli.....	251
Appendix D: Stimulus Sets.....	252
Appendix E: TurboBasic Program to Administer Test Trials.....	254
Appendix F: Instructions to Subject.....	259
Appendix G: Identity Matching Sets.....	260
Appendix H: Experimental Task: Stimulus Sets-- Mean Number of Semantic Matches (and SDs) over 4 Trials (across age groups).....	261

Appendix I: Experimental Task: Stimulus Sets-- Means and Standard Deviations for the Number of Semantic Matches over 4 Trials by Age Group.....	262
Appendix J: Individual Subject Data.....	263
References.....	265

List of Tables

	Page
Table 1: Experimental Task: Number of Perceptual and Semantic Matches by Age and Visual Hemifield.....	160
Table 2: Experimental Task: Response Patterns to Experimental Stimulus Sets by Age.....	167
Table 3: Experimental Task: Reaction Time (msec) for Perceptual and Semantic Matches by Age and Visual Hemifield.....	170
Table 4: Experimental Task: Reaction Time (msec) for Semantic Matches by Age and Visual Hemifield (n = 60).....	171
Table 5: Experimental Task: Reaction Time (msec) for Perceptual Matches by Age and Visual Hemifield (n = 38).....	174
Table 6: Follow-up Task--Shape Matching: Number and percentage correct responses by Age and Visual Hemifield.....	182
Table 7: Follow-up Task--Identity Matching: Number and percentage correct responses by Age and Visual Hemifield.....	183
Table 8: Follow-up Task--Shape Matching: Reaction Time (msec) for Correct Responses by Age and Visual Hemifield.....	186
Table 9: Follow-up Task--Identity Matching: Reaction Time (msec) for Correct Responses by Age and Visual Hemifield.....	189
Table 10: Experimental Task: Reaction Time Variability (msec) for Correct Responses.....	192
Table 11: Experimental Task: Reaction Time Variability (msec) by Age, Visual Hemifield, and Type of Match.....	193

Table 12: Follow-up Tasks--Shape and Identity Matching:
Reaction Time Variability (msec) for Correct
Responses by Age.....197

Table 13: Follow-up Tasks--Shape and Identity Matching:
Reaction Time Variability (msec) for Correct
Responses by Age, Visual Hemifield, and Task..198

List of Figures

	Page
Figure 1: Sample standard stimulus and comparison stimuli.....	137
Figure 2: Subject seated at apparatus.....	143
Figure 3: Experimental Task: Mean number of Perceptual and Semantic responses by age.....	161
Figure 4: Experimental Task: Response Patterns to Stimulus Sets by Age.....	165
Figure 5: Experimental Task: Mean reaction time (msec) for Semantic matches by age and visual hemifield.....	172
Figure 6: Experimental Task: Mean reaction time (msec) for Perceptual matches by age and visual hemifield.....	175
Figure 7: Follow-up Task--Shape Matching: Mean reaction time (msec) for correct matches by age and visual hemifield.....	187
Figure 8: Follow-up Task--Identity Matching: Mean reaction time (msec) for correct matches by age and visual hemifield.....	190

Introduction

The present experiment examined age-related changes in children's perceptual and semantic (categorical) matching of laterally-presented line drawings of familiar, everyday objects. Using a forced-choice matching-to-sample paradigm in which children (3 groups of right-handed males: aged 4-6 years, 7-9 years, 10-12 years) chose one of two comparison pictures as a match with a previously shown standard (sample) stimulus, we examined the following issues:

1- age differences in children's preferred mode of matching picture stimuli which can be matched in either of two ways: (1) on the basis of a common perceptual/configurational/physical stimulus feature (e.g., shape), or (2) on a semantic/taxonomic basis, either by common membership in a basic taxonomic level category (e.g., cars) (Rosch, 1972), superordinate category (e.g., transportation vehicles), or by functional relationship (e.g., key-lock). It was hypothesized that there would be age differences in the preferred type of matching, with the younger children expected to make more "perceptual" matches than the older children, and the older children expected to match more frequently on the basis of category membership or functional relationship;

2- age differences in hemispheric asymmetries in matching pictorial representations of common objects in children. If the laterality invariance theory (discussed below) was to be supported, there would be a general adult-like pattern (for all age groups) of a Left Visual Field/Right Hemisphere (LVF/RH) advantage for matching on the basis of perceptual/configurational stimulus features, and a Right Visual Field/Left Hemisphere (RVF/LH) advantage for semantic (categorical) matches. The hypothesized "superiority" (advantage) would be manifested by shorter reaction times to match the stimuli. In contrast, the progressive lateralization theory (discussed below) would be supported if the younger children demonstrated little, if any, visual hemifield advantage for either perceptual or semantic (categorical) matching, whereas the older children exhibited the expected adult-like visual hemifield superiority (i.e., a RVF/LH advantage for semantic/ categorical matches, and a LVF/RH advantage for perceptual matches;

3- the relationship between age differences in perceptual vs. categorical matching and age differences in hemispheric asymmetries. Interactions between age and preferred type of match, and between age and visual hemifield superiority were predicted, such that there would be a shift from significantly more (and faster)

perceptual matching of pictures and concomitant LVF/RH (or no) superiority for these matches in younger children, to a significant preference for (and faster reaction to) categorical/functional matches and a RVF/LH advantage in older children.

This investigation stems from two major theoretical and empirical areas: (1) the development of classification and categorization behavior in children, and (2) hemispheric asymmetries in children with reference to whether hemispheric specialization/lateralization develops progressively, as argued by Lenneberg (1967) and others, or whether functional cerebral asymmetry is "wired-in" at birth and therefore invariant over time, as argued by Kinsbourne (1975, 1981) and others.

I. MATCHING, GROUPING, CLASSIFYING, AND CATEGORIZING IN CHILDREN

"A child is able to grasp a problem and to visualize the goal it sets at an early stage in his development; because the tasks of understanding and communication are essentially similar for the child and the adult, the child develops functional equivalents of concepts at an extremely early age, but the forms of thought that he uses in dealing with these tasks differ

profoundly from the adult's in their composition, structure, and mode of operation..."(Vygotsky, 1962, p.56).

When children (and adults) are given a set of objects and told to "put things together that are alike," it is assumed that some rule determines which objects are to be included and which are to be excluded. The "rule" or strategy used to match, group, classify or categorize items may vary, frequently depending on the type of stimuli or experimental paradigm used (Bomba & Sigueland, 1983; Cohen & Strauss, 1979; Denney, 1972; Ross, 1980; L. B. Smith 1979, 1981), prior familiarity and experience with the objects to be matched or categorized (Bomba & Sigueland, 1983; Greenfield & Scott, 1986; Inhelder & Piaget, 1964), and acquisition of new skills and competencies (Rosch & Mervis, 1978). Although developmental theorists generally agree that the ways in which children group, classify, and categorize objects and events change with age, there is disagreement as to whether these changes are continuous, with uniform changes that reflect increasing consistency and efficiency in performance, or discontinuous, characterized by abrupt shifts in the types of mental operations used (Kagan, 1979; Penk, 1969; Piaget & Inhelder, 1969; L.B. Smith, 1979, 1981).

A. Infant Studies

In order to study the nature of conceptual categories for human infants and the processes by which infants form conceptual categories from their experiences, the visual habituation-dishabituation paradigms used to measure visual recognition and familiarity/novelty in infants have been adapted to assess the infant's ability to classify novel objects as a new example of a familiar category or as an instance of a novel category. In these experiments, the infant is familiarized with (habituated to) a series of stimuli which share membership in a common category (which may be wide or narrow, as defined by the range represented in the series). The investigator infers that the infant demonstrates an ability to classify or categorize objects if the infant indicates visual recognition (by generalized habituation) when shown a new stimulus that is a category member, but dishabituates (shows novelty preference for, no recognition of) to a new stimulus from a novel category. The two dependent measures commonly used are 1) decrement in looking time during familiarization (indicating habituation), and 2) preference for novelty (incremented looking time at novel category non-member stimulus).

Using representational stimuli, Cohen and Strauss (1979) presented 18-, 24-, and 30-week old infants with slide photographs of female faces that varied across three dimensions: (1) side facing (left or right), (2) looking up or down, and (3) expression (smile, frown, or surprised). In Condition I, infants were repeatedly shown the exact same photograph, female looking upper left. In Condition II, the infants saw the same female in a different side orientation on each trial. In Condition III, the photographs were of different females in different side orientations on each trial. Infants were habituated to criterion (mean fixation time on 3 consecutive trials was 50% of mean of first 3 habituation trials). Two test trials were then presented, one with the familiar female face and one with a totally novel female. However, both test faces had a neutral expression and were looking straight ahead. The results indicated that, at both 18 and 24 weeks of age, the infants looked significantly longer at the two test stimuli than at the post-habituation stimulus (checkerboard pattern) in all three conditions. However, at 30 weeks of age, the three conditions had a differential effect on fixation times to the test stimuli. In Condition I, the infants looked significantly longer at both test stimuli; in Condition II, they looked longer only at the novel face, and in Condition III, they looked

the same or less at both test stimuli than at the posthabituation stimulus. The results at 30 weeks were what Cohen and Strauss had predicted for infants who could abstract (differentiate) appropriate conceptual categories ranging from a particular orientation of face (narrow), to female faces in general (broad). Strauss (1979) proposed that the ability to categorize facial patterns by 10-month old infants was based on a "prototypical representation" of the category which was comprised of an average (mean value) of the feature values of the exemplars.

Using actual toy objects, Ross (1980) found that 12, 18, and 24 month old infants habituated to groups of the letter M, the letter O, and toy men figures, but not to presentations of food, furniture or animal categories. Ross concluded that the infants had habituated to the most basic taxonomic (objects) categories that consisted of items which were perceptually most similar (shape). Foods, furniture and animals (as opposed to groups of apples, chairs, and cats) are superordinate categories (more abstract) and the exemplars in these categories varied in shape within each group. However, when the children were shown a series of category exemplars (same categories) and then shown two additional objects, one a category member and the other a "nonmember" stimulus, all age groups

fixated longer on the "nonmember," suggesting that some concept of category membership had been abstracted. This finding occurred for all categories, even those that the children had not habituated to in the first experiment.

Rosch and her associates (Rosch, 1973; Rosch & Mervis, 1978; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) hypothesized the existence of "natural" prototypes for form and color categories. They found that, at a basic taxonomic level of abstraction, categories of concrete objects were found to have the following properties:

(a) clusters of attributes which, by general consensus, are possessed by category members (e.g., chairs have seats, legs);

(b) interaction with objects in a category involve sets of common motor programs (e.g., sitting on chairs); (Rosch proposed that this property may be important developmentally, since it indicates that this basic level of object categorization is the most inclusive for which a Piagetian sensorimotor schema can be formed.);

(c) commonalities in shape and the consequent "overall look" of the category members;

(d) an average shape of an object in that category may be abstracted and recognized; and

(e) a concrete image of a typical member of the category may be formed (Rosch & Mervis, 1978). The authors propose that objects forming groups at this basic level of categorization should be those "first learned by means of visual perception and sensory motor interaction with the object and thus, should be the first divisions of the world at which it might make sense to a child to put things together because they are the same type of thing" (Rosch & Mervis, 1978, p. 127).

Bomba and Sigueland (1983) studied the nature and development of non-representational form categories in 3 to 4-month old infants, using the familiarity-novelty paradigm. In a series of experiments using 3 form categories (triangle, diamond, square) made up of dot patterns, visual preference for novelty was used to assess categorization behavior in the recognition of visual forms. According to Bomba and Sigueland, the natural prototypes for form stimuli are "perceptually salient" shapes, such as circles, squares, and triangles. Using dot patterns of prototypical triangles, diamonds and squares, as well as patterns that were systematic distortions (i.e., some dots were moved above or below, left or right of the prototypical form) of these form prototypes in Experiment 1, the infants were presented with two patterns simultaneously: (1) the prototype and (2) a distortion of

one of the form categories, to determine if there was a visual preference for either the "good" (prototypical) or distorted pattern. No visual preference was demonstrated. In Experiment 2, infants were familiarized with two exemplars or distortions at each of the three levels of distortion for a particular form category (e.g., triangle). In the preference testing phase immediately following familiarization, the infant was presented with the prototype of the familiarization category and the prototype of a novel category (one of the other 2 shapes). The infants demonstrated a reliable preference for the novel category prototype, providing strong evidence that the infants recognized (habituated to) the previously unseen category prototype as a member of the familiar form category.

In Experiment 3, half the infants were familiarized with a form prototype, while the other half were familiarized with a slight distortion of the form category. Testing consisted of pairing the prototype with the distortion. A highly reliable mean novelty preference score was obtained, indicating that the infants discriminated between the familiar stimulus and the novel one, regardless of prototypicality or distortion. As these infants were able to discriminate between the form prototypes and their lowest level of within-category

distortion, one cannot invoke "failure to discriminate" to account for the generalized habituation to prototype in Experiment 2. Experiments 4 and 5 tested the "prototype" model which suggests that the prototype (central tendency) of a category is abstracted as a function of experience with instances of a category and that this prototype is used to classify subsequent exemplars of the acquired category. Infants were familiarized with the three distortions in a given form category, and tested with the prototype of that category as well as with one of the familiar distortions. In Experiment 4, infants were tested immediately following familiarization and no visual preference was found. A 3-minute delay interval between familiarization and recognition testing was introduced in Experiment 5, and a highly significant preference for the old exemplar was obtained, providing evidence that the infants categorized (habituated to) the previously unseen prototype as a better example of the acquired form category, even when it was paired with an old (familiarized) exemplar (distortion) of that category. Bomba and Sigueland (1983) proposed that this finding reflected a significant facilitation of the "prototype" effect as a result of introducing a delay interval between familiarization and recognition testing. In Experiment 6, infants were familiarized with prototypes and distortions

of a form category, and tested with a prototype and distortion of the same category (both familiarized stimuli). It was hypothesized that exposure to the prototype would increase the likelihood of an accurate prototypical representation being abstracted, and that, on testing, the infants would demonstrate a visual preference for the distortion. The overall significant preference for the distortion exemplar supported the hypothesis that the infants more reliably recognized the prototype as a familiar category member. That the effect was larger when the prototype was not included in the familiarization, lends strong support to the hypothesis that the infants were able to accurately abstract a form category prototype and use it in recognizing familiar patterns. The number of exemplars was increased from the six shown to the infants in Experiment 4, to 12 in Experiment 7, to test whether increasing sample size during familiarization, categorization for the prototype, and new exemplars, would result in an increase in accuracy, while categorization for old exemplars would either decline or stay the same. Infants were familiarized with 12 exemplars representing the three distortions in a given form category (same total familiarization time period), and tested with the prototype and one of the familiar (distorted) exemplars. A significant "preference for old exemplar" was obtained,

indicating that 3-4 month old infants reliably recognize (habituate to) the prototype as a familiar category member. That the effect was larger with 12 exemplars than with six exemplars, supports the authors' hypothesis that infants rely on prototypical representations in recognizing forms.

Using non-representational square-wave gratings in habituation/dishabituation experiments with 4-month old infants, Quinn and Bomba (1986) found that infants were able to extend a general category of oblique orientations, having acquired an "oblique" (or "not vertical") category that extended beyond the range of the familiarized stimuli.

Additional support for a prototype model of categorization in infants was obtained by Sherman (1985), who presented 10-month olds with black-and-white drawings of schematic male faces in which mean and modal prototypes were distinct. Faces making up the target category had identical hairlines and chins, differing from each other only in amount of eye separation, nose width, and nose position. There were three values for each of the three feature dimensions that varied. Two other male faces were constructed with novel features. The experiments were designed to examine: (1) whether the data are best accounted for by a context model (in which the subject

stores distinct memories of the familiarized instances and makes similarity judgments when categorizing [Medin & Schaffer, 1978]), or some category level representation, and (2) if category level representations are abstracted, whether the infant's performance conforms best to (a) the mean prototype (Bomba & Sigueland, 1983; Cohen & Strauss, 1979), (b) a feature-count theory (in which the representation abstracted is a count, not average, of the observed feature values of the exemplars in the category (central tendency represented by mode, rather than mean), or (c) the category-density model (in which what is learned is influenced by top-down processes, such as prior expectations [Flannagan, Fried & Holyoak, 1986; Fried & Holyoak, 1984])). In Experiment 1, the infants were familiarized with four category instances and tested with three paired comparisons:

1- old (first) category member versus new category member,

2- novel face versus new category member (modal face), and

3- novel face versus category mean (mean, or averaged, face).

Each comparison test was presented twice, once immediately following familiarization and again after a 15-minute interval. Control subjects were tested to rule

out any a priori visual preference for any of the stimuli. All the infants demonstrated a high novelty preference for the out-of-category faces over both the mean and modal faces, although the effect was significantly stronger in the immediate over the delayed condition. In Experiment 2, the infants had the same exposure experience, but were directly tested on the modal versus the mean face, on the assumption that the more familiar face was more similar to the infants' representation of the category-level information (Cohen & Strauss, 1979). The infants showed a significant novelty preference for the mean over the modal face, clearly regarding the modal face as the more familiar. In Experiment 3, a 15-minute delay interval was introduced between familiarization and recognition testing. No preference in looking at either mean or modal prototype was found. Sherman (1985) concluded that, while 10-month old infants can and do maintain some category representation over 15 minutes after familiarization with 4 category exemplars (discriminating novel face from new category member), this representation is insufficient to mediate a within-category discrimination. The information that is robust enough to be retained over a 15-minute delay probably pertains to those features common to all members of the category and that serve to distinguish category members from nonmembers. The information that

enabled the infant to discriminate one category member (modal) from another (mean) seemed to be available only briefly to the 10-month old infants in this study.

Using the habituation-dishabituation paradigm and stimuli that previously had been shown to be discriminable, Roberts (1988) familiarized 48 nine-month old infants to three line drawings of good to moderately good birds (e.g., parakeet, hummingbird, hawk) as determined by Rosch (1975). Test stimuli consisted of in-category stimuli (e.g., novel prototype-robin, familiar stimulus-hummingbird, novel bird ranked between prototypical and poor-toucan) and out-of-category stimulus (e.g., horse). In both immediate and 5 minute-delayed-testing groups, infants appeared to generalize habituation to all within-category exemplars and showed visual preference for the out-of-category stimulus and the posttest stimulus, a checkerboard pattern. Roberts concluded that 9-month old infants are able to form and retrieve a novel, nonlinguistic category at a basic (by Rosch's definition) level of abstraction. He considered this performance a higher level than that demonstrated in Sherman's (1985) study, which consisted of within-category male face stimuli, consistent with membership in a subordinate category-- that is, all appeared to exhibit nearly complete overlap in overall shape. Although the

birds in Roberts' (1988) study were substantially similar in overall shape, the exemplars were chosen to reflect several subordinates and sufficient variability in overall shape that defines the basic level of abstraction (Rosch, et al., 1976). Roberts (1988) proposes that this early ability to form nonlinguistic categories by prelinguistic infants may facilitate the learning of object words at a later stage. He notes that the infants in his study had little or no prior exposure to the target category (bird) according to parent report, unlike the face stimuli used in other research. He also argued that, because the infants had no knowledge of function with respect to this category, the acquisition of prelinguistic form categories at a basic level of abstraction is possible for infants, even in the absence of functional information.

Younger (1988) investigated infant sensitivity to correlations among attributes of category members using artificial categories. Based on the premise that although attribute values may vary continuously across objects, some combinations are more likely to occur than others. Category boundaries are created by forming breaks between clusters of correlated attributes (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). The stimuli used by Younger (1988) were schematic drawings of animals with identically shaped bodies, ears, and feet. The features that varied

(five values of each) were: leg length, neck length, tail width, and ear separation. Ten-month old infants were presented with sets of eight animals representing either the broad category (full range of all values on all features) or narrow categories (restricted range, either high or low, on all features). The recognition test stimuli consisted of "mean animals" (average value on all features), modal animals (all low or all high values on all features), and novel animals (different ears, feet, and tail). Infants who had been familiarized to the broad condition spent proportionately more time looking at the modal stimulus, indicating that the average (mean) stimulus was more familiar than either extreme. In contrast, infants familiarized with the narrow categories fixated longer on the mean (average) animal, suggesting that the modal stimulus animal (either extreme) was more familiar than the average prototype. The results obtained from the broad categories condition suggested that, when presented with a wide range of category members, infants form a single category, best exemplified by an average prototype. When familiarized to a restricted range of values, the modal stimulus appears more familiar. In a second experiment, infants were familiarized with animals with high values on all dimensions, with low values on all dimensions, and with mean (average) values on all

dimensions. Under these conditions, habituation to unfamiliar stimuli over the modal and average prototype would support the hypothesis that the items had been segregated into two distinct categories. It was found that infants fixated significantly longer on the modal and average prototype, suggesting that the previously unseen stimuli (containing moderately low or moderately high values) were responded to as though they were more familiar than the stimulus containing the modal and average values (which had been part of the familiarization phase). Younger concluded that the perception of correlated attributes plays an important role in defining category boundaries, that is, distinguishing between categories in the object world.

The studies cited above clearly demonstrate that 3-10 month old, and older, infants are competent at grouping or classifying items by perceptual characteristics, abstracting prototypes of a category by modal and mean representations, determining category boundaries, and extending perceptually-based categories. However, Ross's results suggest that 2-year olds do not have the necessary conceptual or linguistic skills to categorize by superordinate labels that require grouping by abstract features that are not given in the stimulus events.

B. Matching and Categorizing in Preschoolers

Vygotsky (1962) argued that "generalization is a verbal act of thought and reflects reality in quite another way than sensation and perception reflect it..."(p.5) He noted that "progress in thought and progress in speech are not parallel. Their two growth curves cross and recross"(p.33). Thought and speech functions emerge from different genetic roots, developing along different lines, independently of each other. There exists a pre-linguistic phase of thought development and a pre-intellectual stage of speech development up to a certain point in time, whereupon thought becomes verbal and speech rational (pp.41-44). At this time, thought development is determined by language, and the intellectual growth of the child is "contingent on his mastering the social means of thought, that is, language" (p.51).

The close relationship between thought and language was acknowledged tacitly by Inhelder and Piaget (1964) when they used the term "recognitive assimilation" to identify the process whereby a young child names an object (e.g., "chair") or indicates by using the object in a familiar, conventional way (sitting on chair - identification by function) that s/he recognizes the

object. The concept of chair derives from multiple individual experiences as well as from observations of others. This interpretation would appear congruent with the context theory referred to earlier (Medin & Schaffer, 1978), although Inhelder and Piaget do introduce the role of naming, implying semantic competency as important to the categorization acquisition process.

Inhelder and Piaget (1964) proposed that even when the young child recognizes that the chair is a piece of furniture that may be purchased from a furniture store, the child's judgment is still bound to the immediate experience, and involves little abstraction from the basic (taxonomic) level category of chair. The observer may not infer the superordinate category of "furniture" from the child's behavior at this time (Inhelder & Piaget, 1964, p. xiii).

Piaget and other developmental theorists argue and provide empirical evidence that the young child (2-4 years old), when presented with an array of items, tends to group those items on the basis of common perceptual features, e.g., shape, size, and color (Denney, 1972; Piaget, 1952; Ross, 1980). Piaget attributes this tendency to the preoperational child's inability to decenter. Children in this age group (2-4 years) have a tendency to focus their attention on one salient feature of the

stimulus, without simultaneously attending to other dimensions. Hence, according to Piaget, they are unable to group on the basis of two dimensions simultaneously (Gross, 1985). Inhelder and Piaget (1964) identified three main phases in the development of classification of geometric stimuli:

1) a first phase of "graphic" or "figural" collections (about 2 1/2 to 5 years of age)--in the early stage of which children are unable to ignore the spatial configuration of the items in the array and, therefore, are not able to group on the perceptual similarity of the items alone. In the later stage of this phase, children may place similar stimuli together, but the criteria for grouping items fluctuates;

2) a second phase of "non-graphic" collections (between the ages of 5 and 7 or 8 years) in which objects are grouped according to similarity, with increasing accuracy and completeness: (a) in the first substage, only some of the stimuli are placed in a few groups which are organized on differing criteria; (b) a second substage, in which all the stimuli are grouped, but the groups are still based on different criteria; (c) a third substage in which all items are grouped by the same criterion; and (d) a fourth substage, in which the stimuli are classified by two criteria serially, that is, first according to one

criterion, and then subdivided according to the second criterion;

3) in the third phase, "true classification" occurs, and children (beginning at about 8 years of age) start out with an overall classification plan, grouping items by two criteria on a single sorting (Inhelder & Piaget, 1964).

Inhelder and Piaget's (1964) observations concerning the classifying abilities of preschoolers (ages 2-5 years) are consistent with those of Vygotsky who noted that a first step toward concept formation occurs when a young child puts together a number of objects in unorganized "heaps," either without basis, or based on "a diffuse, undirected extension ... linked by chance in the child's perception" (Vygotsky, 1962, p. 59). From this trial-and-error stage, the child progresses to a stage where the composition of the collection is determined largely by spatial position of the objects, or by a "syncretic organization of the child's visual field. The syncretic image or group is formed as a result of the single elements' contiguity in space or in time, or of their being brought into some other more complex relationship by the child's immediate perception" (Vygotsky, 1962, p.60). Thus, both Piaget and Vygotsky view the earliest matching and categorization behavior of the preschool child as

lacking anything but the simplest perceptual bases for organization.

Using two sizes of colored cardboard shapes, Denney (1972) asked 2-, 3-, and 4- year old children to put into groups the things that were alike or went together. She found that the 4- year old children grouped more accurately and completely on one dimension (either color, size, or shape) than the younger children, whose performance was less consistent. In contrast to the 2- and 3- year olds, the 4-year olds were also able to group by two physical dimensions (stimulus features) simultaneously (e.g., shape and color). Denney claimed that the children's categorization behavior contradicted the stages proposed by Inhelder and Piaget, and, instead, fell into three different stages: 1) a stage in which the child cannot group according to (dimensional) similarity , 2) a stage in which the child groups only partially according to (dimensional) similarity, and 3) a stage in which the child is able to group the entire stimulus array according to (dimensional) similarity. According to Denney, development of category acquisition appears to become more accurate, more efficient, and more complex (sorting on two dimensions) in a quantitative fashion with increasing age. This contrasts with the view of Piaget and Vygotsky, who

suggest that the developmental changes in grouping and categorizing are qualitative.

Odom and Cook (1984) presented 4-year old children and adults with compound geometric (square) stimuli (9 values of each of three dimensions: size, color, and orientation of line radiating from center of square) which they were asked to classify by similarity. Prior to the classification task, the salience of the dimensions of size, color, and orientation was assessed by asking each child to match one of 2 comparison cards (constructed by combining the values of 1, 5, and 9 from the three dimensions) with a standard (value 5 on all dimensions). One comparison item matched the standard on one of the three dimensions and the other comparison matched the standard on a second dimension. The dimension serving most frequently as the basis for choice was designated "high" in predisposed salience, and the dimension serving least frequently was designated "low". Subjects were then presented with either a triad set of unidimensional compound stimuli (in which a single dimension was varied differentially between the items (i.e., one value step between A and B and 5 value steps between B and C on the same dimension) or a triad of bidimensional compounds, with the two varying dimensions either size and color, color and size, orientation and size, size and

orientation, color and orientation , or orientation and color. In each bidimensional set, the first dimension consisted of highly distinctive values, e.g., 1,5,9, and the second dimension consisted of values of low distinctiveness (e.g., 1,2,3 or 3,4,5). The two independent variables were salience of dimension and distinctiveness of dimension (by choice of values presented). The classifications of both the 4-year olds and the adults (no significant age differences) were more accurate when the salience of the relevant dimension was high than when it was low. Both salience and distinctiveness were reliable in 4-year olds, as was the salience by distinctiveness interaction, indicating that the efficacy of distinctiveness on performance accuracy was less in the high-predisposed-salience condition than in the low-predisposed-salience condition. When groups were given training on their less salient dimension (with corrective feedback on those trials), the salience scores in that condition increased, but not above the values of the high-predisposed-salience dimension. Odom and Cook (1984) concluded that salience components determined different levels of accuracy; as the salience of the solution-relevant dimension increased, so did the accuracy of similarity judgments. They proposed that, beyond a minimal level, the effects of salience and distinctiveness

are additive. With respect to salience, the percentages of 4-year olds with color, size, and orientation highest in their hierarchies were 58, 32, and 10, respectively. Whereas the majority of the 4-year olds had color highest and orientation lowest, approximately one third of the adults had each of the three dimensions as highest and lowest in their hierarchies. These age-related differences in hierarchies as well as the demonstrated influence of salience in classification support the hypothesis that the salience characteristics of the relations or dimensions that comprise classification play a significant role in the accuracy of similarity judgments for both children and adults.

Using representational stimuli of common objects (e.g., animals, toys), Fenson, Cameron and Kennedy (1988) varied perceptual and categorical similarity independently in a concept-matching task, administered to 26-month old children. Forty-four test sets of stimuli were presented, each consisting of a 3-dimensional standard (toys, common every day objects, animals, all made of plastic) and an array of 4 line drawings, only one of which was a member of the same basic or superordinate category as the standard. The test sets varied in their perceptual (shape) and categorical resemblance to the standard (identical, same basic taxonomic category, same superordinate

category/high perceptual similarity, same superordinate category/moderate perceptual similarity, same superordinate category/low perceptual similarity), and the nonmatch (same basic category, same superordinate category/high perceptual similarity, same superordinate category/moderate perceptual similarity, same superordinate category/low perceptual similarity, different superordinate category). The results indicated that overall, the children matched correctly most of the time. However, there was a significant effect of set type; the children found the set with a basic category match (high perceptual similarity) and different superordinate nonmatches the easiest. These nonmatches were perceptually dissimilar from the standard and the basic level match stimulus. The most difficult sets (those with the lowest accuracy scores) were 1) basic level/moderate similarity match and same superordinate category/moderate similarity nonmatches, and 2) same superordinate category (low perceptual similarity) match and different superordinate category nonmatches. From these results, the authors concluded that perceptual similarity was the primary determinant of difficulty level. When the standard and the match array were equated for perceptual resemblance (high and moderate similarity), matches to basic level and to superordinate categories were equally difficult. When

perceptual similarity of correct match to standard was reduced (moderate and low similarity), more than half the children were unable to recognize matches at either the basic or the superordinate level.

The salience of perceptual stimulus features in children's categorizations was noted earlier by Birch and Bortner (1966), who argued that children as young as three years of age do indeed have the capacity to group by category or function under specific task conditions. They presented 3 to 10 year old children with groups of objects from which to match an index item. Test A groups contained items (foils) with a physical feature (color or form) common to the index object as well as a categorical or functional match item (e.g., index object: white plastic hat; choices with stimulus competition: red glove <categorical choice>, white box <color similarity>, red dome <shape similarity>). The results indicated clear developmental trends, with younger children making more matches on the basis of stimulus similarity, and older children more frequently using class and functional attributes as the basis for matching. When stimulus competition was eliminated, such that the physical/perceptual items were omitted (test B, e.g., index object: white plastic hat; choices without stimulus competition: red glove <categorical choice>, ABC block,

eraser), all age groups (except for one nursery school group) made class and functional category matches. Birch and Bortner (1966) therefore claimed that young children could categorize by class or by function, but because stimulus identity or similarity of physical features was a compelling aspect of the situation and prepotent in the organization of the response, they prefer perceptual matches. This preference for stimulus-bound responding diminishes as children get older and they demonstrate an increasing tendency to respond to class and functional features of relatedness in the competitive as well as in the non-competitive situation.

Alexander and Enns (1988) examined the boundaries of categories formed by 3-, 4-, 5-, and 24-year olds following exposure to a continuum of new objects. Subjects were first introduced to two stuffed animals (one exemplar of each of two concepts, "Meagle" and "Borg") that differed widely on a variety of features (e.g., body color, height, width, mouth shape, nose shape and color, size of limbs). In three tests of categorization (free-sorting-with no names given, selection from set of distractors-with names of the category exemplars given, and naming-in which the subject was asked "What should this one be called: Meagle or Borg?"), subjects were asked to classify the animals that shared some family

resemblance with the familiarized animals, and to state the reason for the category placement. (The "fuzzy" category concept is explained in terms of the membership of nonprototype exemplars being graded, rather than member versus nonmember. Hence, the boundaries are "fuzzy" rather than clearly defined. If younger children base category decisions on idiosyncratic and inconsistent use of rules, one might predict fuzzy categories for younger children, whereas older children would use conventional rules as the basis for categorization, leading to a prediction of clearly defined boundaries for them.) The investigators found that category boundaries for this task were fuzzy in all age groups, but became reliably less fuzzy with increase in age. Alexander and Enns (1988) noted three developmental trends between 3 and 5 years of age:

- 1 - category boundaries became less fuzzy with age, with increased individual consistency across tasks;

- 2 - the uncommunicated (unverbalized) or idiosyncratic reasons offered for category decisions shifted to conventional explanations based on specific visual (perceptual) features; and

- 3 - the decisions about animals close to category boundaries (the fuzziest) became less sensitive to verbal labels and spatial configurations.

It is interesting to note that for the younger children, verbal labels interfered with the form categorization in the Alexander and Enns' (1988) study, and perceptual salience interfered with functional matching in the Birch and Bortner (1966) study and with taxonomic categorization in the Fenson, Cameron, and Kennedy (1988) study. This vulnerability to "interference" and/or lack of consistency in matching and categorizing, regardless of type of task, may be characteristic of children at this age. This may be a quantitative phenomenon as noted by Denney (1972) previously, or reflect the immature cognitive and semantic (language-related) processes noted by Vygotsky (1962) and Piaget (1952), who found a dissociation between children's performances and their explanations regarding their performances.

For the most part, the findings on grouping, matching and categorizing in preschool aged children support the hypothesis of the prepotency/salience of perceptual characteristics, even when children have acquired some competency at taxonomic categorization at both the basic and superordinate levels. For this age group, classification of non-representational stimuli appears to increase in accuracy with age in a more-or-less linear fashion. Even when young children, having acquired some

linguistic competency, attempt taxonomic categorization, it appears that the salience of perceptual characteristics of the stimuli can either facilitate or impair performance, depending on the degree of congruency with the other classification system.

C. Matching, Classifying, and Categorization in School Age Children

By school age, even nursery school, the young child has acquired some linguistic competency, and the research regarding the development of matching, classifying and categorizing skills appears to range from studies that stress visual perception and integration (Enns & Girus, 1985, 1986; L. B. Smith, 1979, 1981; Smith & Kemler, 1977) through associative cognitive processes (Ackerman, 1986b; Greenfield & Scott, 1986; Medin & Schaffer, 1978) to those emphasizing the linguistic and semantic nature of the tasks (Ackerman, 1986a, 1987; Keil, 1983; Whitney & Kunen, 1983).

Based on the developmental principle of a trend from wholistic to differentiated perception, Smith and Kemler (1977) proposed that wholistic perception is organized by overall stimulus similarity (e.g., separation of those maximally similar on relevant dimensions from those maximally dissimilar on those dimensions) whereas

differentiated perception is organized by component dimensions according to rules. Wholistic perception is a systematic, although nondimensional, method for categorizing objects which are grouped together because they are, overall, very much alike (e.g., with respect to size and color: grouping 1-inch white cube with 1/2-inch gray cube rather than with 1-inch black cube). L. B. Smith (1979) argued that as overall similarity is the structure underlying many natural categories, the similarity classification structure seems useful and appropriate for young children, perhaps more useful than a dimensional one. However, she claims that the ability to classify according to dimensional identity is an achievement critical for the development of sophisticated problem-solving, such as formal reasoning about sets and inclusional relations that were considered so important by Vygotsky (1962) and Inhelder and Piaget (1964). L. B. Smith (1979) investigated children's preference for similarity and/or dimensional organizing principles when she presented 16 kindergartners, 16 second-graders and 16 fifth-graders with isosceles triangles of equal area that varied in height, base width, and color. All differences were highly discriminable to adult observers and to kindergartners (as determined by prior "same-different" oddity task).

Four types of stimulus set conditions were established: 1) exemplar items shared a value on color and were highly similar on shape; 2) exemplars shared value on shape and were highly similar on color; 3) exemplars were dissimilar and test items may have matched with exemplar by color dimension; and 4) exemplars dissimilar and test item may match with exemplar by shape dimension. Each stimulus set consisted of 30 items, 6 of which formed the two exemplar groups, and the remaining 24 items (assembled in two random orders) formed the test series with: six items that should be included by a criterial dimension rule, six items that should be included according to a similarity rule, six items that did not match according to either rule, and six items that were replications of each of the six exemplar items that formed the exemplar groups. Half of the children in each age group were assigned to the group presented with conditions 1 and 2 (similarity + dimension). The other half were assigned to the group presented with conditions 3 and 4 (dimension alone). Within each of these groups, half of the children were assigned to each level of dimension X (X= color, X= shape). The results indicated that in conditions 1 and 2, kindergartners' classifications conformed to the similarity organization reliably more often than expected by chance. Fifth-graders classified dimensionally, and the

second-grade pattern of performance did not differ from that expected by chance. The pattern of performance in dimensional classification (conditions 3 and 4) was less clear. Kindergartners were somewhat less accurate than the second- or fifth-graders when presented with dimensionally match-able items. However, they were considerably more likely to include "similar" items that were correctly rejected by the fifth-graders. The second-graders demonstrated intermediate values. Smith concluded that young children generalize a classification systematically by means of wholistic similarity.

In a second experiment (L. B. Smith, 1979) with eight kindergartners and eight second-graders, the kindergartners' performance confirmed the hypothesis that young children will use a similarity solution to a category-inclusion problem if it is available. The second-graders were more sensitive to the dimensional structure of a category and easily extended a category by its dimensional structure, especially in the absence of competing similarity organization. In a third experiment 16 kindergartners and 16 second-graders were presented with the SIM+DIM and DIM stimulus sets of Experiment 1 and asked to "find the special reason" why the items in one group belonged together and the items in the other group belonged together. The exemplar items were then shuffled

and the child was asked to put them back into the two former groups according to the "rule." All sorting errors were corrected. Sorting continued until the child sorted correctly on five consecutive trials to a maximum of 12 trials (failure criterion). Children who passed this pretraining task were then shown each test item and asked to indicate appropriate classification (either exemplar group or "don't go"). The kindergartners did not appear to have discovered (or learned) either a similarity or dimensional rule, as their mean number of inclusions and noninclusions by a dimensional (and reciprocally, a similarity) strategy did not differ from that expected by chance. This result contrasts with those of the first two experiments where, in a free generalization task, kindergartners' preferred and systematically used a wholistic similarity strategy. When they were required to learn a classification organized by wholistic similarity, they appeared to abandon the strategy. L. B. Smith (1979) concluded that the pretraining task increased the kindergartners' attention to the component dimensions of the items. In the absence of a good similarity solution, they were able to generalize a category according to a criterial dimension when directed to discover a general classification rule. Second graders again demonstrated greater accuracy in using criterial dimensions in

classification, even in the presence of strong competing similarity organization. Whereas a substantial number of second-graders had generalized by wholistic similarity in Experiments 1 and 2, no child abstracted a rule of wholistic similarity when required to discover a classification rule. At both kindergarten and second-grade levels of development, attention to dimensional relations was increased when the task required discovery or learning of a classification rule. L. B. Smith (1979) concluded that wholistic similarity is perceptually salient at early levels of development, and this relation is used by the young child to categorize objects. Dimensional relations become perceptually salient as the child develops and the older child classifies by these relations. It is not that the young child cannot categorize and classify. The categories of the young and older children are defined by differing relational organizations that determines category membership. It is the ability to classify by specific relations, specifically identity on one of two dimensions, that depends on developmental level. L. B. Smith (1979) concluded by noting that wholistic similarity as a perceptual relation may not be available to conscious awareness and may serve to organize only intuitive, unanalyzed categories. "It is conceptually simpler to make

a dimensional structure explicit than a similarity structure and.... identity relations may serve to organize intentional classifications" (L. B. Smith, 1979, p.714). L. B. Smith's results are consistent with Piaget's (1969) distinction between perceptually- and intellectually-based classification.

Noting the consistency and apparent logic of young children's similarity classifications and the congruency between this organization and the hypothesized structure of natural categories of concrete objects, L. B. Smith (1981) argued that overall similarity classifications might be characteristic of all humans, and particularly useful when the objects to be categorized differed on not just two, but many dimensions. She presented kindergartners, second-graders, fifth-graders, and college undergraduates with geometric figures (a black trapezoid atop a vertical rectangle with a white arrow superimposed on the rectangle) that varied (5 values) on either 2 or 4 dimensions (height of rectangle, color of rectangle, shape of trapezoid, angle or orientation of arrow). There were three major stimulus conditions: a) the 2-D simple condition, in which only two of the dimensions varied across the five values, and the remaining two dimensions were "not present" (arrow, trapezoid) or held constant (height at 3.81 cm, color=black); b) the 2-D complex

condition in which a constant value was present on the two nonvarying dimensions; and c) the 4-D condition in which the stimuli varied over the five values on all four dimensions. The 72 adults were given stimuli in a free sort paradigm and told to "put together the ones that go together." In both 2-D conditions, subjects classified primarily by one-dimensional identity and similarity classifications occurred rarely. However, in the 4-D condition, similarity classifications occurred reliably more often than dimensional ones. Similar stimuli (more discriminable values on the four dimensions) were presented as triads to 24 kindergarten, 24 second-grade and 24 fifth-grade children and the children were asked to "put the two together that go together." After classifying the triads twice, the children were asked which of the two classifications was "best" and to reproduce that one. The kindergartners produced reliably more similarity classifications than second graders, and second graders produced reliably more similarity classifications than fifth graders when only two dimensions varied. The frequency of classifying by overall similarity did not differ reliably between the 2-D and 4-D conditions for kindergartners, whereas significantly more similarity classifications were made by second- and fifth-graders in the 4-D condition than in the 2-D

condition. L. B. Smith (1981) argued that the trend from similarity to dimensionally structured classifications was evident only with simple stimuli. When objects vary on several dimensions (as they do in real-world objects), overall similarity is the basis by which objects are perceptually segregated into categories across developmental levels. Hence, this strategy seems to remain available and useful at least through early adulthood.

Greenfield and Scott (1986) claim that the young child has at least two potentially competing conceptual systems with which to organize objects and events in the world. In addition to the taxonomically based system of basic level and superordinate categories (e.g., fruits, animals), the "complementary relationships" conceptual system results from the child's direct observation of those objects and events which occur simultaneously in time and space. Thus, babies "go with" cribs and dogs "go with" bones. Twelve children in each of eight age groups, ranging from 3 to 15 years of age, were presented with 10 stimulus sets of magazine pictures or colored line drawings of familiar objects, each set consisting of a single picture card (e.g., banana) and a card with two comparison pictures: 1) a complementary pairing (e.g., monkey) and 2) a taxonomic pairing (e.g., apple). The subject was asked to name the single picture card and then

asked to place it below one of the pictures on the two-picture card in response to the question "Where do you want to put this?" Subjects were asked to explain their choices. The average number of complementary choices for each age group was significantly greater than chance, indicating a strong preference for complementary pairings over taxonomic pairings for these children, when presented with pictures familiar to the youngest subjects in the study. The finding that all age groups responded similarly argues for long-term memory for paired-associate learning, congruent with the context theory of categorization (Medin & Schaffer, 1978).

Ackerman (1986b) asked 90 second-graders, 90 fifth-graders, and 90 college students to remember target words (underlined) in presented word strings consisting of four nouns grouped by category (e.g., Bus-Airplane-Car- Train), by theme (e.g., Suitcase-Coat-Ticket- Train), or unrelated (e.g., Bottle-Lake-Brick-Train). (For the thematic stimuli, the related context words represented objects in typical scenes or thematic events that involved the target object, but were from different taxonomic categories than the target.) Retrieval was cued by either one, two or all three ("whole context" to Ackerman) words presented prior to the target word. For the adults there was little variability for stimulus relation (category vs. theme) or

retrieval cue. For fifth-graders, recall did not vary significantly for retrieval cue for the category stimuli, but for the thematic stimuli, recall improved in linear fashion with increasing number of context words presented. However, recall for the category stimuli exceeded thematic stimuli for one- and two-word cues, but there was no difference for the three-word cues. For second-graders, recall for both category and thematic stimuli improved in monotonic fashion with the increase in retrieval cues presented. While there were no significant differences for category and thematic stimuli for the one- and two-word cues, thematic recall exceeded category recall for the three-word (whole context) cues. Ackerman (1986a) concluded that retrieval search differed for children and adults and for category and thematic stimuli. For categories, young children require more associative structure (more associated words) in a stimulus to provide an effective search medium than is required for either the older children or the adults, and more structure (more words) in a cue to reinstate or invoke the stimulus structure. In the whole context (three-word) cue condition, developmental recall differences were reduced. Ackerman (1986) reasoned that category and thematic structures differ in preexperimental status as integrated representations in permanent memory, and the use of

thematic associations to provide retrieval constraint is more strongly dependent on stimulus structure, especially for children. Both the fifth-graders and the second-graders made good use of thematic associations when fully structured in the all-related stimuli and fully reinstated in the whole context cues when compared to recall of unrelated stimuli. Ackerman (1986a) concluded that the elements of the thematic stimuli are relatively unstructured or unorganized in children's permanent memory, but can be integrated and structured episodically. When this integration occurs and is reinstated in retrieval, thematic representations appear exceptionally meaningful to children to the extent that they are memorable, and perhaps more so than category representations under certain conditions.

In a follow-up experiment, Ackerman (1986a) presented 60 second graders, 60 fifth-graders, and 60 college students with two-, three- and four-word sequences of category and thematic stimuli. However, subjects were given event names (e.g., category = transportation vehicles; theme = trip) during acquisition, and the event names were used as retrieval cues instead of the context cues. For all-related stimuli the second-graders showed greater retrieval for the thematic over the category stimuli, but there were no differences for the fifth-

graders or the adults. The significant advantage of the theme name over the category name for the second-graders provides additional converging evidence that integrated and structured thematic events are more meaningful to young children than category events, at least to the extent that themes are easier to recall. Adult recall did not vary for stimulus relation, and developmental recall differences were larger for the category stimuli, suggesting that the meaningfulness of category events increases with age. Ackerman (1986b) proposed that the differences in retrieval between thematic stimuli and category stimuli stems from the differences in the structural representations of noun concept associations in memory. Category structures seem more organized or structured preexperimentally than thematic structures. The theme representations appear more experientially based than category structures and are seemingly more dependent on the organization and integration processes that occur during the encoding of stimulus information. Young children seem particularly sensitive to the thematic representations when the structures are fully activated at acquisition and reinstated at retrieval.

The child's ability to sort and group objects may depend upon the child's sensitivity to constraints on the names of objects and word meanings. The name of an object

may imply an overall description, a defining characteristic, a function or use, a basic-level or superordinate category, a salient feature of the object or any combination of these attributes. Thus, linguistic competency and proficiency play a role in children's sorting and classifying.

Ackerman (1987) found developmental differences in the relative salience of features in semantic memory and their contribution to cued recall. 120 second-graders, 120 fifth-graders, and 120 college students were presented with 42 cue-target noun pairs (e.g., Knife-Axe) and an orienting question that reflected either category (Are these weapons?), functional definition (Are these used to kill?), characteristic feature (Are these sharp?), incidental characteristic (Do these have handles?) , or a difference between the two items (Would you use this during dinner?). During retrieval, subjects were presented with the cue word of each pair and a question (either the same as during acquisition or another). When the same question was posed during acquisition and retrieval, the results for second- and fifth-graders showed the following pattern for successful recall: defining > characteristic > category = incidental. The following pattern was obtained by the adults: defining > characteristic = category > incidental. When the same

question reinstated the acquisition structure, the functional definition became prepotent for all ages (75.6% correct recall for second-graders, 81.1% for fifth-graders, and 92.2% for college students). When the question during acquisition and retrieval referred to category, second-graders recalled 16.7% of the words, fifth-graders 36.1% and college students 73.3%, from which Ackerman (1987) concluded that category features do not figure strongly in concept representations for second-graders.

Keil (1983) presented 24 children (eight each from kindergarten, second and fourth grades) and eight adults with 90 sentences and asked them to judge whether they "sounded silly" or not (e.g., "The storm is excited.", "The birthday is green."). A silly judgment was followed by the question "Why can't a [term] (e.g., storm) be [predicate] (e.g., green)? An "OK" judgment was followed up with questions as well, until the examiner was certain of the child's analysis of the terms or arguments that rendered each statement 'OK' or 'silly'. The results indicated that the adults' responses conformed to flowchart (semantic tree) expectations, with predictable responses, consistent with English syntax and semantics. The children, in contrast, demonstrated considerable confusion and uncertainty, with many "don't know"

responses. Although the children observed semantic constraints at a level significantly above chance, there were significant age differences, with 114 misapplications of a given predicate to a given term by kindergartners, 32 by second graders and only 5 by fourth graders. Some of the younger children seemed unable to distinguish the physical objects that are normally associated with many events from the events themselves. (This would appear consistent with the contextual and thematic relationships noted by Ackerman [1986b] and Greenfield and Scott [1986]). Keil (1983) argued for two patterns of knowledge development, reflecting distinctions between ontological categories of events (hours, birthday, thunderstorm) and all physical objects, and between the ontological categories of animals, plants, and other physical objects. In the events/physical -objects case, a totally new distinction was discovered and was first learned in an all-or-none fashion by means of "predicates" (outcomes) relevant to that distinction. Assigning terms to appropriate categories developed gradually as children learned more about the instances of the distinction, which was first understood in principle. In the animals/plants/physical-objects case, no new distinction was learned. The children seemed to know what animals were and the properties they could conceivably possess that

plants could not. However, they did not understand how a plant could be alive or sick, believing those properties could only be true of animals. Rather, development in this domain consisted of a gradually emerging awareness of the properties of a superordinate category, living things that encompassed both plants and animals. Keil (1983) proposed that basic conceptual categories are demarcated by patterns of normal language use, which constrains the categories formed and the process by which they are formed.

Whitney and Kunen (1983) presented 60 kindergartners, 60 second graders, and 60 fourth graders with a cued recall task, a sorting task and an inclusion task to examine typicality and superordinate labels in the development of hierarchical conceptual relationships in children's semantic memories. In the cued recall task, children were randomly assigned to one of three stimulus groups--superordinate (e.g., fruit), prototypical instance (e.g., apple), moderate instance (e.g., lemon),--to one of two orienting tasks (semantic, sensory [rhyming nonsense]), and to one of two cue lists for the assigned stimulus type. Each child was presented with ten target words in the following fashion: the child was told one target word, shown it on a card and asked a question. For the semantic orienting task, the question might be "Plane,

can you fly in it or eat it?" For the sensory orienting task, the question might be, "Plane, does it sound more like flane or lant?" Following a one-minute distractor number game, the cued recall phase began and the experimenter cued the child with stimuli from a different stimulus group (e.g., a prototypical instance to cue a superordinate). When subjects were tested for recall of superordinates when given prototypical and moderate instances as recall cues, recall increased reliably with increasing age, semantic orienting tasks were associated with higher recall than sensory tasks, and prototypical cues produced better recall than moderate cues. However, the critical comparison in the significant Age x Task x Cue interaction involved the effects of semantic versus sensory orienting within each age group. Both prototypical and moderate cues were significantly more effective after semantic than after sensory processing for the second- and fourth- graders. However, for the kindergartners the difference between recall after semantic and sensory orienting was significant only for the prototypical cues. The recall of prototypical instances when subjects were given superordinates and moderate instances as cues resulted in recall generally increasing with age, with the 5-year olds recalling significantly fewer items than the two older groups. Higher recall was associated with

semantic tasks and superordinate cues. Although superordinate cues produced higher recall than moderate cues regardless of task, the difference between the two cue types was greater following semantic than sensory tasks. Consistent with the previous analysis, semantic orienting led to greater recall than sensory (nonsense rhyming) orienting for 5-year olds when they were cued with superordinates but not when they were cued with moderate instances. For the 7- and 9- year olds, semantic orienting resulted in higher recall than sensory orienting under both cue types. Recall of moderate instances when subjects were given superordinates and prototypical instances as recall cues yielded the following significant differences: age: 9-years > 7-years > 5-years; semantic orienting > sensory orienting; superordinate cue > prototypical cue. Recall following semantic questions was significantly higher than recall following sensory questions for the 7- and 9-year olds, but not for the 5-year olds, suggesting that moderate instances (less typical exemplars) are not well represented in the 5-year olds' conceptual memories since neither superordinates nor prototypical class members served as effective cues for that age group. Whitney and Kunen (1983) noted that even under optimal encoding (prototypical targets and semantic orienting) and retrieval (superordinate cuing) conditions,

a significant developmental increase in recall was obtained. Since the recall task involved incidental learning, and since encoding and retrieval processes were similarly constrained at each age, the investigators concluded that the results were unlikely to be due to differences in strategies or metamemorial knowledge.

For the object sorting tasks, toys were selected that belonged to four conceptual categories not used elsewhere in the study: vehicles (airplane, car, motorcycle, boat); people (man, woman, boy, girl); jewelry (necklace, earring, bracelet, ring); kitchen utensils (plate, cup, fork, spoon). Subjects were asked to put the toys that go together in clear plastic bags, using as many bags as they needed. Out of a possible four for perfect sorting, the mean number of perfect sorts for the 5-, 7- and 9- year olds, respectively, was 2.1, 3.1, and 3.4. The 7- and 9-year olds did not differ reliably, but the 5-year olds made significantly fewer perfect sorts. Justifications given for each sort were classified, and it was noted that the 5-year olds use category labels only 28.4% of the time, whereas more than half of the older subjects' responses were category labels. The 5-year olds used nontaxonomic justifications 30.5% of the time, usually mentioning a superficial common feature such as color, compared to the older children who used nontaxonomic

justifications less than 5% of the time. Correlations between the two tasks were examined for the 5- and 7-year olds and found not to be significant, suggesting to the authors that different abilities might underlie the two tasks.

The class inclusion problem consisted of eight identical pictures of roses and eight identical pictures of daisies mounted on 2 cm cardboard squares. After establishing that the child understood the concept more, the experimenter varied the ratio of roses to daisies, and asked the subjects four questions, including "Are there more roses or more flowers?, Are there more flowers or more daisies?" None of the 5-year olds passed the inclusion problem and only two 7-year olds did. In fact, only 22 of the 60 9-year olds were correct. Whitney and Kunen noted the contrast between these results and those obtained on the other tasks, and argued that inclusion problem solving probably requires conceptual and/or linguistic competencies beyond the capacity of these age groups. They summarize their findings by noting that, under optimal encoding and retrieval conditions, 5-year olds will demonstrate hierarchical conceptual organization, and that conceptual systems of young children develop considerably between the ages of 5 and 9. The investigators suggest that the object-sorting task

does not address the age-related changes in hierarchical organization as children could and did sort by non-taxonomic strategies when not constrained by specific instructions. The traditional class-inclusion problem was problematic for almost 2/3 of the oldest children, although they had clearly demonstrated in the cued recall task that they possessed well-established hierarchical conceptual relations in memory.

D. Issues in Acquisition of Categorizing Skills

Some investigators argue that grouping objects by category or by function rather than in accordance with physical features requires qualitatively different skills which do not emerge or develop until children are about 7 or 8 years old (L. B. Smith, 1979, 1981). There is disagreement as to whether the age-related changes in these skills are conceptual or linguistic in nature.

Rosch and her associates (Rosch & Mervis, 1978; Rosch et al. 1976) claim that conceptual complexity is the mechanism of age changes. Using groups of three pictures in a standard sorting procedure and an oddity problem, with children 3 to 10 years of age, Rosch and Mervis (1978) found that all children were able to group at the basic taxonomic level (e.g., chairs, birds, fish, cars) at which category members possess common physical attributes

(e.g., chairs have 4 legs; birds have feathers and beaks), evoke similar motor programs (e.g., chair-look, turn back to, bend knees, feel for seat) and have similar shapes. However, they did find a developmental trend for superordinate classifications, e.g., clothing, furniture, and vehicles, where nursery-school aged children, kindergartners, and first-graders were significantly less accurate than the children 8 years of age and older. Rosch and her associates (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) also found that 3-year olds could sort into basic categories (99% correct sorts) even though they named the items correctly only 65% of the time. At all ages (3 to 10 years), correct sortings of superordinate categories (vehicles and animals) were superior to correct naming.

Mervis and Pani (1980), investigating the best-example theory of category acquisition, hypothesized that categories based on initial exposure to good exemplars (physical similarity) were easier to acquire than those based on poor exemplars, and that children should generally learn that good exemplars are category members before they learn that the poor exemplars are category members. Five-year olds and adults were taught nonsense category names (e.g., "naete") of six (good example) three-dimensional non-representational objects from each

of six categories. They were then asked to apply the names to 24 objects. In the second condition, subjects were taught the nonsense names of poor examples and then asked to name all the items. The results indicated that the 5-year olds had little difficulty grouping when the standards were "good" examples, but were significantly less accurate with "poor" exemplars. (The task was deemed too easy for the adults, who make no errors in either condition.) The investigators concluded that category structure principles (similarity) determined "goodness of example" rather than the label or name given to the first exemplar. For the 5-year olds, a category name was not as salient as perceptual cues in determining category membership.

Blewitt and Durkin (1982) used representational colored line drawings of typical and atypical examples of basic level categories (e.g., bird, dog, boat, shoe) in a non-verbal sorting task, a picture-naming task, and a name-recognition task with preschoolers (3-5 years of age) and adults. Three year olds were consistent across the three tasks -- they were more likely to match, name, and recognize pictured items which were typical of a basic level category than the atypical items. In the sorting task, the typicality effect was no longer significant for the 4- and 5-year olds (or the adults) but the effects of

typicality persisted in the picture-naming and name-recognition tasks, suggesting a dissociation between conceptual and linguistic processes. Typicality effects were seen in the adult name-recognition task, as well. The investigators suggested that children's developing skill at abstraction and/or increasing experience with atypical category members may underlie the improvement in performance with advancing age. However, linguistic processes cannot be ruled out as relevant to complex abstraction and superordinate categorization.

Bjorklund and Thompson (1983) presented Kindergartners, third, and sixth graders with a cued (by superordinate category label) input/cued output word recall task, using category typical (e.g., clothing = shirt) and atypical (e.g., clothing = socks) items that were based on either (1) children's conceptions of item typicality or (2) adults' conceptions of item typicality. At all grade levels, recall was greater with the child-defined lists than with the adult-defined lists, and typical items were recalled to a greater extent than atypical items. The "typicality" effect appeared to be due to the children not identifying many of the atypical word items as appropriate category members. Hence, children's categories were smaller and more narrowly defined than those of adults (a quantitative difference). The percent

of adult-defined atypical items not included by at least 75% of the same-age peers as category members decreased from 55% (kindergarten) to 27% (third grade) to 23% (sixth grade). The typicality effects in the child-defined lists appeared to be due to the qualitative differences in the "goodness of example" of the typical and atypical items. The results obtained by Bjorkland and Thompson (1983) support the role of increasing conceptual competence in categorizing with increase in age.

Piaget and Inhelder (1969) viewed "true" classification as distinctly semantic in nature. They concluded from their research that, prior to eight years of age, although children apparently sorted objects logically, they were unable to perform inclusion problems successfully and, therefore, were not "true" classifiers. Whitney and Kunen's (1983) findings support this view. Additional support for age-related changes in linguistic proficiency was provided by Milanti and Cullinan (1974) who found that, with tachistoscopic presentation of line drawings of common objects, six-year olds took significantly longer than nine-year olds to name the objects and to say "yes" or "no" when the experimenter said a word and then presented a matching or nonmatching picture. Since word-picture matching response latency was not related to word frequency (a variable in their study),

they concluded that the major source of variance in latency of object naming was not attributable to the perceptual identification of the object, but rather was a function of the type of responding required by the task. Milanti and Cullinan's (1974) results provide additional support for the separation of conceptual and linguistic skills in object identification and, by inference, categorization.

Other researchers regard the acquisition of sophisticated language skills (e.g., naming, rapid word-finding, knowledge of low frequency words) to be prerequisite to functional or superordinate categorical matching (Ackerman, 1987; C.L. Smith, 1979; Wiegel-Crump and Dennis, 1986), and argue that children under 8 years of age have not acquired the necessary level of linguistic proficiency.

Wiegel-Crump and Dennis (1986) investigated word-finding (naming: 45 words divided into the categories of animals, foods, clothing, household items, and actions) in children 6 to 14 years of age, in response to three lexical access conditions (a semantic description, a rhyming form, and a picture). The semantic condition began with a category cue and continued with a set of progressively limiting pieces of information about the target name. Both accuracy and speed of word-finding

improved with age, with six-year olds performing significantly worse than the other age groups in all three conditions. The investigators concluded that six-year olds lack a fully hierarchical semantically-based lexical organization, noting that, although the naming errors of all the children bore some discernible semantic relation to the target name, the errors of the six-year olds were not as close to the target name as those of the older children.

White (1982) showed slides of pictures that had been adult-rated as either typical (e.g., robin as bird) or atypical (e.g., turkey as bird) in six categories (animal, bird, food, clothing, plant, furniture) to two groups of nursery school age children. Each child was asked, "Is this a _____ (category name)?" The results indicated that young children underextend superordinate class labels, even when they are able to name the object correctly. From observations of mothers' language samples, White concluded that superordinate categories were more likely to be used when referring to paired typical instances (e.g., robin and bluejay as birds) than when referring to paired atypical instances (e.g., robin and turkey), and that the children's performances reflected the language modeled by the mothers.

Markman and Hutchinson (1984) proposed that children's sensitivity to linguistic constraints on nouns may help them acquire new categories rather than words being mapped onto concepts that have already been worked out nonlinguistically. Forty-one preschoolers were presented with 10 sets of pictures, each set consisting of a standard target picture of a common object (e.g., tennis shoe) and two comparison pictures, one a basic-level taxonomic match (e.g., high-heeled shoe), and the other a thematic match (e.g., foot). The children were divided into two groups: the "No Word" condition group was told, "See this? Find another one that is the same as this."; the "Novel Word" condition group were given a nonsense word to identify the object, "See this? This is a sud. Find another sud that is the same as this sud." Children in the No Word condition chose thematic related objects (e.g., dog and bone) as often as category members. When children were given a (nonsense) label for the target picture, they chose the categorical match (e.g., poodle with German shepherd) significantly more often than thematic matches. Markman and Hutchinson (1983) concluded that the children's tendency to match and group by thematic relations is attenuated by attaching labels to the objects, and this naming of objects induces a taxonomic categorizing strategy. In follow-up experiments,

preschoolers were presented with either a No Word condition, a Novel Word condition (as in the previous experiment), a Basic Level Word (actual label for target, e.g., cow), or a (Superordinate) No Word condition (in which the instructions "Find another one" was less explicit than the No Word in Experiment 1 and the categorical match was at the superordinate level, e.g., animal). When no word (either the original No Word or the Superordinate inducing condition) was presented, the children made as many thematic as categorical choices (at chance level). Children who heard the target described with the basic level word chose the categorically related object at chance level also. However, when the target picture was labeled with an unfamiliar word, children chose either the basic level categorical match or the superordinate level categorical match significantly more often than would be expected by chance. The children were asked to justify their choices. Children used fewer thematic justifications when presented with an unfamiliar word. Even when children chose thematically in the Novel Word condition, they justified the thematic choice with a thematic explanation 44% of the time. Children in the No Word condition justified thematic choices thematically 79% of the time. Thus, although young children often classify things thematically, simply hearing a new word induces the

children to focus more on categorical relationships. In a final experiment, Markman and Hutchinson (1983) presented preschoolers with line drawings of artificial objects which the children were told were categorical (e.g., "This swims in the water and this one swims in the water") and thematic ("This catches this", showing the interaction of two objects) information. Then the children were divided into a No Word condition and a Novel word condition. Children in the No Word condition chose the thematically (interacting) related picture significantly more than chance. When presented with a nonsense label, they chose the categorical match significantly more than chance. The investigators concluded that the simple presence of a noun (even an unfamiliar one) causes children to search for objects that share perceptual or functional properties. By 4 or 5 years of age, a word induces the child to search for categorical relations even among objects that can only be related at the superordinate level of categorization. Children who heard a novel word tended to give more justifications that referred to the categorical relations between the objects, whereas children who did not hear a label for the objects referred more often to thematic relations.

It may be that increasing ability to categorize beyond the physical, stimulus-bound features of objects

reflects a continuous developmental trend in complex conceptualization and abstraction, with verbal names applied to label and describe the processes. Contrary to this, it may be argued that the ability to categorize can develop to some basic taxonomic level and perhaps a few common superordinate categories (e.g., animals, clothing), but that adult-level proficiency in abstraction and categorization requires semantic, and specifically--linguistic, mediation.

Warrington and Taylor (1978) postulated a hierarchical and lateralized model of object recognition in adults. The first stage is that of perceptual categorization, both postsensory and presemantic, which is lateralized to the right cerebral hemisphere. The second stage is semantic categorization, consisting mainly of the categorized output of the perceptual system and is lateralized to the left hemisphere. The perceptual --> semantic sequence of the model is consistent with the developmental model in which semantic, taxonomic based categorization develops from the perceptually-based categories of infants.

According to the levels-of-processing model proposed by Craik and associates (Craik & Lockhart, 1972; Craik & Tulving, 1975), information is processed in hierarchical fashion- from the visual, nonsemantic, physical

characteristics of the stimulus, through the auditory stage of how the name or verbal label sounds, to the semantic properties regarding taxonomy, function, and superordinate categories. Craik and his associates argued that effective recall and recognition are a direct function of level of processing, hence semantic elaboration is more likely to facilitate retention than other types of encoding. The processing of thematically related events would seem to occur at a level closer to the perceptual than the semantic end of the spectrum. However, the results obtained by Greenfield and Scott (1983), Whitney and Kunen (1983), and Ackerman (1986, 1987) suggest that thematically-related or contextual matching remains a viable strategy for matching and grouping objects, having evolved from processing real-world events.

The processes and strategies by which children match, group and categorize objects appear to emerge at different, yet overlapping, stages and develop increasing breadth and sophistication with increasing age. The role of previous instruction and of (language) constraints on task performance is difficult to separate from spontaneous performance.

II. THE DEVELOPMENT OF FUNCTIONAL HEMISPHERIC ASYMMETRIES IN CHILDREN

A. Historical Background of Hemispheric Specialization of Function

There is an extensive literature relating behavioral asymmetries to underlying functional and anatomical asymmetries of the brain (Bradshaw & Nettleton, 1983; Bryden, 1982; Springer and Deutsch, 1981). Although hemiparesis and unilateral motor deficits had been noted with contralateral brain trauma by the ancient Greeks, the localization of other functions was not investigated until the 19th century. In 1825 Bouillaud noted the frequent association of language loss to lesions of the frontal lobes. Although Dax clearly related aphasia to lesions of the left cerebral hemisphere as early as 1836, it remained unpublished for 25 years. In 1861 Broca presented the case of "Tan" and asserted four year later (after collecting autopsy data from eight aphasic patients) that "Nous parlons avec l'hémisphère gauche." By 1974, Wernicke's findings that lesions of the left superior temporal gyrus resulted in language disturbances indicated that at least two separate language functions could be affected by lesions in two different left hemisphere locations-- anterior in the frontal lobe (Broca's area) and posteriorly in the temporal lobe.

The notion of different, complementary specializations for the right hemisphere was raised by Hughlings Jackson as early as 1865 when he wrote, "If it should be proved by wider experience that the faculty of expression resides in one hemisphere, there is no absurdity in raising the question as to whether perception--its corresponding opposite--may be seated in the other" (Jackson, cited in Springer & Deutsch, 1981, p. 13).

The concept of a verbal-nonverbal dichotomy of hemispheric specialization, wherein the left cerebral hemisphere of most right-handed individuals is specialized for processing verbal, speech-related stimuli and the right hemisphere is specialized for nonverbal, primarily visuo-spatial, stimuli (Bryden, 1965, 1973; Bryden & Allard, 1976; Kimura, 1966, 1969) has been supported by anatomical evidence of a larger left than right planum temporale in normal adults (Geschwind & Levitsky (1970). Clinical studies of commissurotomy patients (Gazzaniga & Sperry, 1967; Levy & Trevarthen, 1976, 1977) have generally supported the view of left hemisphere superiority for processing verbal stimuli and right hemisphere superiority for spatial processing of visual stimuli. Studies using standardized testing measures as well as newly devised language tasks with adult patients

who had undergone cerebral hemispherectomy in infancy (Dennis, 1980; Dennis & Kohn, 1975; Dennis & Whitaker, 1976, 1977; Kohn, 1980; A. Smith, 1966, 1969; Smith & Burklund, 1966) provide additional support for the verbal-nonverbal functional dichotomy between the hemispheres, although it must be noted that the dichotomy is a relative one as many of the studies indicate some (and occasionally, considerable) right hemisphere language capabilities. Clinical investigations of brain-damaged patients (Benton, 1970, 1972; De Renzi, 1978; Gates & Bradshaw, 1977; Joynt & Goldstein, 1975; Milner, 1971; Warrington & Taylor, 1978) have indicated that right hemisphere damage is associated with a number of nonverbal visuospatial deficits --in size discrimination, in perception of direction (in both the visual and tactile modalities), in stereopsis, in the perception of part-whole relationships, in facial recognition, and in picture completion, picture arrangement, and picture copying.

B. Functional Hemispheric Asymmetries in Adults

Results of tachistoscopic studies of normal right-handed adults have indicated a right visual field/left hemisphere (RVF/LH) advantage for identifying letter and digit stimuli, words, and pseudowords (lexical decision tasks) (Bradshaw, Nettleton, & Taylor, 1981; Bryden 1965,

1973; Bryden & Rainey, 1963; Cohen, 1975; Hines, 1978; Kimura, 1961, 1966, 1969, 1973; McKeever & Huling, 1971). A left visual field/ right hemisphere (LVF/RH) superiority has been found when subjects perform physical matches of letters (e.g., AA, gg), letter detection with transformations such as mirror-reversals (Bradshaw, Bradley, Patterson, 1976), and unusual typefaces (Bryden & Allard, 1976). A LVF/RH advantage has also been reported for brightness discrimination (Davidoff, 1975), color discrimination (Hannay, 1979), perception of line orientation (Umiltà, Rizziolatti, Marzi, Zamboni, Franzini, Carmada, & Berlucchi, 1974), dot detection (Davidoff, 1977), dot localization (Kimura, 1969), matching arcs to circles (Hatta, 1977), and facial recognition (Hilliard, 1973; Ley & Bryden, 1977).

Auditory studies of left- and right-ear advantages in dichotic listening tests (Bryden, 1963, 1982) indicate a right ear advantage (REA/LH superiority) for dichotically presented digits (Kimura, 1961), words (Yeni-Komishian & Gordon, 1974), consonant-vowel syllables (Shankweiler & Studdert-Kennedy, 1967), sentences (Zurif & Sait, 1969, Zurif & Mendelsohn, 1972) as well as articulation factors such as fricatives (Darwin, 1971). A left ear advantage (LEA/RH superiority) has been found for such nonverbal stimuli as melodies (Kimura, 1964), musical chords

(Gordon, 1970), notes from musical instruments (Kallman & Corballis, 1975), piano tones (Sitdis & Bryden, 1978), synthetic musical tones (Cutting, 1974), environmental sounds, such as ringing phone, ticking clock, and barking dog (Knox & Kimura, 1970), and nonverbal vocalizations, such as crying, and laughing (Carmon & Nachshon (1973).

With respect to asymmetries in tactile perception, the left hand (right hemisphere) appears to be superior to the right hand for perception of line slant (Benton, Levin & Varney, 1973), of three-dimensional block letters and digits (Oscar-Berman, Rehbein, Porfert, & Goodglass (1978), and for reading Braille (Harris, 1980).

It should be noted that varying the complexity of the task or the stimuli can reduce or alter hemispheric asymmetries, leading Bradshaw and Nettleton (1983) to conclude that the nature of the task interacts with the stimulus type (verbal versus nonverbal) in determining hemispheric advantage/superiority.

Other contrasting dichotomies have been offered to describe the functions that characterize and differentiate the two cerebral hemispheres: focal (left hemisphere) versus diffuse (right hemisphere) processes (Semmes, 1968); propositional (LH) versus appositional (RH) (Bogen, 1969); verbal (LH) versus imaginal (RH) (Paivio, 1971); serial (LH) versus parallel (RH) processing (Cohen, 1973);

analytic (LH) versus holistic (RH) processes (Bever, 1975; Bradshaw & Nettleton, 1981,1983). Bradshaw and Nettleton (1971, 1973) proposed that the right hemisphere acquires its superiority in certain holistic, Gestalt functions because left hemisphere space has been preempted by the analytical, sequential, and temporal ordering of language processes. This argument implies that the hemisphere specialized for one type of processing (e.g., holistic, non-verbal) is necessarily opposite to the hemisphere specialized for the other (e.g., analytic, linguistic) functions. Goldberg, Vaughan, and Gerstman (1978) proposed still another set of differing hemispheric functions: the left hemisphere is specialized for processing stimuli by means of pre-existing descriptive systems whereas the right hemisphere processes stimuli for which no descriptive system pre-exists in the cognitive repertoire. What determines the left hemisphere's preference for processing a particular type of material is the codability of the material in terms of a discrete set of features, specifically relevant to the type of material and the presence of a descriptive code for that material in the person's cognitive repertoire.

According to an alternative view (Bryden, 1982; Kinsbourne, 1973, 1975), the cerebral cortex is a dynamic system and the behavioral processing asymmetries reflect

those dynamic factors that change the overall level of activity in one hemisphere relative to the other hemisphere. In this view, the intrahemispheric spread of neural excitation from one cortical area to adjacent areas is emphasized. The functional differences between the cerebral hemispheres may be related to optimizing conditions under which each hemisphere functions most efficiently (Bryden, 1982). Kinsbourne (1973,1975), discussing the factors of context versus content in experimental tasks, argued that attentional and priming factors had been ignored in the exploration of hemispheric asymmetries while sensory input factors (i.e., types of stimuli) had been overemphasized. He suggested that hemifield differences are due to differential activation of the hemispheres (not structural differences) which result in an attentional gradient across visual space instead of a split between the visual fields; the asymmetries in vision are essentially spatial rather than hemiretinal. (However, Corballis [1986] claims that there is no adequate test of whether laterality effects are tied to a retinal or a spatial definition of left and right.)

C. Development of Lateralization of
Function in Children

Although the neuroanatomical asymmetries in adult brains noted by Geschwind and Levitsky (1970) have been documented in the newborn (Witelson & Pallie, 1973) and even in the 28 week old fetus (Wada, Clarke, & Hamm, 1975), there is considerable disagreement as to whether the associated behavioral asymmetries so clearly documented in adults and older children are present at birth or emerge as children develop.

Witelson and Pallie (1973) studied 16 adult and 14 infant and neonatal brains at postmortem and found that, in agreement with Geschwind and Levitsky (1968), both the infants and the adults had a larger left than right planum temporale. Autopsy data confirming the larger left planum temporale in fetuses as young as 28 weeks gestational age was provided by Wada, Clarke, and Hamm (1975). Witelson and Pallie (1973) argued that the morphological asymmetry found in infants "favouring a left temporal lobe area of known significance for the reception of language in adults supports the hypothesis that the human newborn has a pre-programmed biological capacity to process speech sounds" (p. 644). The anatomical asymmetry in brain areas later associated with linguistic processing did not preclude the

investigators' acceptance of early bilateral representation of language and hemispheric transferability of speech, although they suggested that the upper limits of right hemisphere language acquisition might be limited by the absence of a "pre-programmed" anatomical structure which is specific to the left hemisphere.

Bryden (1982) argued that the study of the ontogenetic origins of lateralization must address the question of whether there is any developmental change from infancy to adulthood in functional lateralization over and above the changes in the capacity to perform certain tasks.

There are two major theories of development of functional hemispheric asymmetries. One is Lenneberg's (1967) progressive lateralization theory which views higher mental functions such as language as being represented bilaterally at the onset of development in the immature brain. Lenneberg proposed that the cerebral hemispheres are initially equipotential and uncommitted to specific psychological functions and that cerebral dominance for language is not established at the start of language development during the first two years of life. Therefore, Lenneberg (1967) argued, both cerebral hemispheres initially possess the neural substrate capable of subserving language functions. During the first two

years of life, damage to either hemisphere would result in few, if any, permanent effects on the development of cognitive or language functions. He hypothesized that the emergence in ontogeny of left hemisphere dominance for language is a result of the progressive decrease in right hemisphere involvement as the child matures and acquires language. Furthermore, the progressive lateralization theory postulates that certain functions will develop greater representation in either the left hemisphere (e.g., language skills, sequential/analytical processing) or the right hemisphere (e.g., visuospatial, parallel/holistic processing) and that asymptotic asymmetry may occur at five years of age (Krashen, 1973), at puberty (Lenneberg, 1967) or as late as old age (Brown, 1978; Brown & Jaffee, 1975). Brown (1978) extended Lenneberg's original theory by positing that cerebral dominance for language functions occurs as an intermediate stage between the more primitive and ontogenetically earlier bisymmetric functions (e.g., controlling axial and/or proximal movements) and the ontogenetically later completely contralateral representation (e.g., distal fine motor control, visual field dichotomies). He proposed that, in the course of maturation, the development of lateralized representation causes an "asymmetrization" of earlier bilateral levels (in representations of acts and

percepts), and may "account for certain psychological 'deficits' of aging. These would reflect an increasing specification of the left-lateralized system rather than a process of cellular decay" (Brown, 1978, p.261).

Lenneberg's theory of progressive lateralization additionally postulates that the ages of complete lateralization of functions also vary, depending upon the specific neuropsychological function involved (e.g., consonant discrimination, reading) as well as on gender (Hiscock, 1988). With respect to the last, the evidence seems to suggest that women are less clearly lateralized than men (Bryden, 1979a; Levy, 1974) and investigators have sought to explain some of the gender-related differences in cognitive functioning in terms of different patterns of cerebral lateralization.

Initially, evidence supportive of the progressive lateralization theory was provided by studies of acquired aphasia following head injury in children (Basser, 1962; Zangwill, 1964). These studies reported that speech was disrupted following injury to either hemisphere and that children demonstrated greater recovery of speech than adults with similar injuries. In reviewing the literature on the development of hand preference, Witelson (1977) found conflicting evidence for handedness in infancy, although by five years of age, a right-hand preference

appeared to be firmly established. She offered this as additional supportive evidence for the progressive lateralization theory. Moscovitch (1977) suggested that, while the evidence from infant electrophysiological data strongly supports the existence of some functional asymmetries in newborns and young children, changes in the degree of asymmetry and the emergence of new asymmetries as the child develops argue for some process of developing lateralization. The longitudinal studies of Dennis and her associates (Dennis, 1980; Dennis & Kohn, 1975; Dennis & Whitaker, 1976, 1977), which document the acquisition of functional language and normal verbal intelligence in patients, left-hemispherectomized as infants, support some degree of hemispheric equipotentiality (at least during the first year of life) with respect to the development of functional language, regardless of the cerebral hemisphere removed. Krashen (1973) proposed that 5 years of age was the upper limit of the critical period for hemispheric equipotentiality for language, based upon his review of Bassler's (1962) study of acquired aphasia in children in which Krashen noted that there were no cases of crossed aphasia after age 5. That is, before 5 years of age, incidents of right hemisphere trauma resulted in acquired aphasia but there were no such cases cited after age 5.

Hence, Krashen concluded that the right hemisphere was capable of subserving language functions until age 5.

The second major theory of the development of functional lateralization is diametrically opposed to that of Lenneberg . The invariant lateralization theory (Kinsbourne, 1975) hypothesizes that functional hemispheric asymmetries are present at birth and are invariant throughout development. The acquisition of each higher mental function reflects developmental sequences that begin and culminate in proficiency in the same cerebral hemisphere, whether left or right. Kinsbourne (1981) has argued that early lateralization of a particular higher mental function is evidenced by the demonstration of lateral asymmetry in "precursor" behaviors (e.g., auditory evoked potentials to linguistic stimuli; see Eimas, 1971; Entus, 1977; Molfese and Molfese, 1986) in the developmental sequence of that function (e.g., receptive language processing). Kinsbourne points out that Geschwind and Levitsky's (1968) finding of neuroanatomical asymmetries (from autopsy data) in human adults is compatible with the known behavioral asymmetries. Similarly, in the longitudinal studies of hemispherectomized children, Dennis and her associates (Dennis, 1980; Dennis & Kohn, 1975, Dennis & Whitaker, 1976, 1977) noted that the children with intact left

hemispheres were capable of processing sentences of greater semantic and syntactic difficulty (e.g., passive voice, negative interrogatives, sentences with 3 or more grammatic transformations) than were the children with intact right hemispheres. They reasoned that the right hemisphere was capable of subserving language and speech processes, but not to the extent and degree of sophistication of the left hemisphere. Thus, the hemispheric advantage or superiority obtained in laterality studies may not reflect an absolute dichotomy, but rather a slightly greater proficiency or efficiency for that particular task. The goal of the researcher must be to determine those factors that contribute to the relative hemispheric advantage-- factors relating to type of material, sensory system involved, task demands, sensory and/or motor limitations and demands of the experimental procedure, and attentional and priming factors-- and whether these factors are stable or dynamic and changing in relative prepotency during the growth and development of the child.

1. Development of Neuroanatomical Asymmetries

Investigations of neuroanatomical asymmetries in infants and children have sought to clarify the relationship between emerging behavioral asymmetries and

their underlying neuroanatomical substrates and thereby to provide support for either Lenneberg's theory of developing lateralization or the invariant lateralization theory. Studies of brain morphology and its relation to behavioral asymmetries have focused on two major areas of investigation: (1) comparison of homologous areas in the cerebral hemispheres (Geschwind & Levitsky, 1968; Witelson & Pallie, 1973; Wada, Clark & Hamm, 1975) as noted above, and (2), the differential development of the cerebral hemispheres in fetal brain growth (Best, 1988) and its interaction with the fetal environment (Turkewitz, 1988).

Best (1988) argues that the neuroanatomical asymmetries reflect a right-to-left gradient in the embryological development of the cerebral hemispheres. Initially, the fetal brain develops in a general anterior-to-posterior direction which is later complicated by an interaction with the ventral->dorsal gradient and the primary-> secondary -> tertiary developmental gradient. Best hypothesizes that the "earlier onset in the formation and growth of a given region of telencephalon will strongly tend to result in a larger volume of that region..."(p.12). Her prediction of a three-dimensional growth vector begins with the earlier emergence of right primary motor, premotor, and sensory regions (lying more frontally and ventrally). Simultaneous development along

all three gradients would result in the earlier emergence of left hemisphere tertiary association areas (including Wernicke's area) in more posterior and dorsal regions. Based on her model of a morphological growth vector, Best (1988) proposed a basis for developing functional and behavioral asymmetries, stating that development of "regional functional maturity should proceed according to the same growth vector as already outlined for the morphological development of the hemispheres" (p. 27). Thus, right hemisphere functions should develop in frontal motor and premotor regions, and in primary sensory regions before the homologous left hemisphere areas. As support for her proposal, Best and her associates (Best, Hoffman, & Glanville, 1982) cite their finding of a right-hemisphere advantage for memory-based discrimination of musical notes by two-month old infants, but no left-hemisphere advantage for memory-based discrimination of speech syllables until infants were three months old.

Turkewitz (1988) proposes that the differential development of the cerebral hemispheres during gestation, with the earlier convolution of the right hemisphere (Galaburda, 1984) and the ultimately larger and more complex left hemisphere, interacts with the growth of the fetus to alter the nature of, and the fetal response to, the acoustic environment. These changes both contribute to

and result in "elaboration of developing specializations" (Turkewitz, 1988, p. 78). Thus, during the early months of gestation, while the fetus is small and the uterine walls relatively thick, flaccid, and a poor conductor of sounds produced externally, the earlier developing right hemisphere is exposed primarily to internal sounds: gastrointestinal noises, the maternal and fetal heartbeats--hence, the predisposition of the right hemisphere to specialization for environmental sounds. During the later months of gestation, the thinner uterine wall coupled with the surge in left-hemisphere development, make maternal vocalizations a salient acoustic stimulus--biasing the developing left hemisphere for the later superior processing of language. DeCasper and Fifer's (1980) finding that 1 to 3 day old infants were able to discriminate their mothers' voices from other female voices and that this discrimination was due to prenatal exposure to maternal speech were offered by Turkewitz (1988) as support for his position.

The anatomical asymmetries found in fetal and infant (and adult) brains, as well as the dynamic differential gradients in fetal development, have been linked to behavioral asymmetries (e.g., discrimination of CV syllables) corresponding to the (left hemisphere) verbal/ (right hemisphere) nonverbal dichotomy in normal infants.

In general, these findings have provided considerable support for the invariant lateralization theory, modified to acknowledge emerging behavioral competencies whose lateralized nature may not be evident until later in development.

2. Development of Electro cortical Asymmetries

Studies of hemispheric differences in averaged evoked responses (AERs) to auditory and visual stimuli in infants and children have been conducted in an attempt to examine the relationship between neuroanatomical and behavioral asymmetries. Following the Eimas study (Eimas, Siqueland, Jusczyk, & Vigorito, 1971), which indicated that 3 month old infants could discriminate consonant sounds, Molfese (1972) conducted electrocortical studies as a way of investigating the development of lateralization of pre-linguistic language functions. Auditory event-related potentials were recorded from the left and right temporal regions of 10 infants (age range = 1 week to 10 months, mean age = 5.8 months), 11 children (age range = 4 to 11 years, mean age = 6.0 years) and 10 adults (age range = 23-29 years, mean age = 25.9 years) (Molfese, Freeman, & Palermo, 1975). The stimulus events were speech (CV combinations: ba and dae, the words boy and dog) and non-speech sounds (piano chord and white noise), presented

through a speaker above the subject's head. Differences in amplitude between the largest positive and largest negative peaks of the resulting AERs in the right and left hemispheres were compared. The left hemisphere ERPs (N1P2 component) were larger in magnitude for speech stimuli than the right hemisphere ERPs (for 27 of the 31 subjects), and the right hemisphere ERPs (N2P3) were larger than the left hemisphere ERPs for the nonspeech piano chord (30 of 31 subjects) and white noise (29 of 31 subjects). Since the proportion of subjects in each age group with lateralized responses did not differ, it is clear that hemispheric differences were present in infants, long before the progressive lateralization theory would predict. (Interestingly, Molfese et al. [1975] noted that the magnitude of the hemispheric differences appeared to decrease with age.) However, since there were so few subjects in groups with wide age ranges, one cannot justifiably argue for unequivocal support of the hemispheric invariance theory.

Subsequent evoked potential studies revealed a right hemisphere effect (wave peaks not found with recordings from the left hemisphere) for category discrimination of voiced and unvoiced consonants in 4-year olds (Molfese & Hess, 1978), and in infants 2 to 5 months of age (Molfese and Molfese, 1979). However, with infants under 48 hours

of age, no right-hemisphere or bilateral effects (wave form peaks) were obtained (Molfese and Molfese, 1979), although, by two-months of age, infants could make VOT categorical discriminations of voiced versus unvoiced consonants, and they demonstrated a right hemisphere effect (wave form peak) for this task. It should be noted that the direction of these early differences is opposite to that which occurs later. Clearly, there is a laterality change/shift during development. Functional asymmetries appear early in development, although their relation to later left-hemisphere linguistic functions remains unclear. While these right-hemisphere effects do not support the hemispheric invariance theory (Kinsbourne, 1975, 1981), they also fail to support the concept of hemispheric equipotentiality in infancy (Lenneberg, 1967).

Molfese and his associates (Molfese, 1978; Molfese and Molfese, 1979, 1980; Molfese & Schmidt, 1983) also studied hemispheric differences in infant electrocortical responses to consonant place of articulation (second formant transitions) and found (left) lateralized and bilateral components. Also, Molfese and Molfese (1979) found that PLACE discrimination is present from birth (<48 hours old), unlike the VOT discriminations. They (Molfese & Molfese, 1980) also found the left-hemisphere component

(but not the bilateral component) in 11 preterm male infants (32-37 weeks gestation).

Hemispheric asymmetries in auditory phonemic processing are clearly present soon after birth, although the relative left- and right- hemisphere contributions at 48 hours of age are not clear. However, Molfese (1988) argues for a strong relationship between ERP discrimination of speech-related sounds in infancy and later acquisition of language skills. Based upon a longitudinal study (Molfese & Molfese, 1985, 1986) of 16 infants from birth to three years of age (AERs at birth and every six months thereafter), it was found that the newborn infants who demonstrated a reliable left-hemisphere superiority in discrimination of consonant sounds scored higher on tests of verbal ability (e.g., PPVT, McCarthy Scales of Children's Abilities) at three years of age. The high-scoring group also demonstrated a right-hemisphere component that discriminated between different nonspeech stimuli during the neonatal period. The low scoring group did not demonstrate lateralized discrimination for either type of sound. Molfese and Searock (1986) noted that the ability of 1 year olds to discriminate vowel sounds (ERPs) supported the relationship between early ERP findings and later language competency. While no argument was advanced for early

bilaterality as an abnormal, or pathological condition, Molfese (1988) proposed that children who were able to discriminate speech and nonspeech sounds at an early age were at an advantage in language development because their nervous systems were capable of finer discriminations along various dimensions.

Various studies have supported greater right than left hemisphere electrocortical responses to nonlinguistic visual stimuli in infants. Davis and Wada (1977) recorded visual evoked potentials from 16, 2-11 week old infants, where the VERs were time-locked to a 10-microsecond flash of light from a photostimulator approximately 30 inches from the infant's face. Recordings from left and right temporal and occipital regions were analyzed for coherence and by power spectra analysis. The coherence procedure revealed no hemispheric differences in VER. However, the power spectra analysis indicated greater right occipital than right temporal frequencies, while left hemisphere temporal and occipital regions did not differ.

Crowell and associates (Crowell, Jones, Kapuniai, & Nakagawa, 1973) measured electrical brain activity and subsequent photic driving (increase in EEG spectral frequency to same frequency as driving stimulus) in 97 neonates. Light flashes were presented at a rate of 3 per second for 4 seconds. Of the 18 infants who showed

unilateral driving, 16 showed significantly greater activity in the right hemisphere, contrasting with the typical bilateral driving found in adults. A developmental sequence was noted in a subsequent study (Crowell, Kapuniai, & Garbanati, 1979) of 217 infants tested serially, with 12% displaying bilateral driving at 2 days of age, and 48% by 30 days of age. This decrease in hemispheric asymmetry with increase in age (similar to that noted by Molfese et al. 1975) may be a function of maturing commissures and inter-hemispheric communication (Molfese, 1988). The neonatal findings were thought to represent early functional asymmetries, perhaps related to hemispheric asymmetries in brain maturation. Although the visual ERP studies of infants do not address the language acquisition issue, the results suggest that the right-hemisphere ERP response to visual flash stimuli may be a "precursor" activity to later visuo-spatial processing.

Consistent with the findings from studies of neonates, studies with children from 6 to 16 years of age have also found greater right hemisphere response (consisting of higher amplitude late wave components) to visual flash stimuli (Bigum, Dustman & Beck, 1970; Rhodes, Dustman, & Beck 1969; Richlin, Weisinger, Weinstein, Giannini, & Morgenstern, 1971).

Bakker and his associates (Bakker, 1979, 1984; Bakker, Licht, Kok, & Bouma, 1980; Licht, Kok, Bakker, & Bouma, 1986) have obtained electrocortical data to support their hypothesis of right-hemisphere involvement, even prepotence, in the early stages of learning to read. Licht et al. (1986) recorded visual ERPs from left and right temporal and parietal sites as 61 kindergarten children read four 3-letter, one-syllable words (Dutch equivalents of chicken, cup, berry, and knife) in normal or degraded condition (parts of letters deleted) which were presented tachistoscopically at the center of a viewing screen. The children had been taught the words prior to the testing, and had been divided into slow and fast Reading Acquisition Score (RAS) groups, depending upon whether they scored above or below the median acquisition score. There were 17 fast and 15 slow RAS boys, and 14 fast and 15 slow RAS girls. The obtained ERPs were averaged separately for the normal and degraded words. Regression analysis indicated that only right hemisphere ERP components were significantly correlated with rate of reading acquisition. Bakker et al (1986) concluded that subprocesses involved in early reading acquisition are mediated primarily by the right hemisphere, perhaps because visuospatial analysis of printed script, for the novice reader, requires right-

hemisphere strategies similar to those employed by adults when presented with perceptually demanding typeface (Bryden & Allard, 1976).

Bakker et al. (1980) also found differential hemispheric (ERP) involvement in the reading of left- and right-ear dominant children (determined by dichotic digit testing), as well in those with as different reading styles. They recorded ERPs from left and right temporal and parietal sites as elementary school children read short, meaningful words. Children who were right-ear dominant for linguistic stimuli read relatively fast and inaccurately, making substantive errors, e.g., substitutions, omissions, and intrusions of letters and words. Children who were left-ear dominant read slowly but accurately, making more "time consuming" errors such as repetitions and fragmentations.

In a subsequent study, Bakker and Vinke (1985) attempted to change the between-hemisphere differences in word-elicited ERP amplitudes with "hemisphere-specific" stimulation. From a group of 136 learning-disabled elementary school children, 35 were selected for inclusion as L-type dyslexics who showed a right ear advantage for dichotic digits and 35 were selected for the P-type dyslexic group (left ear advantage for dichotically presented digits). Each group was subdivided into 5

treatment groups of 7 subjects each (L1-L5, P1-P5), and each group was stratified to minimize between-group differences in years of reading experience. Groups L1 and P1 received hemisphere-specific training by presenting words tachistoscopically in the left visual field of L1 subjects (to stimulate the right hemisphere) and the right visual field of P1 subjects (to stimulate the left hemisphere). Groups L2 and P2 had words presented in the central visual field to serve as controls for L1 and P1. The other groups received varying degrees of training. Group L1 demonstrated significant scholastic improvement, with increased word reading efficiency and improved sentence reading. A correlation between parietal ERP changes and substantive error indicated that the errors increased with increases in left hemisphere ("leftening of") early parietal positivity. Relative decrements (L1 group) in substantive errors were correlated with arrested "leftening" of the parietal positivity. Bakker and Vinke (1985) concluded that the right-hemisphere stimulation arrested the "leftening" of early parietal positivity in L-dyslexics which, then, improved reading accuracy. (An alternative explanation, that training induced a change in reading strategy that was, then, reflected in altered ERP components, was not discussed.) Direct left-hemisphere stimulation in P-dyslexics (P1) did not result in improved

text reading scores, but the children in this group did tend to make fewer mistakes in reading the tachistoscopically flashed words. "Leftening" of parietal positivity (correlated with decreases in reading accuracy) was increased in P-dyslexics with left hemisphere stimulation, and "leftening" of temporal positivity was associated with increased errors in flashed word reading for these P-dyslexics.

Cohen and Breslin (1984) analyzed hemispheric VER differences in 16, 11-year old normal readers and 16, 11-year old dyslexics in response to tachistoscopic presentation of blank flash stimuli and simple three- and four-letter words. They postulated high intrahemispheric correlations when the cerebral hemisphere acted as a whole, and reduced intercorrelations if different parts of the hemisphere were processing information differentially. High interhemispheric correlations would indicate a lack of hemispheric differentiation for processing the stimuli, whereas low correlations would reflect differential responses to the stimuli. The results indicated significant differences in the amount of synchrony or intrahemispheric specialization in processing verbal stimuli. In normal readers, the activity of the right and left hemispheres differed during reading, while the lack of interhemispheric specialization was seen in the higher

cross correlations between the right- and left-hemispheres of the dyslexic children. Cohen and Breslin (1984) hypothesized that if the activity of one hemisphere is not suppressed, interacting processes in both hemispheres may result in competing information that leads to delays and misidentifications in performance. This is a contemporary restating of Orton's (1937) hypothesis of incomplete cerebral lateralization as the cause of poor reading.

Recording ERPs to word and musical-chord stimuli in 13 normal 8-12 year old readers, Fried, Tanguay, Boder, Doubleday, and Greensite (1981) found that wave form differences between ERPs were significantly greater to both words and chords over the left hemisphere as compared to the right, supporting the results of Cohen and Breslin (1984) discussed above.

In general, the reported hemispheric differences in averaged evoked responses to visual and auditory stimuli appear to support the view that the left cerebral hemisphere in children is specialized for complex linguistic and musical processing, and that this specialization has electrophysiological correlates in infancy.

3. Development of Behavioral Asymmetries:

a. Auditory Asymmetries

As 60% of the auditory fibers from each ear cross to the contralateral cerebral cortex, the simultaneous presentation of auditory stimuli to both ears (dichotic listening) offers a method of investigating hemispheric specialization for, and developmental changes in, the auditory processing of verbal and non-verbal stimuli. An ear advantage, defined as either greater accuracy or shorter latency in recalling the stimuli presented to that ear has been interpreted as reflecting the superior processing (speed and/or efficiency) of the contralateral cerebral hemisphere. Considerable evidence has been collected in developmental studies of dichotic listening which supports the verbal-nonverbal dichotomy and hemispheric asymmetry.

To assess hemispheric asymmetry in infants, Entus (1977) combined the dichotic listening paradigm with a High Amplitude Sucking procedure in which the presentation of a dichotic stimulus pair was made contingent on the infant's sucking. When sucking rate decreased with the continued presentation of the same stimulus pair, a novel stimulus was presented to one ear while the other ear received the original stimulus. Discrimination of the stimulus change is inferred from recovery of predecrement

sucking rate. If a novel stimulus in one ear results in greater recovery of sucking than does a novel stimulus in the other ear, we may assume that the hemisphere contralateral to the ear associated with a greater recovery rate processes the stimulus more efficiently. Thus, a significant difference between ears in the rate of recovery can be said to reflect differences in hemispheric processing of the stimulus material (Entus, 1977). In one experiment, Entus (1977) presented CV stimuli (syllables: /ma/, /ba/, /da/, /ga/) spoken by a male voice to 48 infants (24 boys and 24 girls in two age groups: under 75 days old and over 75 days old, and found greater recovery of sucking in response to stimulus change in the right ear than in the left (71% of the infants showed an REA.) When musical stimuli, the note A (440 Hz) on four instruments--viola, cello, piano, and bassoon-- were presented, Entus (1977) found significantly greater recovery following the stimulus change in the left ear (79% showed an LEA). An age effect was noted only for the musical stimuli, with the younger infants demonstrating greater overall recovery of sucking than the older infants. Entus (1977) noted that of the 16 infants who participated in both experiments, 13 showed a LEA for the musical stimuli and an REA for the linguistic stimuli. Her results indicate that infants as young as 22 to 140 days of age demonstrate the typical

adult pattern of functional cerebral asymmetry for speech and non-speech stimuli.

As children develop, free recall (verbal report) is often used as the response and the number correctly recalled per ear as the dependent measure. A right ear advantage/left hemisphere superiority for reporting one to three digit pairs has been demonstrated in both boys and girls from 2 1/2 to 13 years of age (Borowy & Goebel, 1976; Bryden, 1970; Bryden & Allard, 1981; Geffen, 1978; Hiscock & Kinsbourne, 1977, 1980; Kamptner, Kraft, & Harper, 1984; Kimura, 1963, 1967; Kinsbourne & Hiscock, 1977; Kraft, 1984; Witelson, 1977). In addition to the overall REA for verbal material, no developmental change in the magnitude of the ear advantage was noted in these cross-sectional developmental studies. These results have been interpreted as reflecting the early lateralization of language function and the data support the invariance theory. Studies using other verbal stimuli, such as CV combinations (Bryden & Allard, 1981; Caplan & Kinsbourne, 1981; Dorman & Geffner, 1974; Hynd, Obrzut, Weed, & Hynd, 1979), and word pairs (Bryden & Allard, 1981; Ingram, 1975; Obrzut, Boliek, & Obrzut, 1986; Piazza, 1977; Schulman-Galambos, 1977, Yeni-Komishian & Paul-Brown, 1982) similarly found a consistent REA and no

developmental changes in magnitude of the REA in 3- to 18-year olds.

In addition to reports of overall increases in accurate performance on dichotic listening tasks with increase in age (Berlin, Hughes, Lowe-Bell, & Berlin, 1973; Kinsbourne & Hiscock, 1977), however, some developmental changes in ear asymmetries have been reported. Bryden (1970) noted that with 7-, 9-, and 11-year olds, an increasing percentage of subjects showed an REA for linguistic stimuli with increase in age. Similar findings were reported by Kinsbourne and Hiscock (1977), who noted that 63% of the children up to and including grade 2 demonstrated an REA for digits, whereas for grade 3 and above, 70% of the children showed an REA. Berlin et al. (1973) reported greater numbers of children exhibiting REA with increase in age: 53.3% of the 5-year olds, 70% of the 7-year olds, and 77% of the 9-year olds.

The results of dichotic listening developmental studies using non-linguistic stimuli are somewhat confusing. A left ear advantage (LEA) for environmental sound stimuli was found by Knox & Kimura (1970) for 7-year old boys and girls, 6-year old girls (not boys) and 8-year old boys (not girls). No ear advantage was shown in the 5-year olds for environmental sounds, although 5-year old boys (not girls), and all 6-, 7-, and 8-year olds

demonstrated an LEA for animal sounds. Piazza (1977) obtained a significant LEA in 3-, 4-, and 5-year old boys for environmental sounds, but only in the 3- and 5-year old girls. Bryden and Allard (1981) found no ear advantage for 7-, 9-, and 11-year olds (boys and girls) with environmental stimuli. In general, when an ear advantage is obtained, it is the LEA/RH advantage for environmental stimuli that is demonstrated.

Based on findings of LEAs for emotional content of linguistic stimuli with adults (Ley & Bryden, 1982), Saxby and Bryden (1984) presented 31 Kindergartners, 32 fourth graders and 32 eighth graders with short sentences spoken in happy, sad, angry and neutral tones of voice by two women and two men. For the two older groups, two sentences were presented in dichotic competition (target and competing sentence) with a subsequent binaural presentation of a comparison sentence. For the kindergartners, the binaural presentation came first, followed by the dichotic pair. Speaker and verbal contents were held constant, and the emotional tone of the sentences varied. The subject's task was to determine if the target and comparison sentences were the same or different. On the verbal task, the verbal content of the target and comparison sentences varied as speaker and emotional tone were held constant. Again, the task was to

judge the target and comparison sentences as same or different. Saxby and Bryden (1984) found a significant LEA for the emotional task (all emotional categories) and a significant REA for the verbal task. However, the investigators noted that only 17 of the 66 subjects who showed an LEA on the emotional task also showed an LEA on the verbal task and only 2 of the 12 showing an REA on the emotional task demonstrated an LEA on the verbal task, suggesting that a particular ear advantage/hemispheric superiority for one task does not imply the opposite ear/hemispheric superiority for the other task. The failure to find age differences in degree of ear asymmetry was interpreted as reflecting right hemisphere specialization for processing emotional stimuli throughout childhood. However, gender differences were found, with girls demonstrating greater laterality effects, particularly on the verbal task.

In addition to the gender differences noted by Saxby and Bryden (1984) and others (Gordon, 1983; Kimura, 1963,1967; Nagafuchi,1970), the magnitude of ear asymmetries (but not the direction) in children has been found to vary with socioeconomic level (SEL) (no REA for low SEL 6-year old boys noted by Davidoff, Done, & Scully [1981]; Geffner & Hochberg [1971] found no REA for low SEL 4-,5-, and 6-year old boys and girls), handedness (Bryden

[1970] found greater and more frequent REAs for right-handed boys and girls), familial sinistrality (fewer subjects with REAs reported by Bryden [1970] and Lokker and Morais [1985]; no EA found by Kraft [1984]), and EA decreases with age (Kraft, 1981; Larsen 1984).

A few developmental studies examined the test-retest reliability of ear advantage over sessions (Bakker, Licht, Kok & Bouma, 1976; Bakker, Van der Vlugt, & Claushuis, 1978; Harper & Kraft, 1986; Hiscock & Kinsbourne, 1977). Bakker et al. (1978) found preserved ear advantage for verbal material in 72.2% of their subjects (250 5-10 year old boys and girls) when they were retested a week after initial testing. Harper and Kraft (1986) found that over two testing sessions, a week to 9 days apart, 89% of the 29 3 to 5 1/2 year old subjects maintained the same ear advantage. Neither study reported any age-related differences in reliability.

Bakker, Licht, Kok, & Bouma (1976) conducted a longitudinal study to test their hypothesis of a developmental shift from right- to left-hemisphere superiority for processing language. They hypothesized that the young child, facing perceptually complex letters and words (of the look-say method taught in first grade in Holland), would use right-hemisphere strategies for processing the printed word. Once perceptual analysis

became organized and automatic, the semantic aspects of reading would become critical and left-hemisphere strategies would better subserve attainment of reading fluency (speed and accuracy). All subjects were administered a dichotic listening test (digits) in kindergarten, and again at the beginning and end of first grade. A reading test was administered in fifth grade. The children who demonstrated a left ear advantage (LEA) in kindergarten read better at fifth grade than those kindergartners who had shown a right-ear advantage (REA). However, an REA at the end of first grade tended to correlate with better reading than an LEA. The children who shifted from an LEA in kindergarten to an REA at the end of first grade were the best readers, and those who shifted in reverse were the worst readers ultimately.

Morris, Bakker, Satz and Van der Vlugt (1984) reanalyzed the data from two longitudinal studies of children from Kindergarten through sixth grade (Bakker et al., 1979 and Fennell, Satz, & Morris, 1983) and found that ear advantage shifted from either an REA to an LEA or an LEA to an REA in 41 to 64% of the subjects in two Dutch and two American cohorts. They concluded that almost any theoretical position could be supported by part, but not all, of the data.

For the most part, the developmental dichotic listening literature supports the view of hemispheric asymmetries based on the material-specific verbal-nonverbal distinction. However, the inconsistencies noted above make the argument for either progressive lateralization or laterality invariance equally plausible.

b. Tactile and Haptic Asymmetries

Somatosensory sensitivity usually refers to passive stimulation of cutaneous sensory receptors, whereas haptic perception tasks involve recognition or identification of stimulus objects following active manipulation (including passive tactile stimulation, motor activity, and proprioceptive feedback). The concept of hemispheric specialization for tactile/ spatial haptic recognition contralateral to the superior hand depends on the functional superiority of the crossed over uncrossed pathways from sensory receptor to primary somatosensory cortex (Hiscock, 1988). Indeed, Brinkman and Kuypers (1972) determined that discrete sensory input to the fingers is transmitted only along crossed fibers to the contralateral somatosensory cortex.

Rose (1984) presented 72 right-handed children (24 1-year olds, 24 2-year olds, 24 3-year olds, 12 boys and 12 girls in each age group) with shapes (shielded from the

child's view) that were palpated with either the left or the right hand for 25 seconds and then, following a 5 second ISI, visually presented the same shape with a novel stimulus shape. Noting that children typically show a greater preference for novel stimuli as measured by longer fixation times (see habituation-dishabituation studies above), Rose (1984) postulated that the information obtained during haptic familiarization would provide the only basis for any hand differences in responsiveness (i.e., fixation on visually presented stimuli). The results indicated that the children as young as two years of age not only reliably recognized visually the stimuli presented for tactual exploration, but also demonstrated a left hand advantage for this task. While the 1-year olds reliably discriminated familiar from novel stimuli, there were no significant hand differences. However, once the hemispheric differences emerged at two years of age, the magnitude of the left hand superiority remained constant, with no age-related changes in either the number of children demonstrating the left hand advantage or the size of the novelty response.

To assess hemispheric asymmetries in children for perception by haptic (active) touch, Witelson (1974) used a dichaptic stimulation technique which consisted of presenting two differently shaped 3-dimensional stimuli

simultaneously (one in each hand). Stimulus identification (recognition) of previously palpated forms was indicated by pointing to a visual display (for nonsense shapes) or by verbal report (for alphabet letters). Forty-seven, 6 to 14 year old right-handed boys were divided into three groups (mean ages = 5.2, 10.2, and 13.1 years, respectively). Nonsense shapes and letters were tested in separate sessions, one to two weeks apart. The results indicated a significant left hand advantage for nonsense shapes and a nonsignificant right hand advantage for letters. There were no age differences in hand superiority.

A subsequent study (Witelson, 1976) of 100 right-handed boys and 100 right-handed girls, 6 to 13 years of age, confirmed the left hand advantage for nonsense shapes in boys, but no hand superiority was obtained for girls. Another study (Witelson, 1977) using dichaptic presentation of shapes and letters with 156, 10 year old right-handed boys again supported the left hand superiority for nonsense shapes and, again, no significant hand asymmetries for letter identification (recognition).

Hiscock (1988) posited that nominally linguistic stimuli, such as letters and word shapes, used to induce linguistic processing may still require considerable spatial analysis and nonlinguistic processing, thereby

suggesting an explanation for the lack of a significant right hand effect for letter stimuli.

Flanery and Balling (1979) presented 64 subjects (8 males and 8 females in each of 4 age groups: Mean ages = 7 years 2 months, 9 years 4 months, 11 years 3 months, and 23 years 2 months) with a tactile shape-discrimination task in which the subject palpated a nonsense shape for 10 seconds (shielded from view) and then judged a comparison form as either the same as or different from the first stimulus. In the first condition, the standard and comparison forms were presented successively to the same hand. In the second condition, the two hands simultaneously manipulated a stimulus form for 10 seconds followed by the palpation of a comparison stimulus (either the same stimulus presented to that hand or a third form) presented to one hand only. All groups demonstrated a left hand superiority for accurate shape discrimination, and there were no age-related differences in the magnitude of hand difference with respect to accuracy. However, using a laterality coefficient $((L-R)/(L+R))$, Flanery and Balling (1979) noted a significant developmental trend in lateralization with no significant differences between hands for the two younger groups and significant and increasing right-hemisphere specialization for tactuo-spatial ability. Increases in laterality quotient with

increases in age were also reported by Yamamoto (1980), who presented 42 boys and girls (three age groups, mean ages = 8.4, 10.5, and 12.6 years) with meaningful miniature object forms (e.g., tree) for identification. The 12 year olds demonstrated left hand superiority for accuracy but no significant hand asymmetries were manifested by the younger children. The 8 year olds were significantly faster (RT) with their right than their left hands, but the older groups were significantly faster with their left hand identifications.

In general, the results of tactile/haptic laterality studies in children indicate a left-hand/right-hemisphere advantage for recognizing representational /concrete objects (Yamamoto, 1980), nonsense shapes (Flanery & Balling, 1979; Witelson, 1974, 1976), and dot patterns (Rudel, Denckla, & Hirsch, 1977). Most of these studies utilized a same/different paradigm, a uniformity across investigations not seen in laterality studies in other sensory modalities. Although several tactual/haptic laterality studies in children are consistent with Witelson's findings (1974, 1976), suggesting that boys demonstrate greater asymmetry at a younger age than do girls (Affleck & Joyce, 1979; Dawson, 1981; Gibson & Bryden, 1983; Yamamoto, 1984), other investigators have

failed to find any sex differences (Cranney & Ashton, 1980, 1982; Etaugh & Levy, 1981; Klein & Rosenfield, 1980).

The influence of material-specific, task-specific, and response-specific factors and their interactions in developmental studies of tactual and haptic laterality make simple generalizations regarding age differences in children difficult.

c. Visual Hemifield Asymmetries

The results of many visual laterality studies with children parallel the results reported in studies of adults, generally supporting the (LH) verbal- (RH) visuospatial (nonverbal) dichotomy.

(i) Non-verbal stimuli - dots/lines/colors

Using unilateral and central tachistoscopic presentation of randomly generated collections of 2, 3, 4, 5 or 6 dots, Young and Bion (1979) asked 60 right-handed boys and girls in three age groups (mean ages = 5.8, 7.8 and 11.3 years) to count the dots. Central stimuli were used to insure fixation, and only the results of children whose accuracy with the central stimuli was equal to or greater than the accuracy achieved for RVF or LVF stimuli were analyzed. Exposure durations of 100 msec. were used with the five year olds; 80 msec durations were used for the 7- and 11- year olds. An overall LVF/RH superiority

for both accuracy and reaction times were obtained, but there were no age differences in either the direction or the magnitude of the LVF superiority in either accuracy or RT. The boys demonstrated stronger LVF advantages for accuracy than did the girls.

Lewandowski (1982) presented 48 boys and girls (Mean ages=8.7, 11.1, 13.2, and 15.0 years- 92% strongly right handed) with unilateral tachistoscopically flashed slanted lines (one at a time) and asked the children to match each to a visual array of ten lines. Using the laterality quotient formula $(R-L / R+L)$, no visual hemifield differences in accuracy were found.

Using monocular viewing of lateralized tachistoscopic presentations of achromatic and chromatic square color patches, Grant (1980) asked 120 boys and girls (in three groups with mean ages of 5.6, 7.6, and 10.1 years) to name the colors and obtained a LVF/RH advantage for the youngest group (boys and girls) and for the 10-year old girls. In a follow-up test session (Grant, 1981), the LVF superiority for color naming was obtained only by the 10-year olds.

(ii) Non-verbal stimuli - faces/figures

In general, a LVF/RH advantage has been obtained for visual tasks requiring the matching of faces and figures in same/different paradigms.

Broman (1978) measured the RTs to match laterally presented faces in a (S+) "go"/(S-) "no-go" paradigm (80 males, 7-, 10-, 13-year olds, adults). Subjects used a rocker switch which was to be moved toward the subject when he saw an S+ ("go") but to refrain from moving it when an S- ("no-go") appeared. Analysis of RT scores for correct matches indicated an overall LVF/RH superiority. There was a significant LVF advantage for accuracy in the 7- and 10- year olds, but no visual field advantage for 13-year olds or adults.

Using unilateral tachistoscopic presentation of photographs of faces followed by a bilateral mask, Marcel and Rajan (1975) asked 40 7-9 year old boys and girls to match faces by pointing to one of two faces shown after each trial. The dependent measure was the criterion exposure duration or "recognition threshold" and a left visual field superiority was obtained.

Young and Ellis (1976) presented 42 right-handed boys and girls (Mean ages = 5.7, 7.7, and 11.8 years) with pictures of faces in the right and left visual fields and at central fixation. The subjects indicated "same" or "different" by verbal report and the number of errors at each position was scored. An overall LVF/RH advantage was obtained, with no age-related differences in visual hemifield superiority noted.

Using lateralized tachistoscopic presentation (150 ms. exposure durations) of faces for identification, Young and Bion (1980) found that although 10-13 year old children were more accurate than 7-year old children, a LVF/RH superiority (accuracy in matching to same face on a matrix) was demonstrated in all age groups. Similar results were reported by Turkewitz and Ross-Kossak (1984) using briefer exposure durations (140 msec for 8 year olds; 110 msec for 10 and 13 year olds). They presented 72 right-handed boys and girls with unilateral tachistoscopic presentations of photographs of female faces. The subjects indicated their choice by pointing to the matching face from an array of four faces. Counting the number of errors for each visual hemifield presentation, an overall LVF/RH superiority was obtained with no developmental change in visual hemifield advantage.

Sex differences were noted by Jones and Anuza (1982) when 3- and 4- year old right-handed boys and girls were shown unilaterally presented photographs of male and female faces and asked to verbally identify the sex of the individual. While girls were generally more accurate, no visual hemifield advantage was obtained. The boys demonstrated a RVF/LH superiority for sex identification.

Using unilateral tachistoscopic presentation of pairs of identical or different human figures in a vertical

orientation to either the right or left visual field, Witelson (1977c) recorded the number of correct matches in each visual hemifield for 85 boys in four age groups (6-7 years, 8-9 years, 10-11 years, and 12-14 years) who responded to the same/different matching task by verbal report. Again, an overall LVF/RH superiority was demonstrated.

Although the above-cited studies confirm the typical LVF/RH superiority for face/figure matching, it is interesting to note that when Jones and Anuza (1982) altered the task to require sex identification of the laterally-presented picture, a RVF/LH advantage was obtained by boys. It could be argued that the verbal report response may have biased the results, but that would not explain the lack of visual asymmetry in the girls in that study, or the LVF/RH advantage with verbal report found by Witelson (1977c).

(iii) Non-verbal stimuli: shapes/line drawings

Sixty right handed males and females (Grades 1,2,3,4 and college) responded verbally to recognition of lateralized tachistoscopic presentations of random shapes and line drawings of common objects (Turner & Miller, 1975). When the proportion of shapes and drawings correctly recognized in each visual hemifield were

compared, an overall LVF/RH for both types of stimuli was obtained, with no age-related changes in magnitude.

In a same-different matching task, Tomlinson-Keasey, Kelly and Burton (1978) presented three groups of right-handed male and female subjects (44 third graders, 50 seventh graders, 60 graduate/undergraduate students) with pairs of pictures taken primarily from the Peabody Picture Vocabulary Test (Dunn, 1959). The initial stimulus and the subsequent (2 sec ISI) probe stimulus were presented unilaterally for 100 msec. Half of the trials were identical matches, half unmatched. Only those trials in which the presentation and probe stimuli were presented to the same visual hemifield were used in the statistical analysis. The subject indicated "same" or "different" by means of a key press, and reaction time was measured from the onset of the probe stimulus. Overall, matched stimuli ("same" responses) were processed significantly faster than unmatched stimuli ("different" responses). There was an overall RVF/LH advantage for matches (i.e., "same" responses), although this was accounted for by the left hemisphere superiority in the junior high school and adult groups. No visual field advantage was obtained in the third graders. With respect to the unmatched stimuli ("different" responses), no visual hemifield advantage was demonstrated by the third or seventh graders. The adults,

however, exhibited a significant LVF/RH advantage for the unmatched stimuli. The investigators concluded that their results supported the idea of progressive left hemispheric specialization for processing matched stimuli which is not complete until adolescence.

Young and Bion (1981b) found a RVF/LH advantage for naming line drawings in children as young as five years of age. Line drawings of common objects (e.g., house, tent, table, banana, fly) were presented tachistoscopically (bilaterally- one picture in each visual field) to four groups of 20 right-handed subjects (10 males and 10 females--ages 5 years, 7 years, 11 years, and adults). One picture per trial was underlined in red to indicate first report. Stimuli were presented for 100 msec for the 5-year olds, 50 msec for the 7- and 11-year olds, and 30 msec for the adults. A comparison of the mean accuracy scores revealed an overall RVF/LH superiority, with a significant hemifield x report interaction, indicating that the overall RVF advantage was due primarily to second report responses. The presence of a significant main effect of age suggested that the duration exposures chosen had not eliminated variations in overall accuracy across age.

Verbal RTs to same/different matching of line drawings of common objects were recorded by Barroso (1976)

as 150 right-handed boys and girls in five age groups (mean ages = 6.4, 8.5, 9.6, 10.4, and 12.5 years) performed two different tasks: 1) a verbal task in which the name of the stimulus was presented aurally and the line drawing appeared in either the left or right visual field, and 2) a non-verbal task in which same or different pairs of stimuli were presented unilaterally to the left or right visual field. Developmental differences were noted, such that whereas there were no significant differences in RT between tasks or visual hemifields for the three younger groups, the two older groups demonstrated a RVF/LH advantage for the verbal task and a LVF/RH superiority for the non-verbal task.

(iv) Linguistic stimuli

Using unilateral tachistoscopic presentation of 3- and 4-letter words to 144 males and females in grades 2 through 10, and college students, Forgays (1953) compared the number of words recognized (via verbal report) in each visual hemifield and found a LH/RVF for older subjects, beginning with eighth graders. As no visual hemifield superiority was obtained in the second through seventh graders, these results were seen as supporting the developmental lateralization theory via the mechanism of reading experience.

In response to Forgay's (1953) reading experience hypothesis, McKeever and Huling (1970) argued that if LH/RVF superiority were the result of more than seven years of reading instruction, seventh grade normal readers should demonstrate little or no RVF superiority and poor readers should demonstrate even less. In other words, children with over 7 years of reading experience should demonstrate a greater RVF magnitude than those with fewer years of such experience, and good readers should manifest a greater RVF superiority than poor readers. McKeever and Huling (1970) hypothesized that a RVF advantage, even for the poor readers, would contradict the reading experience hypothesis and offer support for the "hemispheric language dominance theory," according to which the left hemisphere is prewired for language. Ten seventh grade normal readers (mean reading level = 8.1 grades, PPVT IQ = 117.2) and ten seventh grade poor readers (mean reading level = 3.8 grades, PPVT IQ = 86.6) were presented with ten common four-letter nouns to either the left or the right visual hemifield. A number from 2 to 9 was typed at the central fixation point and the subject was to report the central fixation digit before naming the word. A decreasing method of limits was used with the stimulus cards being shown at 100 msec., then at 70, 30, and 20 msec. Both good and poor readers demonstrated a RVF advantage for recognition of

common 4-letter nouns, which the authors interpreted as supporting the left-hemisphere language dominance view as opposed to the reading-training/experience hypothesis.

Miller and Turner (1973) presented 60 males and females in grades 2, 4, 6, and college with 4- and 5-letter words at three exposure durations and recorded the number of correct verbal identifications from each visual hemifield at each exposure duration. Recognition accuracy increased with age and a RVF/LH advantage was obtained by all groups except the second graders. However, when 60 right-handed males and females in grades 1, 2, 3, 4 and college were presented with 3-letter words unilaterally in either a horizontal or vertical orientation (Turner & Miller, 1975), an overall RVF/LH superiority was demonstrated even by the first and second graders. Interestingly, when the response was changed from recognition (verbal report) to indicating the target word (manual pointing) from an array of alternatives, no visual hemifield differences were obtained. No age differences were noted.

A developmental shift in hemispheric advantage for reading unilaterally presented Hebrew words was noted by Silverberg and associates (Silverberg, Gordon, Pollack, & Bentin, 1980), who tested 24 Israeli second- and 24 third-graders. The LVF/RH advantage found in the second graders

contrasted with the RVF/LH superiority demonstrated by the third graders. While there was virtually no age difference in RTs to LVF presentations, the shift in hemispheric advantage was due to the significant 150 msec reduction in response time to RVF presentations. Interestingly, both groups had shown an REA for dichotically presented words.

In addition to studying visual hemifield asymmetries with line drawings (discussed above, pp. 106-107), Tomlinson-Keasey et al. (1978) also used linguistic stimuli. They presented 3-, 4-, and 5-letter high-image nouns to third- and seventh- graders and adults, in the same/different matching paradigm, with the unilateral 200 msec probe stimulus following the unilateral 200 msec initial stimulus after an ISI of 2 sec. Again, the data from only those trials in which the presentation and probe stimuli were presented to the same visual hemifield were analyzed. For word matches ("same" responses), all three groups demonstrated an RVF/LH advantage. (The third graders had not demonstrated any hemifield advantage for the picture matches; see pp 89-90). For the unmatched words ("different" responses), a LVF/RH superiority was obtained by the third and seventh graders. No visual hemifield advantage was demonstrated by the adults for unmatched data. Comparing the visual hemifield differences for word and picture matched data, the third graders

demonstrated a RVF/LH superiority for words, but no visual hemifield advantage for pictures. The seventh graders demonstrated a significant RVF/LH advantage for both matched pictures and words, as did the adults. At this point, one might ask whether the picture matching strategy of third graders differed from the older subjects, and whether the randomly intermixed word stimuli may have primed the older subjects to the atypical LH advantage for matching identical pictures.

Reynolds and Jeeves (1978) unilaterally presented the letters A, K, F, and R to three groups of right-handed girls (7-8 years, 13-14 years, college students- mean age = 19.5 years), one at a time. For two of the letters, the subject was to press one key, and for the other two letters, another key. The youngest group was significantly slower in responding than the older subjects. Both the adults and the 13/14 year olds demonstrated the predicted RVF/LH superiority, but no visual field advantage was obtained for the 7/8 year olds, which the investigators attributed to the greater variability in (motor) responding. In comparing the absence of hemispheric differences for visually perceived language material (letters) in 7/8 year olds with the REA/LH advantage found in dichotic listening studies with this age group, Reynolds and Jeeves (1978) hypothesized that there may be

a difference between auditory and visual processes in the timing of development of language lateralization.

Carter and Kinsbourne (1979) found the expected LVF/RH advantage for shape matching and RVF/LH for digit report in children 5 to 12 years of age and concluded that there was no evidence of progressive lateralization of either left hemisphere verbal functions or right hemisphere visuo-spatial functions. Caplan and Kinsbourne (1981) argue that the lack of evidence of age changes in magnitude of lateralization supports a non-developmental (invariant) theory of lateralization of behavior and indicates that children, like adults, have a left hemisphere superiority for language (verbal) processing and a right hemisphere advantage for visuospatial processing.

In a longitudinal study of 34 right-handed boys and girls (aged 5.2 years at start of study, tested 4 times at 7 month intervals), Davidoff and Done (1984) used consonant trigrams and three-letter words in an identity matching task with lateralized tachistoscopic presentation. They noted a reliable RVF/LH for consonant trigrams at all ages and an RVF/LH advantage for words at the second, third and fourth sessions. There was no increase in visual hemifield advantage with age. However, they found that in a group of 4-year olds who had not

learned all the letter names, the boys exhibited a LVF/RH superiority for letter and word-matching whereas there was no visual hemifield advantage for the girls. The investigators concluded that without names for the letters, the 4-year old boys had matched on a configurational basis, consistent with the literature on right hemisphere specialization for difficult visual discriminations in males. They suggested that the RVF/LH advantage for visual-verbal material is present soon after letter naming is achieved, and is the result of mapping visual language onto an already existing left hemisphere (phonological) language system. This interpretation would also account for the similar findings of Reynolds and Jeeves (1978) discussed earlier (p. 112).

Broman (1974) measured reaction times to match laterally presented letters in a same/different paradigm in 80 male subjects, 7-, 10-, and 13-year olds, and adults. Analysis of reaction time scores for correct matches indicated no significant visual hemifield differences for letter pairs. With respect to accuracy, 7-year olds demonstrated a LVF/RH advantage, 10- and 13-year olds showed no preference, and a RVF/LH advantage was obtained with the adults. While this evidence might suggest progressive lateralization of a language function (matching letter pairs), Broman proposed that children

adopt different strategies toward these stimuli at different stages of development, with concomitant changes in degree and direction of lateralization. The 7-year olds may have processed the letters visually (configurationally) due to lack of experience with alphabetical material--hence the LVF/RH advantage at this age. Comparing visual hemifield differences within individual subjects, Broman noted a nonsignificant "switchover" from a more "primitive" configurational approach and LVF advantage with letter pairs at age 7, to a more "advanced" naming approach and RVF advantage in adults.

Several of the studies noted above reported a RVF/LH advantage for letter and word matching or recall in the youngest children (Broman, 1978); Butler & Miller, 1979; Carmon, Nachshon, & Starinsky, 1975; Davidoff & Done, 1984), which is consistent with the findings of Bakker's (1973) electrocortical studies. Taken together, these results suggest a developmental "shift" from LVF/RH perceptual processing of linguistic stimuli in young children and beginning readers, to a RVF/LH semantic processing in older children as they become more experienced, fluent readers.

Additional evidence for a LVF/RH superiority for processing complex visual displays of verbal material was

reported by Miller (1984). Forty-eight right-handed males and females (mean ages = 8.8, 11.9, and 22 years) were presented with common four-letter words either singly or in pairs, the pair being arranged vertically (unilateral presentation), horizontally (bilateral presentation) or diagonally (bilateral presentation). A RVF/LH advantage for word identification was obtained by the 11 year olds for vertical arrays, and by the 22-year olds for single words. However, an LVF/RH advantage for diagonal arrays (an atypical and, therefore, more complex task) was obtained by the 8 year olds.

In a task combining verbal and nonverbal elements, Koenig (1989) investigated hemispheric asymmetries in the processing of Stroop color-word stimuli in 108, 7- to 15-year old right-handed males, who were presented with three tasks: 1) reading color names, e.g., pink, blue, green; 2) naming color spots, e.g., . pink, blue, green; and 3) an interference condition in which subjects named the color of color words printed in a different color, e.g., the word "pink" printed in green letters. Stimuli were presented to the left, right, and central visual fields. With respect to both errors and reaction time, a RVF/LH advantage was found for the reading condition and a LVF/RH superiority for naming the colors. The results are consistent with the hypothesis of a RH advantage for

processing colors flashed briefly and a LH advantage for processing verbal stimuli. In the interference condition, a RVF/LH advantage appeared (tending to significance). There was a general decrease in RT with age in all experimental conditions. Across age groups, RT for reading was significantly faster than for naming which, in turn, was significantly faster than for the interference task. Contrast analyses of RTs to LVF versus RVF presentations for each age group in the interference condition resulted in significant RVF/LH advantages for the 7- and 11-year olds, an LVF/RH advantage at age 9. A similar shift appeared between ages 11 and 13. Koenig (1989) proposed that the asymmetries observed in the Stroop interference condition may be explained in terms of a dynamic process model (Kinsbourne, 1975) of cerebral functioning, with fixed structures that are influenced and/or controlled by attentional and strategy factors. Koenig (1989) argued that age differences in lateral specialization can only be observed in relatively complex tasks (e.g., the interference task) for which different cognitive strategies are employed at different ages.

In general, the developmental visual hemifield studies support the (LH) verbal/ (RH) visuospatial dichotomy in hemispheric specialization. However, the dichotomy seems to be one of processing strategy rather

than of material-specific factors, as a change of task or instruction may alter the magnitude and even the direction of the hemispheric advantage.

4. Laterality in Atypical Children

Atypical and dysfunctional children have served as subjects in laterality studies investigating the possibly disordered neural substrate of the behavioral dysfunction.

Both visual and auditory laterality studies of dyslexic (reading-disabled) children provide conflicting, equivocal evidence of hemispheric asymmetry, with some results supporting normal lateralization of language function as measured by visual letter recognition (Gross, Rothenberg, Schottenfeld, & Drake, 1978), visual word recognition (McKeever & Huling, 1970; McKeever & VanDeventer, 1975), and auditory dichotic listening performance (Aylward, 1984). However, some electrocortical studies have yielded results which support the hypothesis that although reading-disabled children do develop normal hemispheric specialization, they use more immature, less effective right hemisphere strategies for language-mediated tasks (Bakker & Vinke, 1985; Fried, Tanguay, Boder, Doubleday & Greensite, 1981; Licht, Kok, Bakker & Bouma, 1986; Rosenblum & Dorman, 1978).

Atypical lateralization in dyslexic populations has been reported with recorded ERPs to auditory word and musical-chord stimuli (Fried et al., 1981) and to visually presented words (Bakker & Vinke, 1985), as well as in dichotic listening tasks (Bakker et al., 1976; Witelson, 1976), dichaptic tasks with nonsense shapes (Witelson, 1976), and lateralized tachistoscopic presentation of pictures of people (Witelson, 1976). Witelson (1976) suggested that dyslexics have bilateral representation of spatial functions in contrast to the normal right hemisphere specialization for processing spatial stimuli. She argued for an association between the developmental dyslexia syndrome and dysfunctional left hemisphere language functioning in addition to the lack of unilateral right hemisphere specialization for spatial processing.

Atypical patterns of cerebral lateralization have also been associated with early infantile autism (Dawson, Finley, Phillips, & Galpert, 1986; Dawson, Warrenburg, & Fuller, 1982) and with idiopathic precocious puberty in adolescent females (Meyer-Bahlburg, Bruder, Feldman, Ehrhardt, & Healey, 1985). The apparently contradictory findings, from reduced magnitude of lateralized functions to absence of lateral differences and reversed laterality. and the different tasks used in these studies make it difficult to draw definitive conclusions regarding

hemispheric asymmetries in atypical and dysfunctional populations.

5. Conceptual Issues in Development of a Laterality "Shift"

The observation, noted primarily in visual hemifield studies, of a developmental age-related "shift" from an LVF/RH advantage in young children for processing verbal stimuli to a RVF/LH superiority in older children and adults has been attributed (Bakker, 1973, 1979; Broman, 1978; Davidoff and Done, 1984) to the "perceptual" nature of the young child's processing becoming subordinated to semantic, linguistically based strategies for language processing for which the left hemisphere is specialized in older children and adults. The earlier "perceptual" strategies, for which the right hemisphere is specialized, are employed in the processing of "complex" visual displays of verbal material (e.g., single letters and words, unusual orientation) which are not processed as linguistic stimuli. This view reflects the verbal versus visuospatial dichotomy with respect to cerebral lateralization noted earlier. Additional support for this view was provided by Levy and Trevarthen (1976), who presented split-brain patients with line-drawings (standards) of common objects (e.g., cake on plate, open pair of scissors) and asked them to match these

unilaterally-presented drawings with comparison stimuli, consisting of either a functional match (e.g., cake-crossed spoon and fork, scissors- needle over two spools of thread) or an appearance (perceptual) match (e.g., cake-hat, scissors-crossed spoon and fork). When the standard stimulus was presented to the RVF/LH, the commissurotomed patients tended to chose the functional match; when it was presented to the LVF/RH, the patients tended to match by appearance. This argues for two distinct information-processing styles that differentiate the cerebral hemispheres (Springer & Deutsch, 1981). Klatzky (1972) also found that adults demonstrated a LVF/RH advantage for identity matches of line drawings of common objects and a RVf/LH superiority for "name" matches (Rosch's basic taxonomic level, e.g., two different types of dogs). One could then postulate that if there is a developmental shift in children from matching predominantly with a processing style characteristic of one hemisphere to a strategy characteristic of the other, the observed "laterality shift" will reflect this change in processing.

A role for the right hemisphere (with its concomitant superiorities) in the acquisition of specific language functions has been proposed (Bryden, 1982; Schneiderman, 1986), although the evidence is not conclusive. Witelson

(1977) argued that although children show a left hemisphere superiority for language functions, their language is less lateralized than adults, and she interpreted this as implying greater right hemisphere involvement in the early years. However, the studies in which no age differences in lateralization were found would appear to refute this argument, although Schneiderman (1986) notes the Segalowitz (1983) proposal of a qualitative difference in kind of lateralization between infants and adults (rather than a quantitative difference). If an infant's responses tend to be governed by inborn reflexive asymmetries to a greater degree than adults, the lack of increase in left hemisphere lateralization with increase in age may reflect the adult's greater freedom to selectively engage the two cerebral hemispheres in processing stimuli (Segalowitz, 1983). The ability of the right hemisphere to take over language functions following left hemisphere damage (Lenneberg, 1967) and/or left hemispherectomy (Dennis & Kohn, 1975; Dennis & Whitaker, 1976) may provide tentative support for right hemisphere language functions, but also may be attributed entirely to plasticity of the young brain without postulating right hemisphere involvement in language acquisition (Schneiderman, 1986). However, Schneiderman argues that the efficient processing of

linguistic stimuli by the left hemisphere depends upon the ability of the learner to identify, decode, and attach meaning to relevant language stimuli. This complex task requires integrating incoming linguistic stimuli with previously encountered language data and "extralinguistic information from the situational/emotional context of the incoming stimuli. The right hemisphere, with its holistic-parallel mode of functioning, would appear to be ideally suited to such a task" (Schneiderman, 1986, p. 239). Citing parallels with adult acquisition of a second language, Schneiderman claims that the adult focus on comprehension of the target language corresponds to the natural strategy adopted by most children and the observation that children's receptive language (comprehension) exceeds their expressive language (production). The semantic role of the right hemisphere may be to use "heuristic strategies" to mediate between linguistic stimulus inputs and pragmatic knowledge of their real world referents. Dennis' (1980) study of the semantic abilities of the right hemisphere of hemidecorticate children suggests that the right hemisphere may be more efficient in mediating the process by which words become connected to visual arrays. Schneiderman (1986) also cites right hemisphere involvement in processing prosody and interpreting emotion

in adults as support for the role of the right hemisphere in intact language processing. She concludes that "the most plausible characterization of right hemisphere participation in normal language acquisition is that of a limited, specialized, perhaps essential role in the initial perception, retention, and rudimentary comprehension of novel language stimuli" (Schneiderman, 1986, pp. 243-244). With respect to this hypothesis, the "laterality shift" would reflect a developmental sequence in language acquisition in which the right hemisphere plays a salient part in later infancy and early childhood which is later subsumed under dominant left hemisphere processes and strategies.

An alternative, but compatible, view was proposed by Goldberg and Costa (1981). Due to differences in neuroanatomical structure and organization, the right hemisphere, with its proportionally greater areas of intermodal association, plays a critical role in the process of acquiring a new descriptive system because of its greater ability to process novel stimuli and perform intermodal integration. In contrast, the left hemisphere, with its proportionally greater area devoted to distinct modality-specific representations, is superior in unimodal and motor processing as well as storing and utilizing compact, well-routinized codes. This would account for the

age-related right-to-left shift of hemispheric advantage as a function of increased competence (from training and experience) with respect to a particular type of processing. Goldberg and Costa (1981) propose that the right hemisphere is involved in the initial stages of language acquisition, and, indeed, in the initial stages of different aspects of linguistic processing. If tasks rely on processes whose acquisition is fully accomplished by infancy (e.g., phonologic categorical discriminations), no age-related laterality shift will be observed. However, they cite hemifield-age interactions in the studies by Forgays (1953), Miller and Turner (1973,1975) and Carmon, Nachshon, and Starinsky (1976) as supporting the emergence of left-hemisphere-mediated descriptive systems. The implicit left hemisphere superiority "is overwhelming for phonetic and orthographic processing, less decisive for syntax, and least decisive for semantic processing" (Goldberg & Costa, 1981, p.160). The capacity of the right hemisphere to establish categorical (functional rather than perceptual) connections between objects is only on the level of a 6-year old (Zaidel, 1977 cited in Goldberg & Costa, 1981). Therefore, Vygotsky's (1962) proposal of a shift from preconceptual, perceptual based organization to a categorical, definition based lexical organization, occurring between 6 and 12 years of age requires left

hemisphere involvement, "essential for the formation of hierarchic categorical networks with interrelated referential entries. It appears, therefore, that the right hemisphere may play a critical role in the early, preconceptual stages of semantic acquisition which decreases with age "(Goldberg & Costa, 1981, p.161). If the developmental time course for the acquisition of descriptive systems which underlie various language processes differs, the concomitant time course of left- and/or right-hemispheric involvement will, necessarily, reflect those differences.

The present study examined both the question of emerging strategies for classification and categorization in children, and that of functional hemispheric asymmetries as they relate to those developing strategies. It was hypothesized that:

- 1) the 4-6 year olds would make significantly more perceptual matches than the 7-9 or 10-12 year olds, who were expected to make significantly more semantic matches;
- 2) all age groups would demonstrate an overall LVF/RH advantage for perceptual matching and an overall RVF/LH advantage for semantic/categorical matching;
- 3) there would be a shift in hemispheric asymmetry with increase in age as the LVF/RH mediated perceptual

matching of the 4-6 year olds yielded to RVF/LH mediated semantic matching in the older children.

Method

Subjects.

Sixty (60) right-handed boys, 20 in each of three age groups (4-6 years, 7-9 years, and 10-12 years of age) served as subjects. The mean ages of the groups were 5.05 years (SD=0.76), 7.85 years, (SD=0.81), and 11.00 years (SD=0.92), respectively. The children were recruited from Queens and Nassau counties by local advertising and word-of-mouth. Parents were interviewed prior to testing and children with a history (from parental report) of neurological disturbance, learning disability, Attention Deficit Disorder, below average intelligence, or with evidence of familial sinistrality were excluded from participation in the study. Informed written parental consent was obtained for each subject (See Appendix A). Subjects were paid for their participation.

Prior to testing, handedness (hand preference) was determined by performance on ten (10) selected items from the Harris Tests of Lateral Dominance (Harris, 1974; see Appendix B). The Experimenter placed each item at midline in front of the child and asked him to use the item (e.g., cut with scissor, write with pencil, wind watch, turn door handle) or pretend to use item (e.g., comb hair, use a toothbrush, cut with a knife, throw a ball). Right-

handedness, a criterion for inclusion in the study, was a minimum of 70% use of the right hand for the ten tasks.

Following the handedness inventory, the Vocabulary subtest of the Stanford-Binet Intelligence Scale: Fourth Edition (1984) was administered by the Experimenter and a verbal IQ score of 90 was used as the minimum score for inclusion of the child in the study.

Stimuli.

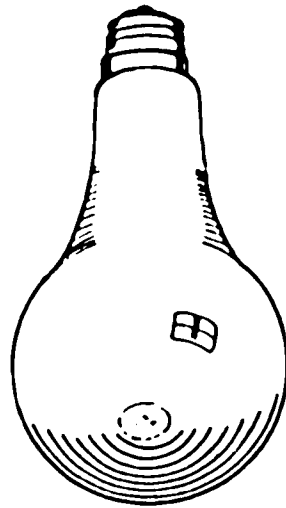
The stimuli consisted of 35 line drawings of common everyday objects, adapted from either the Snodgrass and Vanderwart (1980) set or the Peabody Picture Vocabulary Test (Dunn, 1959). (See Appendix C for names of pictures used and their source.) The 36 pictures (one item was used twice, once as a standard and once as a comparison), were divided into 12 sets of three (3) pictures, each set consisting of a standard stimulus (St) presented to one side of central fixation and two comparison stimulus pictures (Co1 and Co2) presented side-by-side. (See Figure 1.) One of the comparison pictures (Co1) was similar in shape to the standard, and the other (Co2) was semantically related to the standard by function (e.g., pencil-paper) or by category (e.g., baseball-football). Each standard picture and each pair of comparison pictures was presented on an individual slide. The standard stimuli

were presented singly. The inner edge of the standard stimulus picture subtended 12 degrees of visual angle either to the left or right of central fixation. Each picture subtended a maximum visual angle of 12 degrees horizontally and 12 degrees vertically, and the viewing distance from the child, whose head rested on a chinrest, was 2 meters. Each comparison pair of pictures consisted of one stimulus to the left and the other to the right of central fixation. The comparison pictures also subtended 12 degrees of visual angle to the left and right of central fixation. On half the comparison set presentations, the picture which matched the standard semantically was on the left and the picture which matched the standard perceptually was on the right. On the other half of the trials, the semantic match was on the right side and the perceptual match on the left side.

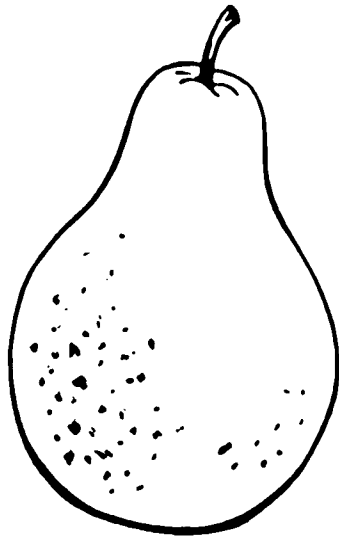
The 12 stimulus sets were chosen from a larger pool of 21 sets, based upon pilot testing of the stimuli on eight (8) adults and five (5) children. The eight adults (Queens College Psychology Department faculty and graduate students) rated the sets for perceptual similarity between the standard and perceptual comparison stimuli, and for clarity of the semantic relationship between standard and semantic comparison stimuli. Eight (8) sets were eliminated, either because the "perceptual" match was

Figure 1. Sample standard stimulus and comparison stimuli.

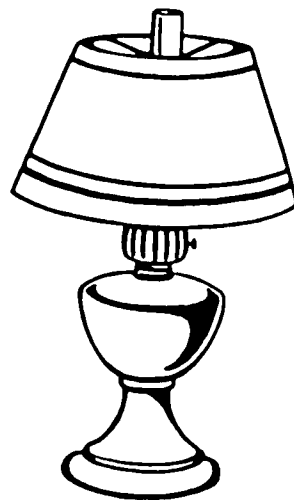
SAMPLE STANDARD STIMULUS:



COMPARISON STIMULI:



PERCEPTUAL MATCH



SEMANTIC MATCH

considered poor, the semantic relationship was ambiguous, or a comparison stimulus could be matched to the standard on both perceptual and semantic bases. To ensure that even the youngest children would be familiar with the pictured items, the remaining pictures were presented singly to five 4-year olds (on slides) for naming. One set was discarded as three of the children had difficulty naming one of the items in the set, leaving a total of twelve (12) sets of three (3) pictures each.

Each of the twelve (12) sets was presented four (4) times, for a total of 48 trials (each set presentation comprising a trial). In the four trials per stimulus set the visual hemifield presentation of the standard stimulus and the comparison stimuli was varied systematically, as follows:

- 1- St in LVF -- Co1 in LVF, Co2 in RVF
- 2- St in LVF -- Co2 in LVF, Co1 in RVF
- 3- St in RVF -- Co1 in LVF, Co2 in RVF
- 4- St in RVF -- Co2 in LVf, Co1 in RVF

The order of 48 trials was divided into 4 quasi-randomized blocks of 12 trials each, with the following restrictions:

- a- no more than one presentation of a given set in a block of 12 trials,

b- no more than two successive presentations of the standard stimulus to a given visual field in a 12-trial block, and

c- no more than three successive presentations of the same visual hemifield of the comparison stimuli (e.g., Co1 to LVF and Co2 to RVF) in a 12-trial block.

The same quasi-randomized order of 4 blocks of trials was used for all subjects (See Appendix D).

Five (5) sets of stimuli were selected from the discarded sets in the original pool of 21 sets to be used during practice trials to familiarize the subjects with the apparatus and the task.

Apparatus.

A Gerbrands Three-channel Projection Tachistoscope Model # 1175 was used to display the stimuli. The tachistoscope was driven by an IBM PC-XT computer, through a Lab Tender Digital In/Digital Out opto-isolator interface (Scientific Solutions, Inc, 1985).

TurboBasic language was used to program the IBM PC-XT computer to advance the slides, control the exposure durations, open and close the shutters, sound the preparatory tones and control the interstimulus and intertrial intervals (See Appendix E).

The child's choice of comparison picture was indicated by his moving the handle of a manipulandum, consisting of a double switch connected to the opto-isolator interface noted above. Moving the handle of the "joystick" either to the left or right closed the switch, terminating the trial. The computer was programmed to record and store the responses: the choice of match (matchtype-either perceptual or semantic) and the reaction time (msec), determined from the onset of the comparison slide to the closing of the switch. During the experimental matching procedure (but not during practice trials), the computer was programmed to store the trials on which the reaction times were under 200 msec. or over 3000 msec., and to readminister these trials (as per Tomlinson--Keasey et al., 1978) immediately following the 48 test trials (See Appendix C).

Procedure.

Each child was tested individually. Following the administration of the handedness inventory and the Vocabulary test, the laboratory room was darkened.

The child was seated at a small desk with his head in a chinrest two (2) meters from the projection wall (See Figure 2). The child was asked to fixate on a central stimulus (black dot) when he heard a tone (1 second

duration). The manipulandum was demonstrated and the child was told to hold the "joystick" with both hands. Instructions were read and the subject was led through one sample trial. (See Appendix F for instructions to subjects.) The Experimenter stressed the importance of maintaining central fixation, keeping both hands on the manipulandum, and responding as quickly as possible.

Practice trials

A single picture (St) appeared on the left or right side of the central (dot) stimulus for 150 msec. Following a 500 millisecond delay to allow for iconic image decay, the pair of comparison pictures appeared, side-by-side. The child's task was to choose from the two comparison pictures the one that "goes best" with the single picture that preceded it, and to indicate his choice by moving the handle of the "joystick" in the direction of the chosen picture (i.e., either to the left or the right). The trial was terminated when the child moved the joystick either to the left or the right, thereby closing the switch. There was a 5 second intertrial interval, followed by the tone signalling the next trial. Practice blocks of 10 trials (with 5 of the previously discarded stimulus sets) were administered until the following criteria were met for five consecutive trials:

Figure 2. Subject seated at apparatus.



- 1- chin on chinrest and looking "straight ahead" at dot (central fixation point) on wall,
- 2- manipulandum held with both hands,
- 3- no responding before onset of comparison slide,
- 4- reaction times within the 200 to 3000 msec range,
- 5- subject quiet during procedure (no verbalizing or naming).

No subject required more than two blocks of practice trials to meet the criteria.

Parents were permitted to observe their child during the administration of the handedness inventory, Vocabulary test and practice trials, but were seated outside the laboratory during the testing session that followed.

Experimental testing:

After the practice trials, the slide trays were changed for the 48 test trials and the child was instructed to continue to pick the comparison picture that "goes best" with these new standard pictures. The four blocks of 12 trials were administered without interruption or pause. The stimulus exposure durations (150 msec) and intertrial (5 sec) and interstimulus intervals (500 msec) were the same as during the practice trials. Any test trials that needed to be readministered were presented

immediately following the 48 experimental trials. After the test trials the child was given a few minutes to rest.

Following the experimental matching task, the subject was asked to identify, by name, definition or function, each of the 35 stimulus pictures as they were projected singly. This was done to assure that the child was familiar with the items. All 60 children correctly identified all of the 35 items, either by naming accurately, describing the item functionally (e.g., "you blow it and it makes tunes" for "trumpet"), naming a similar item (e.g., "spoon" for "ladle"; "jacket" for "coat"), or a combination of words and gestures (pantomime) to explain. (This last was seen only in a few of the 4- and 5-year olds.)

Follow-up Tasks:

About two months after experimental testing, twenty (20) of the 60 boys, consisting of ten of the 7-9 year olds (mean age = 8.2 years) and ten of the 10-12 year olds (mean age = 11.3 years) returned for a second testing session, during which two follow-up tasks-- Shape Matching and Identity Matching-- were administered. The procedure and apparatus used for the follow-up tasks were identical to those used in the experimental matching tasks, although no practice trials were administered. The procedure was

reviewed for the children by the Experimenter. Half of the children in each of the two age groups were administered the Shape Matching task followed by the Identity Matching task; the other half were administered the tasks in the reverse order. The stimulus exposure durations, the preparatory tones, and the interstimulus and intertrial intervals were the same as during the previous experimental testing session.

Shape Matching:

The procedure was identical to the original experimental task, but the instructions to the subjects were changed. The subject was told that "everything is the same, except-- this time, pick the picture that looks like the fast (standard) picture. That is, the picture that has the same or similar shape." The same 48 trials were presented and the responses (type of match- perceptual or semantic, and reaction time to make the match) were recorded and stored by the computer. The same quasi-randomized order was administered to all 20 subjects.

Identity Matching:

The 20 boys were shown five sets of slides. Each set consisted of a standard stimulus slide (from the original 12 sets) and a comparison slide in which one picture was identical to the standard and the other picture was the

semantic match from the original experimental task. Each of the five stimulus sets was presented four times, in counterbalanced order, for a total of 20 trials (See Appendix G). The instructions were to "pick the picture that is identical, the one that is 'exactly' the same as the fast (standard) picture." Type of match (correct identification or semantic error) and reaction time to make the match were recorded and stored by the computer. The same quasi-randomized order of stimulus presentation was administered to all subjects.

Data Analysis

Experimental Task:

Stimuli--The Cochran Q Test of Correlated Proportions (Siegel, 1956) was performed to determine if any of the stimulus sets resulted in a significantly different response pattern (i.e., more or fewer semantic responses) from the others.

Type of Match--The mean number of perceptual matches and the mean number of semantic matches were calculated for each age group and tested for significant differences by a 3-way Analysis of Variance with Age as the between group variable (3 levels) and Type of Match (2 levels) and Visual Hemifield (2 levels) as the within group variables.

Practice effects were assessed by comparing the number of semantic matches in the first block of 24 trials with the number of semantic matches in the second block of 24 trials in an 4-way ANOVA with Age as the between group and Matchtype, Visual Hemifield and Block as within group variables.

To determine the consistency of matches (perceptual or semantic) for each age group, the responses were also analyzed according to pattern of responding. As each of the 12 stimulus sets were presented 4 times, the 5 possible patterns of matching for each set were:

- 1 -- 4 Perceptual responses and 0 Semantic responses;
- 2 -- 3 Perceptual responses and 1 Semantic response;
- 3 -- 2 Perceptual responses and 2 Semantic responses;
- 4 -- 1 Perceptual response and 3 Semantic responses;
- 5 -- 0 Perceptual responses and 4 Semantic responses.

The number of sets with each matching pattern were entered into an ANOVA with Age (3 levels) as the between-group variable and Match Pattern (5 levels) as the within-group variable. Post hoc pairwise comparison tests were subsequently conducted to determine specific age differences in pattern of response.

Reaction Time- The median reaction times for each subject were averaged and (age) group mean RT scores were calculated. An initial ANOVA was performed on the reaction times for both perceptual and semantic matches, with Age (3 levels) as the between group factor and two within-group factors: type of match (2 levels- perceptual and semantic) and visual hemifield of standard stimulus presentation (2 levels- LVF and RVF).

Practice effects were assessed by comparing RTs to the first 24 trials (Block1) to the RTs of the second 24 trials (Block 2) as a function of age and visual field presentation.

As many subjects in the 7-9 year old group and the 10-12 year old group did not make any perceptual matches, the overall ANOVA was performed on only 38 subjects, and the RTs for the Perceptual and the Semantic matches were analyzed separately. (See nos. 4 and 5 below.)

The following ANOVAs on RT data were performed:

1- for all RTs (perceptual and semantic matches combined) with Age as the between-group factor and Visual Hemifield of Standard Stimulus presentation as the within-group factor;

2- for all RTs, with Age as the between-group factor and Type of Match as the within-group factor; followed by

3- for each age group separately, all RTs (perceptual and semantic matches combined) with Visual Field and Type of Match as the within-group factors;

4- for semantic matches (N=60, with 2,524 responses), with Age as the between-group factor, and Visual Field as the within-group factor,

5- for perceptual matches (N=51, with 455 responses), with Age as the between-group factor, and Visual Field as the within-group factor.

Post hoc analyses, including t-tests and Tukey pairwise comparison procedures, were subsequently conducted where indicated to determine which age groups differed significantly.

The Levene test of Homogeneity of Variance (Keppel, 1973), an ANOVA of reaction time (absolute) difference scores (Z score = observed score - group mean score) was performed to compare the variability of Semantic and Perceptual Reaction Time scores for each Visual Hemifield for each of the three age groups.

Follow-up Tasks: Shape Matching, Identity Matching-
The number of correct matches was converted to percent correct. For each task, the mean percentage correct responses was calculated separately for the two age groups (7-9 year olds and 10-12 year olds). An analysis of variance (ANOVA) was performed on the accuracy scores

(percent correct) to test for significant differences between Age groups (between groups factor); between Task (within groups factor, 2 levels: shape matching, identity matching), and between Visual Field presentation of the standard stimulus (within groups factor, 2 levels: Left Visual Field, Right Visual Field). A second ANOVA was performed on the reaction time scores for correct responses to test for significant differences between Age groups, Task and Visual Field, as above.

The Levene test (ANOVA) of homogeneity of variance was also performed on the data from the two follow-up tasks in order to compare the variability in RT for Shape Matching with the variability in RT for Identity Matching. Absolute RT difference scores were entered into an ANOVA with Age as the between group variable (2 levels: 7-9 years, 10-12 years), and Task (2 levels: Shape Matching, Identity Matching) and Visual Field of standard stimulus presentation (2 levels) as the within-group variables.

Probability values less than or equal to .05 were considered statistically significant. P values between .055 and .10 were considered a trend or tending to statistical significance.

Methodological Considerations

The experimental paradigm used in the present study consisted of the presentation of lateralized tachistoscopic pictures, which could be matched either perceptually or semantically, to children, 4 to 12 years of age. The paradigm was adapted from the Levy and Trevarthen (1976) study of commissurotomed patients in which chimeric stimuli could be matched on the basis of shape or function. The pictures used in the present study were taken from the Peabody Picture Vocabulary Test (PPVT) (Dunn, 1959), as they had been used by Tomlinson-Keasey and her associates (Tomlinson-Keasey et al., 1978) with school age children. Additional pictures were taken from the Snodgrass and Vanderwart (1980) set if they provided a better perceptual match than the PPVT to the standard. Occasionally, a picture was rotated from its original orientation of 45 degrees off vertical (e.g., the light bulb was rotated so that the threaded end was at the top) to make a better perceptual match (with the pear). A recent study (Berman, Friedman, Hamberger, & Snodgrass, 1989) investigated age differences among 14 second graders, 8 third graders, 18 fourth graders, and 20 college students with respect to name agreement, familiarity and visual complexity in response to the PPVT

and Snodgrass and Vanderwart pictures. Children and adults generally agreed on the names of pictures, with the children producing the same modal names as adults for 295 of the 320 pictures. Although children's ratings were somewhat lower than adults on all measures, for most pictures the differences were minor. Berman et al. (1989) concluded that the strength of the correlations between ratings of children and adults indicated that judgments of complexity, familiarity, and (to a lesser extent) the names of the PPVT and Snodgrass and Vanderwart pictures are based on information processing completed before age 7, with relatively little modification thereafter.

It was decided to use a manual double-switch manipulandum for subjects to indicate their responses in order to avoid the possible left hemisphere priming effects of verbal report. The handle on the manipulandum was large enough to accommodate both of the child's hands so that the factor of responding hand would not have to be addressed and the testing session could be kept brief enough for 4-year olds.

The decision to consider the unilateral presentation of the standard stimuli as a main effect (visual hemifield) was based on the study conducted by Berrini and his associates (Berrini, Della Sala, Spinnler, Sterzi, & Vallar, 1982) in which they systematically and separately

varied (unilaterally-presented) stimuli at input and at recognition (output). Their results indicated that the stimulus input factor was significantly more effective for eliciting hemispheric asymmetries in normal adults. Furthermore, as the comparison pictures remained visible until subject termination, these stimuli were available for more than 200msec and, therefore, not appropriate for analysis with respect to lateral asymmetries.

Although stimulus exposure durations ranging from 30 msec to 200 msec have been used with children (Jones & Anuza, 1982; McKeever & Huling, 1970; Young & Bion, 1980;), it was decided to use 150 msec with all subjects in the present study. Woodworth (1938, cited in Bryden, 1982) is considered the seminal source for evidence that 180msec are required to initiate a saccadic eye movement that transports the eyes from one fixation point to the next. More recent evidence indicates that it may take up to 300 msec to initiate an eye movement when the subject does not know which of two locations (i.e., which visual field) will be stimulated (Hulme, 1979). In tachistoscope experiments, the stimulus is degraded by being exposed briefly to an area of reduced visual acuity (Bryden, 1982). Although 16-year olds were comfortable with 100 msec exposure durations (during pilot testing), a more conservative 150 msec was chosen to allow the youngest

subjects sufficient time to identify the standard picture clearly for deeper semantic processing.

A black dot was used for central fixation as the two other choices, a cross and the letter 'x', appeared to elicit more verbalization (specifically, naming) from the subjects during piloting. Kershner, Thomas and Callaway (1977) found that laterality effects with digits depended on the nature of the fixation stimulus. They induced (primed) a visual hemifield superiority shift with verbal or spatial central fixation stimulus. An LVF/RH advantage for digit recall (pointing to correct digit from matrix array) was obtained with a geometric form as fixation control, and an RVF/LH superiority with a letter at central fixation.

It was decided to readminister any trials in which the subject responded in less than 200 msec or took longer than 3000 msec. as per Tomlinson-Keasey et al. (1978). During pilot testing of the procedure, some of the younger children (mostly four year olds) tended to wiggle the manipulandum and close the switch accidentally. Occasionally, attention wandered and the subject (again, mostly the youngest children) "forgot" to look. It was determined that if a subject required more than 10% of the trials readministered (i.e., 5 or more), the data for that subject would be considered unreliable and discarded.

Practice trials were administered to familiarize subjects with the experimental procedure and to instruct the subjects as to the appropriate motions with the manipulandum. No subject's data had to be discarded.

Results

Stimuli

The Cochran Q Test of Correlated Proportions (Siegel, 1956) was conducted on the twelve sets of stimuli and it was determined that none of the stimulus sets yielded significantly more perceptual responses than the others ($Q(11) = 17.62, p = .10$).

Experimental Task

I. Type of Match: Semantic versus Perceptual

The number of Semantic and Perceptual matches in each visual field of standard stimulus presentation were calculated for each subject, and the means and standard deviations calculated for each age group (See Table 1). The number of perceptual and semantic responses was entered into an Analysis of Variance, resulting in a highly significant effect of Matchtype ($F(1,57) = 324.082, p < .001$); a significantly greater number of semantic than perceptual matches were made across the three age groups. (See Table 1 and Figure 3.)

To determine which age group(s) showed a significant "preference" for semantic matching, t-tests for dependent samples were performed. All three age groups made significantly more semantic than perceptual match

responses (4-6 year olds: $t(19)=-3.10$, $p<.01$; 7-9 year olds: $t(19)=-20.49$, $p<.001$; 10-12 year olds: $t(19)=-33.18$, $p<.001$).

However, the three age groups did not demonstrate similar patterns of semantic and perceptual matching, as indicated by the highly significant Age by Matchtype interaction ($F(2,57)=23.333$, $p<.001$). Post hoc Tukey pairwise comparison testing of the Semantic-Perceptual difference scores was performed. The 4-6 year olds made significantly fewer semantic responses (and, consequently, significantly more perceptual responses) than the 7-9 year olds and the 10-12 year olds ($p<.01$). The number of semantic (and perceptual) matches made by the 7-9 year olds did not differ significantly from the number of semantic (and perceptual) matches made by the 10-12 year olds.

Neither the main effect of Visual Field ($F(1,57)=1.000$, $p=.32$), the Visual Field by Matchtype interaction ($F(1,57)=0.041$, $p=.84$), nor the Age by Visual Field by Matchtype interaction ($F(2,57)=0.410$, $p=.67$) was statistically significant.

As each stimulus set was presented four times, a measure of the consistency of pattern of responding could be obtained by calculating the number of Semantic (Sem) and Perceptual (Per) responses for each set presented to

Table 1.

Experimental Task: Number of Perceptual and Semantic Responses by Age and Visual Hemifield

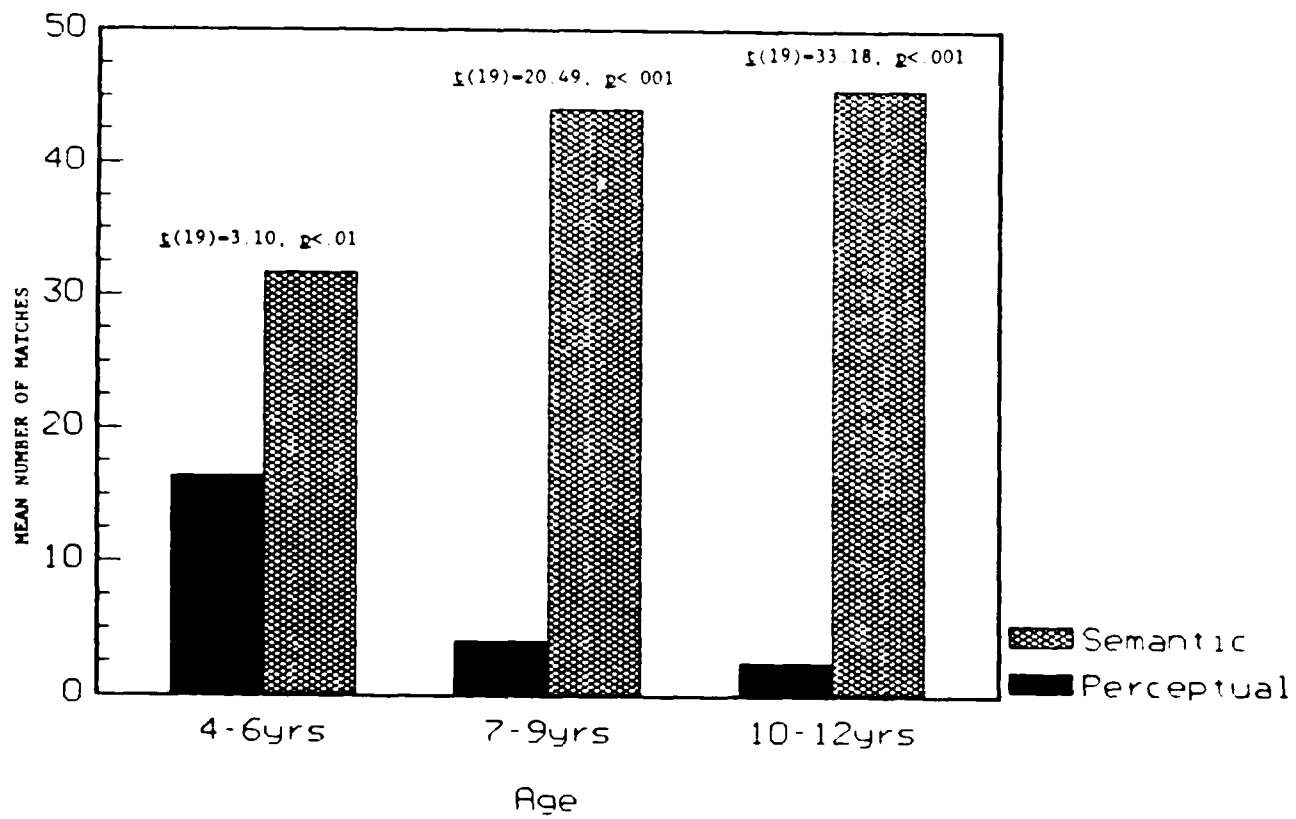
AGE	Perceptual Responses			Semantic Responses		
	Total	Visual LVF	Field RVF	Total	Visual LVF	Field RVF
4-6yrs*						
Mean	16.35	8.20	8.15	31.35	15.80	15.85
SD	11.05	6.03	5.14	11.05	6.03	5.14
7-9yrs**						
Mean	4.00	1.85	2.15	44.00	22.15	21.80
SD	4.36	2.08	2.46	4.43	2.08	2.46
10-12yrs***						
Mean	2.40	1.25	1.15	45.5	22.7	22.85
SD	2.91	1.92	1.31	2.9	1.92	1.31
Total						
Mean	7.58	3.77	3.82	40.40	20.22	20.18
SD	9.36	4.93	4.55	9.35	4.92	4.55

*4-6 year olds: N=19 for Total, LVF, and RVF Perceptual Responses

**7-9 year olds: N=16 for for Total Perceptual Responses
N=15 for LVF Perceptual Responses
N=13 for RVF Perceptual Responses

***10-12 year olds: N=16 for Total Perceptual Responses
N=11 for LVF Perceptual Responses
N=12 for RVF Perceptual Responses

Figure 3. Experimental Task: Mean Number of Perceptual and Semantic Responses by Age.



each subject. The patterns of responding could range from all perceptual responses (Per4/Sem0) to all semantic responses (Per0/Sem4) with intermediate values of Per3/Sem1, Per2/Sem2, and Per1/Sem3. Per2/Sem2 would represent chance level, with 2 Semantic and 2 Perceptual responses to the same stimulus set. The total number (sum) of sets and mean number of sets for each response pattern was calculated for each age group (see Figure 4 and Table 2). To examine age differences in pattern of matching, an ANOVA was performed with Age (3 levels) as the between-group variable and Match Pattern (5 levels: Per4/Sem0, Per3/Sem1, Per2/Sem2, Per1/Sem3, Per0/Sem4) as the within-group variable. The highly significant main effect of Response Pattern ($F(4,228)=140.123$, $p<.001$) indicated that the match patterns varied in frequency of occurrence (see Figure 4.) Post hoc Tukey pairwise comparison tests demonstrated that, collapsed across age groups, the Per0/Sem4 (all semantic) response pattern occurred significantly more often than any other pattern ($p<.01$). The Per1/Sem3 pattern occurred significantly more frequently than the Per3/Sem1 ($p<.01$) and the Per4/Sem0 ($p<.01$) patterns, but did not differ significantly from the Per2/Sem2 pattern ($p=.10$). The Per4/Sem0, Per3/Sem1, and Per2/Sem2 patterns did not differ significantly from each other when collapsed across age groups.

The Age by Response Pattern interaction was highly significant ($F(8,228)=12.617$, $p<.001$) and follow-up ANOVAs were performed for each of the five (5) patterns with Age as the between group variable.

For the Per4/Sem0 (all perceptual) response pattern, the effect of Age was significant ($F(2,57)=5.453$, $p<.01$). Post hoc Tukey pairwise comparison tests showed that 4-6 year olds demonstrated this pattern of responding significantly more often than did both the 7-9 year olds ($p<.05$) and the 10-12 year olds ($p<.01$). The two older groups did not differ significantly (See Figure 4).

For the Per3/Sem1 pattern of responding, the effect of Age was highly significant ($F(2,57)=9.837$, $p<.001$) and post hoc Tukey pairwise comparison tests indicated that the 4-6 year olds responded with this pattern significantly more often than did the 7-9 year olds ($p<.01$) and the 10-12 year olds ($p<.01$), who did not differ significantly from each other.

For the Per2/Sem2 (chance level responding) pattern of responding, the effect of Age was again highly significant ($F(2,57)=9.477$, $p<.001$). Post hoc Tukey pairwise comparison tests showed that the 4-6 year olds responded with this pattern significantly more often than did the 7-9 year olds ($p<.01$) and 10-12 year olds ($p<.01$). Again, the two older groups did not differ significantly.

Figure 4. Experimental Task: Response Patterns to Stimulus Sets by Age.

Pattern: $F(4,288)=140.12, p < .001$
Age x Pattern: $F(8,228)=12.62, p < .001$

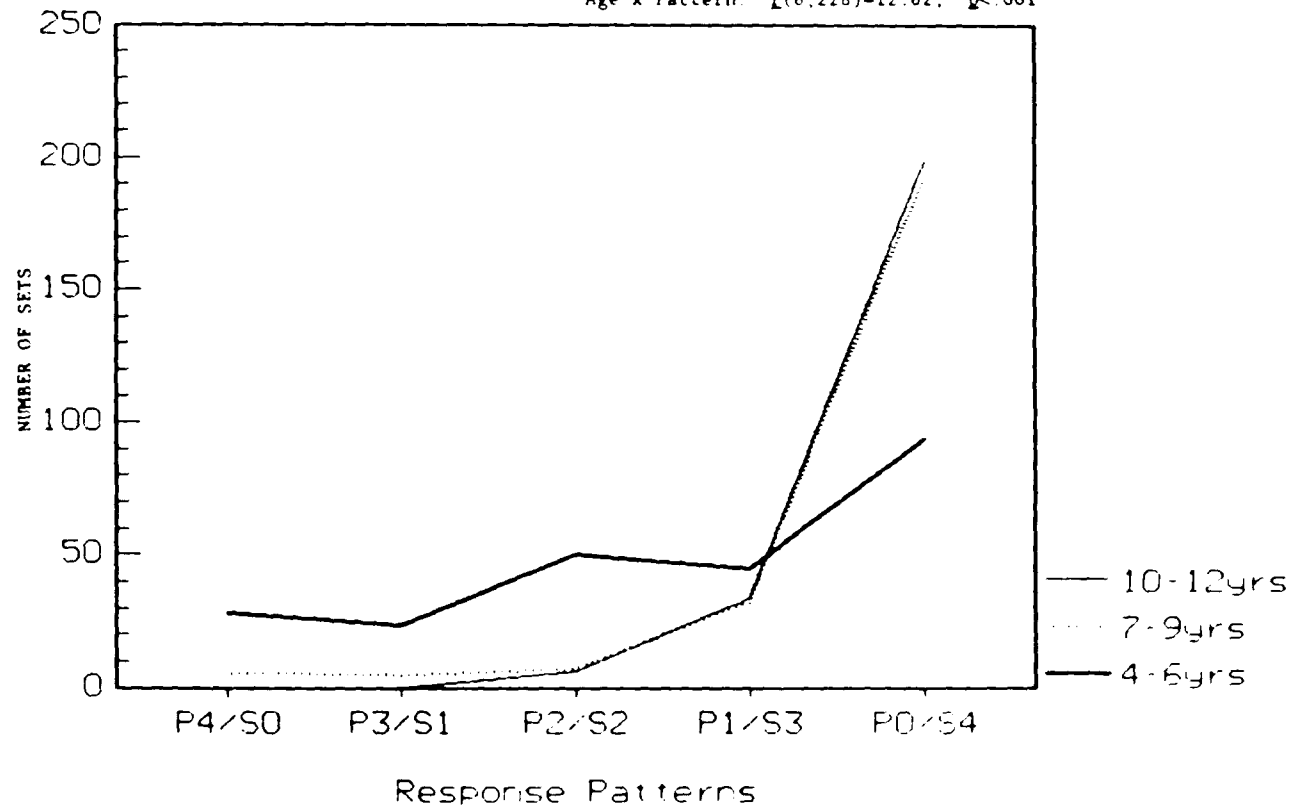


Table 2.

Experimental Task: Response Patterns to Experimental Stimulus Sets by Age (n=60)

AGE (yrs)	Response Pattern									
	Per4/Sem0		Per3/Sem1		Per2/Sem2		Per1/Sem3		Per0/Sem4	
	SUM	<u>M</u>	SUM	<u>M</u>	SUM	<u>M</u>	SUM	<u>M</u>	SUM	<u>M</u>
4-6	28	1.40	23	1.15	50	2.50	45	2.25	94	4.70
7-9	5	0.25	4	0.20	7	0.35	32	1.60	192	9.60
10-12	0	0.00	0	0.00	6	0.30	34	1.70	199*	9.95
Total	33	0.55	27	0.17	63	1.05	111	1.85	485	8.08

* Note: one response missing so one set was omitted from analysis--only 239 sets for ages 10-12 yrs. (However, the other 3 responses in the set were Semantic Rs)

KEY:

Per4/Sem0 = 4 Perceptual responses and 0 Semantic responses
(all Perceptual responses)
 Per3/Sem1 = 3 Perceptual responses and 1 Semantic response
 Per2/Sem2 = 2 Perceptual responses and 2 Semantic responses
 Per1/Sem3 = 1 Perceptual response and 3 Semantic responses
 Per0/Sem4 = 0 Perceptual responses and 4 Semantic responses
(all Semantic responses)

With respect to the Per1/Sem3 response pattern, the effect of Age was not significant ($F(2,57)=0.939$, $p=.40$).

For the Per0/Sem4 (all semantic) response pattern, the effect of Age was highly significant ($F(2,57)=18.963$, $p<.001$). The post hoc Tukey pairwise comparison tests indicated that the 4-6 year olds demonstrated this pattern significantly less often than did the 7-9 year olds ($p<.01$) and the 10-12 year olds ($p<.01$). The 7-9 year olds did not differ significantly from the 10-12 year olds.

To examine practice effects, an ANOVA comparing the number of semantic responses in the first 24 trials (Block 1) to the second 24 trials (Block 2) was conducted with Age as the between groups factor. The proportion of semantic and perceptual responses did not change from the first half of the trials to the second half ($F(1,57)=0.00$, $p=1.00$). As the Age by Blocks interaction approached statistical significance ($F(2,57)=2.772$, $p<.08$), follow-up t tests were conducted for each age group. None were significant (4-6 year olds: $t(19)=-1.369$, $p=.17$; 7-9 year olds: $t(19)=1.140$, $p=.27$; 10-12 year olds: $t(19)=1.502$, $p=.15$).

II. Reaction Time

Group means of individual median reaction times were calculated for semantic and perceptual matches, separately

and combined, for each of the three age groups. (See Table 3 for age group mean RTs and standard deviations for all matches; see Figure 5 and Table 4 for semantic matches; see Figure 6 and Table 5 for perceptual matches.)

A. Semantic and Perceptual matches combined

Group mean reaction time scores (of individual median RTs) for all matches were entered into a 3 x 2 ANOVA with Age as the between-group factor (3 levels) and Matchtype (2 levels: perceptual, semantic) as the within-group factor.

The main effect of Age was highly significant ($F(2,57)=7.494$, $p<.01$) (see Table 3A). Post hoc Tukey pairwise comparison tests indicated that the 4-6 year olds took significantly longer to respond than did the 7-9 year olds ($p<.05$) and the 10-12 year olds ($p<.01$). The difference in the reaction times of the 7-9 year olds ($M=973$, $SD=376$) and the 10-12 year olds ($M=816$, $SD=249$) was not statistically significant.

There was no significant difference in the RTs between perceptual ($M=1107$, $SD=519$) and semantic matches ($M=982$, $SD=329$) when collapsed across age groups, and the Age by Matchtype interaction was not statistically significant ($F(2,57)=0.848$, $p=.44$).

Table 3.

Experimental Task: Reaction Time (msec) for Perceptual
and Semantic Matches by Age and Visual Hemifield

AGE	All Rs	LVF	RVF	Semantic	Perceptual
4-6yrs					
<u>M</u>	1206	1153	1260	1249	1172
<u>SD</u>	308	320	293	368	325
7-9yrs					
<u>M</u>	973	1049	898	956	1032
<u>SD</u>	376	429	308	290	605
10-12yrs					
<u>M</u>	816	784	848	743	1061
<u>SD</u>	249	187	300	88	764
Total					
<u>M</u>	999	995	1002	982	1107
<u>SD</u>	352	308	376	329	519

Table 4.

Experimental Task: Reaction Time (msec) for Semantic
Matches by Age and Visual Hemifield (n = 60)

AGE	Total		Visual Hemifield			
	M	SD	M	SD	M	SD
			LVF		RVF	
4-6yrs	1249	368	1177	301	1320	420
7-9yrs	956	290	972	278	940	307
10-12yrs	743	88	768	93	718	77
Total	982	343	972	292	993	390

Figure 5. Experimental Task: Mean reaction time (msec) for Semantic matching by age and visual hemifield ($n = 60$).

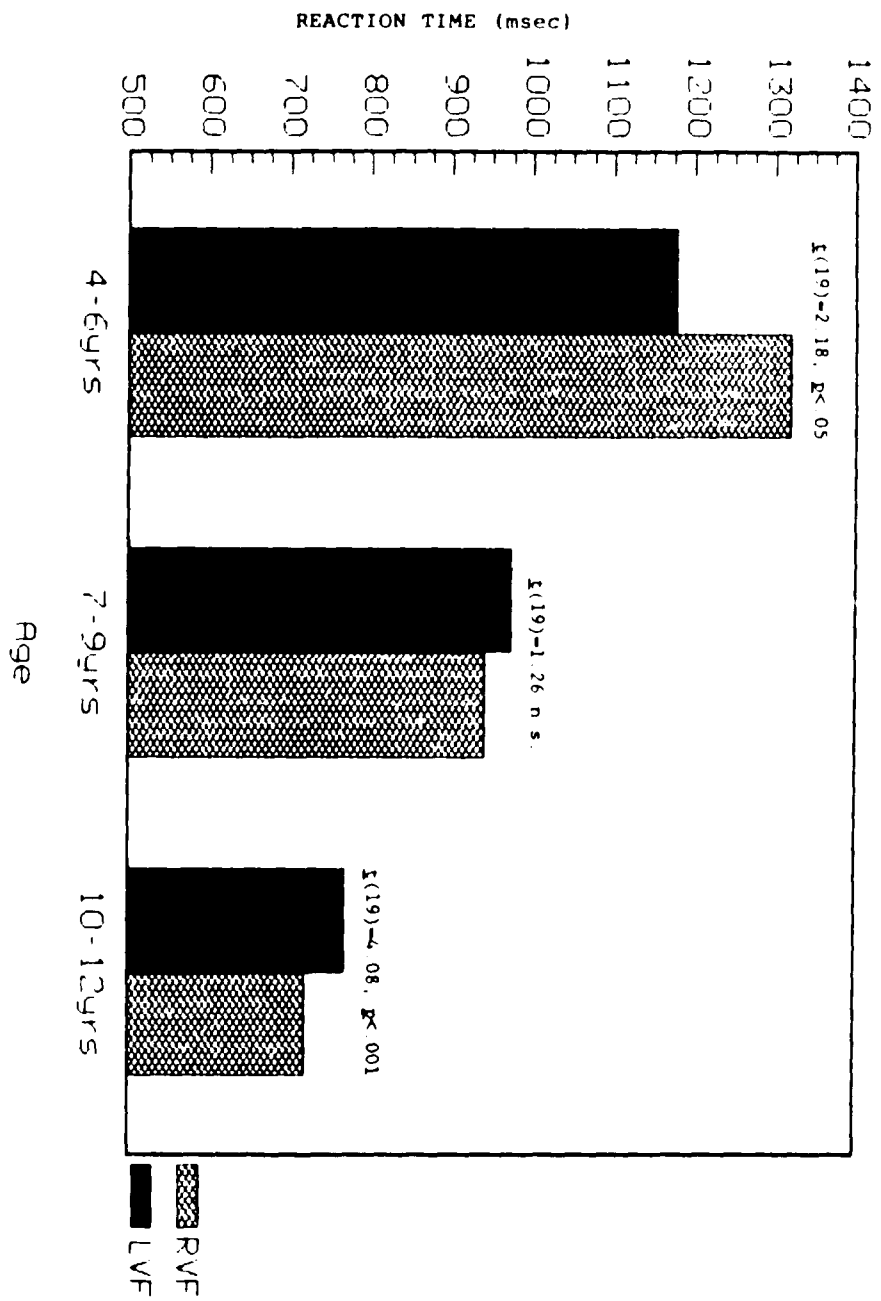


Table 5.

Experimental Task: Reaction Time (msec) for Perceptual Matches by Age and Visual Hemifield (n = 38)

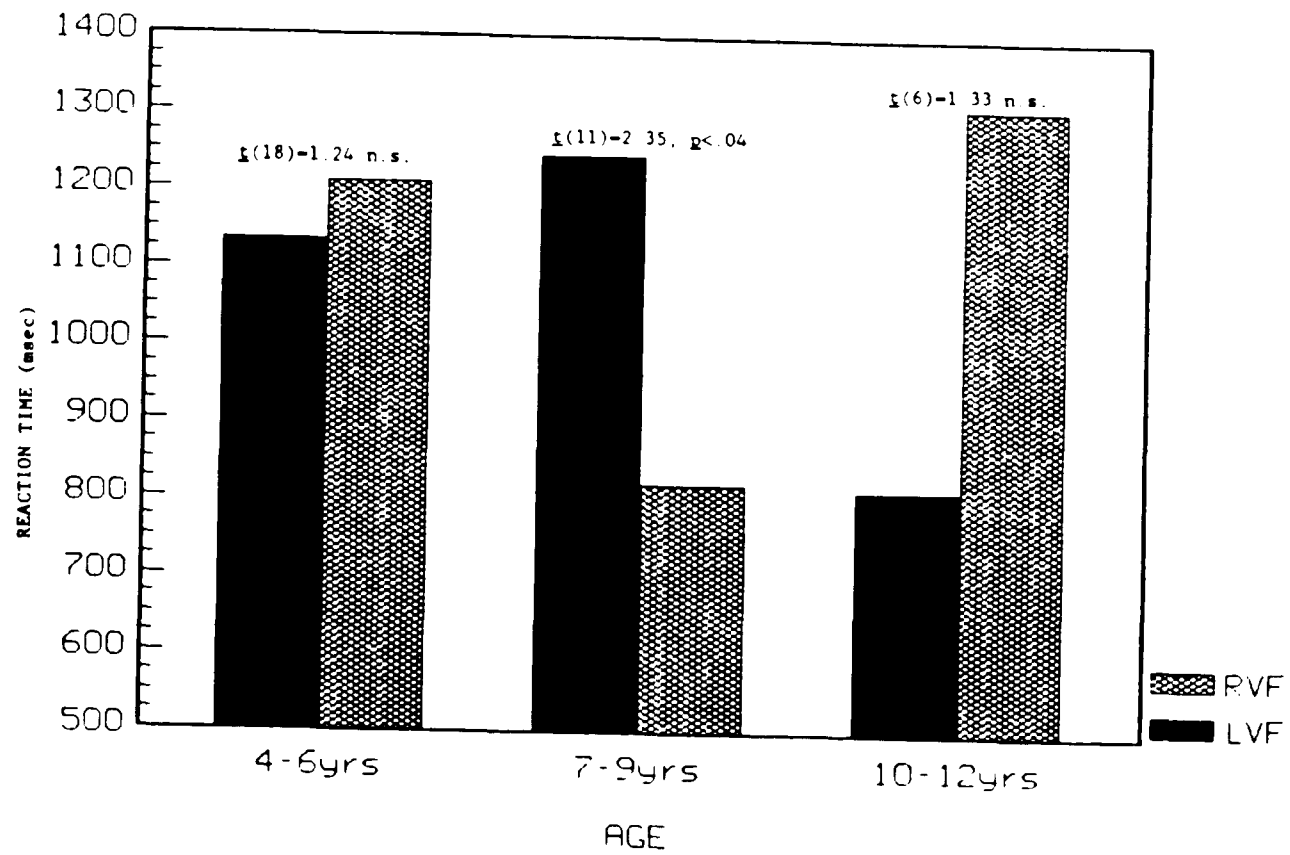
AGE	Total		Visual Hemifield			
	M	SD	LVF		RVF	
	M	SD	M	SD	M	SD
4-6yrs*	1172	325	1134	393	1210	243
7-9yrs**	1032	605	1245	707	820	407
10-12yrs***	1061	764	813	572	1309	890
Total	1107	519	1110	548	1105	497

* 4-6 year olds: N=19 for Total, LVF, RVF Perceptual Responses

** 7-9 year olds: N=16 for Total Perceptual Responses
N=15 for LVF Perceptual Responses
N=13 for RVF Perceptual Responses

*** 10-12 year olds: N=16 for Total Perceptual Responses
N=11 for LVF Perceptual Responses
N=12 for RVF Perceptual Responses

Figure 6. Experimental Task: Mean reaction time (msec) for perceptual matches by age and visual hemifield ($n = 38$).



The Age (3 levels) by Visual Field (2 levels) ANOVA for RTs yielded a highly significant main effect of Age ($F(2,57)=9.555$, $p<.001$), consistent with the results noted above. RTs for LVF presentations ($M=995$, $SD=308$) did not differ significantly from RVF presentations ($M=1002$, $SD=376$) ($F(1,57)=0.039$, $p=.84$) when collapsed across age groups, but the Age by Visual Field interaction was significant ($F(2,57)=5.405$, $p<.01$). Paired difference t -tests for each age group indicated that for the 4-6 year olds, RTs for LVF standard stimulus presentations ($M=1153$, $SD=320$) were significantly faster than for RVF presentations ($M=1260$, $SD=293$), ($t(19)=2.970$, $p<.03$); 7-9 year olds demonstrated significantly faster RTs to RVF ($M=898$, $SD=308$) than to LVF presentations ($M=1049$, $SD=429$), ($t(19)=-2.527$, $p=.0205$); for 10-12 year olds, the RTs to LVF presentations ($M=784$, $SD=187$) did not differ significantly ($t(19)=0.908$, $p=.38$) from those to RVF presentations ($M=848$, $SD=300$).

To test for practice effects, the RTs for the first 24 trials (Block 1) were compared with the RTs for the second 24 trials (Block 2) in an ANOVA with Age as the between group factor and Visual Field and Blocks as the within group factors. There was a significant practice effect, as RTs were significantly faster for the second half of the trials ($F(1,57)=22.908$, $p<.001$). Neither the

Age by Blocks interaction ($F(2,57)=0.637, p=.54$), the Blocks by Visual Field interaction ($F(1,57)=0.4357, p=.5$), nor the Age by Blocks by Visual Field interaction ($F(2,57)=0.158, p=.86$) were statistically significant.

B. Semantic Matches ($n=60$)

The mean RTs and standard deviations for the semantic matches made by each age group are shown in Table 4 and Figure 5. An ANOVA of RTs for the three age groups and the two visual hemifields yielded a highly significant main effect of Age ($F(2,57)=19.257, p<.001$). Post hoc Tukey pairwise comparison tests indicated that the RTs of the 4-6 year olds ($M=1249, SD=368$) were significantly slower ($p<.01$) than those of the 7-9 year olds ($M=956, SD=290$) and the 10-12 year olds ($M=743, SD=88$). The 7-9 year olds were significantly slower than the 10-12 year olds ($p<.05$).

The main effect of visual field was not statistically significant ($F(1,57)=0.727, p=.4$), indicating that RTs for semantic matching did not differ significantly between LVF presentations and RVF presentations. However, a highly significant Age by Visual Field interaction ($F(2,57)=6.729, p<.003$) indicated that the different age groups varied in their RTs according to visual hemifield presentation. For the 4-6 years olds, RTs for semantic

matches in the LVF ($M=1177$, $SD=301$) were significantly faster ($t(19)=2.184$, $p<.05$) than in the RVF ($M=1320$, $SD=420$). The mean RTs for LVF ($M=972$, $SD=278$) and RVF ($M=940$, $SD=307$) semantic matches in the 7-9 year olds did not differ significantly ($t(19)=1.262$, $p=.22$). In contrast, the 10-12 year olds demonstrated significantly faster RTs for RVF ($M=718$, $SD=77$) presentations than for LVF ($M=768$, $SD=93$) presentations ($t(19)=-4.076$, $p<.001$).

C. Perceptual Matches ($n=38$)

(22 Ss made no perceptual matches to either LVF or RVF presentations.)

The Mean RTs and standard deviations for the total number of perceptual matches made by each age group to each visual hemifield presentation are shown in Table 5 and Figure 6.

An ANOVA of RTs of perceptual matches for the 3 age groups and the 2 visual hemifields did not yield a statistically significant main effect of Age ($F(2,35)=0.463$, $p=.64$), or of Visual Field ($F(1,35)=0.003$, $p=.96$). However, the Age by Visual Field interaction was highly significant ($F(2,35)=6.094$, $p<.01$) (See Figure 6).

Paired difference t-tests were performed on the RT scores for LVF vs RVF presentations for each age group

(See Table 5). For the 4-6 year olds, RTs to LVF ($M=1134$, $SD=393$) and RVF ($M=1210$, $SD=243$) presentations did not differ significantly ($t(18)=1.242$, $p=.23$). Likewise, the RTs of the 10-12 year olds to LVF presentations ($M=813$, $SD=572$) did not differ significantly ($t(6)=1.327$, $p=.23$) from the RTs to RVF presentations ($M=1309$, $SD=890$). However, in the 7-9 year old group, the RT to RVF presentations ($M=820$, $SD=407$) was significantly faster than to LVF presentations ($M=1245$, $SD=707$) ($t(11)=-2.345$, $p<.04$).

Follow-up Tasks: Shape Matching and Identity Matching

A. Frequency of Correct Responses

The number of correct responses (perceptual matches) and errors (semantic responses) were tallied and converted into percentages. The mean number and percent correct responses by age and visual field for Shape Matching are shown in Table 6. The 7-9 year olds matched accurately 88% of the time, whereas the 10-12 year olds demonstrated 96% accuracy. The accuracy scores for Identity Matching are shown in Table 7. Both age groups achieved almost perfect accuracy (98% for the 7-9 year olds, 99% for the 10-12 year olds). The percentages of correct matches were entered into an ANOVA with Age as the between-group variable (2 levels: 7-9 years, 10-12 years) and two (2)

within-group variables (Task-- 2 levels: shape-matching, identity matching; Visual Field--2 levels: LVF, RVF). Neither the main effect of Age ($F(1,18)=1.051$, $p=.32$, nor the main effects of Task ($F(1,18)=2.656$, $p=.12$) or of Visual Field ($F(1,18)=1.511$, $p=.23$) were statistically significant. None of the interactions were found to be statistically significant: Age x Task ($F(1,18)=0.681$, $p=.42$); Age x Visual Field ($F(1,18)=0.256$, $p=.67$); Task x Visual Field ($F(1,18)=0.190$, $p=.67$); Age x Task x Visual Field ($F(1,18)=1.121$, $p=.30$).

B. Reaction Time

Median reaction time scores for correct responses were calculated for each subject. The group mean RTs and standard deviations by age and visual hemifield for Shape Matching are shown in Table 8 and Figure 7. Mean RTs and standard deviations by age group and visual hemifield for Identity Matching are shown in Table 9 and Figure 8. A 2 (Age) x 2 (Task) x 2 (Visual Field) Analysis of Variance yielded a significant main effect of Age ($F(1,18)=5.900$, $p=.0258$) with the 10-12 year olds responding more quickly than the 7-9 year olds (see Figures 7 and 8). The main effect of Task was highly significant ($F(1,18)=86.075$, $p<.0001$) with faster RTs for matching identical pictures ($M=541$, $SD=82$) than for matching pictures similar in shape

Table 6.

Follow-up Task - Shape Matching: Number and percentage correct responses by Age and Visual Hemifield

AGE	Total Correct			Visual Hemifield					
	<u>M</u>	<u>%</u>	<u>SD</u>	<u>M</u>	<u>LVF</u> <u>%</u>	<u>SD</u>	<u>M</u>	<u>RVF</u> <u>%</u>	<u>SD</u>
7-9yrs	42.4	88	12.0	21.3	89	5.93	21.1	88	5.93
10-12	46.0	96	4.22	23.0	96	1.05	23.0	96	1.05

Table 7.

Follow-up Task - Identity Matching: Number and percentage correct responses by Age and Visual Hemifield

AGE	Total Correct			Visual Hemifield					
	<u>M</u>	<u>%</u>	<u>SD</u>	<u>M</u>	<u>LVF</u>			<u>RVF</u>	
					<u>%</u>	<u>SD</u>	<u>M</u>	<u>%</u>	<u>SD</u>
7-9	19.6	98	0.97	9.8	99	0.42	9.8	99	0.42
10-12	19.8	99	0.42	10.0	100	0.0	9.8	99	0.42

($M=760$, $SD=161$). The Age by Task interaction was also significant ($F(1,18)=6.205$, $p<.03$). For the Shape Matching task, the 10-12 year olds responded significantly faster than the 7-9 year olds ($t(18)=2.50$, $p<.03$), whereas for Identity Matching, there was no significant difference in reaction time between the two groups ($t(18)=1.09$, $p=.29$). The main effect of Visual Field was not statistically significant ($F(1,18)=0.020$, $p=.89$) nor was the Task by Visual Field interaction ($F(1,18)=2.306$, $p=.15$) or the Age x Task x Visual Field interaction ($F(1,18)=1.816$, $p=.19$).

Variability in Reaction Times

The discrepant findings between the perceptual match RTs of the two older groups in the experimental task and the RTs for follow-up shape and identity matching suggested that a closer look at the variability in RTs for these tasks might support an error hypothesis (to be elaborated in the Discussion section) for the few perceptual matches made by the 7-9 and 10-12 year olds in the experimental task.

A. Variability in Experimental Task

In order to examine further the differences in semantic versus perceptual matches, analyses of measures

of variability (i.e., standard deviations) were performed (see Tables 10 and 11).

Absolute Reaction Time variability scores were calculated by subtracting the mean RT (of individual median RTs) value for each age group from each individual median RT observation in that age group. The absolute variability scores for the subjects who made both semantic and perceptual responses ($n=38$) were then entered into an Analysis of Variance (Levene Test) with Age as the between-group factor (3 levels) and Visual Field (2 levels) and Matchtype (2 levels) as the within-group factors (Keppel, 1973). The main effect of Age was not statistically significant ($F(2,35)=0.361$, $p=.70$), nor was the main effect of Visual Field ($F(1,35)=0.011$, $p=.92$). The Age by Visual Field interaction approached statistical significance ($F(2,35)=2.931$, $p<.07$), suggesting that 7-9 year olds and 10-12 year olds demonstrated somewhat more variability of RT scores as a function of visual field presentation than did the 4-6 year olds. However, the main effect of Matchtype was highly significant ($F(1,35)=12.064$, $p<.002$), indicating that RTs for Semantic matches were significantly less variable than RTs for Perceptual matches. The Age by Matchtype interaction was also highly significant ($F(2,35)=10.777$, $p<.001$), indicating that the RT variability of Semantic and

Table 8.

Follow-up Task - Shape Matching: Reaction Time (msec) for
Correct Responses by Age and Visual Hemifield

AGE	Total		LVF		RVF	
	M	SD	M	SD	M	SD
7-9yrs	840	155	869	181	811	126
10-12yrs	681	125	678	123	683	134

Figure 7. Follow-up Task - Shape Matching: Mean reaction time (msec) for correct matches by age.

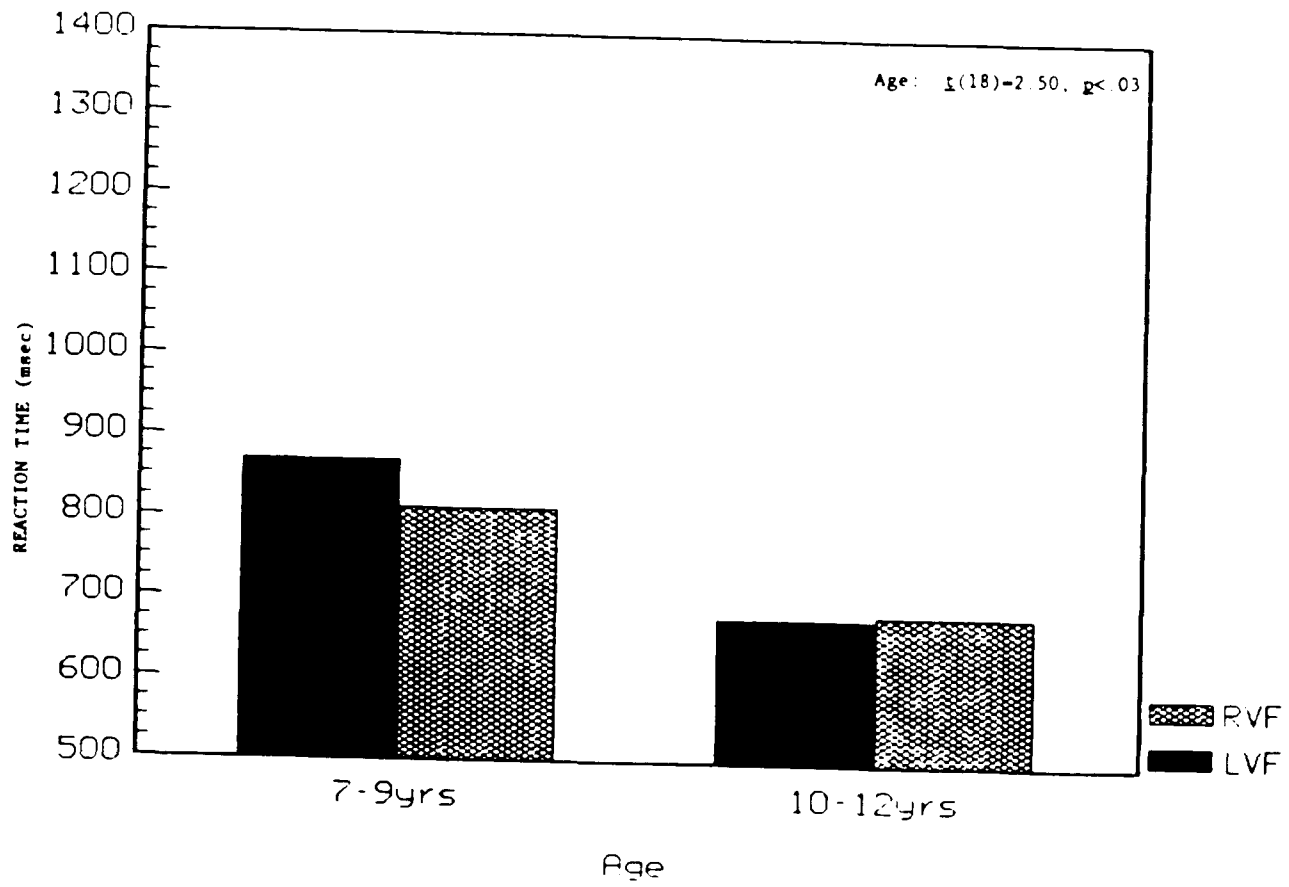


Table 9.

Follow-up Task - Identity Matching: Reaction Time (msec)
For Correct Responses by Age and Visual Hemifield

AGE	Total		Visual Hemifield			
	M	SD	LVF		RVF	
			M	SD	M	SD
7-9yrs	553	99	544	89	579	123
10-12yrs	516	38	514	33	525	50

Figure 8. Follow-up Task - Identity Matching: Mean Reaction Time (msec) for Correct Responses by Age and Visual Hemifield.

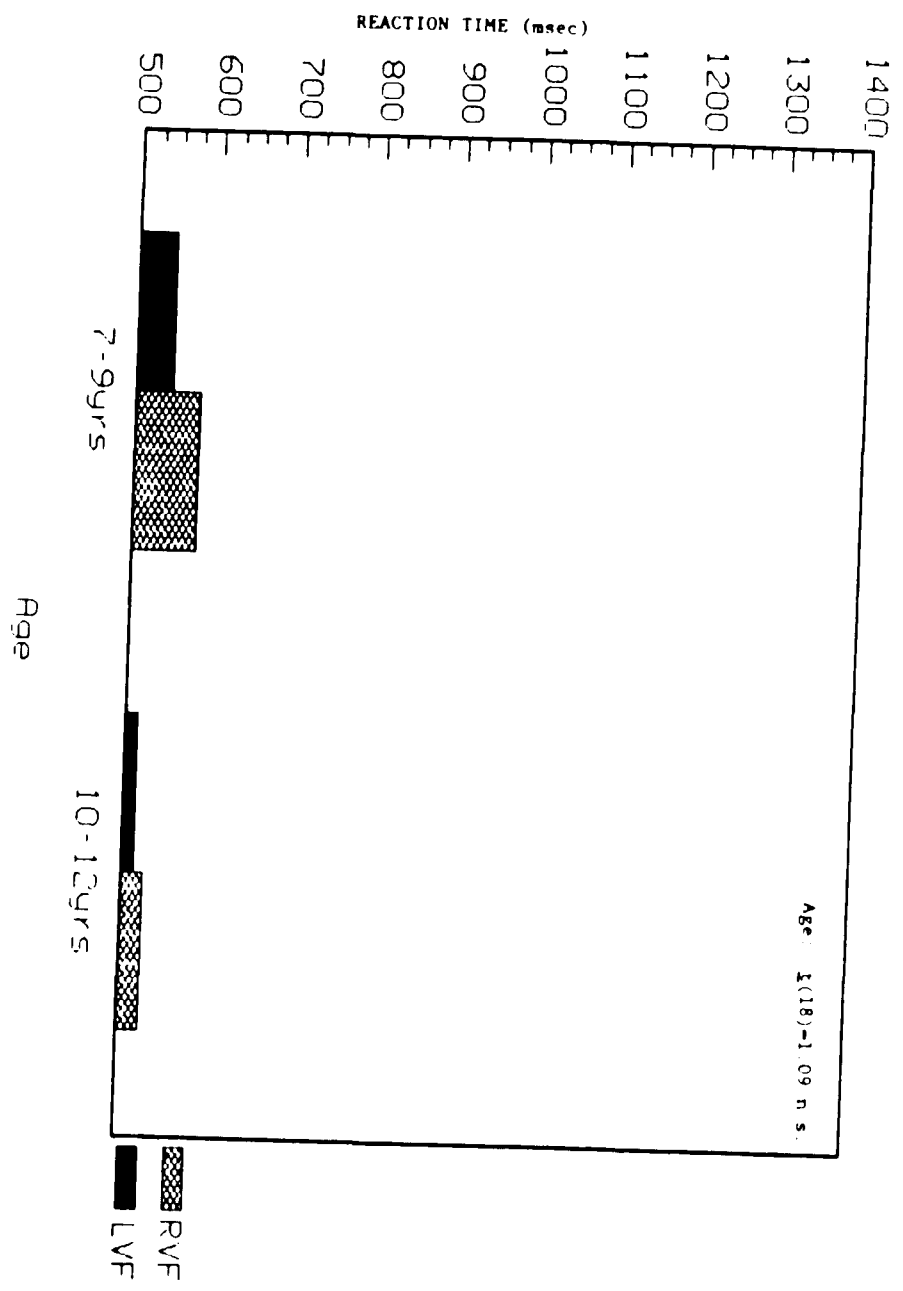


Table 10.

Experimental Task: Reaction Time Variability (msec) for Correct Responses

(RT Variability (msec) = individual RT score - group mean RT)

AGE	<u>Visual Hemifield</u>			<u>Type of Match</u>	
	Total	LVF	RVF	Per n=38	Sem n=60
4-6yrs					
<u>M</u>	272	278	266	257	283
<u>SD</u>	211	209	215	200	218
7-9yrs					
<u>M</u>	335	389	281	455	198
<u>SD</u>	378	431	316	453	208
10-12yrs					
<u>M</u>	318	222	415	573	69
<u>SD</u>	527	419	618	660	50

Table 11.

Experimental Task: Reaction Time Variability (msec) by Age, Visual Hemifield, and Type of Match

(RT Variability (msec) = individual RT score - group mean RT)

AGE	Perceptual Matching		Semantic Matching	
	LVF	RVF	LVF	RVF
4-6yrs				
<u>M</u>	310	203	245	328
<u>SD</u>	238	139	176	259
7-9yrs				
<u>M</u>	587	322	191	241
<u>SD</u>	494	383	243	243
10-12yrs				
<u>M</u>	376	770	68	59
<u>SD</u>	567	729	56	47

Perceptual responses varied across age groups. The Visual Field by Matchtype interaction was not statistically significant ($F(1,35)=1.849$, $p=.18$), but the Age by Visual Field by Matchtype was significant ($F(2,35)=4.143$, $p<.03$). Separate ANOVAs were performed for Semantic and Perceptual responses to examine the nature of these significant interactions.

Absolute difference (variability) scores for Semantic responses ($n = 60$) were analyzed in an ANOVA for Age and Visual Field. A highly significant main effect of Age ($F(2,57)=8.733$, $p<.001$) was obtained. Post hoc Tukey pairwise comparison tests indicated that the 4-6 year olds and the 7-9 year olds were significantly more variable than the 10-12 year olds ($p<.01$ and $p<.05$, respectively). The 4-6 year olds did not differ significantly in variability from the 7-9 year olds.

The main effect of Visual Field was statistically significant ($F(1,57)=3.999$, $p=.05$), with RTs to LVF presentations less variable than RTs to RVF presentations. The Age by Visual Field interaction approached significance ($F(2,57)=2.910$, $p\leq.06$), indicating that the variability of RTs between visual hemifield presentations tended to vary across age groups. Follow-up paired difference t-tests showed that 4-6 year olds tended to be more variable in reaction time to RVF than to LVF

presentations for semantic matches ($t(19)=1.893$, $p=.08$). Visual hemifield differences in variability were not statistically significant for the 10-12 year olds ($t(19)=-1.338$, $p=.20$) nor for the 7-9 year olds ($t(19)=1.758$, $p=.10$).

Absolute difference (variability) scores for Perceptual matches ($n=38$) were analyzed in an ANOVA for Age and Visual Field. The main effect of Age was significant ($F(2,35)=3.447$, $p<.05$). Follow-up t-tests indicated that the RTs of the 4-6 year olds were significantly less variable than those of the 10-12 year olds ($p<.03$) and tended to be significantly less variable than the RTs of the 7-9 year olds ($p<.09$).

The main effect of Visual Field presentation for Perceptual matches was not significant ($F(1,35)=0.611$, $p=.44$), but the Age by Visual Field interaction was significant ($F(2,35)=3.842$, $p<.04$), indicating that the differences in variability of RTs between LVF and RVF presentations varied across age groups. Follow-up paired difference t-tests indicated that the variability of RTs to LVF presentations was significantly greater than to RVF presentations in the 4-6 year old age group ($t(18)=-2.078$, $p=.05$), but the differences were not statistically significant for either the 7-9 year olds ($t(11)=-1.688$, $p=.12$) or the 10-12 year olds ($t(6)=1.154$, $p=.29$).

B. Variability in Follow-up Tasks

Variability of RT scores for correct responses on the follow-up Shape matching and Identity matching tasks was determined by subtracting the mean RT for each age group from each child's RT score in that group, and the resultant score were entered into an ANOVA for Age, Task, and Visual Field (See Tables 12 and 13). The main effect of Age was not significant ($F(1,18)=1.870$, $p=.19$), nor was the main effect of Visual Field of Standard stimulus presentation ($F(1,18)=0.039$, $p=.85$) or the Age by Visual Field interaction ($F(1,18)=1.221$, $p=.28$). However, the main effect of Task was significant ($F(1,18)=9.750$, $p<.01$), indicating that the RT variability for the Shape Matching task was significantly greater than for the Identity Matching task. The Age by Task interaction was not significant ($F(1,18)=2.584$, $p=.13$), nor was the Task by Visual Field interaction ($F(1,18)=2.720$, $p=.12$), or the Age by Task by Visual Field interaction ($F(1,18)=1.517$, $p=.23$).

Summary of Results

A. Experimental task

Type of Match: Each of the three age groups made significantly more semantic than perceptual matches. However, the 4-6 year olds made significantly more

Table 12

Follow-up Tasks--Shape and Identity Matching: Reaction Time Variability (msec) for Correct Responses by Age

(RT Variability (msec) = individual RT score - group mean RT)

AGE	Total	Visual Hemifield		Task	
		LVF	RVF	Shape	Identity
7-9yrs					
M	97	104	98	109	85
SD	83	89	76	102	57
10-12yr					
Mean	71	67	76	109	34
SD	57	55	60	56	23

Table 13

Follow-up Tasks--Shape and Identity Matching: Reaction Time Variability (msec) for Correct Responses by Age, Visual Hemifield, and Task

(RT Variability (msec) = individual RT score - group mean RT)

AGE	Shape Matching		Identity Matching	
	LVF	RVF	LVF	RVF
7-9yrs				
Mean	134	85	75	96
SD	114	88	42	70
10-12yrs				
Mean	107	111	26	41
SD	50	65	18	25

perceptual (and fewer semantic) matches than the two older groups. The 4-6 year olds demonstrated more consistent perceptual matching with significantly more Per4/Sem0 and Per3/Sem1 response patterns than the 7-9 year olds or the 10-12 year olds. The 4-6 year olds also responded significantly more often than the two older groups to stimulus sets with the Per2/Sem2 response pattern.

Matching strategy (proportion of semantic responses) did not change over the course of the testing session.

Reaction Time: The 4-6 year olds had significantly slower RTs than the two older groups. LVF presentations did not differ from RVF presentations, and Perceptual match RTs did not differ from Semantic match RTs, collapsed across age groups. The Age x Matchtype interaction for RTs was not significant, but RTs varied significantly by age group according to visual hemifield presentation of standard stimulus, with faster RTs to LVF than to RVF presentations in the 4-6 year olds, faster RTs to RVF than LVF presentations in the 7-9 year olds, and no difference in the 10-12 year olds.

There was a significant practice effect with faster RTs for the second half of the experimental trials. However, there was no change in visual hemifield asymmetries between the first and second halves of the testing session.

For Semantic matches, 4-6 year olds demonstrated a significant LVF advantage; no visual hemifield advantage was obtained by the 7-9 year olds, and the typical adult pattern RVF advantage was shown by the 10-12 year olds.

The 4-6 year olds showed no significant visual hemifield advantage for Perceptual matches, nor did the 10-12 year olds. However, the 7-9 year olds demonstrated a significant LVF advantage.

B. Follow-up Tasks: Shape Matching and Identity Matching Accuracy

Both the 7-9 year olds and the 10-12 year olds demonstrated almost 100% accuracy in both tasks, and none of the main effects or interactions were significant with respect to number of correct responses.

Reaction Time: The 10-12 year olds had significantly faster RTs than the 7-9 year olds and faster RTs were obtained in the Identity Matching task than in matching pictures similar in shape. A significant Age x Task interaction was obtained, with the 10-12 year olds responding significantly faster than the 7-9 year olds on the Shape Matching task. There were no significant age-related RT differences for Identity Matching. There were no significant visual hemifield main effects or interactions.

C. Variability in Reaction Time scores

Experimental task: There were no significant differences in variability of RT as a function of age or visual field, but RTs for semantic matches were significantly less variable than for perceptual matches. The 4-6 year olds and the 7-9 year olds demonstrated significantly more variability than did the 10-12 year olds for Semantic matches. In contrast, for Perceptual matches the 4-6 year olds demonstrated significantly less variability than the 10-12 year olds, and somewhat less than the 7-9 year olds. Only the 4-6 year olds demonstrated more variability in responding to LVF presentations than to RVF presentations; no significant differences were found for the two older groups.

Follow-up tasks: Shape Matching and Identity Matching. The only significant difference in variability of RT was found between tasks, with more variability in the RTs for Shape Matching than for Identity Matching. None of the interactions were statistically significant.

Discussion

I. Age Differences in Perceptual and Semantic/Categorical Matching

The findings of the present study support the hypothesized decrease in the proportion of perceptual matches and the corresponding increase in the proportion of semantic matches with increase in age. In terms of both the overall number of semantic and perceptual matches (See Table 1 and Figure 3) and the consistency of matching stimulus sets (See Table 2 and Figure 4), the matching performance of the 4-6 year old subjects differed significantly from the two older groups, whose matching was very similar. The greater number and consistency of perceptual responses in the younger than in the older groups, and the greater number and consistency of semantic responses in the older than in the younger groups, provide support for the hypothesis of a developmental shift from perceptual, gestalt-like processing in younger children, to a more adult-like semantic, categorical processing in older children, as proposed by Piaget (Piaget, 1952; Piaget & Inhelder, 1969) and other developmental theorists (Bakker, 1973, 1979, 1983; Birch & Bortner, 1966; Bortner & Birch, 1970).

The matching performances of the three age groups in the present study generally follow the later stages of the

developmental categorization sequence proposed by Piaget (see pp. 17-18). Inhelder and Piaget (1958, 1964; Piaget, 1952) argued that the attention of young children was captured by the salient physical characteristics of stimuli, and they matched and grouped objects accordingly. Piaget noted that young children were quite inconsistent in their matching and grouping performances, with the children's criterion for matching often changing within a single task, shifting from one perceptual characteristic such as color to another, perhaps shape. The importance of perceptual saliency for young children's categorizations was supported by Birch and Bortner's (1966) finding that children's ability to make functional matches was compromised when objects of similar color or shape were introduced into the stimulus array. To meet the criterion of "true" classification, Inhelder & Piaget (1964) argued that the child must be able to sort accurately on one or two dimensions, and to perform inclusion tasks that relate a subordinate (or basic taxonomic) category to its superordinate category. To Inhelder and Piaget, failure to perform these tasks and to verbally indicate subordinate and superordinate relationships successfully meant that the child was unable to perform "true" classification. If Piaget's stringent criteria are applied to the data of the present experiment, only the 10-12 year olds and one nine-

year old might be considered true classifiers since they were the only subjects who spontaneously made such comments as "I put the ones in the same category together." Although there was no systematic collection of data concerning the subjects' verbal descriptions and/or explanations of their task performances, some other children in the 7-9 year old group spontaneously commented, "I put the fruits together and the instruments together," and "The apple and banana go 'cause they're fruits, and the bat and the tennis racquet are sports stuff." Therefore, it appears that several of the 7-9 year old children were matching by category while not using the word "category" in their description. In contrast, those 4-6 year olds who did speak about the task said, "I put'em together, like you said" and "The ones that go together, go together," neither naming the superordinate category nor using the word "category." Thus, according to Piagetian criteria, the 10-12 year olds and some of the 7-9 year olds may be said to have achieved true classification, a qualitatively different, emergent stage of conceptual competency.

The significant differences in matching strategy between the 4-6 year olds and the two older groups are consistent with experimental findings from developmental studies of concept hierarchies and linguistic competency,

in which significant quantitative and qualitative changes in performance occurred at about 6 or 7 years of age. For example, Whitney and Kunen (1983) found a sharp age distinction in a familiar-object free-sorting task in which kindergartners made significantly fewer correct sorts than did the second graders. Also, compared with children 7 years and older, the conceptual categories of 3 to 6 year olds are generally smaller (fewer category members) and more narrowly defined with a tendency to include (proto)typical category members and reject atypical exemplars (Blewitt & Durkin, 1982; Bjorklund & Thompson, 1983; Mervis & Pani, 1980); finally, children at these ages generally underextend superordinate categories (White, 1982; Whitney & Kunen, 1983).

With respect to developing linguistic competency, Milanti and Cullinan (1974) found that 6-year olds took significantly longer than 9-year olds to name tachistoscopically presented line drawings of familiar objects and to correctly identify word (auditory)-picture (visual) matches and nonmatches. Wiegel-Crump and Dennis (1986) found that 6-year olds had significantly more difficulty than older children naming words (in categories) in response to semantic descriptions, rhymes, and picture presentations. The investigators concluded that a fully hierarchical semantically-based lexical

organization developed after 6 years of age. This interpretation was supported by Alexander and Enns (1988) who found that verbal labels (names for stuffed animals) interfered with forming category boundaries in 3-, 4-, and 5- year olds, whereas the names did not affect the performance of adults. Keil (1983) noted that kindergartners violated semantic constraints significantly more often than did second and fourth graders, frequently confusing objects associated with events with the events themselves.

Collectively, these studies suggest that conceptual and linguistic development undergoes some substantive changes at about 6-7 years of age. Certainly, children begin formal reading training in first grade (age 6-7 years) and there is a strong formal emphasis on the acquisition of categorization and language skills at this stage. Reading instruction is predicated on the child's having already acquired the appropriate readiness skills, including matching and categorizing, which are presented both informally and formally in nursery and preschool programs. These changes in conceptual and linguistic development at 6-7 years of age were reported by Ricco (1989), who divided 101 first-graders into preoperational and concrete operational groups according to Piagetian operativity criteria, e.g., seriation and conservation,

and found that both preoperational and concrete operational children could categorize accurately with typical category members, but the concrete operational children performed significantly better than the preoperational children when atypical category exemplars were used. Ricco (1989) concluded that the emergence of concrete operational thought facilitated the formation of relationships between both typical and atypical exemplars of a category, and between the category name and the atypical exemplars. Although it is not possible to separate the maturational from the instructional aspects of the age changes in performance on cognitive tasks, the hypothesis of an age-related decline in the consistency of perceptual matching and a corresponding increment in consistent semantic/categorical matching, with significant differences between the pre-reading (4-6 year olds) group and the school-age (7-12 year olds) group, is supported by the results of the present study.

Although the 4-6 year olds in the present study made more perceptual matches than the older children, they made more semantic than perceptual matches. This finding contrasts with the results of Piaget's (1952) and Birch and Bortner's (1966) studies. Birch and Bortner (1966) concluded that younger children prefer to match on the basis of perceptual similarity when both categorical and

perceptual choices are available. While the 4-6 year olds in the present study did not offer taxonomic explanations for their performance, the significantly greater proportion of semantic matches and the greater proportion of semantically matched sets does not support the view that children are primarily "perceptual" matchers at this age.

What can account for the differences in results? First, the task used in the present study differed considerably from that used in earlier investigations in which children categorized actual objects (Birch & Borntner, 1966; Inhelder & Piaget, 1958, 1964; Piaget, 1952) in a free sort paradigm (Inhelder & Piaget, 1958, 1964; Piaget, 1952). Manipulating three-dimensional, colored objects may be more effective in evoking perceptual matching strategies than projected, two-dimensional black-and-white line drawings. Second, the subjects in the present study may differ considerably from those participating in the earlier studies. In general, children today may be more sophisticated with respect to conceptual and linguistic information than their counterparts of 25 to 30 years ago. More preschool age children attend nursery schools and day-care centers in which pre-reading skills are presented both formally and informally. In fact, Fenson et al (1988) found categorical

matching (albeit inconsistent) in 2 year old children. A third factor may be that the participants in the present study were self- (or parent-) selected volunteers from upper middle class urban and suburban families who expressed interest and curiosity in the study. Thus, the 4-6 year old participants in the present study may not be representative of the population of 4-6 year olds in general. Subjects in previous studies consisted of entire classes of day-care, nursery and kindergarten children (Birch & Bortner, 1966, Fenson et al (1988), perhaps reflecting a broader range of abilities and competencies.

The results of the present study do not provide clear support for either side of the continuity versus discontinuity issue in cognitive development (Kagan, 1979). One can argue for both quantitative and qualitative changes in performance with increasing age, by focusing on different aspects of the same data.

The response pattern of the 4-6 year olds differs sharply from that of the 7-9 and the 10-12 year olds (see Figure 4), supporting a view of qualitative, discontinuous development. The use of descriptive terms e.g., "category" by the 10-12 year olds and by some of the 7-9 year olds in contrast to the absence of such terms by the the younger children offers additional support for discontinuous stages.

The opposing view of developmental continuity, with primarily quantitative changes in competency with increase in age, is supported by the finding of an increase in consistent semantic/categorical matching from the youngest to the oldest subjects. Bortner and Birch (1970) emphasized the importance of distinguishing between cognitive capacity and cognitive performance, where functional and/or superordinate concepts may be possessed by children and yet not be available under specific experimental conditions. They hypothesized that young children may possess such higher-order concepts but not utilize them "under conditions in which their behavior could be guided by information at a sensory level" (Bortner & Birch, 1970, p.736). Referring to their earlier study (Birch & Bortner, 1966) in which perceptual salience (similarity) interfered with the functional matches of preschool age children, Bortner and Birch (1970) concluded that changes in "problem solving and cognitive style as a function of age are based upon alterations in hierarchical selection set rather than simply on the acquisition of new concepts or new capacities" (p.737), suggesting that increase in age is accompanied by an increase in refinement and competency within specific cognitive strategies (e.g., functional or semantic matching). While perceptual salience might have interfered with semantic/categorical matching in the 4-6

year olds in the present study, the increase in semantic/categorical matching with increase in age argues for a continuous, quantitative developmental trend. These children may have acquired superordinate categorization concepts before they could express them competently and consistently in performance, similar to what has been found in studies of the acquisition of language, in which receptive vocabulary and understanding precedes and far exceeds expressive language competency in childhood and, even, adulthood. This "continuous" interpretation is consistent with that of C.L. Smith (1979), who found that 3-7 year olds were capable of solving at least 1 of 3 types of inclusion problems when asked to make "all/some" inferences such as, "Are all magnets on the box? Are some magnets on the box?"; class inferences (e.g., "A pug is a dog." "Is a pug an animal?"); and property inferences (e.g., "All milk has lactose. Does chocolate milk have lactose?"). Smith found a decreasing ability to answer questions as a function of the total number of questions asked, suggesting that many errors were a result of language confusions. She found that even the preschoolers were at better than chance performance, suggesting that they were capable of understanding some inclusion concepts, although the linguistic demands of the tasks (actual objects were only used for a few all/some

questions) interfered with performance. And Winer (1980) noted that when young children were presented with class-inclusion problems using familiar representative objects and pictures which are simpler than the original tasks set by Piaget, they were more competent (accurate) categorizers, although their explanations, too, fell short of Piagetian criteria for "true" classification.

Although both the Birch and Bortner (1966) and the Fenson et al. (1988) studies suggested that perceptual similarity (salience) actively interfered with functional and categorical matching (see pp.21 -24 above), another interpretation is possible in the context of the results obtained in the present study. Whereas most of our 4-6 year olds appear to have acquired a categorical matching strategy, it was not applied universally. The number of stimulus sets matched in consistent perceptual fashion decreased significantly by 7-9 years of age, but their presence is congruent with the view that categories emerge gradually. Ross (1980) noted that 12-, 18-, and 24-month olds had acquired some basic taxonomic categories (e.g., the letters "O" and "M," and toy men figures) but not superordinate categories (e.g., toy furniture and animal figures). Some categories may be more familiar to young children, perhaps as a result of perceptual similarity, as in the case of basic taxonomic level categories, and thus

are acquired earlier than the more abstract superordinate categories (e.g., furniture, animals), for which non-perceptual category features must be extracted. The "igloo-house-turtle" set used in the present experiment appeared somewhat problematic for the 4-6 year olds, who responded with an average of only 1.75 semantic responses (to the superordinate category "home") out of a possible four. These children appeared to match the igloo with the turtle more than 50% of the time, even though they identified the igloo by name or as an "ice house" or "house for Eskimos." It might be argued that these children matched the "turtle" to the "igloo" because the turtle "carries its house on its back." Although no subject offered this explanation, it had been suggested by an adult during pilot testing of the stimuli. Other semantic matches which seemed less certain as categorical matches for the youngest age group (with mean semantic responses <2.5 out of 4) were the "knife-ladle-pencil," the "butterfly-fly (bug)- bow," and the "toothbrush-comb-screwdriver" match. If these semantic/functional matches are less familiar, or even unfamiliar, to the younger children, the greater inconsistency and greater proportion of perceptual matching may be due to the fact that some objects are more familiar as "good" category exemplars (e.g., drum and trumpet as instruments) whereas other

objects, although familiar in everyday life, are "poor" category exemplars (e.g., house and igloo as homes, knife and ladle as flatware, toothbrush and comb as grooming implements), as proposed by Mervis and Pani (1980). Rosch et al. (1976) point out that prototypical category exemplars frequently evoke similar motor programs (schemata) in young children (e.g., eating apples and bananas). Knife and fork may be more readily matched than knife and ladle, comb and hairbrush more easily than comb and toothbrush. It is suggested that if poor category exemplars were not readily recognized as category members, especially by the younger children, some children may have used a perceptual matching strategy as the "best" match. Support for this interpretation comes from the relatively consistent perceptual matching strategy utilized by 14 of the 4-6 year olds and 3 of the 7-9 year olds on at least 1 stimulus set (See Appendix J). The gradual acquisition of categories may be seen as another example of continuous cognitive development, although the shift from the perceptually-based categories in the infant studies (Ross, 1980; Sherman, 1985) to taxonomically-based categories with children (Fenson et al., 1988) seem to reflect a discontinuous process.

An alternative to the "good exemplar" model of taxonomic categorization (Mervis & Pani, 1980) as a means

of explaining the developmental changes in categorization found in the present study is the proposal that the younger children may have used a non-categorical matching strategy that nevertheless resulted in a semantic/categorical match. Several investigators (Ackerman, 1986a, 1986b, 1987, 1988; Greenfield & Scott, 1986; Medin & Schaffer, 1978) have argued that thematic/complementary/contextual matching based on learned paired-associates is a common, frequently-used alternative strategy to taxonomic matching. Greenfield and Scott (1986) found that 3- to 15-year olds were more likely to match a dog with a bone than with a cat, and concluded that complementary/thematic/contextual matching is a strategy that is readily available to children early in development. Tversky (1989) found that thematic completions were the most common error made when 4-11 year old children were asked to identify missing parts from pictures of common objects, e.g., saying "paper" for a pencil that was missing a point, and "leg" for a shoe missing a shoe lace. He noted that the number of thematic completions decreased significantly with increase in age. Markman and Hutchinson (1984) found that preschool-age children offered thematic justifications of their matches 79% of the time in the absence of names or labels for the objects. They noted that labels for the stimuli appeared to induce categorical

matching and attenuate matching by thematic relations, arguing for a potent effect of linguistic constraints during acquisition of categorical concepts. And Ackerman (1987) noted that the greater word retrieval for thematic over category stimuli by second graders disappeared by fifth grade as category structures become more organized. Since verbal labels for the pictures were not used until after the experimental matching task in the present study, it is possible that what was designated (by this experimenter) as a semantic/ categorical match may have been processed by the younger children as a thematic or contextual match, a contextual event that may have been familiar to some children but not others (e.g., fish and frog as water dwellers). Although neither the children's responses nor their spontaneous comments offer strong support for this hypothesis, it cannot be ruled out as a possible strategy, since many of the stimulus sets could be matched thematically/complementarily/contextually (e.g., eye and ear as parts of the face, apple and banana in a bowl of fruit; knife and ladle in the kitchen).

Perceptual Matching in 7-9 and 10-12 year olds

Three aspects of the perceptual matching data suggested that many of the "perceptual matches" made by the older children may have been errors. First, 6 of the

40 older children, on making a perceptual choice, said, "Oops, I made a mistake" or "I want to change that answer, it's wrong." Second, analyses of the individual and the group response patterns to stimulus sets (see Figure 4 and Table 2) suggested that the "perceptual matches" of the 10-12 year olds were randomly distributed as were many of the "perceptual matches" of the 7-9 year olds. (See Appendix J.) And third, the greater variability of RTs for the "perceptual matches" of the older children than for those of the 4-6 year olds supports the view that most of these responses were errors. The follow-up shape and identity matching tasks, in which a subset of the 7-9 and 10-12 year olds were specifically instructed to use a perceptual matching strategy, resulted in performances that contrasted sharply with their "perceptual matches" in the experimental task. In the follow-up tasks, accuracy was nearly perfect, indicating that the perceptual matching strategy was used. Furthermore, RTs were very fast and variability was very low, similar to the variability scores for semantic matching by the 7-9 and 10-12 year olds on the experimental task.

Based on the children's spontaneous statements, the distribution and variability of the "perceptual matches" in the experimental task, and the shape and identity task matching performances, it was concluded that the

experimental task "perceptual matches" of the 7-9 and 10-12 year olds were mostly errors and henceforth will be referred to as "perceptual responses," as opposed to the "perceptual matches" made by the 4-6 year olds.

("Perceptual matching" will also refer to the shape and identity task performances by the 7-9 and 10-12 year olds.)

II. Hemispheric Asymmetries

There was no evidence of visual hemifield differences across age groups in terms of the number of semantic and perceptual matches made (See Table 1). It is possible that the problem-solving aspect of the task, i.e., determining category membership, is not sensitive to lateralized input. Urcuioli, Klein, and Day (1981) presented adults with two semantic/category matching tasks in which Ss determined 1) whether the laterally presented word and a centrally presented word belonged to the same category (category matching) and 2) whether a laterally presented word was subsumed under a foveally presented category word (category membership). While the number of correct responses did not vary according to hemifield stimulation, Urcuioli et al. (1981) found that RT did vary as a function of lateralized presentation, obtaining an RVF/LH advantage for category matching (but not for category

membership). In the present study RT was found to be similarly sensitive to lateralized standard stimulus presentation for semantic/categorical matching, although there was no such effect for the matchtype (semantic versus perceptual) response.

A. Lateralization of Semantic/Categorical Matching

The hypothesis of an overall RVF/LH advantage for semantic/categorical matching was not supported by the results of the present study. Instead, the results indicate a developmental shift in hemispheric asymmetry for semantic/categorical matching (See Figure 6). The faster RTs to LVF presentations (implying right hemisphere superiority) shown by the 4-6 year olds contrasts with the performance of the 7-9 year olds, who demonstrated no visual hemifield asymmetry, and the RVF advantage (faster RTs, implying left hemisphere superiority) obtained by the 10-12 year olds. It should be noted that the RVF/LH advantage of the oldest group is consistent with the typical adult findings for semantic/linguistic processing (Bradshaw et al., 1981; Bryden, 1965, 1973; Bryden & Allard, 1976; Kimura, 1966, 1969; Urcuioli et al., 1981). The age-related laterality "shift" for a semantic task is consistent with results obtained in developmental studies by Broman (1978) for letter pairs, Butler and Miller

(1979) for English words and word approximations, Davidoff and Done (1984) for CCC letter strings and words, Bakker (1973) for Dutch words, and Silverberg et al. (1980) for Hebrew words. The usual explanation for the shift is that there is an age-related change from a right-hemisphere mediated perceptual, holistic, Gestalt strategy for letter or word matching (identity matching) or letter/word identification (sight vocabulary) to a left-hemisphere mediated semantic/linguistic/phonetic strategy (Bakker, 1973; Broman, 1978; Davidoff & Done, 1984).

In contrast to the studies in which the shift from LVF/RH to RVF/LH advantages for apparently semantic/linguistic tasks occurs from one age group to the next, e.g., as between the 4- and 5-year olds reported by Davidoff and Done, 1984. Barroso (1976), Miller and Turner (1973), and Reynolds and Jeeves (1978) reported no visual hemifield asymmetries for 7-9 year old children, the youngest age groups used in their studies. The lateral asymmetries found by Barroso (1976) and by Tomlinson-Keasey et al. (1978) were only obtained for 10 and 12 year olds, whereas there were no visual hemifield asymmetries for same/different picture matching for children 6/7-9 years of age. These results are consistent with the age-related change from no hemispheric asymmetries in 7-9 year olds to lateral asymmetries in older children with

linguistic stimuli in the studies cited above, as well as with the results of the 7-9 and 10-12 year olds in the present study.

The LVF/RH superiority for semantic/categorical matching of line drawings by the 4-6 year olds in the present study is consistent with the results obtained by Turner and Miller (1975), who reported a LVF/RH advantage for children in grades 1-4 for a same/different recognition task using random shapes and line drawings of common objects, with no age-related changes in the magnitude of the hemifield advantage. However, Young and Bion (1981) found a RVF/LH superiority in children as young as 5 with no age-related changes for naming line drawings. The apparently contradictory findings in the developmental literature may be related to the different task demands, i.e., same/different recognition of configurations with no naming or identification necessary; a task requiring verbal identification and response measures (pointing vs. naming) with similar stimuli; or matching on the basis of superordinate category membership. These tasks differ according to the level of processing proposed by Craik and his associates (Craik & Lockhart, 1972; Craik & Tulving, 1975), who assume that information is processed hierarchically--from the visuoperceptual characteristics of the stimulus, through

the auditory stage of naming, to the most complex semantic properties including categorization. Young and Bion's (1981) identification task required naming at a level deeper than the visual processing needed for Turner and Miller's (1975) perceptual matching task. Barroso (1976) varied task and response demands using the same picture stimuli, and found a RVF/LH advantage for auditory-visual matching and a LVF/RH superiority for same/different recognition matching using the same picture stimuli. The obtained differences in visual hemifield asymmetries may be related to the levels of processing as well as the differing task and response demands of these tasks. These studies argue persuasively for the idea that visual/hemispheric asymmetries are task- and process-specific rather than modality-specific (e.g., visual vs auditory) or material-specific (e.g., linguistic vs. visuospatial stimuli). It may be argued that matching line drawings in a same/different paradigm (Barroso, 1976; Tomlinson-Keasey et al., 1978; Turner & Miller, 1975) is a more "perceptual" and right hemisphere biased task than the semantic/categorical matching of line drawings task in the present study and can be performed using "visuospatial/perceptual" processing (Broman, 1978; Davidoff & Done, 1984).

B. Lateralization of Perceptual Matching

With respect to visual hemifield differences, neither the number of perceptual matches nor the RTs for perceptual matches indicated any visual hemifield asymmetry in the 4-6 year olds; RTs for LVF presentations were somewhat faster than for RVF presentations, although the difference was not statistically significant. There was also no evidence of visual hemifield asymmetries in either the accuracy or the RTs scores of the 7-9 and 10-12 year olds for shape and identity matching. Thus, the hypothesis of an overall LVF/RH advantage for perceptual matching was not supported.

III. The development of hemispheric asymmetries

There appear to be two general patterns reported in the developmental literature with respect to hemispheric asymmetries, with some studies reporting changes in hemispheric asymmetries with increase in age (Barroso, 1978; Broman, 1978; Carmon, Nachschon, & Starinsky, 1975; Davidoff & Done, 1984; Grant, 1980; Tomlinson-Keasey et al., 1978), and others reporting a consistent visual hemifield effect with no age-related changes (Carter & Kinsbourne, 1979; Witelson, 1977c; Turner & Miller, 1975; Young & Bion, 1981; Young & Ellis, 1976).

The first set of studies, citing no evidence of hemispheric asymmetry until 10 years of age (Barroso, 1976; Miller and Turner, 1973; Tomlinson-Keasey et al. 1978), can be viewed as supportive of the progressive lateralization theory (Lenneberg, 1967), which postulated age-related changes in the magnitude of left-hemisphere lateralized linguistic functions. However, the LVF/RH superiority for semantic/categorical matching found in the 4-6 year olds in the present study, as well as the LVF/RH superiority demonstrated by 7 year olds for letter matching (Broman, 1978), by 4 year old boys for letter and word matching (Davidoff and Done, 1984), and by second graders for reading words (Silverberg et al., 1980) fail to support Lenneberg's view of left-lateralized linguistic functions having emerged from a bilateral equipotential basis, although they clearly indicate age-related changes in laterality.

If one views the semantic matching demonstrated in the experimental task as representative of a single linguistic process, the shift from LVF/RH superiority in the 4-6 year olds to an RVF/LH advantage in the 10-12 year olds also fails to support Kinsbourne's (1975, 1981) theory of developmental invariance in hemispheric asymmetry/specialization of language function which postulated no age-related changes in either the direction

or the magnitude of hemispheric specialization of function. It may be that a relatively simple linguistic process, such as consonant discrimination, does not change or undergo elaboration as children grow older, so one might expect to obtain a LH advantage throughout the life span. However, semantic/categorical matching requires deeper levels of processing, and only emerges with consistency as children acquire perceptual and taxonomic categories (Rosch et al., 1976; Rosch & Mervis, 1978) and linguistic proficiency (Wiegel-Crump & Dennis, 1986). Kinsbourne (1981) proposed that lateral asymmetries for "precursor" tasks should be in the same direction as the later emerging lateralized function. His developmental invariance theory may be appropriate for simpler linguistic tasks such as consonant discrimination and motor/speech aspects of language. Superordinate categorization may be acquired in developmental stages, from the perceptual categorization of infants through paired-associate contextual learning and, then, basic level taxonomic grouping and, finally, abstract superordinate categorization. One may not assume that the same strategy is used in all these stages or that the same neural substrate is involved. Thus, the age-related laterality shift demonstrated in the present study supports neither the developmental lateralization

hypothesis (Lenneberg, 1967) nor the developmental invariance of laterality view (Kinsbourne, 1975, 1981).

If the shift found in the present study from a LVF/RH advantage for semantic matching in the 4-6 year olds through a period of no hemispheric asymmetries in the 7-9 year olds, to the adult-like RVF/LH superiority in the 10-12 year olds, is seen as a developmental progression, there are several alternative, albeit not necessarily contradictory, hypotheses that may explain the process: 1) a shift from a specific function or process for which the right hemisphere is specialized (e.g., "perceptual") to another specific function or process for which the left hemisphere is superior (e.g., "linguistic"); 2) a laterality shift reflecting the Goldberg and Costa (1981) theory of right hemisphere specialization for the initial processing of novel information and forming descriptive codes that yields to left hemisphere specialization for processing well-routinized conceptual tasks; 3) right hemisphere processes in the early acquisition of language functions that become superseded by superior left hemisphere proficiency in sequential, semantic processing; or 4) some right-hemisphere mediated "perceptual" process in the 4-6 year olds not immediately apparent.

As noted above, Bakker and his associates (Bakker, 1973, 1979, Bakker et al., 1979), Barroso (1976), Broman

(1978), and Davidoff and Done (1984) suggested that the stimuli they used could be processed using a right-hemisphere "perceptual" strategy or a left-hemisphere mediated "linguistic" strategy. Their results indicated that different age groups may have used different strategies to identify or match stimuli, each strategy with its lateralized neural substrate. The concept of the two cerebral hemispheres being specialized for complementary functions, i.e., the left hemisphere for expressive functions, the right hemisphere for perceptual processes, was suggested as early as 1865 by Hughlings Jackson (Springer & Deutsch, 1981). For line drawings, individual letters and words, it has been argued (Hiscock, 1981) that it is possible to use either visuo-perceptual strategies for matching (e.g., "sight vocabulary" for words) or semantic, linguistic strategies (e.g., phonetic decoding and reading words). This is a plausible argument when the task consists of same/different judgments (Broman, 1978), simple identification (Davidoff & Done, 1984) or matching a tachistoscopically presented stimulus to an item in a visual array (Turner & Miller, 1975). However, the semantic/categorical matches in the present study consisted of perceptually dissimilar stimuli and were deliberately chosen so as to preclude the use of simple perceptual strategies by minimizing similarity of

parts (Tversky, 1989) and overall configuration (Rosch, 1973; Rosch et al., 1976). A simple perceptual matching strategy was hypothesized for the perceptual/configurational matches and the 4-6 year olds clearly demonstrated this type of perceptual matching with no RVF/LH superiority. It would therefore appear that the significant LVF/RH advantage obtained for semantic/categorical matching in the 4-6 year olds, and the shift to an RVF/LH advantage in the 10-12 year olds, reflects some process other than a shift from simple right hemisphere mediated visuo-perceptual matching to a left-hemisphere mediated semantic strategy.

The "shift" from right- to left- hemisphere processing postulated by Goldberg and Costa (1981) is said to occur as a result of increased familiarity and competence due to training and experience, during which the left hemisphere establishes well-routinized codes. At what stage the right hemisphere, with its greater ability to process novel information and integrate it intermodally in the course of acquiring a new descriptive system, become subordinated to the left hemisphere, with its store of compact, systematic codes, is not made clear, although Goldberg and Costa (1981) cite studies in which the shift to an RVF/LH advantage occurs after 10 years of age. Lewkowicz and Turkewitz (1982) reported an LEA/RH

advantage for speech in 6-month old boys and an REA/LH specialization for music sounds in 8-month old boys, which were opposite to the specializations noted in adults, and hypothesized further changes in cerebral asymmetry with increase in age. They proposed a "developmental sequence in which an early appearing and relatively robust asymmetry in responsiveness based on a low-level process may begin to interact with a later appearing asymmetry based on a higher level process" (p. 306). The 4-6 year olds in the present study may be considered within the age range in the process of acquiring language codes, at a lower level of processing. As the skills necessary for semantic/linguistic categorization are novel and unfamiliar to the 4-6 year olds, Goldberg and Cosca (1981) would expect a right hemisphere superiority for this task. If the 7-9 year olds are considered as part of the continuum from LVF/RH specialization for holistic, gestalt processing of novel stimuli to RVF/LH specialization for well-established, coded phonetic, orthographic, syntactic and semantic processing, then the failure to obtain visual hemifield asymmetries in the 7-9 year old group might have been predicted as a result of either 1) the additive properties of RH and LH processes, or 2) competing RH and LH processes in this transition period. Certainly, the lack of visual hemifield asymmetry in this age group has

been noted frequently (Barroso, 1976; Forgays, 1953; Reynolds & Jeeves, 1978; Tomlinson-Keasey et al., 1978), indicating that the findings in the present study are neither anomalous nor discrepant. Thus, if we consider language acquisition as a series of skills and processes acquired over several years, a developmental model of the Goldberg and Costa (1981) hypothesis provides a plausible explanation for the shift from right-to-left hemisphere advantage for semantic/categorical matching in the present study.

The finding of faster RTs for perceptual than for semantic matches in the experimental task by the 4-6 year olds, and for shape matching than semantic matching in the older children, is also consistent with the hierarchical and lateralized model for object recognition by adults advanced by Warrington and Taylor (1978). They proposed that a right-hemisphere mediated perceptual categorical stage, which is postsensory and presemantic, temporally precedes left-hemisphere mediated semantic categorization, which operates mainly on the categorized output of the perceptual system. This model of object perception suggests one process by which the laterality shift proposed by Goldberg and Costa (1981) and the depth of processing model of Craik and his associates (Craik & Lockhart, 1972; Craik & Tulving, 1975) may be integrated.

If one treats Warrington and Taylor's (1978) lateralized model developmentally and assumes that right-hemisphere mediated perceptual processing occurs ontogenetically, as well as procedurally, prior to left-hemisphere mediated semantic/categorical processing, our finding of faster RTs for perceptual than semantic matching is consistent with the theories of Warrington and Taylor, Goldberg and Costa, and Craik and his associates.

Hypotheses of right hemisphere involvement in the initial stages of language acquisition have been derived primarily from evidence of the right hemisphere's capacity to take over language function following damage to or excision of the left hemisphere during the early childhood years (Basser, 1962; Dennis, 1980; Dennis & Kohn, 1975; Dennis & Whitaker, 1976, 1977; Kohn, 1980; Lenneberg, 1967; Zangwill, 1964). Dennis (1980) hypothesized that the right hemisphere may be more effective than the left hemisphere in processing the connection between words/names/labels and their real world counterparts (the visual array). Certainly 4-, 5- and 6-year olds have only recently acquired names and labels for objects and drawings and their categories tend to be fuzzy (Alexander & Enns, 1988), constrained and underextended (White, 1982), and more closely tied to "good" prototypical exemplars (Mervis & Pani, 1980), which are overall

perceptually similar (Denney, 1972; L.B. Smith, 1979, 1981), have parts and functions in common (Tversky, 1985, 1989) and/or reflect similar sensorimotor schemata (Rosch et al., 1976).

Given the LVF/RH advantage for size and number discrimination (Young & Bion, 1979), for facial discrimination (Broman, 1978; Young & Ellis, 1976), for naming colors (Grant, 1980), and for matching figures (Witelson, 1977c), one may postulate additional right hemisphere mediation in the acquisition of perceptual categories. That infants are able to extract mean and modal category representations (Bomba & Siqueland, 1983; Sherman, 1985) and that they form perceptually similar categories before abstracted superordinate categories (Ross, 1980), underscores the role of perceptual salience in early childhood (Birch & Bortner, 1966; Bortner & Birch, 1969; Inhelder & Piaget, 1964) with the implication of some right hemisphere mediation. When these studies are considered in conjunction with those of developmental visual asymmetry studies which report a LVF/RH advantage for perceptual processing of simple and complex visual arrays (Davidoff and Done, 1984; Witelson, 1977c; Young & Bion, 1981, Young & Ellis, 1976), it is reasonable to hypothesize considerable right hemisphere mediation of linguistic stimuli and their real world counterparts

(Schneiderman, 1986) in the acquisition of names and labels for objects, and for perceptual and basic taxonomic categories based on similar perceptual characteristics.

The fourth alternative explanation is that the LVF/RH advantage for semantic/categorical matching demonstrated by the 4-6 year olds in the present study reflects some right-hemisphere mediated, complex non-verbal process. It was suggested earlier that the 4-6 year olds may have used a contextual/ complementary/thematic matching strategy (see Ackerman, 1986a, 1986b, 1987, 1988; Greenfield & Scott, 1986; Medin & Schaffer, 1978) acquired as a function of visual paired-associate learning, and that this matching reflects perceptually-mediated Gestalts. A review of the stimulus sets used in this experiment suggested that many of the semantic/categorical matches may also be related contextually or thematically. For example, apples and bananas are in fruit bowls, eyes and ears are both on the face, and knives and ladles are commonly found in the kitchen. Similarly, bulbs and lamps appear together as do hats and coats, fishes and frogs, and hammers and nails. If these items were thematically or contextually matched by the young children as "perceptual gestalts," this could account for the LVF/RH advantage obtained in the 4-6 year old children. Thus, one would expect right hemisphere mediation of thematic matches made

by young children as they learn the names for items seen in the same visual context. This explanation is consistent with the Goldberg and Costa (1981) proposal nor with Schneiderman's (1986) suggestion of right hemisphere contributions to language acquisition. Thematic matching may offer children an alternative, perhaps developmentally intermediate, strategy that is preparatory to semantic matching by superordinate category, as suggested by the thematic matching in young children being superseded by categorical matching when presented with basic taxonomic level labels and names (Markman & Hutchinson, 1983).

We may conclude that the developmental shift from LVF/RH to RVF/LH superiority for semantic/categorical matching seen in the present study reflects an age-related change in hemispheric asymmetries, although the strategies and mechanisms underlying this shift require further clarification.

Methodological considerations

While the RT data supported the hypothesized visual hemifield asymmetries for semantic/categorical matching, no hemispheric asymmetries for perceptual matching were shown by 4-6 year olds in the experimental task or by the 7-9 and 10-12 year olds in the follow-up shape matching and identity matching tasks. The failure to obtain

hemispheric asymmetries for both perceptual and semantic matching may be due to processing factors (and their neural substrates), task factors, or their interaction.

In a study that investigated tasks differing in difficulty, Turner and Miller (1975) found an RVF/LH advantage for word identification but no hemispheric asymmetry for a word-matching discrimination task. Using individually determined thresholds (+ 5 msec) for subjects in grades 1,2,3,4 and college, they found that at exposure durations necessary for an accuracy measure on the easier discrimination task, matching three-letter words, identification was not possible, and at durations sufficient for the more difficult identification task of reading the words, discrimination was perfect and no accuracy measure could be obtained. The two types of matching in the present study-- perceptual/configurational semantic/categorical-- derive from two different levels of processing according to Craik and his associates (Craik & Lockhart, 1972; Craik and Tulving, 1975) and reflect different levels of difficulty. The perceptual/shape/identity matching tasks are simpler and require less depth of processing than does the semantic/categorical matching.

Varying the values of specific experimental parameters, such as exposure duration, stimulus size, retinal eccentricity, and interstimulus interval, to

increase the difficulty of the perceptual matching task might increase the probability of obtaining hemispheric asymmetries for both matching strategies in the task used in the present study.

Alternatives to the constant 150 msec exposure duration used for all three age groups in the present study are 1) a shorter exposure duration such as 100 msec for all groups (Tomlinson-Keasey et al, 1978), and 2) varying exposure duration according to age (Turkewitz & Ross-Kossak, 1984; Young & Bion, 1981b) or using an accuracy criterion to determine exposure duration (Broman, 1974). Sergent and Lorber (1983) only obtained a LVF/RH advantage for perceptual category matching of line drawings of basic taxonomic animal categories (e.g., horse, cow,) when the exposure duration of the test stimulus was reduced from 250 msec to 50 msec with adults. Using a face categorization task with adults, Sergent (1982) found a LVF/RH advantage for matching at a 40 msec exposure duration, no hemispheric asymmetries at 120 msec, and a LVF/RH superiority at 200 msec exposure duration. It is possible that a reduction in exposure duration from 150 msec used in the present study might elicit asymmetries not apparent at 150 msec. However, the effect of shorter exposure durations on hemifield asymmetries for semantic matches cannot be ascertained at this time.

Reducing stimulus size (Hellige, 1976; McKeever, 1986) and/or increasing retinal eccentricity (Kerr, 1971; Kitterle, 1986) degrade the visual stimulus and thereby increase the difficulty of the task. The use of these manipulations to increase task difficulty in the present study would require pilot testing with the youngest children whose visual acuity and/or ability to sustain attention to the task could be compromised if the pictures are too small. As with Turner and Miller (1975), degrading the visual stimuli could also compromise the performance on the inherently more difficult semantic matching task.

As visual hemifield asymmetries were obtained for semantic/categorical matching at a visual angle of 12 degrees from central fixation, it is highly unlikely that the failure to find lateral differences for perceptual matching in the present study was due to foveal fixation. However, the large size of stimulus pictures used may have attenuated the effect of the extent of retinal eccentricity in the periphery and some manipulation involving a combination of these factors might be successful at eliciting visual hemifield asymmetries for both perceptual and semantic/categorical matches.

The interstimulus interval of 500msec was chosen to allow for the decay of the iconic image of the standard stimulus. Reducing the interstimulus interval may result

in more perceptual matching in the experimental task by increasing the competition between the comparison stimuli.

Thus, it is possible that what is an optimal exposure duration, stimulus size, retinal eccentricity, and/or ISI for eliciting hemifield asymmetries for perceptual matches is less than optimal for the elicitation of semantic matching asymmetries.

In terms of procedure, the stimulus sets used to familiarize the subjects with the task, the testing procedure, and the apparatus were similar to the actual stimulus sets used in experimental testing. This may have precluded obtaining information as to whether the subject's performance, either in terms of type of match or in visual hemifield asymmetry, underwent changes during acquisition. By the time the children faced the test stimulus sets, a cognitive matching strategy appears to have been already decided upon, evidenced by the fact that there was no difference in the proportion of perceptual matches between the first 24 trials and the second 24 trials. As practice effects and some overall decision-making as to strategy cannot be ruled out as having occurred during the practice trials, it is possible that a LVF/RH advantage for processing novel stimuli may have been obscured. To examine this possibility, a different forced-choice matching task might be used to familiarize

subjects with the projection tachistoscope, the timing and the use of the manipulandum-- perhaps, an identity color matching task with the same non-directive instructions to match the one that goes best. The test trials could then be preceded by some explanation that the following pictures should be matched but that they would not be in color so the subject would have to decide which pictures go together. Such a procedure would enable a comparison of visual hemifield asymmetries during familiarization with the test stimulus sets when strategies would be determined.

It was noted earlier that instructions to make the "best" match does not permit experimental control over the use of a particular strategy. Whereas this instruction was important in the context of the present study, which attempted to examine age-related differences in strategy preference, instructing the children to match on the basis of shape during the follow-up tasks resulted in more consistent "perceptual" matching and some measure of confidence that the children were using the matching strategy induced by the instructions. Markman and Hutchinson (1983) found that thematic matching was attenuated by attaching names/labels to the objects being matched. Clearly, instructions can be a potent priming and/or constraining force with respect to an experimental

task. Varying the instructions with all age groups would permit one to determine if changes in strategy affect the consistency of matching, and/or result in reversing or attenuating the laterality effects. This may be an appropriate direction for future research if manipulations of the stimulus characteristics are ineffective in inducing both types of matching with the set of instructions used in the present study.

Hardyck (1986) raises the issue of the effect of stimulus repetition in tasks where the stimuli become more and more familiar as compared to the effect on tasks where new information appears on every trial. He found that using a small set of Chinese and English word stimuli (i.e., 4 to 6, in a same/different paradigm) repeatedly (hundreds of trials) resulted in an automatizing of the response process in adults and an exaggeration of the lateralization of the particular performance, which contrasted with the absence of lateralization effects when he used new items on every trial. The number of stimulus sets in the present study fall into an intermediate range in comparison with Hardyck's (1986) studies. Varying the number of stimulus sets used in the present study could alter the direction and/ or the magnitude of the visual hemifield asymmetries for semantic/categorical matches and

affect the outcome with respect to perceptual matches as well.

Subject variables, such as sex and handedness were not examined in the present study. As girls generally acquire language earlier than boys, one might expect somewhat more semantic/categorical matching by 4-6 year old girls. As they are thought to lateralize later and less completely than boys, one might hypothesize slightly less or perhaps no hemispheric asymmetry for semantic matching in 4-6 year old girls. In other words, the performance of 4-6 year old girls might look similar to the 7-9 year old boys' performance, or be intermediate between the 4-6 and 7-9 year old boys. Preliminary observation of one left-handed and one right-handed 9-year old girl indicated an overwhelming preference for semantic/categorical matching and no visual field asymmetry with respect to standard stimulus presentation. The same results were demonstrated by a left-handed 12 year old boy. As left-handed and ambidextrous individuals are thought to be less completely lateralized than right-handed persons with respect to language functions, one might hypothesize a decrease in the magnitude of the RVF/LH advantage for semantic matching by left-handed subjects.

IV. Implications for Future Research

In addition to the subject variables and methodological issues raised above, the results of the present study suggest several avenues for future investigations.

The question of contextual/complementary/thematic matching as an alternative strategy that may have resulted in the same responses as semantic/categorical matching needs to be examined systematically. To assess differences between semantic and thematic matching preferences, one could use comparison stimuli consisting of 1) a contextual/complementary/ thematic match, and 2) a superordinate categorical match. It would be important to choose category exemplars that were neither thematically related nor atypical ("poor") exemplars that might not be recognized as category members by the younger children. Similarly, it would be important to select thematic/contextual exemplars that were neither poor thematic exemplars nor category members.

Comparisons of thematic and semantic matches with respect to hemifield asymmetries could result in an LVF/RH advantage for both matchtypes, an LVF/RH advantage for thematic matches and an RVF/LH advantage for semantic matches, or some other permutation. Should 4-6 year olds

show a LVF/RH advantage for both thematic and semantic matching and older children a RVF/LH advantage for both types of matching, the results would support a developmental model of Goldberg and Costa's theory of a shift in hemispheric asymmetry with acquisition of routinized codes. If all age groups demonstrate an RVF/LH for thematic matches and an LVF/RH for semantic/categorical matches, the results would support the view of right-hemisphere mediated perceptual processing and left-hemisphere mediated semantic matching. And if the 4-6 year olds demonstrate a LVF/RH advantage for both semantic and thematic matching while the older children show a visual hemifield dissociation (e.g., an LVF/RH advantage for thematic matches and an RVF/LH superiority for semantic matching), the age-related changes would provide evidence for the role of the right hemisphere in the acquisition of both perceptual and language skills.

The significant amount of chance level [Per2/Sem2] responding to stimulus sets by the younger children in the present study raises the question of whether the youngest children are less consistent in terms of developing strategies, or whether the inconsistency is an artifact of the relatively non-specific instructions. Would instructing the youngest children to use a particular matching strategy result in less chance level responding?

Is the chance level responding a function of the rapid tachistoscopic presentation and demand for rapid response? Timed tests make different demands on the subject and the timed nature of the task in the present study may have resulted in more error responses that appear as chance level responses because the stimulus sets were presented four times. Is the chance level responding merely a function of repeated presentation of stimulus sets which were then examined for consistency of responding? Most of the matching and sorting experiments with children (Birch & Bortner, 1966; Blewitt & Durkin, 1982; Fenson et al, 1988) required the subject to sort each set only once, and incorrect sorts were considered errors. Does the chance level responding in the present task represent some competition between matching strategies or are two of the four responses errors with respect to a given strategy? Offering a slowed fifth presentation and asking the children to explain their choice might clarify the question of errors and would reveal whether they provide thematic justifications.

One of the 5-year olds responded at chance level for 10 of the 12 stimulus sets, a pattern similar to that demonstrated by a diagnosed language-impaired 5-year old. This pattern was unusual for the 4-6 year olds, even with their significantly greater proportion of chance level

responding. It raises the question of the proportion of chance level responses on this task that can be considered "normal." Does mostly chance level responding reflect one end of a normal distribution with respect to young children's performance on this task? Or does it reflect a developmental delay, a difficulty with sustained attention, or some subtle cognitive dysfunction? Comparing performance on the present task with standardized measures of attention and problem-solving by normal children and dysfunctional groups such as children who are learning-disabled, mentally-retarded, or have Attentional Deficit Disorder may help to answer this question.

The task used in the present study makes considerable demands on the child's ability to sustain visual attention, on his visual short-term memory, on his semantic coding of picture stimuli, and on rapid decision making and eye-hand coordination. Attempts to test 3-year old boys were not successful, and two 4-year olds did not complete the task. However, by using a free sort paradigm with repeated presentations of the same stimulus sets it might be possible to examine the consistency of matching in children under 4 years of age.

As it was not possible to explore matching in boys under 4 years of age with the procedures used in the

present study, the question of the development of lateralization in the first four years with respect to this type of matching and categorizing remains unexamined. One may speculate from the perceptual nature of the infant's categorizations (Alexander & Enns, 1988; Bomba & Siqueland, 1983; Sherman, 1985), that categorizing may begin as a right hemisphere task. Tracing the development of categorization skills and observing the lateral asymmetries at each stage would clarify the nature of the development of lateralization and the question of age-related changes versus developmental invariance of lateralized functions.

In conclusion, the results of the present study support the developmental literature regarding the sequenced acquisition of categorization skills. Although no visual hemifield asymmetries were found for perceptual matching, the developmental "shift" in visual field/hemispheric asymmetry for semantic/categorical matching provide support for the theory of hemispheric specialization proposed by Goldberg and Costa (1981) and the role of the right hemisphere in the acquisition of categorization/language skills. The present findings suggest that the cognitive strategies and neural substrates involved in young children's matching and categorization differs considerably from those of older

children and adults and, that the cognitive functions involved undergo both quantitative and qualitative changes in the course of development. The present experiment suggests further investigation which would expand and enhance our understanding of normal cognitive development and enable us to explore the implications of that understanding for atypical populations of children.

Appendix A

QUEENS COLLEGE
of the
CITY UNIVERSITY OF NEW YORK
Department of Psychology

CONSENT FORM

Child's Name _____

I understand the following:

- 1- that this study is being conducted by Ms. Gail Kuslansky, a doctoral candidate in the Ph. D. Neuropsychology Subprogram at Queens College of the City University of New York, under the direct faculty supervision of Tina Moreau, Ph.D.;
- 2- that I have been fully informed of the nature of the proposed study including its purposes, procedures, time requirements, and my child's rights. Furthermore, I have been assured of Ms. Kuslansky's availability prior to and after my child's participation, to answer any questions that might arise;
- 3- that this study will involve my child's sitting in a quiet room, manipulating a joystick, answering a questionnaire regarding which side of the body my child prefers to use for various activities (e.g. throwing a ball);
- 4- that this study will not be physically or psychologically harmful to my child;
- 5- that my child's participation is VOLUNTARY and my child's refusal to participate or to discontinue participation at any time will incur no PENALTY;
- 6- that my child's ANONYMITY and CONFIDENTIALITY will be guaranteed;
- 7- that, although the information botained may not be directly beneficial to my child, it will contribute to our understanding of child development;

PLEASE NOTE:

Copyrighted materials in this document have not been filmed at the request of the author. They are available for consultation, however, in the author's university library.

These consist of pages: 250

U·M·I

Appendix C

Picture Stimuli

Standard Stimulus	Comparisons	
	Perceptual	Semantic
apple (SV)	ball (SV)	banana (P)
bulb (P)	pear (P)	lamp (P)
igloo (P)	turtle (P)	house (P)
fish (SV)	eye (SV)	frog (SV)
eye (SV)	football (SV)	ear (SV)
nail (SV)	pen (SV)	hammer (SV)
knife (P)	pencil (P)	ladle (P)
tennis racquet (P)	rope (P)	bat (P)
drum (SV)	cup (SV)	trumpet (SV)
toothbrush (SV)	screwdriver (SV)	comb (SV)
butterfly (SV)	bow (SV)	fly (SV)
hat (SV)	mushroom (SV)	coat (SV)

Note. SV = Snodgrass and Vanderwart (1980)

P = Peabody Picture Vocabulary Test (Dunn, 1959)

Appendix D

STIMULUS SETS

(Note: LVF = Left Visual Field Presentation
RVF = Right Visual Field Presentation)

Standard	Comparisons	
	<u>Perceptual</u>	<u>Semantic</u>
Block 1:		
1. butterfly (RVF)	bow (LVF)	fly (RVF)
2. igloo (LVF)	turtle (LVF)	house (RVF)
3. eye (LVF)	football (RVF)	ear (LVF)
4. bulb (RVF)	pear (LVF)	lamp (RVF)
5. drum (RVF)	cup (LVF)	trumpet (RVF)
6. toothbrush (LVF)	screwdriver (RVF)	comb (LVF)
7. hat (LVF)	mushroom (LVF)	coat (RVF)
8. nail (RVF)	pen (LVF)	hammer (RVF)
9. tennis (RVF)	rope (LVF)	bat (RVF)
10. apple (LVF)	ball (RVF)	banana (LVF)
11. knife (RVF)	pencil (LVF)	ladle (RVF)
12. fish (LVF)	eye (LVF)	frog (RVF)
Block 2:		
13. toothbrush (LVF)	screwdriver (LVF)	comb (RVF)
14. igloo (RVF)	turtle (RVF)	house (LVF)
15. eye (LVF)	football (LVF)	ear (RVF)
16. nail (LVF)	pen (LVF)	hammer (RVF)
17. drum (RVF)	cup (RVF)	trumpet (LVF)
18. butterfly (LVF)	bow (RVF)	fly (LVF)
19. hat (LVF)	mushroom (RVF)	coat (LVF)
20. fish (RVF)	eye (LVF)	frog (RVF)
21. tennis (LVF)	rope (RVF)	bat (LVF)
22. apple (RVF)	ball (LVF)	banana (RVF)
23. bulb (LVF)	pear (RVF)	lamp (LVF)
24. knife (LVF)	pencil (LVF)	ladle (RVF)

Appendix D cont.

Standard	Comparisons	
	<u>Perceptual</u>	<u>Semantic</u>
Block 3:		
25. butterfly(RVF)	bow(RVF)	fly(LVF)
26. hat(RVF)	mushroom(LVF)	coat(RVF)
27. knife (LVF)	pencil (RVF)	ladle (LVF)
28. eye(RVF)	football(RVF)	ear(LVF)
29. bulb(RVF)	pear(RVF)	lamp(LVF)
30. tennis racquet (LVF)	rope (LVF)	bat (RVF)
31. igloo (RVF)	turtle (LVF)	house (RVF)
32. drum (LVF)	cup (LVF)	trumpet (RVF)
33. nail(RVF)	pen(RVF)	hammer(LVF)
34. fish (LVF)	eye (RVF)	frog (LVF)
35. apple(RVF)	ball RVF)	banana(LVF)
36. toothbrush (RVF)	screwdriver(LVF)	comb (RVF)
Block 4:		
37. nail (LVF)	pen (RVF)	hammer (LVF)
38. fish (RVF)	eye (RVF)	frog (LVF)
39. butterfly (LVF)	bow (LVF)	fly (RVF)
40. hat(RVF)	mushroom(RVF)	coat (LVF)
41. toothbrush (RVF)	screwdriver (RVF)	comb (LVF)
42. bulb (LVF)	pear (LVF)	lamp (RVF)
43. knife (RVF)	pencil (RVF)	ladle (LVF)
44. drum(LVF)	cup (RVF)	trumpet(LVF)
45. tennis(RVF)	rope(RVF)	bat(LVF)
46. eye (RVF)	football (LVF)	ear (RVF)
47. apple (LVF)	ball (LVF)	banana (RVF)
48. igloo(LVF)	turtle (RVF)	house((LVF)

PLEASE NOTE:

Copyrighted materials in this document have not been filmed at the request of the author. They are available for consultation, however, in the author's university library.

These consist of pages: 254-258

U·M·I

Appendix F

Instructions to Subject

Sit on this chair and put your chin on this chinrest. I will adjust it if it is not comfortable.

Place both your hands on this joystick (manipulandum) with your elbows resting on the base. Hold the joystick loosely, gently, like this. See, it jiggles from side to side. If you let go, it will go back to the center. Try it.

Now, look at the wall. See that black dot. When you hear the beep, that is your signal to look at that dot. After the beep, a picture will flash very quickly on the wall. It will disappear and two more pictures will appear on the wall. Look at those pictures and decide which one of them goes best with the picture that just disappeared (the fast picture). If you pick the picture on this (left) side push the joystick to this (left) side. If you pick the picture on this (right) side, then push the joystick to this (right) side. There are no wrong answers. You just decide which one you think goes best and move the joystick to that side and then let the joystick come back to the middle, like this.

Let's do one slowly. (Demonstrate with one or more trials, controlled manually.) Now, you do one slowly. (Subject is guided through one or two manually controlled trials.)

Now, let's do some quickly. (Computer driven practice trials) Ready?

(After practice criteria are met:) Now, I am going to change the slide trays. You will do the same thing--only, the pictures are different. Remember, wait for the two choice pictures, and pick one as quickly as you can.

Appendix G

Code _____ Age _____ Date _____

Identity Matching Sets

Standard	Comparisons
___1 (c) bulb (RVF)	bulb (LVF) lamp (RVF)
___2 (a) butterfly (LVF)	butterfly (LVF) fly (RVF)
___3 (d) eye (RVF)	eye (RVF) ear (LVF)
___4 (c) knife (RVF)	knife (LVF) ladle (RVF)
___5 (b) football (LVF)	football (RVF) bat (LVF)
___6 (a) eye (LVF)	eye (LVF) ear (RVF)
___7 (d) bulb (RVF)	bulb (RVF) lamp (LVF)
___8 (b) knife (LVF)	knife (RVF) ladle (LVF)
___9 (a) football (LVF)	football (LVF) bat (RVF)
___10 (c) butterfly (RVF)	butterfly (LVF) fly (RVF)
___11 (d) football (RVF)	football (RVF) bat (LVF)
___12 (b) butterfly (LVF)	butterfly (RVF) fly (LVF)
___13 (c) eye (RVF)	eye (LVF) ear (RVF)
___14 (b) bulb (LVF)	bulb (RVF) lamp (LVF)
___15 (d) knife (RVF)	knife (RVF) ladle (LVF)
___16 (b) eye (LVF)	eye (RVF) ear (LVF)
___17 (c) football (RVF)	football (LVF) bat (RVF)
___18 (a) knife (LVF)	knife (LVF) ladle (RVF)
___19 (d) butterfly (RVF)	butterfly (RVF) fly (LVF)
___20 (a) bulb (LVF)	bulb (LVF) lamp (RVF)

_____ bulb	Id4-Sem0 _____
_____ butterfly	Id3-Sem1 _____
_____ eye	Id2-Sem2 _____
_____ knife	Id1-Sem3 _____
_____ football	Id0-Sem4 _____

Total = 5 sets

Appendix H

Experimental Task: Stimulus Sets--
 Mean Number of Semantic Responses (and SDs)
 over 4 Trials (across age groups)

STIMULUS SET

	Mean # Semantic Rs	<u>SD</u>
1- Butterfly	3.283	1.263
2- Igloo	2.917	1.453
3- Eye	3.483	1.049
4- Light bulb	3.467	0.965
5- Toothbrush	3.017	1.186
6- Drum	3.450	1.032
7- Hat	3.600	0.924
8- Nail	3.583	0.829
9- Tennis Racquet	3.417	1.062
10- Apple	3.333	1.020
11- Knife	3.250	1.188
12- Fish	3.617	0.865

Appendix I

Experimental Task: Stimulus Sets--
 Means and Standard Deviations for the Number
 of Semantic Responses over 4 Trials by Age Group

STIMULUS SET	4-6YRS		7-9YRS		10-12YRS	
	M	SD	M	SD	M	SD
Butterfly	2.40	1.67	3.75	0.55	3.85	0.49
Igloo	1.75	1.59	3.35	1.09	3.75	0.55
Eye	2.90	1.21	3.65	1.09	4.00	0.00
Light bulb	2.75	1.29	3.75	0.55	3.90	0.31
Toothbrush	2.40	1.31	3.20	1.20	3.50	0.69
Drum	2.95	1.28	3.65	0.99	3.80	0.52
Hat	3.10	1.37	3.90	0.31	3.90	0.31
Nail	3.15	1.18	3.90	0.31	3.80	0.41
Tennis Racquet	2.70	1.45	3.80	0.52	3.85	0.37
Apple	2.75	1.25	3.55	0.76	3.75	0.72
Knife	2.35	1.60	3.90	0.31	3.55	0.60
Fish	3.30	1.08	3.70	0.92	3.90	0.31

Appendix J

Individual Subject Data

Subject	Age	P4/S0	P3/S1	P2/S2	P1/S3	P0/S4
<u>4-6 year olds:</u>						
jtq4	4	1	5	4	2	0
mv4	4	1	0	0	4	7
acv4	4	0	2	5	5	0
cza4	4	0	1	6	3	2
ak4	4	1	3	3	3	2
mo5	5	2	0	0	2	8
br5	5	2	1	2	3	5
ajk5	5	0	0	1	1	10
db15	5	11	0	0	1	0
azk5	5	1	0	1	1	9
bb5	5	1	2	4	3	2
jm5	5	1	2	5	4	0
wm5	5	1	1	0	7	3
hs5	5	0	0	0	0	12
wh6	6	1	4	6	1	0
af6	6	0	1	11	0	0
sts6	6	1	1	0	0	10
mwf6	6	1	0	2	2	7
dz6	6	3	0	0	1	8
as6	6	0	0	0	3	9
<u>7-9 year olds:</u>						
ja7	7	0	0	0	3	9
rs7	7	0	0	0	0	12
ks7	7	0	0	0	2	10
lg7	7	0	0	0	1	11
lag7	7	2	1	1	1	7
jsv7	7	1	0	0	2	9
pf7	7	0	0	0	0	12
cs7	7	0	0	1	3	8
mjk8	8	0	1	1	5	4
dc8	8	0	0	0	2	10
je8	8	0	0	1	1	10
pf8	8	0	0	0	2	10
mk8	8	0	1	3	4	4
cs8	8	0	0	0	0	12
bc8	8	2	0	0	0	10
mlp9	9	0	0	0	2	10
bs9	9	0	1	0	0	10
kc9	9	0	0	0	1	11
hk9	9	0	0	0	3	9
plvk9	9	0	0	0	0	12

Appendix J cont.

Subject	Age	P4/S0	P3/S1	P2/S2	P1/S3	P0/S4
<u>10-12 year olds:</u>						
dn10	10	0	0	3	7	2
jap10	10	0	0	0	3	9
jmj10	10	0	0	0	2	10
bpg10	10	0	0	0	2	10
dn10	10	0	0	0	2	9
bkc10	10	0	0	1	2	9
ag10	10	0	0	0	0	12
sic10	10	0	0	1	1	10
sg11	11	0	0	0	2	10
gz11	11	0	0	0	2	10
wpd11	11	0	0	0	0	12
jk11	11	0	0	0	1	11
bw12	12	0	0	1	2	9
bek12	12	0	0	0	2	10
aos12	12	0	0	0	3	9
cat12	12	0	0	0	0	12
cf12	12	0	0	0	0	12
cd12	12	0	0	?	1	11
rd12	12	0	0	0	1	11
bk12	12	0	0	0	1	11

References

- Ackerman, B. P. (1986a). Developmental differences in the use of conceptual features in retrieving episodic information from memory. Child Development, 57, 1109-1122.
- Ackerman, B. P. (1986b). Retrieval search for category and thematic information in memory by children and adults. Journal of Experimental Child Psychology, 42, 355-377.
- Ackerman, B. P. (1987). Developmental differences in episodic retrieval: the role of differences in concept representation in semantic memory. Developmental Psychology, 23, 31-38.
- Ackerman, B. P. (1988). Cued recall for category, thematic, and ad hoc classified events in children and adults. Journal of Experimental Child Psychology, 45, 88-118.
- Affleck, G. & Joyce, P. (1979). Sex differences in the association of cerebral hemispheric specialization of spatial function with conservation task performance. Journal of Genetic Psychology, 134, 271-280.
- Alexander, T. M. & Enns, J. T. (1988). Age changes in the boundaries of fuzzy categories. Child Development, 59, 1372-1386.
- Aylward, E. H. (1984). Lateral asymmetry in subgroups of dyslexic children. Brain and Language, 22, 221-231.
- Bakker, D. J. (1973). Hemispheric specialization and stages in the learning to read process. Bulletin of the Orton Society, 23, 15-27.
- Bakker, D. J. (1979). Hemispheric differences and reading strategies: Two dyslexias? Bulletin of the Orton Society, 29, 84-100.
- Bakker, D. J. (1983). Hemispheric specialization and specific reading retardation. In M. Rutter (Ed.) Developmental neuropsychiatry. New York: Guilford.

- Bakker, D. J., Hoefkens, M., & Van der Vlugt, H. (1979). Hemispheric specialization in children as reflected in the longitudinal development of ear asymmetry. Cortex, 15, 619-625.
- Bakker, D. J., Licht, R., Kok, A., & Bouma, A. (1980). Cortical responses to word reading by right- and left-eared normal and reading-disturbed children. Journal of Clinical Neuropsychology, 2, 1-12.
- Bakker, D. J., Van der Vlugt, H., & Claushuis, M. (1978). The reliability of dichotic ear asymmetry in normal children. Neuropsychologia, 16, 753-757.
- Bakker, D. J., & Vinke, J. (1985). Effects of hemisphere-specific stimulation on brain activity and reading in dyslexics. Journal of Clinical and Experimental Neuropsychology, 7, 505-525.
- Basser, L. S. (1962). Hemiplegia of early onset and the faculty of speech with special reference to the effects of hemispherectomy. Brain, 85, 427-460.
- Bayshore, T. R. (1981). Vocal and manual reaction time estimates of interhemispheric transmission time. Psychological Bulletin, 89, 356-368.
- Benton, A. (1984). Hemispheric dominance before Broca. Neuropsychologia, 22, 807-811.
- Benton, A.L. (1972). The 'minor' hemisphere. Journal of Medicine and Allied Sciences, 27, 5-14.
- Berlin, C. I., Hughes, L. F., Lowe-Bell, S. S., & Berlin, H. L. (1973). Dichotic right ear advantage in children 5 to 13. Cortex, 9, 394-402.
- Berlucchi, G., Brizzolara, D., Marzi, C. A., Rizzolatti, G., & Umiltà, C. (1979). The role of stimulus discriminability and verbal codability in hemisphere specialization for visuospatial tasks. Neuropsychologia, 17, 195-202.
- Berman, S., Friedman, D., Hamberger, M., & Snodgrass, J. G. (1989). Developmental picture norms: relationships between name agreement, familiarity, and visual complexity for child and adult ratings of two sets of line drawings. Behavior Research Methods, Instruments, & Computers, 21(8), 371-382.

- Berrini, R., Della Sala, S., Spinnler, H., Sterzi, R., & Vallar, G. (1982). In eliciting hemisphere asymmetries which is more important: The stimulus input side or the recognition side? A tachistoscopic study on normals. Neuropsychologia, 20, 91-94.
- Best, C. (1988). The emergence of cerebral asymmetries in early human development: A literature review and a neuroembryological model. In D.L. Molfese & S.J. Segalowitz (Eds.). Brain lateralization in children. New York: The Guilford Press.
- Best, C., Hoffman, H., & Glanville, B. (1982). Development of infant ear asymmetries for speech and music. Perception & Psychophysics, 31, 75-85.
- Bever, J. (1975) Cerebral asymmetries in humans are due to the differentiation of two incompatible processes: Holistic and analytic. In. D. Aaronson & R.W. Riever (Eds.). Developmental psycholinguistics and communication disorders. New York: Academic Press.
- Bigum, H. B., Dustman, R. E., & Beck, E. C. (1970). Visual and somatosensory evoked responses from mongoloid and normal children. Electroencephalography and Clinical Neurophysiology, 28, 576-585.
- Birch, H. G., & Bortner, M. (1966). Stimulus competition and category usage in normal children. The Journal of Genetic Psychology, 109, 195-204.
- Bjorklund, D. F. & Thompson, B. E. (1983). Category typicality effects in children's memory performance: Qualitative and quantitative differences in the processing of category information. Journal of Experimental Child Psychology, 35, 329-344.
- Blewitt, P., & Durkin, M. (1982). Age, typicality, and task effects on categorization of objects. Perceptual and Motor Skills, 55, 435-445.
- Bogen, J.E. (1969). The other side of the brain II: An appositional mind. Bulletin of the Los Angeles Neurological Societies, 34, 135-162.
- Bomba, P. C. & Sigueland, E. (1983). The nature and structure of infant form categories. Journal of Experimental Child Psychology, 35, 294-328.

- Borowy, T. & Goebel, R. (1976). Cerebral lateralization of speech: The effects of age, sex, race, and socioeconomic class. Neuropsychologia, 14, 363-370.
- Bortner, M., & Birch, H. G. (1970). Cognitive capacity and cognitive competence. American Journal of Mental Deficiency, 74, 735-744.
- Bradshaw, J. L., & Nettleton, N. C. (1981). The nature of hemispheric specialization in man. The Behavioral and Brain Sciences, 4, 51-91.
- Bradshaw, J. L. & Nettleton, N.C. (1983). Human cerebral asymmetry. Englewood Cliffs: Prentice-Hall, Inc.
- Bradshaw, J. L., & Sherlock, D. (1982). Bugs and faces in the two visual fields: The analytic/holistic processing dichotomy and task sequencing. Cortex, 18, 211-226.
- Bradshaw, J. L., & Umiltà, C. (1984). A reaction time paradigm can simultaneously index spatial compatibility and neural pathway effects: A reply to Levy. Neuropsychologia, 22, 99-102.
- Brinkman, J. & Kuypers, H.G. (1972). Split-brain monkeys: Cerebral control of ipsilateral arm, hand and finger movements. Science, 176, 536-539.
- Broman, M. (1978). Reaction-time differences between the left and right hemispheres for face and letter discrimination in children. Cortex, 14, 578-591.
- Broman, M., Rudel, R. G., Helfgott, E., & Krieger, J. (1986). Inter- and intrahemispheric processing of letter stimuli by dyslexic children and normal readers. Cortex, 22, 447-459.
- Brown, J. (1978). Lateralization: A brain model. Brain and Language, 5, 258-261.
- Brown, J. W., & Jaffee, J. (1975) Hypothesis on cerebral dominance. Neuropsychologia, 13, 107-110.
- Bryden, M. P. (1965). Tachistoscopic recognition, handedness, and cerebral dominance. Neuropsychologia, 3, 1-8.

- Bryden, M. P. (1970). Laterality effects in dichotic listening: Relations with handedness and reading ability in children. Neuropsychologia, 8, 443-450.
- Bryden, M. P. (1973). Perceptual asymmetry in vision: Relation to handedness, eyedness, and speech lateralization. Cortex, 9, 419-435.
- Bryden, M. P. (1979). Evidence for sex-related differences in cerebral organization. in M.A. Wittig & A. C. Petersen (Eds.). Sex-related differences in cognitive functioning. New York: Academic Press.
- Bryden, M. P. (1982). Laterality: Functional asymmetry in the intact brain. New York: Academic Press. Bryden M. P., & Allard, F. A. (1981). Do auditory perceptual asymmetries develop? Cortex, 17, 313-318.
- Bryden, M. P., & Rainey, C. A. (1963). Left-right differences in tachistoscopic recognition. Journal of Experimental Psychology, 66, 568-571.
- Butler, D. C. & Miller, L. K. (1979). Role of approximation to English and letter array length in the development of visual laterality. Developmental Psychology, 15, 522-529.
- Caplan, B., & Kinsbourne, M. (1981). Cerebral lateralization, preferred cognitive mode, and reading ability in normal children. Brain and Language, 14, 349-370.
- Carmon, A., Nachson, I., & Starinsky, R. (1976). Developmental aspects of visual hemifield differences in perception of verbal material. Brain and Language, 3, 463-469.
- Carter, G. L., & Kinsbourne, M. (1979). The ontogeny of right cerebral lateralization of spatial mental set. Developmental Psychology, 15, 241-245.
- Cohen, G. (1973). Hemispheric differences in serial vs. parallel processing. Journal of Experimental Psychology, 97, 349-356.
- Cohen, J. & Breslin, P. W. (1984). Visual evoked responses in dyslexic children. In R. Karrer, J. Cohen, & P. Tueting (Eds.). Brain and information: Event-related potentials. New York: New York Academy of Sciences.

- Cohen, L. B., & Strauss, M. S. (1979). Concept acquisition in the human infant. Child Development, 50, 419-424.
- Corballis, M. C. (1986). Fresh fields and postures new: A discussion paper. Brain and Cognition, 5, 240-252.
- Craik, F. I. M. & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. Journal of Verbal Learning and Verbal Behavior, 11, 671-684.
- Craik, F. I. M. & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. Journal of Experimental Psychology: General, 104, 268-294.
- Cranney, J. & Ashton, R. (1980). Witelson's dichaptic task as a measure of hemispheric asymmetry in deaf and hearing populations. Neuropsychologia, 18, 95-98.
- Cranney, J. & Ashton, R. (1982). Tactile spatial ability: Lateralized performance of deaf and hearing age groups. Journal of Experimental Child Psychology, 34, 123-134.
- Crowell, D. H., Jones, R. H., Kapuniai, L. E., Nakagawa, J. K. (1973). Unilateral cortical activity in newborn humans: An early index of cerebral dominance? Science, 180, 205-208.
- Crowell, D. H., Kapuniai, L. E., & Garbanati, J. A. (1979). Hemispheric differences in human infant rhythmic responses to photic stimulation. In J. E. Sesmedt (Ed.). Cerebral evoked potentials in man. Basel: Karger.
- Davidoff, J. B., & Done, D. J. (1984) A longitudinal study of the development of visual field advantage for letter matching. Neuropsychologia, 22, 311-318.
- Davidoff, J. B., Done, D. J., & Scully, J. (1981). What does the lateral ear advantage relate to? Brain and Language, 12, 332-346.
- Davis, A. E., & Wada, J. A. (1977). Hemispheric asymmetries in human infants: Spectral analysis of flash and click evoked potentials. Brain and Language, 4, 23-31.

- Dawson, G. D. (1981). Sex differences in dichaptic processing. Perceptual and Motor Skills, 53, 935-944.
- Dawson, G., Finley, C., Phillips, S., & Galpert, L. (1986). Hemispheric specialization and the language abilities of autistic children. Child Development, 57, 1440-1453.
- Dawson, G., Warrenburg, S., & Fuller, P. (1982). Cerebral lateralization in individuals diagnosed as autistic in early childhood. Brain and Language, 15, 353-368.
- DeCasper, A. J. & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. Science, 208, 1174-1176.
- Denney, N. W. (1972). Free classification in preschool children. Child Development, 43, 1161-1170.
- Dennis, M. (1980). Capacity and strategy for syntactic comprehension after left or right hemidecortication. Brain and Language, 10, 287-317.
- Dennis, M., & Kohn, B. (1975). Comprehension of syntax in infantile hemiplegics after cerebral hemidecortication: Left hemisphere superiority. Brain and Language, 2, 472-482.
- Dennis M., & Whitaker, H. (1976). Language acquisition following hemidecortication: Linguistic superiority of the left over the right hemisphere. Brain and Language, 3, 404-433.
- Dennis M., & Whitaker, H. (1977). Hemispheric equipotentiality and language acquisition. In S. Segalowitz & F. A. Gruber (Eds.) Language development and neurological theory (pp. 93-107). New York: Academic Press.
- Dorman, M. F. & Geffner, D. S. (1974). Hemispheric specialization for speech perception in six black and white children from low and middle socioeconomic classes. Cortex, 10, 171-176.
- Dunn, L. M. (1959). Peabody Picture Vocabulary Test. Circle Pines, MN: American Guidance Service, Inc.

- Eimas, P. D., Siqueland, E. R., Jusczyk, P., & Vigority, I. (1971). Speech perception in infants. Science, 171, 303-306.
- Enns, J. T. (1987). A developmental look at pattern symmetry in perception and memory. Developmental Psychology, 23, 839-850.
- Enns, J. T. & Girgus, J. S. (1985). Perceptual grouping and spatial distortion: A developmental study. Developmental Psychology, 21, 241-246.
- Enns, J. T. & Girgus, J. S. (1986). A developmental study of shape integration over space and time. Developmental Psychology, 22, 491-499.
- Entus, A. (1977). Hemispheric asymmetry in the processing of dichotically presented speech and non-speech stimuli by infants. In S. Segalowitz & F. A. Gruber (Eds.) Language development and neurological theory (pp. 64-75). New York: Academic Press.
- Etaugh, C. & Levy, R. B. (1981). Hemispheric specialization for tactile-spatial processing in preschool children. Perceptual and Motor Skills, 53, 621-622.
- Fennell, E.B., Satz, P., & Morris, R. (1983). The development of handedness and dichotic ear listening asymmetries in relation to school achievement: A longitudinal study. Journal of Experimental Child Psychology, 35, 248-262.
- Fenson, L. Cameron, M. S., & Kennedy, M. (1988). Role of perceptual and conceptual similarity in category matching at age two years. Child Development, 59, 897-907.
- Flanery, R. C., & Balling, J.D. (1979). Developmental in hemispheric specialization for tactile spatial ability. Developmental Psychology, 15, 364-372.
- Flavell, J. H. (1985). Cognitive development. Englewood Cliffs, NJ: Prentice-Hall, Inc.
- Forgays, D. G. (1953). The development of differential word recognition. Journal of Experimental Psychology, 45, 165-168.

- Fried I., Tanguay, P. E., Boder, E., Doubleday, C., & Greensite, M. (1981). Developmental dyslexia: Electrophysiological evidence of clinical subgroups. Brain and Language, 12, 14-22.
- Fried, L. S. & Holyoak, K. J. (1984). Induction of category distribution: A framework for classification learning. Journal of Experimental Psychology: Learning, Memory and Cognition, 10, 234-257.
- Galaburda, A. M., LeMay, M., Kemper, T., & Geschwind, N. (1978). Right-left asymmetries in the brain. Science, 199, 852-856.
- Gazzaniga, M. S., & Sperry, R. W. (1967). Language after section of the cerebral commissures. Brain, 90, 131-148.
- Geffen, G. (1978). The development of the right ear advantage in dichotic listening with focused attention. Cortex, 14, 169-177.
- Geffen, G., Bradshaw, J. L., & Wallace, G. (1971). Interhemispheric effects on reaction time to verbal and nonverbal visual stimuli. Journal of Experimental Psychology, 87, 415-422.
- Geffner, D. S. & Hochberg, I. (1971). Ear laterality performance of children from low and middle socioeconomic classes. Cortex, 8, 193-203.
- Geschwind, N., & Levitsky, W. (1970). Human brain: Left-right asymmetries in temporal speech region. Science, 161, 186-187.
- Gibson, C., & Bryden, M. P. (1983). Dichaptic recognition of shapes and letters in children. Canadian Journal of Psychology, 37, 132-143.
- Goldberg, E., & Costa, L. (1981). Hemispheric Differences in the acquisition and use of descriptive systems. Brain and Language, 14, 144-173.
- Goldberg, E., Vaughan, H. G. Jr., & Gerstman, L. J. (1978). Hemispheric descriptive systems and hemispheric asymmetry: Shape versus texture discrimination. Brain and Language, 5, 249-257.

- Gordon, D. P. (1983). The influence of sex on the development of lateralization of speech. Neuropsychologia, 21, 139-146.
- Grant, D. W. (1980). Visual asymmetry on a color-naming task: A developmental perspective. Perceptual and Motor Skills, 50, 475-480.
- Grant, D. W. (1981). Visual asymmetry on a color-naming task: A longitudinal study with primary school children. Child Development, 52, 370-372.
- Greenfield, D. B. & Scott, M. S. (1986). Young children's preference for complementary pairs: Evidence against a shift to a taxonomic preference. Developmental Psychology, 22, 19-21.
- Gross, K., Rothenberg, S., Schottenfeld, S., & Drake, K. (1978). Duration thresholds for letter identification in left and right visual fields for normal and reading-disabled children. Neuropsychologia, 16, 653-657.
- Gross, T. F. (1985). Cognitive Development. Monterey, CA: Brooks/ Cole Publishing Company.
- Hahn, W. K. (1987). Cerebral lateralization of function: From infancy through childhood. Psychological Bulletin, 101, 376-392.
- Hannay, H. J., Dee, H. L., Burns, J. W., & Masek, B. S. (1981). Experimental reversal of a left visual field superiority for forms. Brain and Language, 13, 54-66.
- Hardyck, C. (1986). Cerebral asymmetries and experimental parameters: Real differences and imaginary variations? Brain and Cognition, 5, 223-239.
- Harper, L. V. & Kraft, R. H. (1986). Lateralization of receptive language in preschoolers: Test-retest reliability in a dichotic listening task. Developmental Psychology, 22, 553-556.
- Harris, A. J. (1974). Harris Tests of Lateral Dominance. New York: The Psychological Corporation.

- Hellige, J. B. (1976). Changes in same-different laterality patterns as a function of practice and stimulus quality. Perception and Psychophysics, 29, 267-273.
- Hellige, J. B. & Sergent, J. (1986). Role of task factors in visual field asymmetries. Brain and Cognition, 5, 200-222.
- Hines, S. (1978). Visual information processing in the left and right hemispheres. Neuropsychologia, 16, 593-600.
- Hiscock, M. (1988). Behavioral asymmetries in normal children. In D.L. Molfese & S.J. Segalowitz (Eds.). Brain lateralization in children. New York: The Guilford Press.
- Hiscock, M., & Kinsbourne, M. (1977). Selective listening asymmetry in preschool children. Developmental Psychology, 13, 217-224.
- Hiscock, M., & Kinsbourne, M. (1987). Specialization of the cerebral hemispheres: Implications for learning. Journal of Learning Disabilities, 20, 130-143.
- Hynd, G. W., Obrzut, J. E., Weed, W., & Hynd, C. R. (1979). Development of cerebral dominance: Dichotic listening in normal and learning-disabled children. Journal of Experimental Child Psychology, 28, 445-454.
- Ingram, D. (1975). Cerebral speech lateralization in young children. Neuropsychologia, 13, 103-105.
- Inhelder, B., & Piaget, J. (1958). The growth of logical thinking from childhood to adolescence. New York: Basic Books, Inc.
- Inhelder, B., & Piaget, J. (1964). The early growth of logic in the child: Classification and seriation. London: Routledge and Kegan Paul.
- Jackson, J.H. (1865, 1876). In J. Taylor (Ed.) (1958). Selected writings of John Hughlings Jackson. New York: Basic Books. Cited in S. Spring & G. Deutsch (Eds.). Left brain, right brain. San Francisco: W. H. Freeman and Company.

- Jones, B., & Anuza, T. (1982). Sex differences in cerebral lateralization in 3- and 4-year old children. Neuropsychologia, 20, 347-350.
- Joynt, R. J. & Goldstein, M. N. (1975). Minor cerebral hemisphere. In Friedlander, W.J. (Ed.) Advances in neurology. Vol. 7. New York: Raven Press.
- Kagan, J. (1979). The form of early development: Continuity and discontinuity in emergent competences. Archives of General Psychiatry, 36, 1047-1054.
- Kamptner, L., Kraft, R. H., & Harper, L. V. (1984). Lateral specialization and social-verbal development in preschool children. Brain and Cognition, 3, 42-50.
- Keil, F. C. (1983). On the emergence of semantic and conceptual distinctions. Journal of Experimental Psychology: General, 112, 357-385.
- Keefe, B., & Swinney, D. (1975) On the relationship of hemispheric specialization and developmental dyslexia. Cortex, 11, 471-481.
- Kerschner, J. R., Thomae, R., & Calloway, R. (1977). Nonverbal fixation control in young children induces a left field advantage in digit recall. Neuropsychologia, 15, 569-576.
- Kimura, D. (1961). Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 15, 166-171.
- Kimura, D. (1963). Speech lateralization in young children as determined by an auditory test. Journal of Comparative and Physiological Psychology, 56, 899-902.
- Kimura, D. (1966). Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 4, 275-285.
- Kimura, D. (1967). Functional asymmetry of the brain in dichotic listening. Cortex, 3, 163-178.
- Kimura, D. (1969). Spatial localization in the left and right visual fields. Canadian Journal of Psychology, 23, 445-448.

- Kimura, D. (1973). The asymmetry of the human brain. Scientific American, 228, 70-78.
- Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. Acta Psychologica, 33, 193-201.
- Kinsbourne, M. (1973). The control of attention by interaction between the cerebral hemispheres. In S. Kornblum (Ed.). Attention and performance V. New York: Academic Press.
- Kinsbourne, M. (1975). The ontogeny of cerebral dominance. Annals of the New York Academy of Sciences, 273, 244-250.
- Kinsbourne, M. (1981). The development of cerebral dominance. In Filskov, S.B. & Boll, T.J. (Eds.) Handbook of clinical neuropsychology. New York: John Wiley & Sons.
- Kinsbourne, M. & Hiscock, M. (1977). Does cerebral dominance develop? In S. J. Segalowitz & F. A. Gruber (Eds.) Language development and neurological theory (pp. 169-191). New York: Academic Press.
- Kitterle, F. L. (1986). Psychophysics of lateral tachistoscopic presentation. Brain and Cognition, 5, 131-162.
- Klatzky, R. L. (1972). Visual and verbal coding of laterally presented pictures. Journal of Experimental Psychology, 96, 439-447.
- Klein, S.P & Rosenfield, W. D. (1980). The hemispheric specialization for linguistic and non-linguistic tactile stimuli in third-grade children. Cortex, 16, 205-212.
- Knox, C. & Kimura, D. (1970). Cerebral processing of nonverbal sounds in boys and girls. Neuropsychologia, 8, 227-237.
- Koenig, O. (1989). Hemispheric asymmetry in the analysis of Stroop stimuli: A developmental approach. Developmental Neuropsychology, 5, 245-260.

- Kohn, B. (1980). Right-hemisphere speech representation and comprehension of syntax after left cerebral injury. Brain and Language, 2, 350-361.
- Kraft, R. H. (1984). Lateral specialization and verbal/spatial ability in preschool children: Age, sex and familial handedness differences. Neuropsychologia, 22, 319-335.
- Krashen, S.D. (1973). Lateralization, language learning, and the critical period: Some new evidence. Language Learning, 23, 63-74.
- Larsen, S. (1984). Developmental changes in the pattern of ear asymmetry as revealed by a dichotic listening task. Cortex, 20, 5-18.
- Lenneberg, E. (1967). Biological foundations of language. New York: John Wiley & Sons.
- Levy, J. (1974). Psychological implications of bilateral asymmetry. In S. Dimond & J.G. Beaumont (Eds.). Hemisphere function in the human brain. London: Paul Elek, Ltd.
- Levy, J. & Trevarthen, C. (1976). Metacognition of hemispheric function in human split-brain patients. Human Perception and Performance, 2, 299-312.
- Levy, J. & Trevarthen, C. (1977). Perceptual, semantic, and phonetic aspects of elementary language processes in split brain patients. Brain, 100, 105-118.
- Ley, R.G. & Bryden, M. P. (1982). A dissociation of right and left hemispheric effects for recognizing emotional tone and verbal content. Brain and Cognition, 1, 3-9.
- Lewandowski, L. (1982). Hemispheric asymmetries in children. Perceptual and Motor Skills, 54, 1011-1019.
- Lewkowicz, D. J. & Turkewitz, G. (1982). Influence of hemispheric specialization in sensory processing on reaching in infants: Age and gender related effects. Developmental Psychology, 18, 301-308.

- Licht, R., Kok, A., Bakker, D.J., & Bouma, A. (1986). Hemispheric distribution of ERP components and word naming in preschool children. Brain and Language, *27*, 101-116.
- Lokker, R. & Morais, J. (1985). Ear differences in children at two years of age. Neuropsychologia, *23*, 127-129.
- Luria, A.R. (1970). The functional organization of the brain. Scientific American, *222(3)*, 66-78.
- Marcel, T. & Rajan, P. (1975). Lateral specialization for recognition of words and faces in good and poor readers. Neuropsychologia, *13*, 489-497.
- Markman, E. M. & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic relations. Cognitive Psychology, *16*, 1-27.
- McKeever, W. F. (1986). Tachistoscopic methods in neuropsychology. In H. J. Hannay (Ed.). Experimental techniques in human neuropsychology. New York: Oxford University Press.
- McKeever, W. F., & Huling, M. D. (1971). Lateral dominance in tachistoscopic word recognition performances obtained with simultaneous bilateral output. Neuropsychologia, *9*, 15-20.
- McKeever, W. F., & VanDeventer, A.D. (1975). Dyslexic adolescents: Evidence of impaired visual and auditory language processing associated with normal lateralization and visual responsivity. Cortex, *11*, 361-378.
- Medin, D. C., & Schaffer, M. M. (1978). Context theory of classification learning. Psychological Review, *85*, 207-238.
- Mervis, C. B., & Pani, J. R. (1980). Acquisition of basic object categories. Cognitive Psychology, *12*, 496-522.

- Meyer-Bahlburg, Bruder, G.E., Feldman, J. F., Ehrhardt, A. A., & Healey, J. M. (1985). Cognitive abilities and hemispheric lateralization in females following idiopathic precocious puberty. Developmental Psychology, 21, 878-887.
- Milanti, F. J., & Cullinan, W. I. (1974). Effects of age and word frequency on object recognition and naming in children. Journal of Speech and Hearing Research, 17, 373-385.
- Miller, L. K. (1984). Sources of visual field interference in children and adults. Journal of Experimental Child Psychology, 37, 141-157.
- Miller, L. K., & Turner, S. (1973). Development of hemifield differences in word recognition. Journal of Educational Psychology, 65, 172-176.
- Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. British Medical Bulletin, 27, 272-277.
- Molfese, D.L. & Betz, J. C. (1988). Electrophysiological indices of the early development of lateralization for language and cognition, and their implications for predicting later development. In D.L. Molfese & S. J. Segalowitz (Eds.). Brain lateralization in children. New York: The Guilford Press.
- Molfese, D., Freeman, R., Jr., & Palermo, D. (1975). The ontogeny of brain lateralization for speech and nonspeech stimuli. Brain and Language, 2, 356-368.
- Molfese, D. L. & Hess, (1978). Speech perception in nursery school age children: Sex and hemisphere differences. Journal of Experimental Child Psychology, 26, 71-84.
- Molfese, D. L., & Molfese, V. J. (1979a). Hemisphere and stimulus differences as reflected in the cortical responses of newborn infants to speech stimuli. Developmental Psychology, 15, 505-511.
- Molfese, D. L., & Molfese, V. J. (1979b). VOT distinctions in infants: Learned or innate? In J. Whitaker & H. A. Whitaker (Eds.). Studies in neurolinguistics (Vol. 4). New York: Academic Press.

- Molfese, D. L. & Molfese, V. J. (1980). Cortical responses of preterm infants to phonetic and nonphonetic speech stimuli. Developmental Psychology, 16, 574-581.
- Molfese, D. L. & Molfese, V. J. (1988). Right hemisphere responses from preschool children to temporal cues contained in speech and nonspeech: Electro-physiological correlates. Brain and Language, 33, 245-249.
- Molfese, D. L. & Segalowitz, S. J. (Eds.) (1988). Brain lateralization in children. New York: The Guilford Press.
- Molfese, D. L. & Schmidt, A. (1983). An auditory evoked potential study of consonant perception in different vowel environments. Brain and Language, 18, 57-70.
- Morris, R., Bakker, D., Satz, P., & Van der Vlugt, H. (1984). Dichotic listening ear asymmetry: Patterns of longitudinal development. Brain and Language, 22, 49-66.
- Moscovitch, M. (1977). The development of lateralization of language functions and its relation to cognitive and linguistic development: A review and some theoretical speculations. In S.J. Segalowitz & F.A. Gruber (Eds.). Language development and neurological theory (pp. 193-211). New York: Academic Press.
- Moscovitch, M. (1983). The linguistic and emotional functions of the normal right hemisphere. In E. Perecman (Ed.). Cognitive processing in the right hemisphere. New York: Academic Press.
- Nagafuchi, M. (1970). Development of dichotic and monaural hearing abilities in young children. Acta Otolaryngologica, 69, 409-414.
- Obrzut, J. E., Boliek, C. A., & Obrzut, A. (1986). The effect of stimulus type and directed attention on dichotic listening with children. Journal of Experimental Psychology, 41, 198-209.
- Odom, R. D., & Cook, G. L. (1984). Perceptual sensitivity, integral perception, and the similarity classifications of preschool children and adults. Developmental Psychology, 20, 560-567.

- Orton, S. T. (1937). Reading, writing and speech problems in children. New York: W. W. Norton.
- Paivio, A. (1971). Imagery and verbal processes. New York: Holt, Rinehart and Winston.
- Penk, W. E. (1969). Developmental patterns of conceptual area analysis of children's object sorting responses. Proceedings, 77th Annual Convention, APA, 255-256.
- Piaget, J. (1952). The origins of intelligence in children. New York: International Universities Press.
- Piaget, J., & Inhelder, B. (1969). The psychology of the child. New York: Basic Books, Inc.
- Piazza,, D. M. (1977). Cerebral lateralization in young children as measured by dichotic listening and finger tapping tasks. Neuropsychologia, 15, 417-425.
- Quinn, P. C. & Bomba, P. C. (1986). Evidence for a general category of oblique orientations in four month-old infants. Journal of Experimental Child Psychology, 42, 345-354.
- Reynolds, D. McQ., & Jeeves, M. A. (1978). A developmental study of hemisphere specialization for alphabetical stimuli. Cortex, 14, 259-267.
- Reynolds, D. McQ., & Jeeves, M. A. (1978). A developmental study of hemisphere specialization for recognition of faces in normal subjects. Cortex, 14, 511-520.
- Rhodes, L. E., Dustman, R. E., & Beck, E. C. (1969). The visual evoked response: A comparison of bright and dull children. Encephalography and Clinical Neurophysiology, 27, 364-372.
- Ricco, R.B. (1989). Operational thought and the acquisition of taxonomic relations involving figurative dissimilarity. Developmental Psychology, 25, 996-1003.
- Richlin, M., Weisinger, M., Weinstein, S., Giannini, M., & Morgenstern, M. (1971). Interhemispheric asymmetries of evoked cortical responses in retarded and normal children. Cortex, 7, 98-105.

- Roberts, K. (1988). Retrieval of a basic level category in prelinguistic infants. Developmental Psychology, 24, 21-27.
- Rosch, E. H. (1973). Natural categories. Cognitive Psychology, 5, 328-350.
- Rosch, E., & Mervis, C. B. (1978). Children's sorting: A reinterpretation based on the nature of abstraction in natural categories. In M. S. Smart & P. C. Smart (Eds.) Preschool children- development and relationships (2nd edition). New York: MacMillan Publishing Co., Inc.
- Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M. & Boyes-Braem, P. (1976). Basic objects in natural categories. Cognitive Psychology, 8, 382-439.
- Rose, S. A. (1984). Developmental changes in hemispheric specialization for tactual processing in very young children: Evidence from cross-modal transfer. Developmental Psychology, 20, 568-574.
- Rose, S. A. (1985). Influence of concurrent auditory input on tactual processing in very young children: Developmental changes. Developmental Psychology, 21, 168-175.
- Rose, S. A. (1988). Shape recognition in infancy: Visual integration of sequential information. Child Development, 59, 1161-1176.
- Rosenblum, D. R., & Dorman, M. F. (1978). Hemispheric specialization for speech perception in language deficient kindergarten children. Brain and Language, 6, 378-339.
- Ross, E. D., & Mesulam, M. M. (1979). Dominant language functions of the right hemisphere: Prosody and emotional gesturing. Archives of Neurology, 36, 144-148.
- Ross, G. (1980). Categorization in 1- to 2-year-olds. Developmental Psychology, 16, 391-396.
- Rudel, R. G., Denckla, M. B., & Hirsch, S. (1977). The development of left-hand superiority for discriminating Braille configurations. Neurology, 27, 160-164.

- Sadick, T. L. & Ginsburg, B. E. (1978) The development of the lateral functions and reading ability. Cortex, 14, 3-11.
- Saxby, L., & Bryden, M. P. (1984). Left-ear superiority for children for processing auditory emotional material. Developmental Psychology, 20, 72-80.
- Saxby, L., & Bryden, M. P. (1985). Left visual-field advantage in children for processing visual emotional stimuli. Developmental Psychology, 21, 253-261.
- Schneiderman, E. I. (1986). Leaning to the right: some thoughts on hemisphere involvement in language acquisition. In J. Vaid (Ed.) Language processing in bilingualism: Psycholinguistics and neuro-psychological perspectives. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Schulman-Galambos, C. (1977). Dichotic listening in elementary and college students. Neuropsychologia, 15, 577-584.
- Searleman, A. (1977). A review of right hemisphere linguistic capabilities. Psychological Bulletin, 84, 503-528.
- Segalowitz, S. (1986). Validity and reliability of noninvasive lateralization measures. In J. E. Obrzut & G. W. Hynd (Eds.). Child neuropsychology (Vol.1). New York: Academic Press.
- Segalowitz, S. J., & Bryden M. P. (1983). Individual differences in hemispheric representation of language. In S. Segalowitz (Ed.). Language functions and brain organization. New York: Academic Press.
- Segalowitz, S. J. & Chapman, J. S. (1980). Cerebral asymmetry for speech in neonates: A behavioral measure. Brain and Language, 9, 281-288.
- Semmes, J. (1968). Hemispheric specialization: A possible clue to mechanism. Neuropsychologia, 6, 11-26.
- Sergent, J. (1982). Basic determinants in visual-field effects with special reference to the Hannay et al. (1981) study. Brain and Language, 16, 391-396.

- Sergent, J. (1986). Prolegomena to the use of the tachistoscope in neuropsychological research. Brain and Cognition, 5, 127-130.
- Sergent, J., & Hellige, J. B. (1986). Role of input factors in visual-field asymmetries. Brain and Cognition, 5, 174-199.
- Sergent, J., & Lorber, E. (1983). Perceptual categorization in the cerebral hemispheres. Brain and Cognition, 2, 39-54.
- Shankweiler, D., & Studdert-Kennedy, M. (1967). Identification of consonants and vowels presented to left and right ears. Quarterly Journal of Experimental Psychology, 19, 59-63.
- Sherman, T. (1985). Categorization skills in infants. Child Development, 56, 1561-1573.
- Sidtis, J., & Bryden, M. P. (1978). Asymmetrical perception of language and music: Evidence for independent processing strategies. Neuropsychologia, 16, 627-632.
- Siegel, S. (1956). Nonparametric statistics for the behavioral sciences. New York: McGraw Hill Book Company, Inc.
- Silverberg, R., Gordon, H. W., Pollack, S., & Bentin, S. (1980) Shift of visual field preference for Hebrew words in native speakers learning to read. Brain and Language, 11, 99-105.
- Smith, A. (1966). Speech and other functions after left (dominant) hemispherectomy. Journal of Neurology, Neurosurgery and Psychiatry, 29, 476-471.
- Smith, A. (1969). Nondominant hemispherectomy. Neurology, 19, 442-445.
- Smith, A., & Burkland, C. W. (1966). Dominant hemispherectomy: Preliminary neuropsychological sequelae. Science, 129, 1280-1282.
- Smith, C. L. (1979). Children's understanding of natural language hierarchies. Journal of Experimental Child Psychology, 27, 437-458.

- Smith, L. B. (1979). Perceptual development and category generalization. Child Development, 50, 705-715.
- Smith, L. B. (1981). Importance of the overall similarity of objects for adults' and children's classifications. Journal of Experimental Psychology: Learning, Memory, and Cognition, 12, 147-154.
- Smith, L. B. & Kemler, D. G. (1977). Developmental trends in free classification: Evidence for a new conceptualization of perceptual development. Journal of Experimental Child Psychology, 24, 279-298.
- Snodgrass, J. G., & McCullough, B. (1986). The role of visual similarity in picture categorization. Journal of Experimental Psychology: Learning, Memory, and Cognition, 12, 147-154.
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. Journal of Experimental Psychology: Human Learning and Memory, 6, 174-215.
- Springer, S., & Deutsch, G. (1981). Left brain, right brain. San Francisco: W. H. Freeman and Co.
- Strauss, M. S. (1979) Abstraction of prototypical information by adults and 10-month-old infants. Journal of Experimental Psychology: Human Learning and Memory, 5, 618-632.
- Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1984). The Stanford-Binet intelligence scale: Fourth edition. Chicago: The Riverside Publishing Company.
- Tomlinson-Keasey, C., Kelly, R. R., & Burton, J. K. (1978). Hemispheric changes in information processing during development. Developmental Psychology, 14, 214-223.
- Torrance, E. P. (1987). Some evidence regarding development of cerebral lateralization. Perceptual and Motor Skills, 64, 261-262.

- Turkewitz, G. (1988). A prenatal source for the development of hemispheric specialization. In D.L. Molfese and S.J. Segalowitz (Eds.). Brain lateralization in children. New York: The Guilford Press.
- Turkewitz, G., & Ross-Kossak, P. (1984). Multiple modes of right- hemisphere information processing: Age and sex differences in facial recognition. Developmental Psychology, 20, 95-103.
- Turner, S., & Miller, L. K. (1975). Some boundary conditions for laterality effects in children. Developmental Psychology, 11, 342-352.
- Tversky, B. (1985). The development of taxonomic organization in named and pictured categories. Developmental Psychology, 21, 1111-1119.
- Tversky, B. (1989). Parts, partonomies, and taxonomies. Developmental Psychology, 25, 983-995.
- Urcuioli, P. J., Klein, R. M., & Day, J. (1981). Hemispheric differences in semantic processing: Category matching is not the same as category membership. Perception and Psychophysics, 29, 343-351.
- Uyeda, K. M. & Mandler, G. (1980). Prototypicality norms for 28 semantic categories. Behavior Research Methods & Instrumentation, 12, 587-595.
- Vargha-Khadem, F., & Corballis, M. C. (1979). Cerebral asymmetry in infants. Brain and Language, 8, 1-9.
- Vygotsky, L. S. (1962). Thought and language. Cambridge, Mass.: MIT Press.
- Wada, J. A., Clark, R., & Hamm, A. (1975). Cerebral hemispheric asymmetry in humans. Archives of Neurology, 32, 239-246.
- Warrington, E. K. & Taylor, A. M. (1978). Two categorical stages of object recognition. Perception, 7, 695-705.

- Watson, E. S., & Engle, R. W. (1982). Is it lateralization, processing strategies, or both that distinguishes good and poor readers? Journal of Experimental Child Psychology, 34, 1-19.
- Weinstein, S., & Sersen, E. A. (1961). Tactual sensitivity as a function of handedness and laterality. Journal of Comparative and Physiological Psychology, 54, 665-669.
- White, M. J. (1972). Hemispheric asymmetries in tachistoscopic information processing. British Journal of Psychology, 63, 497-508.
- White, T. G. (1982). Naming practices, typicality, and underextension in child language. Journal of Experimental Child Psychology, 33, 324-346.
- Whitney, P. & Kunen, S. (1983). Development of hierarchical conceptual relationships in children's semantic memories. Journal of Experimental Child Psychology, 35, 278-293.
- Wiegel-Crump, C. A., & Dennis, M. (1986). Development of word-finding. Brain and Language, 27, 1-23.
- Witelson, S. F. (1974). Hemispheric specialization for linguistic and nonlinguistic tactual perception using a dichotomous stimulation technique. Cortex, 10, 3-17.
- Witelson, S. F. (1976). Abnormal right hemisphere specialization in developmental dyslexia. In (Eds.) Neuropsychology of Learning Disorders. New York: Academic Press.
- Witelson, S. F. (1977a). Early hemisphere specialization and interhemispheric plasticity: An empirical and theoretical review. In S. J. Segalowitz & F. A. Gruber (Eds.) Language development and neurological theory. New York: Academic Press.
- Witelson, S. F. (1977b). Neural and cognitive correlates of developmental dyslexia: Age and sex differences. In C. Shagass, S. Gershon, & A. J. Friedhoff (Eds.). Psychopathology and brain dysfunction (15-49). New York: Raven Press.

- Witelson, S. F., & Pallie, W. (1973). Left hemisphere specialization for language in the newborn: Neuroanatomical evidence of asymmetry. Brain, 96, 641-646.
- Woods, B. T., & Carey, S. (1979). Language deficits after apparent clinical recovery from childhood aphasia. Annals of Neurology, 6, 405-409.
- Woodworth, R. S. (1938). Experimental Psychology. New York: Holt.
- Yamamoto, M. (1984). Intra- and interhemispheric tactile identification matching in young children. Japanese Psychological Research, 26, 120-124.
- Yeni-Komishian, G. H., & Benson, D. A. (1976). Anatomical study of cerebral asymmetry in the temporal lobe of humans, chimpanzees, and rhesus monkeys. Science, 192, 387-389.
- Young, A. W. & Bion, P. J. (1979). Hemispheric laterality effects in the enumeration of visually presented collections of dots by children. Neuropsychologia, 17, 99-102.
- Young, A. W., & Bion, P. J. (1980). Absence of any developmental trend in right hemisphere superiority for face recognition. Cortex, 17, 97-106.
- Young, A. W., & Bion, P. J. (1981a). Accuracy of naming laterally presented known faces by children and adults. Cortex, 17, 97-106.
- Young, A. W. & Bion, P. J. (1981b). Identification and storage of line drawings presented to the left and right cerebral hemispheres of adults and children. Cortex, 17, 459-464.
- Young, A. W., Bion, P. J., & Ellis, H. D. (1980). Studies toward a model of laterality effects for picture and word naming. Brain and Language, 11, 54-65.
- Young, A. W., Bion, P. J., & Ellis, H. D. (1982). Age of reading acquisition does not affect visual hemifield asymmetries for naming imageable nouns. Cortex, 18, 477-482.

- Young, A. W. & Ellis, H. D. (1976). A experimental investigation of developmental differences in ability to recognize faces presented to the left and right cerebral hemispheres. Neuropsychologia, 14, 495-498.
- Younger, B. A. (1985). The segregation of items into categories by ten-month-old infants. Child Development, 56, 1574-1583.
- Zangwill, O. L. (1964). The current status of cerebral dominance. In Disorders of communication. Association for Research in Nervous and Mental Disease, 42, 103-118.