Order Number 9432845

The relationship between memory for category and memory for specific instance

Wilkes, Glenda Garrett, Ph.D.

The University of Arizona, 1994

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

THE RELATIONSHIP BETWEEN MEMORY FOR CATEGORY AND MEMORY FOR SPECIFIC INSTANCE

by

Glenda Garrett Wilkes

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 9 4

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Glenda Garrett Wilkes

entitled The Relationship Between Memory for Category and Memory for Specific Instance

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Shitala P. Mishra	5-23-94
Shitala P. Mishra, PhD	Date
Mary M. McCaslin	5-23-94
Mary M. McCaslin, PhD	Date
T. L. Good	5-25-94
Thomas L. Good, PhD	Date
	Date
	Date

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Shitala P. Mishra	5-25-94
Dissertation Director	Date
Shitala P. Mishra, PhD	

STATEMENT BY AUTHOR

Signed: Glenda Garrett Wilkes

ACKNOWLEDGMENTS

I would like to thank the director of this effort, Shitala P. Mishra, for his guidance and support during my graduate program and his assistance in the successful completion of this doctoral dissertation. In addition, I express deepest gratitude for the insight, commitment, and integrity of Mary McCaslin and Thomas L. Good, my committee members. A special thanks to Rosemary Rosser and Carol Sigelman who served thoughtfully and well as my minor committee in Psychology. I acknowledge the contribution of Valerie F. Reyna during the early stages of this work, John Fulginiti for his assistance with the data analysis, and Jessie Fryer for her keen eye for detail.

My appreciation is expressed to my parents, Lee and Vene Garrett, who taught me the importance of self-discipline and how to finish a task, and to my maternal grandmother, Dr. Sadie Criswell Stewart, who was an inspiration to me. For their patience and understanding during the long years of graduate school, I thank my children -- Kendall, Tyler, Christopher, Aubry, Adam, Amber, Courtney, and Garrett. And to my husband and friend, Jim, whose encouragement and optimism made this seem possible, I express my love and gratitude.

This work is dedicated to my mother, Alma Vene Stewart Garrett, whose example of constancy and unqualified support has been a guiding force in my life.

TABLE OF CONTENTS

TABLE OF CONTENTS--*Continued*

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

Cognitive scientists have long endeavored to clarify the process by which human beings classify or categorize information. The study discussed here attempts to uncover the underlying nature of the categorization process in children and adults by examining access to information at retrieval. Previous work has suggested that two separate memory systems, memory for the category itself and memory for the specific instance of the category, may exist. This study attempts to further investigate the nature of these two memory systems, their relationship to each other, and their contribution to the process of categorization in children and adults.

Using the prototype plus distractor paradigm, children and adults were asked to categorize a set of visual stimuli, and give confidence ratings for their judgments. The findings in this study suggest that memory for category and memory for specific instance are separate and distinct, and can be selectively accessed according to the demands of the task across age groups. Developmental differences are in

the form of a U-shaped, non-monotonic path. Findings are consistent with a portrayal of memory as a continuum, with age as one factor in freedom of movement along such a continuum.

CHAPTER 1

INTRODUCTION

Without the ability to make conceptual distinctions, the mental life of each of us would be chaos. If each entity were perceived as unique, requiring a distinct name, language would be overwhelmingly complex and communication virtually impossible. Making conceptual distinctions is an attribute that gives our world stability in that concepts capture the notion that many objects or events are alike in some respects. The question of what makes things seem alike or seem different is fundamental to cognition. The core of cognitive development is the acquisition of knowledge of the world around us, but knowledge acquisition is more than the mere accumulation of facts. According to the currently dominant information processing model, knowledge is organized into concepts and categories which promote efficient encoding, storage, and retrieval of the millions of facts accumulated in a lifetime of experience. In short, concepts are critical for perceiving, remembering, and thinking about objects and events in the world.

Cognitive scientists have long endeavored to clarify the process by which human beings classify or categorize information. Much research on concept formation has focused on the types of abstractions that are formed at encoding (Wattenmaker, 1992). But we are often required to retrieve and analyze information in light of objectives that were not apparent at encoding, such as when we must make generalizations about many instances rather than a single case.

This process is particularly salient in classrooms, where the ability to make classification judgments is prerequisite to success in school. In the domains of language and math, for example, it is possible for transfer of learning to occur when common features of many instances can be seen. Categorization, or the ability to see common features and form categories from them, is a critical building block in the higher level process of problem solving (Siegler, 1976; Klahr & Siegler, 1978; and Gelman & Gallistel, 1978). Without some process of categorization, every instance must be learned anew. Although this is a topic of debate, this particular literature defines transfer of learning as seeing commonalities among diverse problems which allows problem solvers to apply previously learned solutions. Forming categories based on how things are alike or different aids in this transfer.

The study discussed here attempts to uncover the underlying nature of the categorization process in children and adults by examining access to information at retrieval. Previous work has suggested that two separate memory systems, memory for the category itself and memory for the specific instance of the category, may exist. This study attempts to further investigate the nature of these two memory systems, their relationship to each other, and how they may contribute differently to the process of categorization in children and adults.

The existence of two memory systems has been addressed by Boswell & Green (1982) and Knowlton, Ramus, & Squire (1992). Knowlton, Ramus, & Squire present evidence for the existence of two separate memory systems that appear to operate independently of one another in adults. Boswell & Green found that adults were unable to access memory for the specific instance. One may ask upon reading Boswell & Green if an interference effect was present that prohibited adults from being able to access memory for specifics. The existence of two memory systems in both adults and children, and the possibility of an interference effect which limits access to one system or the other, is a question that has not been addressed to date. This study was designed to test such an effect. By addressing the questions above, the additonal question of whether access to categorical knowledge differs developmentally, and what the nature of those differences might be, can also be addressed.

For example, Knowlton, Ramus, & Squire (1992) suggest that the actual instances of a category (each individual chair in a person's house) are stored in explicit memory and are separate and distinct from information abstracted about those individual instances (either associations betweeen them or some type of prototype representing all chairs) which is stored in implicit memory. Knowlton, Ramus, & Squire present evidence for the existence of two separate memory systems by testing normal and amnesic adults. One issue addressed here is whether these two memory systems are present in children.

If evidence suggests that two systems indeed exist, then the question follows of whether the relationship between those two systems is similar across development. It would be possible for each system to aid, hinder, or operate independently of the other, and for that balance to differ in children and adults. That is the second issue addressed here.

CHAPTER 2

LITERATURE REVIEW

The origins of psychological theory about how concepts are represented in humans go back to Aristotle, while in experimental psychology the roots can be traced to Hull's 1920 monograph on concept attainment. The concept of a "schema" as an entity mediating the effects of past experience has been prominent in psychology chiefly because of the thinking of Bartlett (1932). Woodworth (1938) modified Bartlett's original notion of a schema by concluding that a new configuration is usually remembered in terms of a "schema with correction." Hebb (1949) elaborated on the notion of a schema to include some representation of the central tendency or commonality of a class of objects. Attneave (1957) suggested that the use of schemata makes for economical information storage and also that learning a class of schemata makes easier the subsequent learning of identifying responses to members of that class.

Models of learning imply that the learning of a task is facilitated if it is similar to another task that is already part of the learner's repertoire (Thorndike, 1966). Stimulus generalization occurs as a function of how similar the new stimulus is to the conditioned stimulus (Pavlov, 1927). In memory models it has been assumed that X reminds people of Y if it is similar to Y (Kolodner, 1984).

In the past, Piaget, Vygotsky, Bruner, and other theorists have argued that the nature and organization of young children's mental categories differ qualitatively from those of adults (Gelman & Baillargeon, 1983). However, recent evidence suggests fewer and less fundamental differences between the two age groups (Carey, 1985a). For example, as Flavell (1985) suggests, children's representations of class-inclusion relations are not qualitatively different from those of older people. Four-year-olds can make valid inferences based on qualitative class-inclusion representations although even older children have difficulty correctly answering quantitative class-inclusion questions of the sort Inhelder and Piaget (1964) made famous.

In theories of categorization it has been assumed that classification of new examples is based on their similarity to known examples or to a category prototype (Medin & Smith, 1984). A framework for discussing the status of current research in the area of concept formation comes from Smith & Medin's (1981) discussion of the three views of the categorization process. Additionally, Rosch, Mervis, Gray, Johnson, & Boyes-Braem (1976) identify "basic level access" and its characteristics, which is elaborated upon by Tanaka (1991). After a discussion of the above background, I move to the two major areas of research in this field which are the acquisition of natural categories (Carey, 1985b; Keil, 1989, 1991), and the acquisition of artificial categories (Attneave, 1957; Posner & Keele, 1968, 1970; and Boswell & Green, 1982). Finally, drawing from a discussion of the prototype-plus-distractor paradigm, which is a subset of the literature on the acquisition of artificial categories, I discuss the rationale for the study described here.

Smith & Medin (1981), in their review of concept acquisition, outline three views of the nature of this central tendency that defines a class of objects. In the first, the classical view, all instances of a concept share common properties. For example, all squares have four sides and even though they may be embedded in other, more complex patterns, the elementary distinguishing properties of all squares have four sides as a common property. The second or probabilistic view states that it is possible for instances to vary in the degree to which they represent the concept. For example, there are many kinds of cups: coffee cups, tea cups, soup mugs, etc. Some have more critical properties than others and are therefore more representative of the concept. Teacups in Chinese restaurants, although not an exception to the category, are at least less representative of the category in that they have no handle and are very small, yet we still recognize them and include them in the category "cups". The third view of central tendency is the exemplar view, in which there is no single representation of an entire concept, but only the specific representations of each exemplar. We may loosely group together people with suicidal tendencies as a category, and yet there would be a separate and possibly different description for each member of the class.

The probabilistic view offers the most flexible approach for education because for many of the concepts taught in school, the instances of the concept are not so simple as to be identical (such as squares), yet are not so idiosyncratic as to be each an instance unto itself (such as people with suicidal tendencies).

Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976), in their classic research on conceptual hierarchies, showed that there is a basic level which plays a primary role in cognition. This basic level is the most inclusive level at which a generalized category of exemplars is identifiable and imaginable. Basic level category labels, such as table, bird, or car, are the first names learned by children. In a series of experiments, Rosch et al. found that subjects used basic level names more frequently to identify objects than either superordinate (furniture, animal, or vehicle) or subordinate level names (coffee table, robin, or sedan). Subjects were also faster to categorize objects at the basic level than the other levels. Rosch et al. interpreted these findings as indicating that people first identify objects at the basic level and then access the superordinate or subordinate categories.

Rosch et al. assumed that in the perceived world, information-rich bundles of perceptual and functional attributes occur, and that basic cuts in categorization are made as these discontinuities. Basic level categories depend not on the objects themselves, independent of people, but on the interaction between the human perceiver and the world, and the ways in which that interaction occurs. This work comes out of the Gestalt tradition which emphasized the perceived value of things. Fruit says "eat me"; water says "drink me"; thunder says "fear me". This tradition is alive in the concept of affordances (Gibson, 1982). Affordances relate the utility of things to the needs of the animals or humans and their actions in fulfilling them. A mailbox affords mailing a letter, even if one has no letter to mail. The essence of the concept of affordance is a person acting in reciprocity with his or her environment. This sense of reciprocity, according to Rosch et al., is a factor in determining basic level access. Domain-specific knowledge was important in determining basic level access such that a subject who was an airplane mechanic answered questions about airplanes differently than subjects with little expertise in that domain.

Tanaka (1991), building on the work of Rosch and her colleagues, addressed the question of whether there is change in the structure of classification hierarchies in object categorization with expertise. Tanaka found that experts added the same number of attributes at the subordinate level as at the basic level, indicating that bird experts knew as much about the distinguishing properties of "robin" and "crow" as "bird", whereas in the novice domain, subjects listed more attributes at the basic level. Tanaka concluded that expert knowledge was primarily organized at the subordinate level rather than at the basic level. This suggests that the various mechanisms operating in the building of expertise are one vehicle for the move from basic to subordinate level access.

Additionally, Tanaka (1991) found that the types of knowledge differed with domains, so that behavioral features distinguished bird experts and novices but not dog experts, suggesting that behavioral cues such as habitat and feeding activity are important in bird expertise but in different domains the distinguishing features may be unique. It follows that subordinate level is accessed by different routes, depending on the requirements for expert knowledge in a given domain. Diamond & Carey (1986), for example, found that within the domain of dog expertise, subjects were experts only for those breeds in which they specialized.

Rosch et al. (1976) predicted that when an object was first perceived, it would be categorized at the basic level of abstraction. Biederman (1987) referred to this initial contact as primal access, and Jolicoeur et al. (1984) referred to it as the entry point. This basic level advantage is a function of two things: distinctiveness and specificity (Murphy & Brownell, 1985). Distinctiveness refers to how dissimilar a category is, and specificity refers to how specific or informative a category is. Superordinate categories are highly distinctive, but not very informative (eg., tipped-wing woodthrush), whereas subordinate level categories are highly informative, but not very distinctive (eg., animal). Therefore, the basic level (eg., bird) represents the optimal level of categorization for general use because it is both specific and distinctive. However, Tanaka (1991) found that expertise enhanced the speed at which subordinate level categories were accessed, making them at least as accessible for experts as basic level categories. This suggests that different amounts of knowledge about objects changes the classification schema, so that subordinate level categories may require a more quantitative visual analysis than is needed at the basic level. The basic level for a bird expert may become robin, woodthrush, and hummingbird -- categories considered to be at the subordinate level for novices. Tanaka refers to this as the "downward shift hypothesis", whereas Rosch considered the possibility that experts create multiple basic levels. Tanaka concluded that while stimulus structure and the human perceptual system impose certain constraints, human categorization appears to be continually reshaped and altered by learning and experience.

Acquisition of Natural Kinds

Two prominent authors in the area of natural categories, who have studied extensively the acquisition of biological knowledge, are Susan Carey and Frank Keil. Based on series of experiments, they have each reached different conclusions, and their work makes an interesting analogue to the artificial category literature.

Carey (1985b) discusses an extensive investigation of conceptual change in children's intuitive theories of biology including: living thing, animal, person, individual animals and plants, and bodily processes. I will briefly review the findings for each category and then discuss her conclusions.

The differences between the child's and adult's concept of what is alive has a semantic component but is not only semantic. Since children do not understand death as the cessation of bodily functions, they conflate the difference between "alive" and "dead" with other contrasts such as "real" and "imaginary", and "functional" and "broken". For example, young children say that a button is alive because you can fasten it, and that a table is alive because you can see it. This kind of reasoning has been called egocentrism by Piaget.

In addition to this semantic component, children are not able to extend the concept of "living thing" to include both plants and animals in a single category. Of the 4 to 7 year-olds tested there was inconsistency in what was judged to be alive. None of the children in this age-group judged all animals and plants to be alive, while at the same time denying life to inanimate objects. Those children who denied life to inanimate objects also denied that plants are alive. Thus the category "alive" is defined differently for young children.

When told by the researcher that dogs and flowers both have golgi (a nonsense word used to refer to a characteristic of dogs and flowers), 6 year-olds could not infer that all and only living things have golgi. Also, not only do children not consider plants to be alive, they consider it a mistake to attribute basic biological states to them such as "being sick" or "starving". In other words, they judge "The flower is starving" to be nonsense, just like "The idea weighs 15 pounds." The basic categories of animal and plant have not yet merged into a single type -- living thing. By age 10, however, children display the adult pattern of responses.

"Animal" functions differently in the thought of young children than 10 year-olds and adults. Although young children attribute animal properties to animals and not to inanimate objects like animals (stuffed animals), they do not realize that all animals eat, breathe, and reproduce. Also, from the knowledge that dogs and bees both have some internal organ, they do not infer that all animals probably also have that organ. Carey (1985b) concludes that young children see animals as behaving beings, whereas the 10 year-old and adult see them as biological beings as well.

It is important to acknowledge that the environment socializes the content of cognition such that the above developmental patterns are also impacted by the fact that by 10 years of age, children are being taught biological concepts in school, and are more responsible for the biological well-being of pets as well as themselves. In other words, the socialization of thought and the cognitive construction of thought may be two different things that are at least influenced by one another.

Young children have a vast amount of knowledge about "people". They know that people live, think, have hearts, have bones, and breathe. Preschool children even have an elaborate theory of mind. Yet, there are changes, here also, between ages 4 and 10. If taught with respect to people, a newly taught internal organ was credited to other animals according to their similarity of those other animals to people; but if taught on dogs or bees, the organ was not projected to people also. By age 10, children see people as just one mammal among many.

With regard to individual plants and animals, young children think that a skunk submitted to cosmetic changes can become a racoon. By age 9, children see this as impossible. Five year-olds think category membership is determined by appearance and behavior; 9 year-olds think it is determined by deeper biological considerations.

Upon probing children's knowledge of bodily processes, Carey (1985b) found that young children are largely unaware of the organs found inside the human body. The ones they do know operate on the principle of "one organ--one function": the stomach is for eating, the heart is for making blood, the brain is for thinking. Processes such as death, growth, reproduction, and ingestion are thought of in terms of the whole person and not in terms of specialized functions of particular parts of the body. All this has changed by age 10.

Carey (1985b) concludes that the biological theories of young children differ from those of 10 year-olds and adults in three ways: First, the base of young children's knowledge is people. Young children decide what things in the world have certain properties by inferring from the knowledge that people have them. Ten year-olds reason from category membership and knowledge of biological function. Secondly, in 4 year-olds the projection of a property to new animals occurs only when it is taught on people. This does not occur with 10 year-olds and adults. And thirdly, adults integrate information about two animals or living things and infer a superordinate category, whereas children find the object known to have the property that is the most similar to the object probed, and then compute the similarity between the two.

Carey (1985b) concludes that a restructuring of biological knowledge occurs between the ages of 4 and 10. The type of restructuring she proposes is in contrast to conclusions drawn by Keil (1989, 1991) from his extensive work in this area. I will now turn to Keil's work, and then compare the conclusions drawn by Carey and Keil.

Keil (1989) suggests that the most compelling evidence for developmental theory is with "natural kinds" or "properties that tend to cluster in tight bundles separated by relatively empty spaces", and which mutually support each other in a highly interactive manner. For example, feathers, wings, flight, and light weight separate the set of things known as birds into a natural kind.

Keil (1989) explores the development of biological knowledge with concepts such as growth, disease, physiology, reproduction, and inheritance. His strategy is to use physical and psychological causes as foils to test biological ones. An interesting example is a series of experiments conducted on disease. Keil examined what sorts of symptoms are considered contagious, in order to separate the child's perception of what is biologically contagious from what is socially caused. Subjects were presented with a picture of a child visiting another child for a weekend and having the two be in close proximity much of the time.

One child had the symptoms, and the subject was asked if the other child was likely to "catch" those symptoms. Four year-olds and kindergartners adamantly maintained that abnormal behaviors were not contagious. These children had absolutely no doubt that phychological and biological causes could not mix. Keil (1989) suggests that preschoolers have concepts with core explanatory beliefs and that at least some of those core beliefs are domain specific at early ages, in contrast to much of the literature which suggests that preschoolers are domain general associative type learners and only later become domain specific theorists.

Both Carey (1985b) and Keil (1989) deny that intuitive theories of biology, as opposed to those taught in school, emerge out of nothing. Keil suggests that intuitive theories may exist as continuous theories that change and are reinterpreted and adjusted as concepts of natural kinds change. Children may have sets of core beliefs which may be domain specific, so that young children may have weaker theories of biological kinds than older children. But growth of a theory in one domain should not be mistaken for a shift in domain-general mechanisms of learning, according to Keil.

Carey (1985b), on the other hand, proposes that young children try to explain and predict the properties of biological kinds in terms of the principles of a domain-general kind of naive psychology, out of which more specific theories emerge. It is the reorganization of domain specific knowledge of the physical, biological, and social world that accounts for cognitive differences between four-year-olds and ten-year-olds. In contrast, Keil (1989) finds no pattern, even in young children, that their judgments are psychologically driven.

The core of cognitive development is knowledge acquisition, but knowledge acquisition is not just the accumulation of facts. Knowledge is restructured in the course of acquisition, and it is that restructuring that is the essence of conceptual change. Carey (1985b) and Keil (1989) differ as to how that restructuring takes place. Carey suggests that knowledge acquisition is domain general because children have general social and psychological theories upon which they build knowledge of biological phenomenon (Carey, 1985b). Carey suggests that children undergo restructuring in the stronger sense because there are changes in their core beliefs as well as changes in the level of individual concepts. Keil, on the other hand, argues for domain specific knowledge acquisition, where sets of core beliefs are specific to one domain. Keil suggests restructuring takes place in the weaker sense, as in theory emergence, where new theories emerge from old ones and there is overlap between the old and the new.

Acquisition of Artificial Categories

The actual role of experience with previously encoded information as it relates to subsequent learning has been explored as far back as Bartlett (1932) and schema theory. More recently, Attneave (1957) was the first to investigate empirically the hypothesis that the learning of a class schema influences the subsequent learning of identifying responses to additional members of the class. Attneave conducted two experiments utilizing prototypes and a set of variations of those prototypes.

The work of Attneave (1957), Posner (1967, 1968, 1970), and Boswell & Green (1982) represent one small subset of the literature addressing the process of categorization. This subset addresses the acquisition of artificial concepts with quantitative dimensional variations. Within this subset, all based their investigations on a set of visual patterns with the most typical or representative pattern being called the prototype, and a number of distortions of that pattern being generated from the prototype. These stimuli were presented to subjects of different ages in a way that allowed observations to be made about how categories are formed and what kinds of categorical information are remembered over others.

This paradigm, as first utilized by Attneave (1957) and later by Posner & Keele (1968, 1970) is referred to as the prototype-plus-distortion technique. It involves the construction of a prototype which is then used in the construction of a set of additional figures which are just slightly distorted versions of the original prototype. A learning set, consisting of a number of the distortions (also called exemplars because they are members of a category created from the prototype) of two or more prototypes are shown to subjects. Subsequently, additional distortions or exemplars, which have not been seen before (news), as well as the prototypes themselves, and a smaller number of foils or other figures that were not constructed from the prototype are added to the set and the subject is asked to make categorization judgments for the entire set. The process of constructing such a set of stimuli is explained in greater detail in the methods section.

The prototype-plus-distortion paradigm is a useful method for studying category acquisition because it transcends the idiosyncracies of experience inherent in using natural language categories, it is not dependent on past experience, the relations among the exemplars approximate relations found in natural categories, and it utilizes stimuli that are structurally related. One part of this task that is like the real world is that it utilizes new catgory exemplars never seen before in addition to those that have been seen.

In Attneave's (1957) first experiment, the prototypes consisted of a series of letters randomly placed in a matrix so as to form a pattern. Variations were created by changing one letter in the pattern to some other letter. (See Appendix A) Two groups of adult male subjects were each given a pretraining task. One group repeatedly viewed one of the prototypes and was given opportunities to reproduce it, whereas the other group was given an equivalent amount of practice in reproducing a completely irrelevant figure. Both groups were then given a paired-associates learning task in which eight variations of the prototype used in the pretraining of the first group were shown and given a man's name (e.g., Sam, Joe). Six learning trials were given, each followed by a test trial. On test trials, subjects attempted to write the correct name of each pattern. Attneave found 21% less error for the pretrained group (mean error was 36.20 for the control group and 28.47 for the experimental group).

Attneave (1957) followed with Experiment II in which polygons were used instead of letter patterns (see Appendix B), and the same format was followed as in Experiment I. Again, familiarization with the central prototype decreased errors on the paired-associates task. The value of Attenave's work is that it suggests a relationship between the mechanisms associated with schemata, as represented by knowledge of the prototype, and stimulus predifferentiation or subsequent identification of exemplars.

In reviewing the evolution of this literature it is clear that the language is problematic. The terminology is not clear cut nor are traditional definitions adhered to. Perhaps because this literature came from the Gestalt tradition and has now been implanted into the information processing camp, terms such as learning and performance, transfer and generalization, encoding and retrieval, and acquisition and retention are used somewhat carelessly and without accurate definition. I will describe the following literature using the terms of the authors, recognizing at the same time that in places the terms seem to have contradictory implications.

A series of experiments conducted by Posner and his colleagues (Posner, Goldsmith, & Welton, 1967; and Posner & Keele, 1968, 1970), utilizing dot patterns (see Appendix C), further explore the relationship between a prototype and its exemplars. The prototype is the model or the archetype. Posner & Keele (1968) found that adult subjects recognized the central tendency (the prototype) better than the other patterns, even though they had not seen the prototype during the learning phase of the experiment. This suggests, according to Posner & Keele, that adult memory is organized around information that is the most prototypical and pattern-like possible. Even though adult subjects had <u>not</u> seen the prototype during the learning phase, they recognized it as "old" significantly more often than other exemplars (the term "exemplar" refers to any one of the stimuli that fits a category).

Adult subjects learned a set of 12 dot patterns, 4 distortions of each of 3 prototypes. The same day they were shown a transfer set of 3 prototypes, 6 distortions of each, and 3 unrelated figures. Twenty-four hours later subjects completed the pattern recognition task four additional times. Posner & Keele (1968) found that on the same day recognition of previous learned exemplars (olds) and prototypes were equivalent, and that both these classes of stimuli were recognized with higher accuracy than new exemplars (error rates: olds - 10%, prototypes - 13%, news - 35%). After 24 hours, errors increased for new exemplars whereas errors on olds and prototypes remained the same. Posner & Keele found that subjects maintained equivalent error rates for prototypes, which they had never seen, as well as old patterns they had actually seen and memorized, and that those error rates remained constant over 24 hours. They concluded that at the very least, the prototype has a higher probability of recognition than other new patterns contained within a concept. They suggest that central tendency information is abstracted from a set of multi-dimensional patterns and that this abstraction occurs at the prototypical level.

In an attempt to answer the question of when central tendency information is abstracted, Posner & Keele (1970) hypothesized that a time delay would lead to less forgetting for the prototype than other learned instances (old exemplars). In a between-subjects manipulation in which half the adult subjects waited one week and half performed the recognition task immediately after the learning task, Posner & Keele found that in the immediate condition subjects recognizied correctly olds with greater accuracy (80%) than prototypes (68%), and both olds and prototypes better than news (44%). With a one week delay, accuracy in recognition of olds decreased more (from 80% correct to 71%), whereas accuracy for prototypes remained the same (from 68% to 66%) as well as new exemplars (from 44% to 42%). Posner & Keele concluded that these findings are consistent with the idea that abstraction occurs during learning rather than recognition, because more forgetting of the stored exemplars occurred than of stored information concerning the schema or prototype.

The seminal nature of Posner's work comes from his finding that adults falsely identified the prototype as having been seen before. Boswell & Green (1982) suggest that Posner & Keele's findings point to the construction of a central representation or prototype, in adults, which then cannot be discriminated from actual experience. Boswell & Green replicate Posner & Keele's findings, and extend the paradigm to a group of children aged four and six. Boswell & Green found that children could distinguish olds from prototypes, whereas adults could not. In other words, children more accurately rejected prototypes as never having been presented whereas adults were unable to do so. However, children were able to classify prototypes with 90% accuracy, indicating that they have some type of representation of the prototype. These findings suggest that the categorization process is different for children than it is for adults in that children rely on each specific piece of information even though prototypical information is available to them, whereas adults form some type of central representation and then rely heavily on that representation in making classification judgments.

One question that is alluded to by Boswell & Green (1982) is that children have some amount of prototypical knowledge or knowledge of the category, yet still prefer to make categorization judgments based on each specific exemplar. This seems to suggest that children may have two separate memory systems which operate independently of each other.

This particular question was addressed in adults by Knowlton, Ramus, & Squire (1992). They tested the hypothesis that category knowledge and exemplar knowledge were distinct, and that one could develop independently of the other. Because amnesic patients have imparied memory for facts (which is generally termed declarative or explicit memory), but have intact implicit memory, Knowlton, Ramus, &

Squire reasoned that if judgments made after studying exemplars were implicit, then amnesics would have equivalent performance to normal subjects. However, if judgments depended on rules, and are explicit as suggested by Medin & Schaffer (1978), then amnesics should do poorly. Knowlton, Ramus, & Squire found that amnesics identified letter strings (implicit memory) as well as normal subjects but were impaired at recognizing the exemplars which were used to teach the rules. They concluded that classification learning could proceed normally without intact explicit memory. Knowlton, Ramus, & Squire further suggested that these findings support the existence of two independent memory systems in classification learning: one system that stores in explicit memory the actual instances presented to the subject; and a second system that stores implicit information that is abstracted about the stimuli.

The Dependency Question

Although previous studies have revealed important information about the nature of the categorization process, most have relied theoretically on the information processing model, which characterizes memory as operating on a unitary representation. That is, in any given instance, subjects store either the representation of the prototype, the categorical information, <u>or</u> that of the specific exemplar. It follows then that developmental changes, when they occur, would be attributed to a change in the nature of that unitary representation. However, Boswell & Green (1982), and Knowlton, Ramus, & Squire (1992) suggest that more than one type of representation may be available. Recall that children classified prototypes above chance (90%), suggesting that although prototypical information was available, they preferred to utilize specific exemplar information. Boswell & Green also imply that in adults, attention to commonalities may limit processing of specific features and create an interference effect. An interesting question that to date has not been addressed is whether memory for one (specific exemplar or prototype) interferes with memory for the other. No one to date has looked at the relationship between the patterns of errors in a way that would answer the question of dependency or interference.

A dependency analysis has three possible outcomes: positive dependency in which memory for one type of information aids in memory for another; negative dependency in which one type of information interferes with memory for another; and independence in which memory for one is not related to memory for another. The question in this study is whether or not memory for the prototype helps, hinders, or is unrelated to memory for the specific exemplars. A test of the existence of two independent memory systems would be a dependency analysis. In order to test dependency, all subjects must be asked to categorize all exemplars. In other words, the categorize questions (Is it an old one, a new one, or a stranger?) must be a within-subjects manipulation. Boswell & Green (1982) separated the questions into two between-subjects conditions (Is it old? [memory condition] Is it old, new, or stranger? [categorize condition]). This study asks all subjects to categorize in order to test dependency.

Extending methods such as the prototype plus distractor paradigm so that a dependency analysis can be utilized adds important information to what we know about the relationship between memory for specific details and memory for the category or pattern as represented by the prototype. If memory for the specific exemplars somehow interferes with memory for pattern and disallows accuracy, the implications for education are powerful. If this is the case, then overemphasis on detail may result in less actual learning than an emphasis on the overall pattern with the details seen as pieces of the pattern.

In statistics, an example of the overall pattern would be an understanding that most tests of significance involve a ratio in which the numerator represents an estimate of the variance of interest between the groups tested, and the denominator represents an estimate of the error, which consists of both variance among subjects' typical responses within the group as well as variance among measures from the same individual across multiple observations. The pieces might be individual formulas for tests of significance (i.e., T test, F test, etc). If students are required to memorize and reproduce the pieces, without an understanding of the overall pattern and how the pieces are illustrative of that pattern, then the kind of learning that we call understanding may be difficult to achieve.

CHAPTER 3

METHOD

Subjects

Three age groups were selected: kindergartners, second graders, and young adults (undergraduate students). Kindergartners were chosen because they were cognitively able to do the task, yet have not had the kind of full-day school-based learning experiences that older children have had. Second graders were chosen because they are in the middle of the primary grades and thus representative of children with a moderate amount of experience in school. Undergraduate students represented the adult population because they were available to the researcher.

Thirty four preschoolers (32 subjects were between the ages of 5 yrs. 2 mo. and 5 yrs. 11 mo., one subject was 4 yrs. 11 mo. and one was 6 yrs. 1 mo.) from a church-based preschool program and a public school kindergarten, thirty four second graders (aged 7 yrs. 5 mo. to 8 yrs. 6 mo.) from a public elementary school, and thirty four undergraduate students (adults) participated in the study. Both samples of children were primarily middle class and were located in the same geographical area in which the pre-school fed into the elementary school. Middle-class students were used because they were those the district made available to the researcher.

Consent forms were sent home with both groups of children, and those whose parents gave consent for their children to participate in the study made up the sample. Young adult subjects were recruited from undergraduate psychology courses and also signed consent forms. All three groups comprised voluntary samples, and all subjects were assured of confidentiality.

In addition to date of birth, the gender of each subject was recorded. As can be seen in Table 1, gender was not equally distributed among agegroups. Gender effects will not be examined because the author offers no hypotheses regarding the possible influence of gender in memory tasks, in addition to the unequal sample sizes.

Table 1

Subjects

	4/5 Yr Olds	7/8 Yr Olds	Adults
Males	21	25	12
Females	13	9	22

Materials

Stimuli were constructed following the process of Boswell & Green (1982). An 8 by 12 centimeter rectangle was drawn on a piece of graph paper. Each rectangle contained 96 one centimeter squares (8 X 12). Each square was numbered consecutively, except a one row border framing the rectangle which was left free for outward movement of the dots. The resulting rectangle contained 60 numbered squares with a one row border of unnumbered squares (See Appendix D).

Nine numbers were selected from a table of random numbers and a dot was placed in the center of each square that contained one of the nine numbers. When all nine dots were placed in the nine corresponding squares, the dots were connected to form a nine sided polygon (See Appendix D). In this manner several nine-sided polygons were constructed and the two that appeared the most dissimilar to the researcher were chosen to be the prototypes. The most dissimilar polygons were chosen so that the sets of distortions made from each prototype formed clear categories.

Each of the two prototypes was then used as the model from which a set of 10 distortions were constructed. This was done by moving each one of the original dots one centimeter in one of eight directions that were numbered corresponding to the marks on a compass. A table of random numbers was again used to designate the direction of each move. For example, the points of a compass were numbered clockwise from 1 to 8, with 1 being at the top (what would be considered N on a compass) and number 9 being in the center. For the first distortion of prototype I, nine numbers were randomly chosen from a table of random numbers (1, 9, 6, 1, 2, 7, 8, 4, 3). The first dot that had been originally placed in the grid was moved one centimeter in direction 1, the second dot in direction 9, the third in direction 6, and so on until all dots had been displaced When this was accomplished, the dots in their new positions were connected to form a slight distortion of the original prototype, different enough to be distinguishable as a new figure yet similar enough to be distinguishable as a category member (See Appendix E for example of an exemplar).

It was possible to connect the dots of the distortions in two ways: in the same order as they had been connected in the prototype, or by using the rule of the least possible distance between dots (See Appendix D). The latter rule was utilized in order to produce distortions more similar to the prototype.

Four unrelated figures or foils were constructed utilizing the same procedure as was used to construct the protytpes. Two foils had 9 sides (the same number as the prototypes and distractors), one had 7 and one 5.

All figures were transferred from the graph paper to plain white paper and the lines were darkened with black pen to remove all traces of the original dots. The entire set of stimuli was as uniform as possible in size and appearance with the exception of the five sided foil which was considerably smaller. Each figure was then photocopied onto a 5 1/2 by 8 1/2 piece of white, heavy bond paper (or half of a regular 8 1/2 by 11 sheet) and laminated.

The resulting set of stimuli consisted of 26 figures: Two prototypes, twenty distortions (ten of each prototype), and four foils. Two identical sets of stimuli were made (See Appendix E for the complete set of stimuli).

In addition to the above data which was collected from each subject in the study, an independent data set was collected in the following manner. A group of 15 advanced graduate students were asked to rate the similarity of each of the stimuli to the two prototypes, on a scale of 1 to 15 with 15 being identical to the prototype. In other words, each exemplar (both daks and zims) as well as the four foils were rated as to how similar in appearance they were to the dak prototype, and then the same set of judgments was made again to the zim prototype. Two sets of ratings were obtained: one of the similarity of the 24 stimuli (10 daks, 10 zims, 4 foils) to the dak prototype; one of the similarity of the 24 stimuli to the zim prototype. The purpose for obtaining these ratings was to have a means of comparison between distance from the prototype and both accuracy and confidence judgments.

Procedure

Each subject was tested in a private room provided by the subject's school. There were three phases of each test session: concept acquisition, interpolated task, and concept retention. Test sessions were generally 20 minutes for the adults, 25 minutes for the 7 year-olds, and up to 40 minutes for the 4 year-olds.

When the subject was seated, the experimenter asked the subject if he/she had ever seen the Star Wars movies or the Star Trek television series (all subjects were familiar with one or the other). The idea of space families was discussed, and in particular the notion that families usually have characteristics that cause them to look alike. For example, brothers and sisters often look alike, but not always. Dogs and cats have distinguishing characteristics that place them in the cat category or dog category, although there is considerable variability within each of those classes. When the experimenter was satisfied that the subject understood the concept of similarity within a family, the following directions were given:

> We're going to play a game today with space families. I'm going to show you some shapes that belong to two space families -- the DAKS and the ZIMS. I want you to guess which ones are DAKS and which ones are ZIMS and I'll tell you if you're right.

Five figures from each of the two sets of prototype distortions were randomly selected to serve as a learning set. These ten figures were sequentially presented in a fixed random order (same set in same order) and subjects were asked, "Is this a DAK or a ZIM?" Subjects were given immediate feedback. Criterion was achieved when all 10 figures were properly categorized. Trials to criterion were recorded.

Upon reaching criterion, the experimenter asked the children if they knew how to play tic-tac-toe. They all replied they did. The experimenter then invited the subject to try and beat her. All children were gleeful at the prospect. This interpolated task was intended as both a break and a reward for both groups of younger children. It was identified during piloting that children needed a break that was rewarding in order to stay with the task until it was completed. It is possible that this acted as a cue to competition and may have influenced the subsequent task in some way. The interpolated task for the adults consisted of having the subject read the first line of the consent form out loud and briefly discussing with the experimenter the idea of informed consent. It is acknowledged that this was probably not a rewarding experience for the adults.

Upon completion of the interpolated task, the following instructions were given:

> Now I'm going to show you the space families again, this time with some new ones added. Here is the stack we just looked at, and here is a new stack of ones you haven't seen. We'll call this first stack "Olds" and

the second stack "News". Watch while I shuffle them together.

In view of the subject, the experimenter then shuffled several times the previously seen acquisition set with the additional set consisting of 10 distortions, the two prototypes and the four foils. There were no visible markings on the stimuli set which would allow subjects to make judgments, during the shuffling, about which were "old" and which were "new".

Now that they're all mixed together, I'm going to show them to you one at a time. We'll just go through them once this time, and I want you to tell me if it's an old one you've seen before, or a new one you haven't seen. In addition to the new DAKS and ZIMS, there will also be some new ones which belong to some other space family. We'll call those "Strangers". So, I want you to tell me if it's "Old", or if it's "New", or if it's a "Stranger".

When the experimenter was sure that the subject understood these instructions, the confidence rating was explained. Anderson (1981), in a review of confidence ratings, states that only graphic scales of confidence, mostly face happiness scales, have been used with children. Such scales, however, seem to entail an indirect judgment in that happiness and confidence are equated. This may represent an inaccurate way of assessing confidence in that it is possible to be either happy, unhappy, or neither with an answer in which one has either little confidence or much confidence. In other words, happiness and confidence are not equivalent states -- one is an emotion and one is a cognitive judgment and they do not necessarily occur in parallel. This study, therefore, used a numerical scale with all groups. Particular care was used in explaining the scale to the four-year olds, so that inasmuch as their ability would allow, their responses would reflect an accurate rating of confidence.

Anderson (1981) also suggests that although the optimal number of steps in a rating scale is uncertain, up to 19 points have been used succcssfully with children as young as 5 years, and that in recent work even 3 year-olds have used confidence scales successfully.

Therefore, in this study a white strip of cardboard 15 inches long, with one inch increments boldly marked with the numbers 1 through 15 was placed in front of the subject. For the two groups of children, three small plastic jars with two containing jelly beans were also brought out and the experimenter offered the following explanation.

> When you're very, very sure of something, it's like having a jar completely full of jelly beans. If I ask you what your name is and you tell me "Jennifer" (using

the child's name) and then I ask you how sure you are of your answer, your answer is like this jar of jelly beans which is full, because you have a jar full of "sureness" in your answer. (The experimenter set the full jar next to the number 15). If I ask you another question and you're not completely sure of your answer, but are somewhat sure, then it's like having a jar that is half full of jelly beans. (The experimenter set the half full jar between the numbers 7 and 8). And if I ask you a question and you have no idea, then it would be like having a jar with no jelly beans at all. (The empty jar was set by the 0).

The child was encouraged to use this perceptual analogue, even though it was assumed that they could count from 1 to 15. This concept was discussed until the child could verbalize being sure on a scale of 0 to 15, with corresponding degrees of "sureness" all along the scale. A variety of questions were generated to illustrate various degrees of "sureness", such as asking the child, without looking, to tell how many buttons were on his/her shirt. Some questions were generated by the experimenter and some by the subject. Particular care was taken with the two groups of children to be sure that they understood fully all the instructions, so that the resulting response patterns would be due to the task and not a misunderstanding of the instructions. However, the additional redundancy produced by more examples did not affect the content in any way. The content of the instructions was the same for all age groups. All subjects utilized the full scale in responding. The experimenter paid special attention to the fact that when subjects were hesitant about an answer, they were correspondingly less confident. This seemed to indicate valid use of the confidence scale. When the confidence scale was understood, the subject was then reminded of the first set of instructions and concluded with:

> O.K. I think we're ready now. You're going to tell me if it's an old one, a new one, or a stranger, and then how sure you are of your answer, right?

For each stimulus, the subject was asked, "Old, New, or Stranger?" followed by "How sure are you of that answer?" No feedback was given during the test phase of the experiment.

When all 26 figures had been classified and confidence ratings obtained, the two groups of children were allowed to pick a jelly bean out of one of the jars and also were given a brightly colored pencil. All subjects were thoroughly debriefed, thanked, and asked if they had any questions. Children usually wanted to know if they had gotten them all right, and adults were quite interested in the task itself and what the experimenter was trying to discover. Conversations continued until all questions had been answered.

Data

Data collected during this study were of three types: trials to criterion for initial acquition of the categories, judgments of stimulus type (transformed scores included accuracy for each stimulus judgment, and proportion correct for stimulus type groups), and confidence in those judgments.

Trials to Criterion were the number of trials it took each subject to correctly identify all ten exemplars in the learning set. Judgments of the various types of stimuli (e.g., all old daks, all new daks, all old zims, all new zims -- See Appendix G) were grouped together and the proportion correct across stimuli in each group became a subject's score. Ratings of Confidence were obtained for each subject on each answer on a scale of 1 to 15. Mean confidence ratings were calculated for individual stimuli across each subject and over ages for each of three age groups.

Statistical Analyses

Several statistical techniques were employed for analyzing the data collected during this study. Analysis of Variance (ANOVA) was used to examine age group and gender effects for proportion correct on all the various combinations of stimulus types. ANOVA was also used to test for differences in confidence across age groups and genders.

Two sets of correlations were used to test the relationship between categories of stimuli and the judgments made about them. In the first set old stimuli were correlated with new stimuli (dakold and zimold with daknew and zimnew) within each age group. A second set of correlations examined the relationship between memory and categorization judgments. In order to compare memory judgments (accurately remembering an old stimulus as old) to categorization judgments (remembering an exemplar of a category [dak or zim] as old <u>or</u> new as opposed to a foil which is not a member of either category), a new set of variables were created from the existing data. For example, in the variable dakold, only a response of "old" was counted as correct. Then a new variable, ddakold, was created in which responses of either "old" or "new" counted as correct, but not "foil" which was incorrect. The logic behind counting both "old" and "new" as correct was that with any dak or zim exemplar, a response of "old" or "new" placed that exemplar in some category, as opposed to not in any category which a "foil" response would have indicated. The creation of this composite of old and new responses for all daks and zims (ddakold, ddaknew, dzimold, dzimnew) allowed a comparison to be made between the memory judgment for the specific stimulus type (old or new) and the categorization judgment of category membership per se.

In addition, contingency analyses were conducted (i.e., likelihood ratio tests) to identify patterns of dependence in memory and categorization. Two by two contingency tables (for examples see Appendix H) were created for each of the two prototypes and each of its five old and five new exemplars. Within each age group, responses were summed across subjects. Those contingency tables with non-significant Chi-square likelihood ratios indicated independence between category amd exemplar judgments. For tables in which the Chi-square likelihood ratio was significant, $p < .05$, the joint probability was compared to the product of the marginals in the following manner to indicate the direction of dependence (positive or negative). The joint probability for each table was considered to be the percent of the total responses occupying the upper-left quadrant (cell 1,1) which indicated a response of "old" to the prototype, and "old" to the exemplar. The product of the marginals for the two adjacent cells, which indicated responses of "old" to the prototype and "new" to the exemplar (cell 1,2) or responses of "new" to prototype and "old" to exemplar (cell 2,1) was then calculated. The product of the marginals was then compared to the joint probability in order to determine direction of dependence. If the joint probability was greater than the product of the marginals, then dependence was positive. If the joint probability was less than the product of the marginals, then dependence was negative.

CHAPTER 4

RESULTS

Trials to Criterion

The mean number of trials to reach criterion was 2.84 (SD 1.74) for all subjects. An interesting pattern emerged when age was taken into consideration. Four year- olds took an average of 3.12 (SD 1.60) trials to accomplish an error-free trial on the learning set. Seven year-olds took an average of 3.56 (SD 2.05) trials, and adults 1.85 (SD .99) trials. In other words, the four year-olds acquired the learning set more quickly, on the average than did the seven year-olds, with adults acquiring it with the least trials of all. This represents a surprising finding and warranted further investigation. Upon a closer look it was discovered that in the seven year-old agegroup, one subject took nine trials to reach criterion. When eliminating that one score, the new mean for that age group is 3.39, which is still higher than the mean for the younger four year-old group.

Accuracy Data

The results of a Gender X Age X Category (dak-zim) X Stimulus Type (old-new) [2 X 3 X (2 X 2)] analysis of variance (ANOVA) produced a main effect for category with zims being correctly categorized more often than daks [$F(1,96) = 4.51$, $p < .05$, $MS_{error} = .03628$]. A significant interaction for category (dak-zim) by stimulus type (oldnew) showed old daks as recognized more easily over new daks, but new zims were recognized more easily than old zims [*F* (1,96) = 8.16, *p* < .01, *MS*error = .04865]. Zims appeared to be easier, as shown in the main effect, and therefore it was harder to be wrong on zims (see Figure 1).

Recall that an independent expert group (N=15) rated the entire set of 24 stimuli as to similarity to the dak prototype and the zim prototype. On a scale of 1 to 10, the ten dak exemplars were rated from 7.45 to 4.26 in closeness to the dak prototype. Zim exemplars were rated 7.86 to 3.86 in closeness to the zim prototype. All ten dak exemplars were rated closer to the dak prototype than any of the other 14 stimuli. However, a different pattern emerged for the zim exemplars. Nine zims were rated closer to the zim prototype than all other stimuli, then two of the foils (X and Y) were rated closer to the zim prototype than the tenth zim exemplar.

Since the zim category had both higher and lower ratings than the dak category, it is more variable in its representativness of the category. The dak category appears to be more well defined and less variable in its representativeness.

A series of planned comparisons produced the following results: a significant main effect for zimonly by stimulus type [Gender X Agegroup X Zimonly X Oldnew; 2 X 3 X (1 X 2)] in which news were recognized more easily than olds [*F*

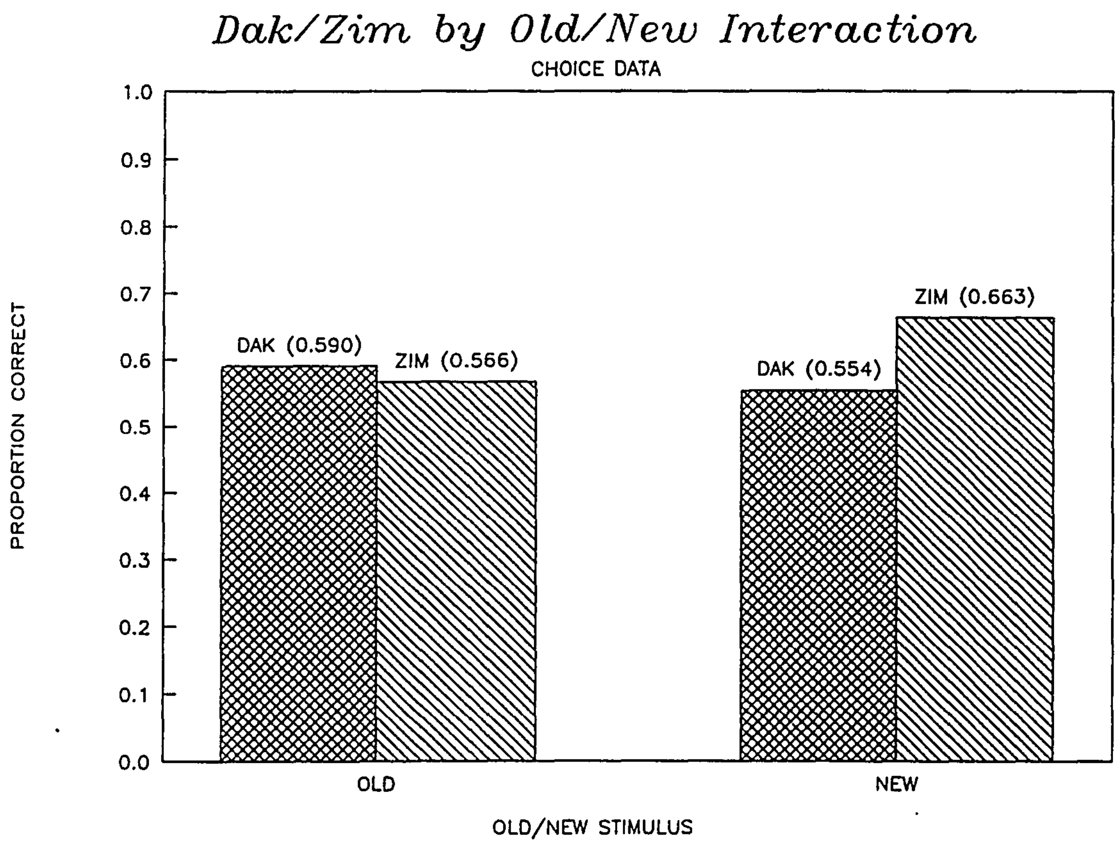


Figure 1: Dakzim by Oldnew Interaction

(1,96) = 5.21, $p < .05$, MS_{error} = .08034]; and a significant interaction of gender X stimulus type (old-new) showed female subjects more accurately recognized new stimuli whereas males recognized olds and news with equivalent accuracy [F (1,96) = 3,71, $p < .05$, MS_{error} = .08034].

When all news--prototypes, foils, newdaks, and newzims--were analyzed as four separate categories (Gender X Agegroup X Newsonly) a main effect was found with new zims recognized with the highest overall accuracy as evidenced by proportion correct (.65), new daks (.62), prototypes (.47) and foils (.35), [F (3,288) = 21.91, $p < .00001$, MS_{error} = .07854]. A significant interaction of news X agegroup, shown in Table 2 shows that overall, category exemplars (both daks and zims) were recognized with a higher percent correct than prototypes and foils [F (6,288) = 4.59, $p <$ 0005, MS_{error} = .07854]. Four year-olds were the most accurate agegroup with prototypes and foils and adults were least accurate; conversely adults were the most accurate agegroup with daks and zims and seven-year olds were least accurate.

Table 2

Proportion Correct: Four Types of New Stimuli

	Prototype	Foil	Dak	Zim
4 yr-olds	.50	.51	.64	.64
7 yr-olds	.45	.40	.54	.60
Adults	.45	.16	.69	.71

The nature of error for four and seven year-olds may be different with four year-olds relying on memory for specific instances that allows them to see new exemplars of the category as new with higher accuracy, whereas seven year-olds may be relying on category membership (which are daks and which are zims?) and therefore inaccurately see new exemplars as having been seen before. This seems to suggest that as subjects get older, they are more likely to see differences based on category membership rather than differences based on memory for specific instances of a category.

The results of a Gender X Agegroup X 6 Different Stimulus Types (dakold, zimold, daknew, zimnew, prototype, and foil) (2 X 3 X 6) analysis of variance (ANOVA) produced a main effect for stimulus type [F (5,480) = 14.50, p < .00001, MSerror = .07643], with zimnew recognized most accurately (.65), then daknew (.62), dakold (.59), zimold

(.57), prototype (.47), and foil (.35). A significant interaction for stimulus type X agegroup (Table 3) revealed that adults showed the pattern most strongly, that is most accurate on news, less accurate on olds, least accurate of the three age-groups on the prototypes, and an even larger drop in accuracy for foils [F (5,480) = 3.13, p. = .001, MSerror = .07643]. The difference in accuracy between olds and news was largest for the adult age-group, whereas with both groups of children the differences were small (also see Figures 2 and 3).

Table 3

Proportion Correct: Six Different Stimulus Types

	Dakold	Zimold	Daknew	Zimnew	Proto	Foil
4yr-olds	.60	.56	.64	.64	.50	.51
7yr-olds	.61	.54	.54	.60	.45	.40
Adults	.56	.60	.69	.71	.45	.16

Confidence Data

Using the confidence data, the results of a Gender X Agegroup X Category (dak-zim) X Stimulus Type (old-new) [2 X 3 X (2 X 2)] analysis of variance (ANOVA) produced main effects for agegroup [F (2,96) = 3.14, p. < .05, MSerror = 15.41677], and oldnew [F (1,96) = 8.66, p < .005, MSerror =

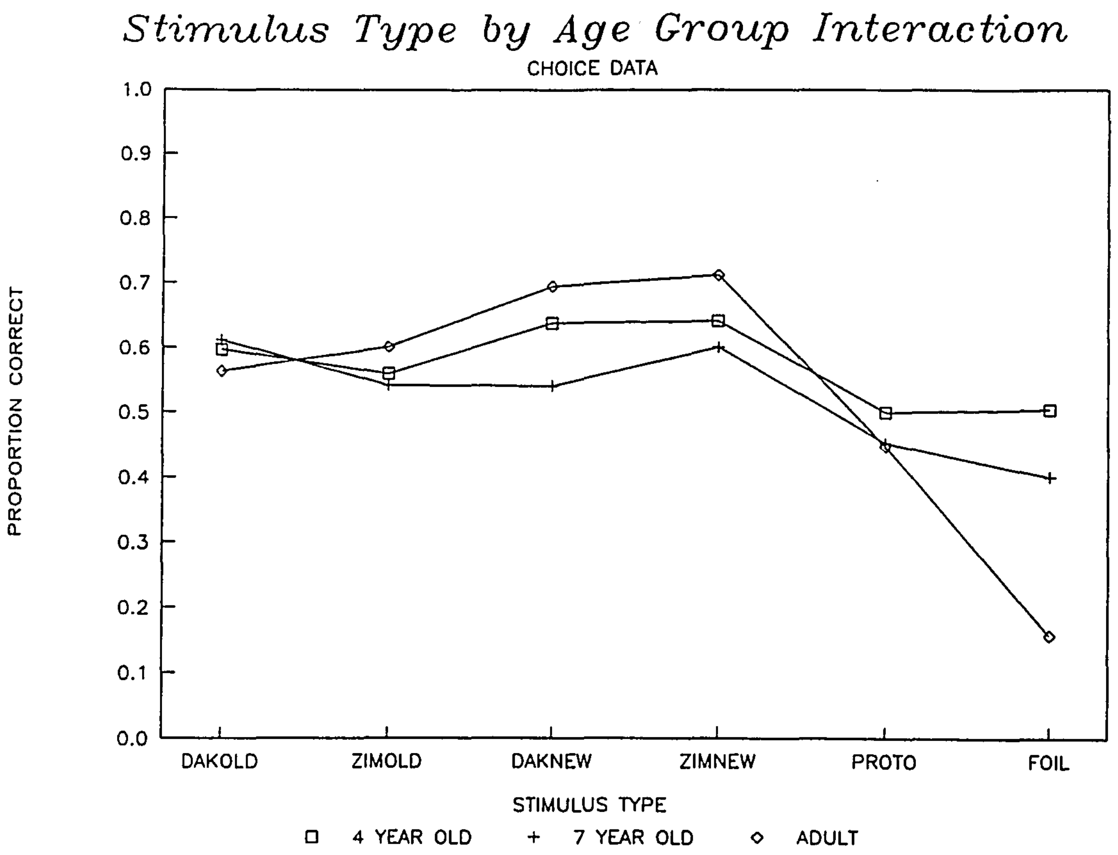


Figure 2: Stimulus Type by Age Group Interaction

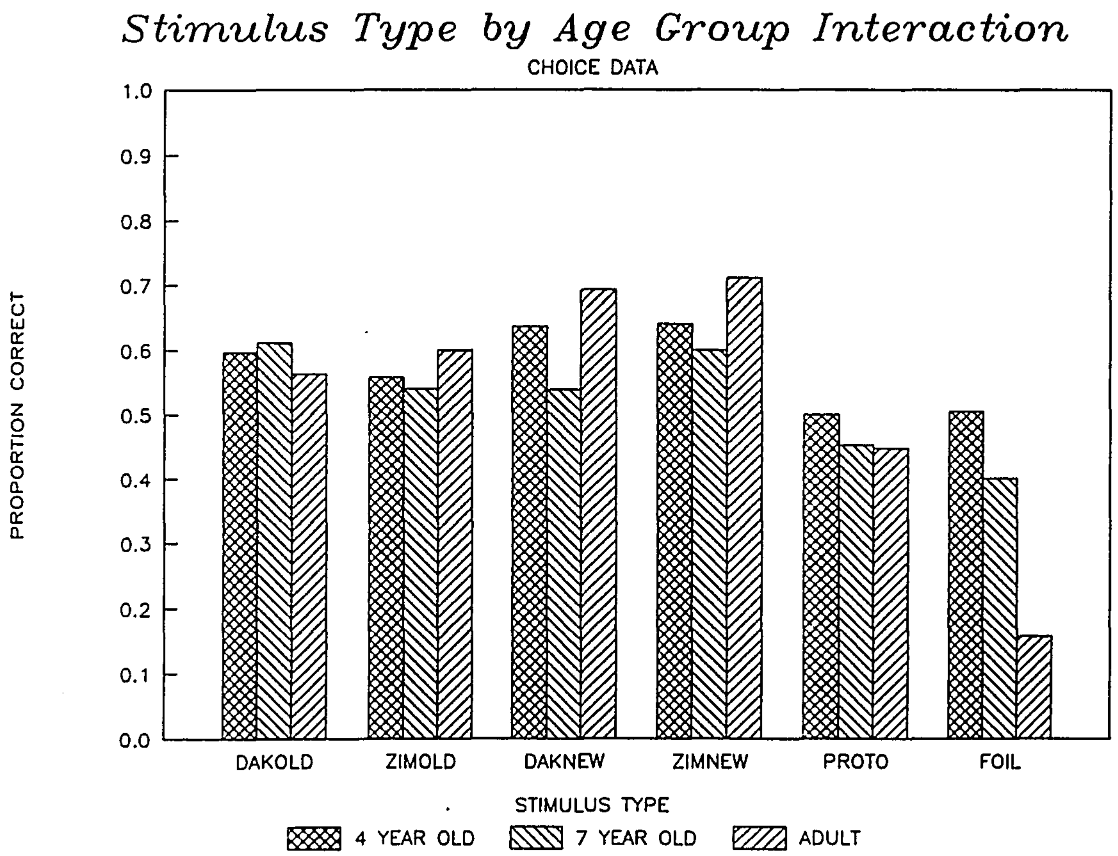


Figure 3: Stimulus Type by Age Group Interaction

3.00219]. Both the four (11.35) and seven year-olds (11.11) were more confident overall than the adults (10.17), and subjects were more confident overall on old (11.15) than new stimuli (10.60). A significant interaction of agegroup X oldnew (Table 4, Figure 4) shows four year-olds equally confident on olds and news, seven year-olds more confident on olds, and adults equally confident on both stimulus types but less so than both groups of children [F (2,96) = 5.49, $p < .01$, MSerror = 3.00219].

Table 4

Confidence on Stimulus Type

	Olds	News
4 year-olds	11.57	11.12
7 year-olds	11.79	10.44
Adults	10.08	10.25

In a planned comparison of gender X agegroup X (dakonly X oldnew), a main effect of oldnew was found [F (1,96) = 6.38, $p < .05$, MSerror = 2.66342]. Subjects were more confident in categorizing old (11.25) than new stimuli (10.63), but this was not true across all age groups as is shown in the significant interaction of oldnew X agegroup [F

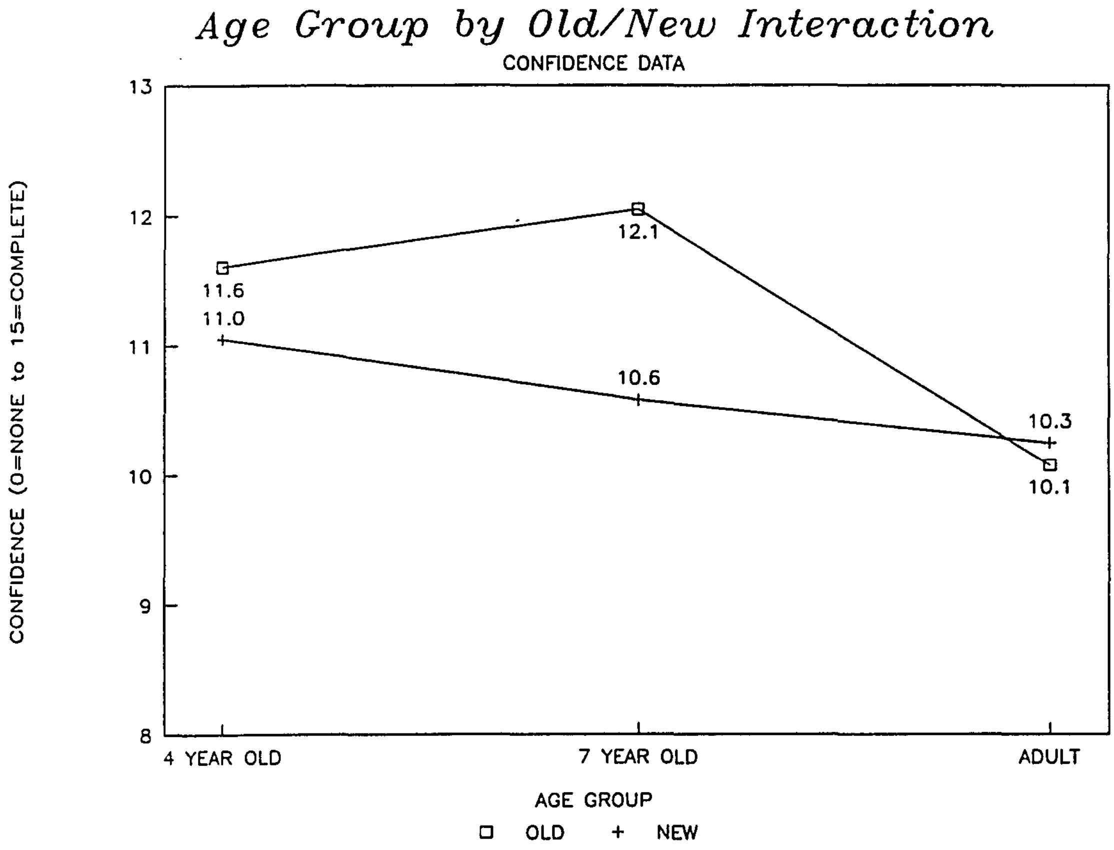


Figure 4: Age Group by Oldnew Interaction

(2,96) = 3.62, p < .05, MSerror = 2.66342]. The age differences shown in Table 4 are the result of differences in the dak category only. Differences for the zim category were not significant. In a comparison of gender X agegroup X oldonly, a significant main effect for agegroup was found [F (2,96) = 6.23, p < .005, MSerror = 8.29731]. The mean confidence for 4 year-olds on old stimuli only was 11:57, for 7 year-olds, 11.79; and adults, 10.08. The difference in these two analyses shows that the confidence scale distinguishes between age groups as well as stimulus types since significant age differences in confidence were found for old stimuli but not for new. This points out that children are not more confident in general than adults, but only on old stimuli.

A 2 X 3 X 6 analysis of variance with the six different stimulus types produced a significant interaction for agegroup X stimtype [F (10,480) = 2.28, p < .05, MSerror = 3.38438], as shown in Table 5. Four and seven year-olds were more confident than adults. There was more variability in confidence for children whereas adults were more consistent across stimulus types (Figure 5).

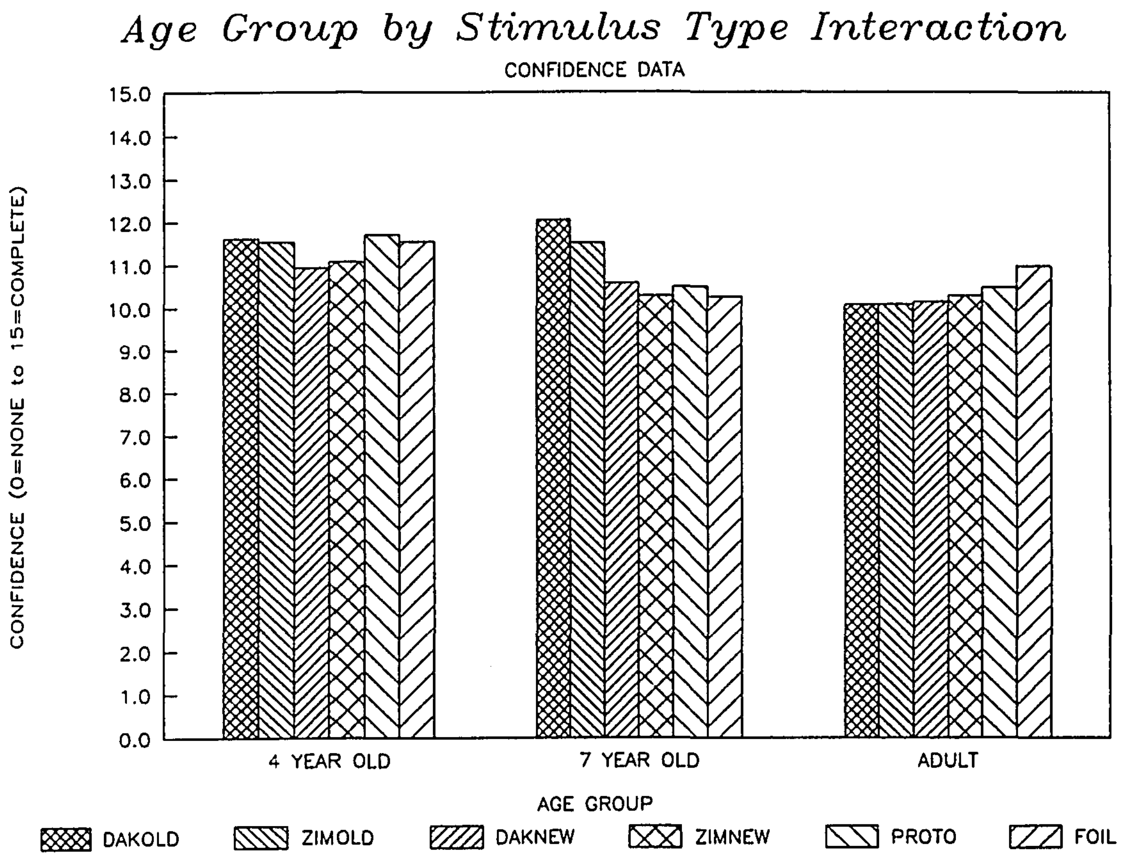


Figure 5: Age Group by Stimulus Type Interaction

Table 5

Average Confidence Rating: Six Different Stimulus Types

	DAKOLD	ZIMOLD	DAKNEW	ZIMNEW	PROTO	FOIL
4 year-olds	11.61	11.53	10.94	11.08	11.71	11.54
7 year-olds	12.05	11.52	10.58	10.28	10.49	10.25
Adults	10.08	10.08	10.13	10.28	10.48	10.97

It is relevant to note that adults were the most confident on foils, the category for which they had the lowest accuracy. Of all the judgments adults were asked to make, they were the most confident that foils were category members even though they were wrong on 84% of the judgments they made on foils.

Correlations

Two sets of correlations were used to test the relationship between categories of stimuli and the judgments made about them. In the first set old stimuli were correlated with new stimuli (dakold and zimold with daknew and zimnew). There were no significant correlations for 4 and 7 year-olds, but for adults zimold and zimnew were significantly negatively correlated ($r = -0.43$, $p < .01$), indicating that for adults correctly labelling an old zim seemed to interfere with to correctly labelling a new zim.

The second set of correlations, which has been described in detail in the Methods section, examined the relationship between memory and categorization judgments, by creating new variables in which a response of "old" or "new" counted as correct. The comparison then is between memory (old - only response of "old " correct; new - only response of "new" correct) and categorization (old or new - response of "old" or "new" correct but not "foil"). New variables were also created for the prototypes (dproto) using the same logic as for any new exemplar.

It was possible to then correlate all combinations of responses between all old and new stimuli (see Appendix I for a complete list of comparisons made in each condition). For example, all combinations of old stimuli were correlated with all combinations of new stimuli using correct answers only (old as old, new as new -- Memory/Memory condition). Then correct responses to all old stimulus categories were correlated to the categorization responses of all new stimuli (old <u>or</u> new as correct). In the third condition, the categorization responses of all old stimulus categories were correlated to the correct responses to all new stimuli. In the fourth condition the categorization responses to all old and all new stimulus categories were correlated.

Thus correlations were made in four conditions: Memory/Memory, Memory/Categorization, Categorization/Memory, and Categorization/Categorization. The last condition, Categorization/Categorization is not discussed here as it addresses a question that is outside the scope of this study. The significant correlations presented in Table 6 show that in the Memory/Memory condition, only zimnew and prototypes were correlated for 4 year-olds, indicating that when new zims were correctly called "new", the prototypes were also correctly called "new". The lack of any other correlations for the 4 year-olds in the Memory/Memory condition suggest that they are evaluating each stimulus presented to them on its own merit, and not in relation to any of the sets or classes of stimuli. The 7 year-olds appear to exhibit some reliance on memory in that when they make a correct judgment of a prototype, it is positively correlated with memory for both dak and zim new exemplars. Interestingly, judgments of prototypes are negatively correlated with memory for old daks, suggesting that memory is interfering with the ability of 7 year-olds to correctly classify prototypes as new. Adults show a different pattern in the Memory/Memory condition, with positive correlations between correct responses to both classes of new stimuli, daks and zims, and correct response to prototypes as new, similar to the 7 year-olds. However, adults show negative correlations in the zim category between olds and news, again suggesting interference between memory for old zims and correct classification of new zims as new.

Table 6

Significant Memory and Categorization Correlations

	4/5 Yr Olds	7/8 Yr Olds	Adults
Memory/Memory			
dakold/proto		-.52**	
zimnew/proto	.42*	.41*	.45**
daknew/proto		.35*	.38*
zimold/zimnew			-.43**
zimold/zimnew5			-.40*
Memory/Categorization			
daknew/dproto			.51**
zimnew/dproto			.52**
daknew5/dproto			.49**
zimnew5/dproto			.44**
Categorization/Memory			
ddakold/daknew			.42*
dzimold/zimnew	.42*		.41*
ddakold/daknew5			.53**
dzimold/zimnew5	.45**		

Table 6--Continued

	4/5 Yr Olds	7/8 Yr Olds	Adults
Categorization/Categorization			
ddakold/ddaknew	.74**	.38*	.85**
ddakold/ddaknew5	.74**	.41*	.65**
dzimold/dzimnew	.74**	.41*	.65**
dzimold/dzimnew5	.75**	.39*	.57**
dzimold/dproto			.61**
dzimnew/dproto			.64**
dzimnew5/dproto			.43**

*p<.05 **p<.01

In the Memory/Categorization condition, accurate memory for the old or new category exemplars was correlated with the categorization judgment for all new category members, including prototypes. There were no significant correlations of any class of stimuli for either 4 or 7 year-olds. Adults showed positive correlations for all classes of new exemplars and the categorization response to prototypes. This suggests that adults categorized prototypes as belonging to "some category" other than foil based on some type of broad category representation that neither group of children possessed.

In the Categorization/Memory condition, the category judgment for all old or new category exemplars was correlated with accurate memory for all new category members, including prototypes. Results showed a significant correlation for 4 year-olds between dzimold and zimnew, indicating that categorizing zims aided in correct identification of new zims, as well as new zims without the prototype. There were no significant correlations for 7 year-olds. For adults, categorization judgments appear to have influenced correct memory judgments in but three of the ten possible pairs.

Contingency Analyses

The contingency analyses, described in detail in the Methods section, produced the following results. The direction of dependency, represented in Table 7, shows independence in every case for adults. For adults, categorization of the prototype as old was independent of categorization of exemplars as old or new. There was no finding of negative dependence, or interference for any age group. For seven year-olds categorization of the prototype as old was positively dependent for categorization of all old exemplars but independent of all new exemplars. Dependency showed a more mixed pattern four year-olds on individual stimulus types, but overall positive dependence for both old and new exemplars.

Table 7

Contingency Analyses Results

	4/5 Yr Olds	7/8 Yr Olds	Adults
Dakproto/Daknew	Independent	Independent	Independent
Dakproto/Dakold	Positive Dep.	Positive Dep.	Independent
Zimproto/Zimnew	Positive Dep.	Independent	Independent
Zimproto/Zimold	Independent	Positive Dep.	Independent
Proto/All News	Positive Dep.	Positive Dep.	Independent
Proto/All Olds	Positive Dep.	Positive Dep.	Independent
Proto/Grand Total	Positive Dep.	Positive Dep.	Independent

CHAPTER 5

DISCUSSION AND CONCLUSIONS

This study resulted in less overall accuracy for all agegroups than the study by Boswell & Green (1982). When the results from this study were compared to Boswell & Green's Categorize condition, which contained the same instructions given to the subjects in this study, a similar pattern emerged. With new stimuli, four year-olds and seven year-olds were more accurate on prototypes and foils, whereas adults were more accurate on exemplars. This study separated children into two groups, one similar in age to Boswell & Green, 4 and 5 year-olds, and one group of second graders, 7 and 8 years old. Although the adult subjects in each study were equivalent undergraduate groups, error rates were higher in this study than in Boswell & Green's for these two equivalent groups. Given that great care was given in the instructions and that the tasks in the two studies were equivalent, there are two possible explanations for the disparate error rates (Boswell & Green's proportion correct for adults: Olds .97, Prototypes .98, News .84, Foils .17; Wilkes' proportion correct for adults: Olds .58, Prototypes .45, News .70, Foils .16). One explanation is that asking for a confidence judgment after each of the 26 categorization judgments produced an interference effect of some kind which resulted in less accurate memory. A second possibility is that the higher error is simply a greater manifestation of the effect found by Posner & Keele and Boswell & Green. Boswell & Green found very small differences in categorization judgments for olds and prototypes for both groups of children and adults. The effect in this study, while in the same direction, is considerably larger, and therefore may clarify the direction and nature of the differences.

Within the two categories of stimuli, zims were easier to classify correctly. Recall that in the independent validation ratings, zims had both higher and lower ratings than daks, indicating greater variability within the zim category. This greater variability may have made the zim category less distinctive, more inclusive, and therefore easier to identify correctly. The commonly held notion is that the closer an exemplar is to the prototype, the easier it is to classify. This study suggests that an additional element of distinctiveness may play a part in categorization.

When trials to criterion and correct responses to the six different stimulus types are considered together, an interesting pattern emerges. In general four year-olds and adults took fewer trials than the seven year-olds to complete the learning set, and four year-olds and adults also had higher accuracy on most of the six stimulus types than did seven year-olds. Overall, four year-olds and adults learned the categories more rapidly and were more accurate in subsequent judgments, with the largest gains in new stimuli of all types. The seven year-olds, conversely took longer to learn the categories and performed less accurately on later judgments of all types except dakolds.

A well-known phenomenon in cognitive psychology is the U-curve, or temporary dip in performance occurring between two correct but qualitatively different aspects of expertise (Strauss, 1982). Such non-monotonic patterns appear at first glance to violate the intuitive principle that learning is incremental, with steps that build upon one another, and lead slowly from novicity to expertise (Patel & Groen, 1990). But U-shaped behavioral growth is informative because anomalies often reflect changes in underlying processes. U-curves suggest a representational reorganization of some kind in which responses in the first and third phases may be qualitatively different.

One explanation for such a reorganization is the dual hypothesis which occurs along many dimensions and suggests that memory representations vary along some type of continuum. A few of those dimensions are piecemeal/configurational, Carey & Diamond, 1977; expression/configural, Bartlett, 1991; holistic/analytic, Kemler, 1983; local/global, Stiles, Delis & Tada, 1991; and perceptual/metaperceptual, Diamond & Carey, 1990. Carey & Diamond's (1977) explanation offers insight into the nature of the underlying process that may be operational in the dip in performance of seven year-olds found in this study. Carey & Diamond propose that young children encode faces by identifying piecemeal, isolated features, and that around age 10 they change strategies to encode the configural properties of a face (ie., distance between features). They found dips in performance across a variety of tasks during the age period in which the encoding switch is being made -- defined as age 10 in their studies. It is possible that in the categorization of artificial objects, the encoding switch is made earlier, and extending the paradigm used in this study to 10 year-olds and 13 year-olds might show where the curve swings upward toward the adult competency.

The findings in this study show the adult pattern of news being recognized with greatest accuracy, followed by olds, then prototypes, and finally foils. This pattern does not replicate the pattern found in Boswell & Green (1982) in which prototypes were recognized with greatest accuracy and only slightly better than olds, then news, and finally foils. When Boswell & Green suggest that adults were unable to distinguish prototypes from olds, they were referring to their Remember Condition, in which the question asked was "Did you see this before"? Adult subjects responded "yes" to the prototypes proportionately more often than to old exemplars (.958 for protos, .941 to olds), indicating they did not distinguish olds from prototypes. In the Categorize

Condition, Boswell & Green asked "Is it an old, a new, or a stranger?", the same question that was asked in this study of all subjects. Again, Boswell & Green found that adult subjects did not differentiate olds from prototypes (.979 for protos, .967 for olds).

The fact that adults show a different pattern in this study, news > olds > protos > foils, is a puzzling finding. Adults and four-year olds recognized news with higher accuracy than the other stimulus types, and for seven year-olds olds and news were equivalent. This seems to suggest that young children and adults are able to access memory for the specific instance to a greater degree than has been shown in previous studies. Category knowledge, as exemplified by the prototypes, is less accessible. This may have been prompted by the addition of the confidence ratings. Accuracy on the judgment requiring identification of non-category stimuli (foils) was equivalent to the prototypical knowledge in four year-olds, but was less available to seven-year olds, and least apparent to adults. Adults see everything as fitting some category, suggesting that the wide range of adult experience broadens the definition of a category such that most anything fits (a beanbag chair is still a chair).
Additionally, as the confidence data suggest, adults are _very_ confident that foils are indeed category members.

Conclusions

The findings in this study implicate at least three questions found in the literature. The first is the question alluded to by Boswell & Green (1982) and specifically addressed by Knowlton, Ramus & Squire (1992), and that is the existence of two memory systems. The findings in this study suggest that memory for category and memory for specific instance of a category are separate and distinct, and can be selectively accessed according to the demands of the task across age groups. In other words it appears that both children and young adults encode information about the category as well as specific instances of that category in parallel, and access the different types of information by choice.

The second question is that of interference effects. The findings of this study do not support the existence of interference effects in either children or young adults. Because adult categories are so broad, virtually every instance is a category member and therefore there is no competition between the two memory systems. Children seem to prefer to access memory for the specific instance, but are able to access memory for the category also.

The third question is whether or not the process of categorization is different for children and adults. This study seems to suggest that, although there are developmental differences, they are in the form of a U-shaped, non-monotonic path, suggesting seven year-olds are in transition cognitively speaking. It is consistent with the findings of this study that children might be moving along a continuum of access to different memory representations ranging from specific to categorical. The transitional nature of cognition in the seven year-old may mean that they have less freedom of movement along the continuum and the resulting rigidity produces more error.

```
 S KYG
F YPYK
P  OF
R I I
 D   W
```

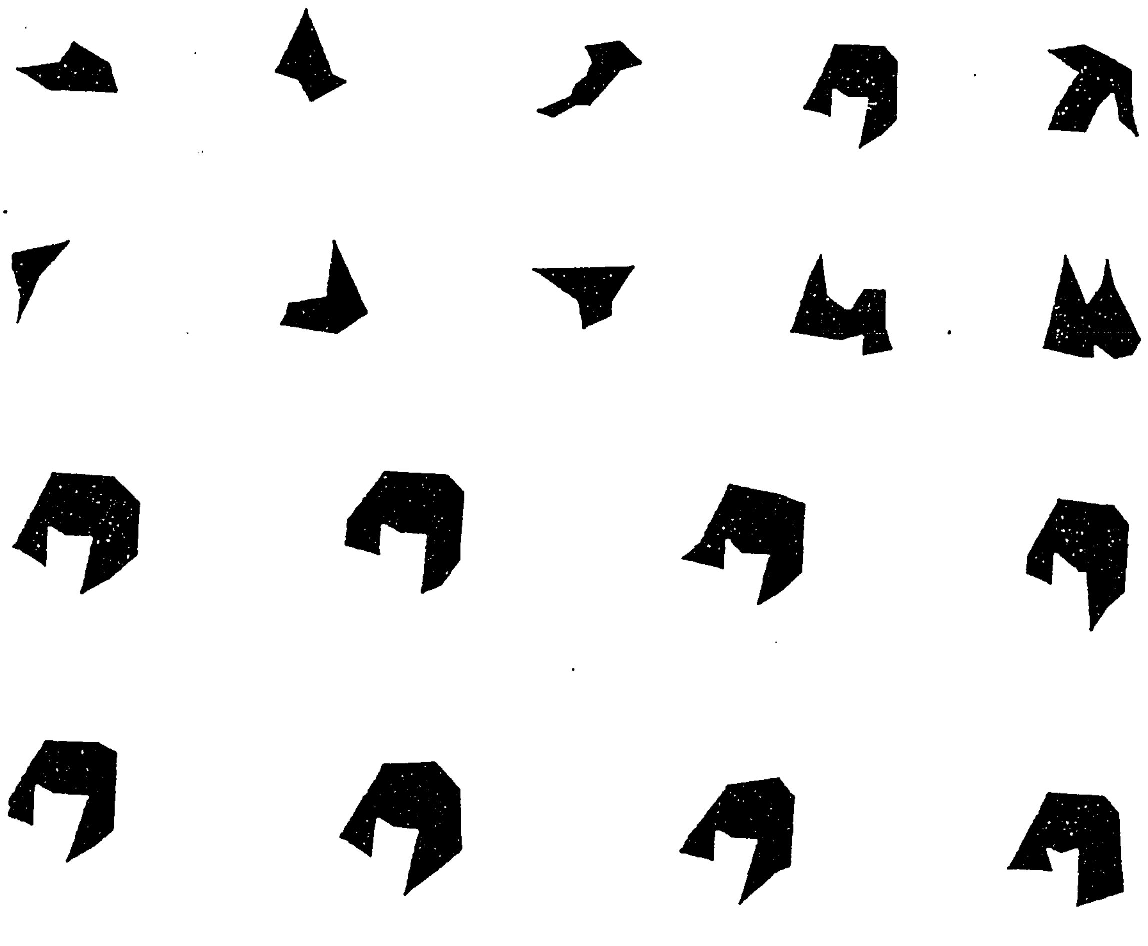
```
 S KYG
F YPZK
P  OF
R I I
 D   P
```

```
 S KYG
F YRZK
P  OF
R I I
 D   W
```

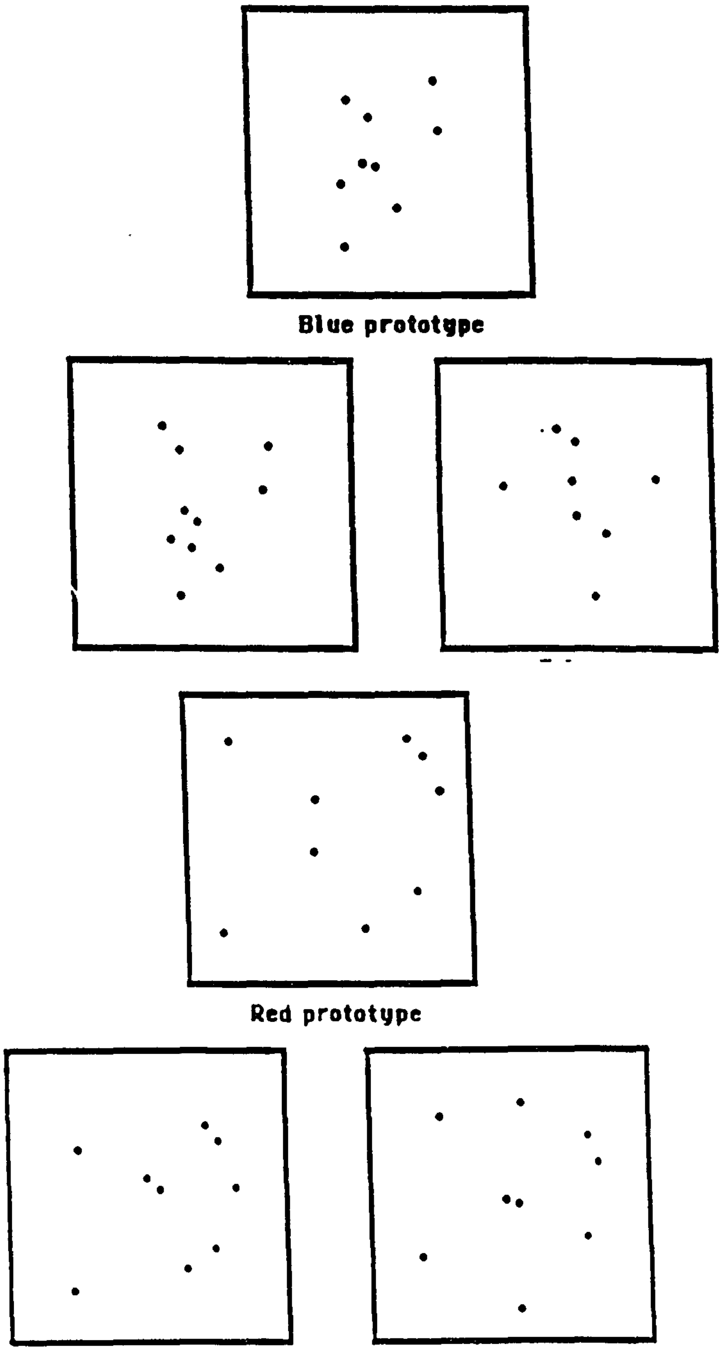
```
 A KYG
F YPZK
P  OF
R I I
 D   W
```

```
 S KYG
F YPZK
P  OF
R I I
 D   W
```

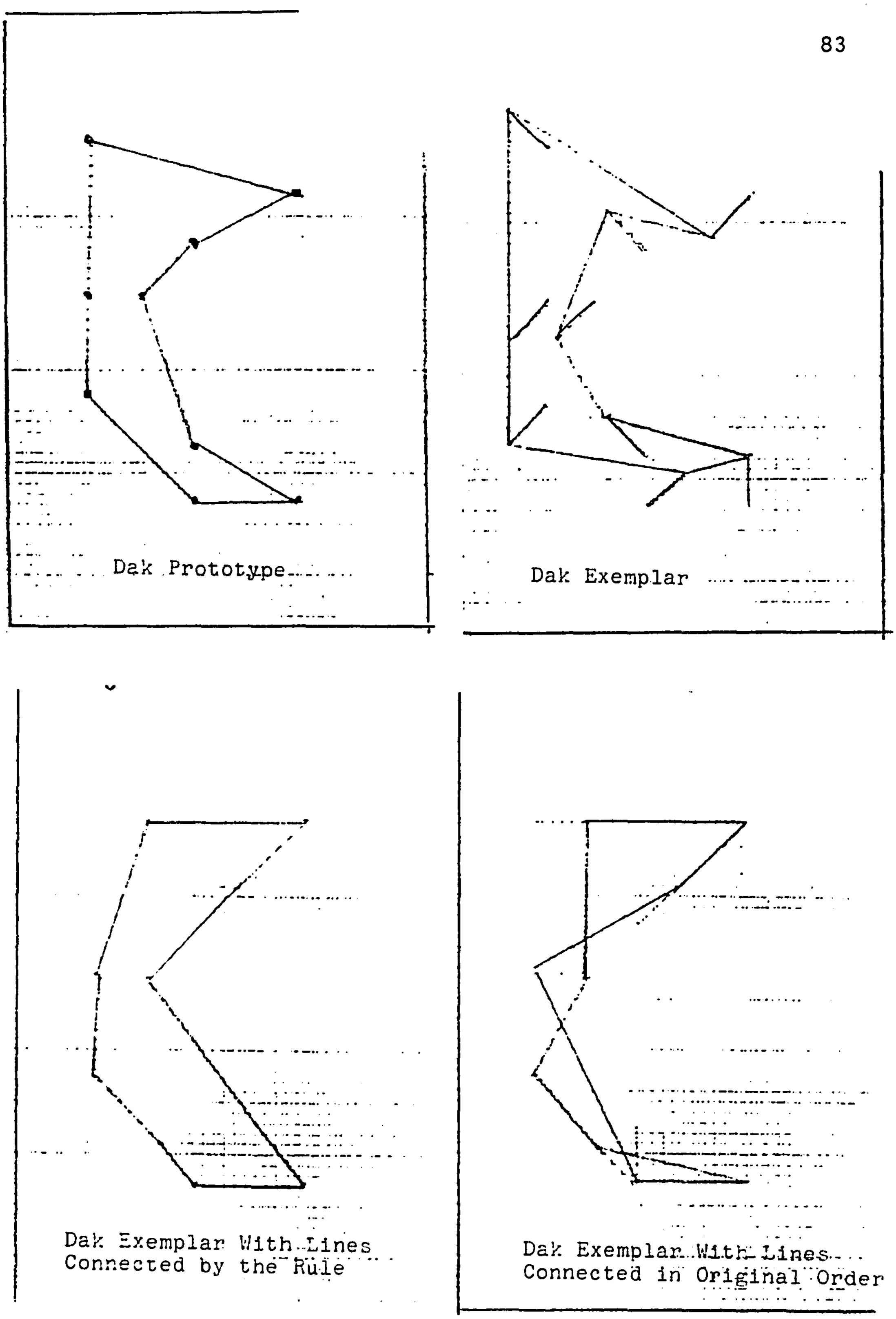
Appendix A: Attneave's Letter Prototypes



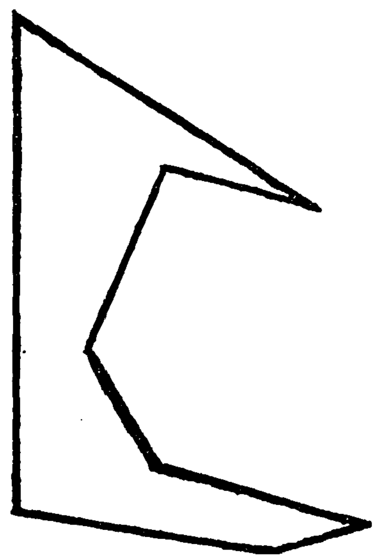
Appendix B: Attneave's Polygons



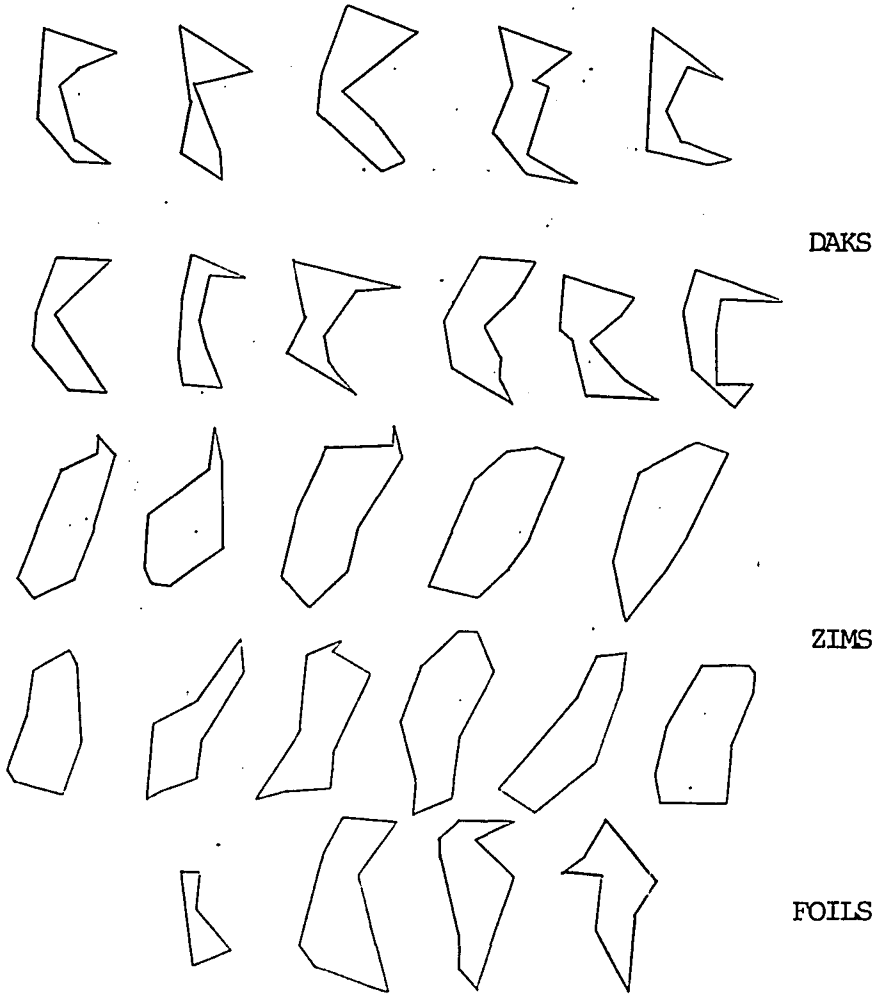
Appendix C: Posner & Keele's Dot Patterns



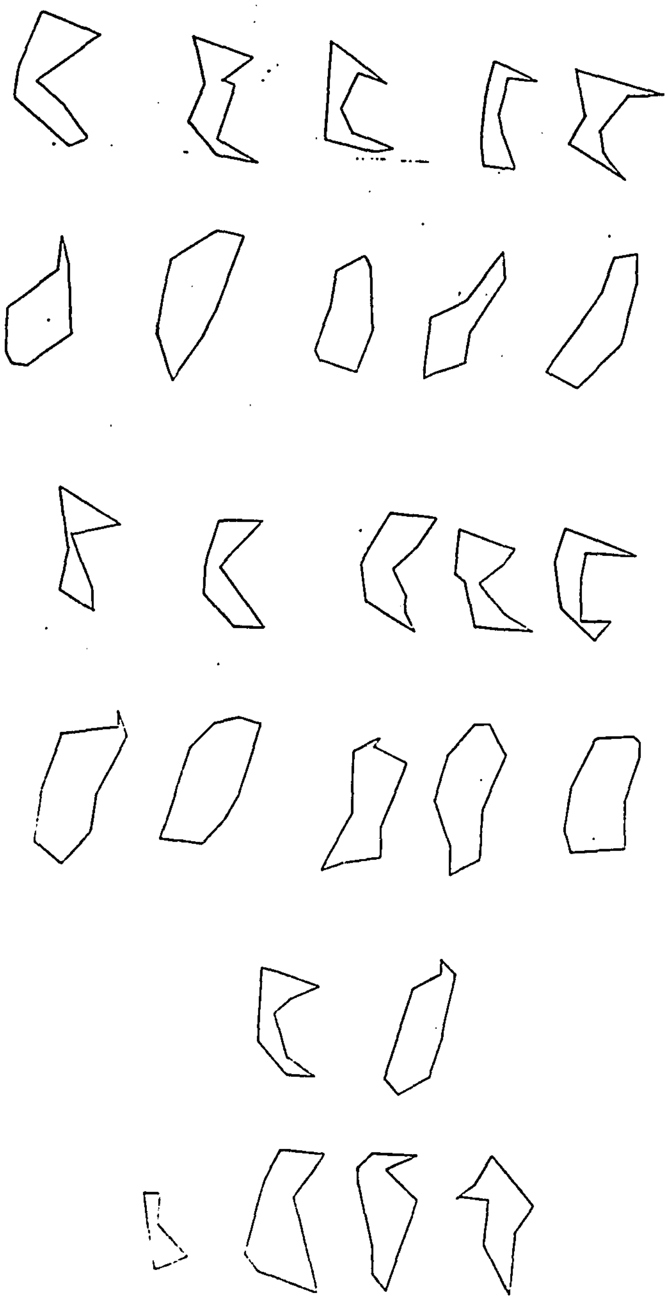
Appendix D: Movement of Dots



Appendix E: Actual Size of Stimulus



Appendix F: Stimulus Set



OLDS

NEWS

PROTOTYPES

FOILS

Appendix G: Stimulus Set

DAK NEW proto by DAK NEWs — 7 year olds
DAKPROTO Choice for dak proto by DAKNEWS Choice for dak news

DAKPROTO	DAKNEWS: Count / Row Pct / Col Pct / Tot Pct	Old 1	New 2	Row Total
Old	1	17	67	84
		20.2	79.8	76.4
		81.0	75.3	
		15.5	60.9	
New	2	4	22	26
		15.4	84.6	23.6
		19.0	24.7	
		3.6	20.0	
	Column Total	21	89	110
		19.1	80.9	100.0

In this table, the non-significant Likelihood Ratio of .57493 indicates a finding of independence.

Chi-Square	Value	DF	Significance
Pearson	.30279	1	.58214
Continuity Correction	.07809	1	.79120
Likelihood Ratio	.31450	1	.57493
Mantel-Haenszel test for linear association	.30004	1	.58386
Fisher's Exact Test:			
One-Tail			.40770
Two-Tail			.77689

DAK OLD proto by DAK OLDs — 7 year olds
DAKPROTO Choice for dak proto by DAKOLDS Choice for dak olds

DAKPROTO	DAKOLDS: Count / Row Pct / Col Pct / Tot Pct	Old 1	New 2	Row Total
Old	1	82	28	110
		74.5	25.5	78.0
		83.7	65.1	
		58.2	19.9	
New	2	16	15	31
		51.6	48.4	22.0
		16.3	34.9	
		11.3	10.6	
	Column Total	98	43	141
		69.5	30.5	100.0

In this table the Likelihood Ratio is significant at .01706. The joint probability of 58.2 is compared to the product of the marginals (78.0 x 69.5) which is 54.9. Since this is less than 58.2, the finding is positive dependence.

Chi-Square	Value	DF	Significance
Pearson	6.00045	1	.01430
Continuity Correction	4.96730	1	.02583
Likelihood Ratio	5.69031	1	.01706
Mantel-Haenszel test for linear association	5.95789	1	.01465

Appendix H: Example of Contingency Tables

APPENDIX I
CORRELATIONS OF
MEMORY AND CATEGORIZATION JUDGMENTS

Accuracy Variables (Memory) = old as old is correct
new as new is correct
dak, zim

Dependency Variables (Categorization) = old as old or new is corr
new as old or new is corr
ddak, dzim

MEMORY/MEMORY	MEMORY/CATEGORIZATION
DAKOLD/DAKNEW	DAKOLD/DDAKNEW
ZIMOLD/ZIMNEW	ZIMOLD/DZIMNEW
DAKOLD/DAKNEW5	DAKOLD/DDAKNEW5
ZIMOLD/ZIMNEW5	ZIMOLD/DZIMNEW5
DAKOLD/PROTO	DAKOLD/DPROTO
ZIMOLD/PROTO	ZIMOLD/DPROTO
DAKNEW/PROTO	DAKNEW/DPROTO
DAKNEW5/PROTO	DAKNEW5/DPROTO
ZIMNEW/PROTO	ZIMNEW/DPROTO
ZIMNEW5/PROTO	ZIMNEW5/DPROTO
CATEGORIZATION/MEMORY	**CATEGORIZATION/CATEGORIZATION**
DDAKOLD/DAKNEW	DDAKOLD/DDAJBEW
DDAKOLD/DAKNEW5	DDAKOLD/DDAKNEW5
DZIMOLD/ZIMNEW	DZIMOLD/DZIMNEW
DZIMOLD/ZIMNEW5	DZIMOLD/DZIMNEW5
DDAKOLD/PROTO	DDAKOLD/DPROTO
DZIMOLD/PROTO	DZIMOLD/DPROTO
DDAKNEW/PROTO	DDAKNEW/DPROTO
DDAKNEW5/PROTO	DDAKNEW5/DPROTO
DZIMNEW/PROTO	DZIMNEW/DPROTO
DZIMNEW5/PROTO	DZIMNEW5/DPROTO

Appendix I: Correlations of Memory and Categorization Judgments

REFERENCES

Anderson, N. H. (1981). Information integration in developmental psychology. In N. H. Anderson (Ed.), Foundations of information integration theory (pp. 1-45). New York: Academic Press.

Attneave, F. (1957). Transfer of experience with a class-schema to identification-learning of patterns and shapes. Journal of Experimental Psychology, 54, 81-88.

Bartlett, F.C. (1932). Remembering: A study in experimental and social psychology. Cambridge: Cambridge University Press.

Bartlett, J. C. (1991). Inversion and configuration of faces. Unpublished Manuscript.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. Psychological Review, 94, 115-147.

Boswell, D. A., & Green, H. F. (1982). The abstraction and recognition of prototypes by children and adults. Child Development, 53, 1028-1037.

Carey, S. (1985a). Are children fundamentally different kinds of thinkers and learners than adults? In S. Chipman, J. Segal, & R. Glaser (Eds.), _Thinking and learning skills_, Vol. 2. New Jersey: Erlbaum.

Carey, S. (1985b). _Conceptual change in childhood_. Cambridge, MA: MIT Press.

Carey, S., & Diamond, R. (1977). From piecemeal to configurational representation of faces. _Science_, _195_, 213-313.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: An effect of expertise. _Journal of Experimental Psychology: General_, _115_, 107-117.

Diamond, R., & Carey, S. (1990). On the acquisition of pattern encoding skills. _Cognitive Development_, _5_, 345-368.

Flavell, J. H. (1985). _Cognitive Development._ New Jersey: Prentice Hall.

Gelman, R. & Baillargeon, R. (1983). A review of Piagetian concepts. In J. H. Flavell & E. M. Markman (Eds.), _Handbook of child psychology: Cognitive development_ (Vol. 3). New York: Wiley. (P. J. Mussen, General Editor)

Gelman, R. & Gallistel, C. R. (1978). _The child's understanding of number_. Cambridge, Mass: Harvard University Press.

Gibson, E. J. (1982). The concept of affordances in development: The renaissance of functionalism. In W. A. Collins (Ed.) The Concept of Development. New Jersey: Erlbaum.

Hebb, D. O. (1949). Organization of behavior. New York: Wiley.

Hull, C. L. (1920). Quantitative aspects of the evolution of concepts. Psychological Monographs (Whole no. 123).

Inhelder, B. & Piaget, J. (1964). The early growth of logic in the child. New York: Harper & Row.

Jolicoeur, P., Gluck, M. A., & Kosslyn, S. M. (1984). Pictures and names: Making the connection. Cognitive Psychology, 16, 243-275.

Keil, F. C. (1989). Concepts, kinds, and cognitive development. Cambridge, MA: MIT/Bradford.

Keil, F. C. (1991). The emergence of theoretical beliefs as constraints on concepts. In S. Carey & R. Gelman (Eds.), The epigenesis of mind (pp. 237-256). New Jersey: Erlbaum.

Kemler, D. G. (1983). Holistic and analytic modes in perceptual and cognitive development. In Tighe & Shepp (Eds.), Perception, cognition, and development: International analysis (pp. 77-102). New Jersey: Erlbaum.

Klahr, D., & Siegler, R. S. (1978). The representation of children's knowledge. In H. Reese & L. P. Lipsitt (Eds.), Advances in child development (Vol. 12. New York: Academic Press.

Knowlton, B. J., Ramus, S. J., & Squire, L. R. (1992). Intact artificial grammar learning in amnesia: Dissociation of classification learning and explicit memory for specific instances. Psychological Science, 3, 172-179.

Kolodner, J. L. (1984). Retrieval and organizational structures in conceptual memory: A computer model. Hillsdale, NJ: Lawrence Erlbaum.

Medin, D. L., & Shaffer, M. M. (1978). Context theory of classification learning. Psychological Review, 85, 207-238.

Medin, D. L., & Smith,, E. E. (1984). Concepts and concept formation. In M. R. Rosenzweig & L. W. Porter (Eds.), Annual review of psychology, 35, 113-138.

Murphy, G. L., & Brownell, H. H. (1985). Category differentiation in object recognition: Typicality constraints on the basic category advantage. Journal of Experimental Psychology: Learning, Memory and Cognition, 11, 70-84.

Patel, V., & Groen, G. (1990). Arguments against stage theoretic approach to development of medical expertise. Paper Presented at the AERA Annual Meeting, Boston, Mass., April, 1990.

Pavlov, I. P. (1927). Conditional reflexes (G. V. Anrep, Trans.). London: Clarendon Press.

Posner, M., Goldsmith, R., & Welton, K., Jr. (1967). Perceived distance and the classification of distorted patterns. Journal of Experimental Psychology, 73, 28-38.

Posner, M., & Keele, S. (1968). On the genesis of abstract ideas. Journal of Experimental Psychology, 77, 353-363.

Posner, M., & Keele. (1970). Retention of abstract ideas. Journal of Experimental Psychology, 83, 304-308.

Rosch, E., Mervis, C. B., Gray, W., Johnson, D., & Boyes-Braem, P. (1976). Basic objects in natural categories. Cognitive Psychology, 8, 382-439.

Siegler, R. S. (1976). Three aspects of cognitive development. Cognitive Psychology, 4, 481-520.

Smith, E. E., & Medin, D. L. (1981). Categories and concepts. Cambridge, MA: Harvard University Press.

Stiles, J., Delis, D. C., & Tada, W. L. (1991). Global-local processing in preschool children. Child Development, 62, 1258-1275.

Strauss, S., (Ed.) (1982). U-Shaped behavioral growth. New York; Academic Press.

Tanaka, J. W. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? Cognitive Psychology, 23, 457-482.

Thorndike, E. L. (1966). Human learning. New York: Century.

Wattenmaker, W. (1992). Relational properties and memory-based category construction. Journal of Experimental Psychology: Learning, Memory, and Cognition, 18, 1125-1138.

Woodworth, R. S. (1938). Experimental Psychology. New York: Holt.