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FIRST STEPS IN CHILDREN'S ACQUISITION OF EXPERTISE ON SHOREBIRDS

A Thesis Presented

by

KATHY E. JOHNSON

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ABSTRACT

FIRST STEPS IN CHILDREN'S ACQUISITION OF EXPERTISE ON SHOREBIRDS

SEPTEMBER, 1989

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This minilongitudinal study investigated the earliest steps in acquiring expertise within the domain of shorebirds. In particular, the relationship between learning shorebird names and learning shorebird attributes was examined. Over four audiotaped sessions, 16 5-year-old girls were given information about the name, a specific physical attribute, and a correlated behavioral attribute for each of 14 shorebird species while playing a specially designed board game. Children also participated in a fifth post-test session. Children's knowledge of the names and attributes of the 14 species was tested during the game and during an interview at the end of each session. During the first and fifth sessions, children completed a triad sorting task involving the 14 birds. Both children's ability to generalize their shorebird knowledge and their ability to verbally justify particular pairings of shorebirds also were tested during the fifth session.

Children's knowledge of both names and attributes increased over the four sessions, and all children were able to generalize at least some of this knowledge to novel exemplars. Overall, children comprehended significantly more names than they produced any other type of information, and attributes were produced more often than names. Brighter children (estimated by scores on the PPVT-R) tended to comprehend and produce more correct information than children who were less bright. A variety of types of evidence for quantitative changes inherent in acquiring expertise was revealed. Children also were able to use their attribute knowledge to justify particular pairings of shorebirds. Children's triad task solutions during the final session provided evidence for the beginnings of qualitative change. Concerns for future investigations of qualitative change in acquiring expertise are addressed.

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CHAPTER 1

INTRODUCTION

As humans acquire more knowledge about a particular domain, important changes, both quantitative and qualitative, occur in the organization of that knowledge. For example, ornithologists are able to name more species of birds than people who have never studied birds. In addition, there are qualitative differences in the means by which ornithologists and novices classify groups of species of birds. Ornithologists tend to classify taxonomically, whereas novices are more apt to base their classifications on superficial morphological attributes. Expertise involves more than just the ability to classify taxonomically, however. A knowledge of abstract, underlying behavioral functions also is inherent in the manifestation of expertise. For example, ornithologists are able to recognize underlying behavioral similarities that exist among species of birds. In some cases, species that share an underlying behavioral function, such as a particular nesting or feeding behavior, are not closely related taxonomically. Therefore, ornithologists' systems of categorization may differ depending on whether they are classifying species on the basis of underlying behavioral similarities or on the basis of taxonomic relations. Consequently, ornithologists demonstrate a flexibility in their bases for classification of species that novices do not share.

Recent studies of expertise have involved both children and adults. These studies have revealed important findings about the differences that exist between novices and experts from several scientific domains. However, the emphasis on differences between groups of novices and groups of experts has implicitly suggested that the states of "being a novice" and "being an expert" are diametrically opposed, rather than two points along a continuum. The transitional stages inherent in the acquisition of expertise and crucial to understanding the nature of such a continuum have not been studied. The purpose of this research is to examine the earliest transitional stages in the acquisition of expertise by 5-year olds who are learning about shorebirds. In particular, this research addresses the relationship between learning names of shorebirds and learning information about two types of attributes relevant to their feeding behaviors: physical attributes and behavioral attributes. The effects of input about shorebirds on children's knowledge reorganization were studied over a 17 day period. The domain of shorebirds was chosen for two reasons. First, 5-year olds (and their parents) are likely to be unfamiliar with its species. Second, children are inherently interested in different kinds of animals and therefore are naturally motivated to learn more about them.

I begin by presenting findings from three major avenues of research. First, I summarize the research that has examined differences between adult novices and experts.

Second, I describe the available literature relevant to the nature of expertise in children. Third, I present findings relevant to the intermediate stages in the acquisition of expertise. I then describe more specifically how the proposed research aims to reveal additional information about what it means to become "more expert."

Expertise Among Adults

Most studies of adult expertise have been aimed at revealing the nature of the novice-expert shift; that is, the underlying knowledge reorganization that occurs when a former beginner in a particular domain has gained substantial expertise. The domains that have been studied most extensively are expertise in mathematical problem solving, in the physical sciences, and in chess (see review by Chi, Glaser, & Rees, 1982). In these studies, expertise has been defined as the possession of a large quantity of specialized knowledge within a particular domain of information. For example, in examining the manifestation of expertise within the domain of physics, Chi, Feltovich, and Glaser (1981) considered advanced PhD students from a physics department to be experts and undergraduates who had just completed a semester of mechanics to be novices. The results of studies of adult expertise indicate that the shift from "being a novice" to "being an expert" typically results in the individual's ability to perform domain-specific tasks more efficiently. Chi, et al. (1982) hypothesize that novices are no less efficient than experts in terms of the overall architecture of their cognitive systems or in terms of their general processing capabilities. Novices simply are less efficient at storing and subsequently retrieving information due to the quality of its organization. In particular, the organization of the novice's domain-specific information appears to be based on superficial relationships among concepts. For instance, novices to the domain of physics typically categorize physics problems on the basis of surface features such as keywords given in the problem statement (Chi, et al., 1981). Experts are at an advantage for two reasons. First, they possess more domain-specific knowledge than novices. Second, this knowledge is organized on the basis of deep functional relationships among concepts (e.g., Chi, et al., 1981; Murphy & Medin, 1985). For instance, physics experts typically sort physics problems according to the major physics principles governing their solutions.

Murphy and Wright (1984) also have found differences in the category structure of novices and experts within the domain of psychopathology. Expert clinicians possessed categories of psychological disturbances that were richer (as measured by an attribute listing task) than novice undergraduates. Furthermore, the categories of experts were less distinct (as measured by the number of features shared by two or more categories) than those of novices. Therefore, an element of the qualitative reorganization of information inherent in the acquisition of expertise within the domain of psychopathology appears to involve a tendency to focus on both the shared and the distinctive features of objects.

Expertise Among Children

Most of the research on children's expertise has been conducted by Chi (e.g., 1983, 1985, Chi & Koeske, 1983; Gobbo & Chi, 1986), for the domain of dinosaurs. Chi's research has succeeded in mimicking developmental differences in classification behaviors with the manipulation of knowledge rather than age. In general, child experts' knowledge appears to be more structured than adult and child novices'. Furthermore, child experts attend to implicit (deep) features of objects, whereas novices focus on explicit (surface) features of objects.

The manifestation of expertise in children has been examined most closely in two recent studies. The first was a longitudinal study performed by Chi and Koeske (1983) examining one child's representation of concepts within the dinosaur domain. In this study, a 4 1/2-year old boy who was an expert on dinosaurs was asked to perform memory tasks on two different sets of dinosaurs: a better known set and a lesser known set. The boy had been exposed to information about dinosaurs for about 1 1/2 years and was very interested in them. The boy's expertness on the better known set of dinosaurs was defined by his mother's subjective judgement of his knowledge of each dinosaur and the frequency of its mention in the child's dinosaur books.

Results indicated that the better known set of dinosaurs also was better structured in memory. After a year of infrequent exposure to dinosaurs, the better known set was better recalled and retained by the child than the less known set.

The second study was a cross-sectional study performed by Gobbo and Chi (1986). Ten 7-year old boys participated; five were considered experts within the domain of dinosaurs and five were considered novices. Judgements of expertise were made on the basis of two pretests. In the first, children were asked to name 20 different pictures of dinosaurs. In the second, children were asked 20 questions about dinosaurs (e.g., The name of the Brontosaurus means ___ reptile.). Children who scored at least 50% correct on both tasks were considered experts, while those who scored less than 25% correct on both tasks were considered novices. Two experimental tasks were administered to children in both groups. In the first, the experimenter showed each child the 20 pictures of dinosaurs from the naming pretest one at a time. In reference to each, the experimenter asked the child to "tell me its name and everything that you know about it" (p. 224). In the second, the child was shown pictures of all 20 dinosaurs at the same time and instructed to put the dinosaurs that "go together" in the same group. Results of the first (production) task indicated that experts were quite consistent among themselves in mentioning behavioral aspects of dinosaurs that should be of interest to those who are learning about groups of dinosaurs (e.g., diet) and then classifying dinosaurs according to these aspects. Novices, however, were unable to recognize these important behavioral aspects and instead classified dinosaurs on the basis of perceptual similarity. Furthermore, experts were able to reason by generalization or by analogy more successfully than novices. Results of the sorting task revealed that experts consistently referred to implicit features (e.g., family and diet attributes) when verbally justifying their sorts, whereas novices referred solely to external physical attributes. Chi did not report qualitative differences in the piles formed by the experts and novices, however. All experts sorted exhaustively, while two of the five novices left a residual group. On the basis of these results, Gobbo and Chi conclude that experts focus on implicit (rather than explicit) functional concepts and have a more integrated and cohesive knowledge structure than novices. Consequently, experts are able to access and use their domain-specific knowledge in a more sophisticated way.

The results of this study are important in that they begin to suggest more specifically the qualitative differences that exist between groups of child experts and child novices. However, several methodological problems underline the importance of further research on these differences. First, the dinosaurs used in this study frequently were illustrated in their typical habitats;

sometimes they were pictured consuming leaves or meat. Clearly, these pictures would have enabled even novices to classify dinosaurs on the basis of eating behaviors. Second, there is a possibility that 7-year olds may have had some difficulty in solving the general sorting task consistently. In addition to the general sorting paradigm, a simpler sorting paradigm (such as a triad task) might have been used to examine differences between novices' and experts' dinosaur categories. Finally, the experts in Gobbo and Chi's study may not really have been experts. The determinants of expertise were the ability to name at least half of a selected group of dinosaurs and the ability to correctly answer at least half of a prepared set of questions relevant to the dinosaur domain. Being able to name half of a selected group of dinosaurs is a relatively lenient criterion for expert knowledge of dinosaur names. Furthermore, correct answers to the prepared set of questions were not necessarily indicative of expertise. Two of the 20 questions were not about dinosaurs. Of the 18 remaining questions, 2 of the expected correct answers were actually incorrect. Six questions involved name translations (e.g., The meat eating dinosaur whose name means "leaping reptile" is the ___.). Only 5 of the questions tapped the children's knowledge of behavioral characteristics of dinosaurs. Because of the minimal number of relevant questions, little information was available regarding children's expertise on functional relationships among dinosaurs. A much greater proportion of information existed in reference to children's knowledge of dinosaur names. The discrepancy between the measures of name and functional relationship information is problematic. In principle, a child who is not able to name many species of dinosaurs may still be aware of their physical or behavioral attributes and therefore be "more expert" than another child who is unaware of any attributes of the species that he or she can name. The assumption that naming ability is evidence of expert knowledge is an empirical issue that requires further investigation. More specifically, the relationship between knowledge of names and knowledge of attributes relevant to the domain is an important empirical question that remains to be addressed.

Intermediate Stages in the Acquisition of Expertise

Based on consideration of both adult and child studies of the nature of expertise, it is apparent that the transition from the state of "being a novice" to the state of "being more expert" involves a restructuring of the domain. This reorganization of knowledge is accompanied by parallel changes in memory structure for the domain (Chi, 1976; Chi & Rees, 1983). Murphy and Medin (1985) suggest that people's background knowledge increases quantitatively to the point where it must be qualitatively reorganized to fit their personal theories about the world.

In a series of experiments designed to investigate the novice-expert shift within the domain of biological knowledge, Carey (1985) has described two models inherent in children's developing knowledge of the biological properties of humans and other animals. Between the ages of 4 years and 10 years, children's concepts of "animal" and "human" undergo a complex development that results in a shift from one model to the other. In Carey's research, children of various ages were engaged in studies that involved attributing physiological attributes to various organisms. In one experiment, children of various ages (4, 6, and 10 years) and adults were taught either that people, dogs, or bees possessed a particular internal organ (e.g., omentum). Subjects then were asked whether other animate and inanimate objects (e.g., aardvarks, dogs, dodos, clouds, harvesters) possessed that organ. When taught that people possessed the target organ, all subjects attributed that organ to other animals on the basis of their similarity to humans. When subjects were taught that dogs possessed the target organ, interesting developmental differences emerged. Four-year olds seldom made any inductions. When they did, they attributed the target organ equally frequently to both animate and inanimate objects. Ten-year olds and adults, however, did make frequent inductions. Their attributions were largely restricted to animals. In fact, the responses of 10-year olds and adults were hardly distinguishable from when they were taught that people possessed the target organ. Six-year olds appeared to be in transition. These children were still more likely to project the target organ to other animals when taught first that it was possessed by people than when taught that it was possessed by dogs. However, when 6-year olds were taught that the organ was possessed by dogs, they were more likely than the 4-year olds to project the target organ to other animals. On the basis of results from an extensive series of attribution studies, Carey suggests that children younger than 10 years possess a psychological model of animals. In this model, humans are clearly differentiated from other animals; they are the prototypical animal but at the same time are not animals at all. By age 10 years, however, children shift to a biological model of animals. At this time, humans are incorporated into the animal domain and children are able to see humans as just one animal among many. This biological model remains in effect throughout adulthood.

With the exception of Carey's (1985) research, few studies have addressed the intermediate stages involved in the acquisition of expertise. Recently, Johnson, Mervis, and Boster (1989) completed a cross-sectional study of developmental changes in the organization of information within the mammal domain. Judgements of similarity among groups of three pictures of mammals were elicited from 7-year olds, 10-year olds, and adults. Results were interpreted in light of Carey's (1985) dual-model theory of animals. Johnson, et al. found qualitative differences in the structure of the mammal domain, stemming from differences in the treatment of the primates, especially human being, that were consistent with Carey's dual-model theory. However, the qualitative shift between the two theories was completed later than Carey predicted; 10-year olds continued to consider primates to be different from other types of mammals and thus did not demonstrate possession of a biological model of animals.

For the mammal domain, there appears to be a qualitative shift in knowledge inherent in the acquisition of expertise. Adults reflect the expert pattern in that their judgments of similarities among mammals are based on deep taxonomic relations, whereas children reflect the novice pattern in that their judgments of similarities are based on explicit perceptual features. Johnson, et al. (1989) interpreted the differences in performance of the 10-year olds that they studied and the 10-year olds in Carey's (1985) studies as evidence for a transitional period in the development of expertise. During this period, 10-year olds "know" the facts on which the expert model is based, but do not consistently use these facts because they are not yet completely integrated into the child's knowledge base. Thus, whether or not 10-year olds employ the biological model is largely dependent on the type of task in which they are engaged.

Early Lexical Development

Although not typically considered in terms of the acquisition and manifestation of expertise, the categorization of concrete objects is an area in which very young children rapidly become more expert. Children's initial basic level categories often do not correspond to those of adults. One manifestion of expertise in very young children is the gradual approximation of their initial basic level categories to those of adults. Mervis (e.g., 1984, 1987) has argued that child-basic categories often overlap adult-basic level categories as a result of children's attending to different attributes of particular objects than adults do. Children are less aware of the culturally appropriate functions of objects and their correlated form attributes. Therefore, children may overlook attributes of an object that are important from an adult perspective while simultaneously emphasizing attributes that an adult would ignore. For example, the presence of a wick on a spherical candle would lead most adults to label it "candle." However, very young children are likely to be unaware of the functional significance of the presence of a wick and instead to attend to the sphericity of the candle and its capacity to roll. They therefore should consider it a ball. Examination of the evolution of children's initial categories to correspond to the adult standard provides another means of studying the intermediate stages involved in the acquisition of expertise.

The evolution of child-basic categories to correspond to adult-basic categories is dependent on the child's recognition of previously overlooked form-function correlations (Mervis, 1984). Recent research has indicated that certain types of linguistic input are more facilitative of this recognition than others. A longitudinal observational study conducted by Mervis and Mervis (1988) on the role of maternal input in early lexical development revealed that different input strategies varied in degree of effectiveness in inducing children to acquire adult-basic labels for objects previously included in different child-basic categories. The most effective method was labeling an object at the adult-basic level at the same time as providing a concrete illustration of the relevant form attributes and correlated function attributes, along with a verbal description. When mothers used this method, comprehension of the adult-basic level label occurred, on the average, after the second concrete illustration. The least effective method of inducing the evolution of children's intitial child-basic level categories was simply providing the adult-basic level label by itself. The effectiveness of this strategy clearly was dependent on children's possession of relatively sophisticated linguistic capacities. Banigan and Mervis (1988) have argued that this strategy should continue to be less effective than the illustration plus description strategy throughout the lifespan.

A recent cross-sectional study conducted by Banigan and Mervis (1988) involved the systematic manipulation of four input strategies used to introduce adult-basic level terms. Two-year olds were randomly assigned to one of four input conditions: 1) concrete illustration of relevant form-function attributes accompanied by a verbal description and a label (IDL condition); 2) concrete illustration of relevant form-function attributes accompanied by a label (IL); 3) verbal description of relevant form-function attributes accompanied by a label (DL); or 4) the adult-basic label only (L). Results indicated that the IDL input was significantly more effective than the other types of input in inducing children to comprehend and produce adult-basic level names for objects that they had previously included in different child-basic categories. The IL input was next most effective, while neither the DL nor the L input was very effective. The IDL input most clearly facilitated children's conceptual understanding of novel form-function correlations that were essential to the formation of adult-basic categories.

Intent of the Present Research

The intent of the present study was to extend the research performed on the evolution of children's initial child-basic categories in order to address one particular question: What is the relationship between knowing names and knowing attributes in the very early stages of acquiring expertise? The focus of the present study was much narrower than children's categorization in general. In particular, the acquisition of knowledge from within the domain of shorebirds was examined. The input used to teach children about shorebirds was modeled largely upon that which was found most effective in facilitating the evolution of children's initial child-basic categories (Banigan & Mervis, 1988; Mervis & Mervis, 1988). Children were provided with a label for each shorebird, as well as information about two correlated attributes possessed by that shorebird: a physical attribute and a behavioral attribute. Input involving physical demonstration was omitted due to its inappropriateness with the shorebird domain, given that neither live birds nor flexible 3-dimensional models were available.

The present study also attempted to improve upon previous methodologies employed in studying expertise among children. Most research on expertise has focused on contrasting the behaviors of groups of current novices with those of current experts. Cross-sectional studies such as these force researchers to speculate on the nature of the transitional stages that exist between novices and experts. The present study was conducted longitudinally in order to avoid such speculation. Over the course of 17 days, a group of novices was studied closely as they acquired domain-specific knowledge. At the beginning of the study, children's receptive vocabulary was measured by the Peabody Picture Vocabulary Test-Revised Form L (Dunn & Dunn, 1981). This test has been found to correlate positively with several measures of general intelligence, including the Stanford-Binet and the verbal component of the Wechsler Intelligence Scale for Children (Dunn & Dunn, 1981). It was used, therefore, to provide a general estimate of overall intelligence. Only children whose vocabulary ages, as measured by the PPVT-R, were equal to or greater than their chronological ages participated. Domain-specific information was then systematically introduced to reveal developmental patterns in the transition from knowing little about the shorebird domain to becoming more expert in that domain.

The medium used to introduce children to domain-specific information was a specially designed board game featuring realistic color drawings of 14 unfamiliar shorebirds. While playing the game, children were told each bird's name plus a verbal description of one specific physical attribute that facilitated a specific feeding behavior. The restriction of physical attributes and behavioral attributes to those relevant to feeding behaviors narrowed the focus of the domain even further, making its mastery by children within a period of a few weeks more feasible.

Several measures of children's developing knowledge of shorebird names and shorebird attributes were used throughout the study. Children's knowledge of shorebird names was evaluated through tests of comprehension and production incorporated into the board game. Children also were interviewed on their knowledge of shorebird names at the end of each session. Children's knowledge of shorebird attributes was tested both directly and indirectly. Direct measures included production tests of both physical and behavioral attributes during the board game, interview questions aimed at revealing children's knowledge of attributes at the end of each session, and a pair justification task at the end of the study. In the board game, children were presented with either a physical or a behavioral attribute and then asked to provide its correlate. During the interview session, children were shown pictures of shorebirds and asked to tell the experimenter what they knew about each one. In the pair justification task, children were presented with two types of shorebird pairs: those that were similar in terms of overall morphological form, and those that shared correlated physical and behavioral attributes. Children were asked to explain why someone might consider the birds in each pair to be "like the same kind of thing."

Indirect measures of children's attribute knowledge included a triad task and a general sorting task. These measures are considered indirect in that children's solutions must be interpreted implicitly on the basis of their categorization decisions. Children completed the triad task twice: once at the beginning of the study and then again at the end of the study. Children were presented with a series of 14 triads (derived from the 14 types of shorebirds to be studied) and asked to indicate which two of the three pictures were most like the same kind of thing. Each triad consisted of a target species (e.g., gallinule), a species that was superficially similar to the target but dissimilar in terms of an underlying functional relationship (e.g., coot), and a species that was superficially dissimilar to the target but similar in terms of an underlying functional relationship (e.g., long-toed lapwing). The general sorting task also was completed twice: once at the beginning of the study and once at the end of the study. In this task, children were presented with pictures of all 14 shorebirds and asked to sort them into piles, putting the ones that were "like the same kind of thing" together in the same pile.

Finally, children's ability to generalize the information that they had learned about the 14 shorebirds to a novel set of 14 subspecies of the target exemplars was examined during the final session. Children completed the triad task, participated in an interview session on both the names and attributes of each of the 14 shorebirds, completed a comprehension test of shorebird names, and performed the general sorting task. For all these tasks, the novel set of exemplars was used.

Predictions

Eight sets of predictions corresponding to general categories of children's performance throughout the five sessions are presented along with their respective bases.

Knowledge of names. Both children's correct comprehensions and productions of shorebird names were expected to increase over time, as a function of repeated exposure to the correct names while playing the board game. In addition, children's correct productions of shorebird names during the interview session were predicted initially to exceed their correct productions during the board game. By the time children participated in the interview session, they had had the opportunity to hear each shorebird named two additional times. Finally, children were expected to begin comprehending shorebird names earlier than they began producing shorebird names. This prediction was made because comprehension has been found typically to precede production in children's vocabulary acquisition (e.g., Benedict, 1979; Huttenlocher, 1974; Thompson & Chapman, 1977). Furthermore, children were expected generally to comprehend more shorebird names than they produced throughout the five sessions.

Knowledge of attributes. Over the course of participating in the board game and the interview session, children's correct productions of both physical and behavioral attributes were expected to increase as a function of repeated exposure to the correct attributes while playing the board game. Within both of the test mediums, however, children were expected to consistently produce more correct physical attributes than behavioral attributes. Each of the correct physical attributes was composed of both a body part (e.g., toes) and a descriptor for that body part (e.g., very long). Each of the correct body part components was visible in the picture stimuli and children needed only to recognize the relevant one. Subsequently, only the correct descriptor for each body part needed to be recalled. Productions of correct behavioral attributes, however, required that children recall all aspects of the behavior correlated with the possession of a given physical attribute. No cues as to the specific natures of the correct behavioral attributes were visible in the picture stimuli. One pervasive finding in the memory literature is that children's performance on recognition tasks is superior to performance on tests of recall (for a discussion of why this finding should obtain, see Myers & Perlmutter, 1978). Since a portion of the physical attribute could be recognized from the picture stimuli, children were predicted to produce more correct physical attributes than correct behavioral attributes.

The provision of an attribute correlate was predicted to be an extremely powerful cue for eliciting children's correct productions of both physical and behavioral attributes. When a particular attribute was provided, it was expected to serve as a scaffold for the child's retrieval of the relevant correlate (e.g., Bruner, 1986; Wertsch & Stone, 1986). Children were therefore predicted to produce more correct attributes during the board game than during the interview session. During the board game, the experimenter provided the child with a particular attribute and asked her to produce its correlate, whereas during the interview session the child was asked simply to tell the experimenter what she knew about each shorebird.

Relationship between knowledge of names and knowledge of attributes. Attribute information was predicted to be more salient to children than information about shorebird names. It seemed inherently probable that children would be more interested in what function each bird was able to perform due to the possession of a particular attribute than in what each bird was called. Furthermore, it was never the case that children would lack an appropriate label for an individual shorebird; children should be perfectly content to refer to each of the shorebirds as "bird." Possessing a viable label for each bird was expected initially to direct children to attend more to the attribute information presented in reference to each shorebird. Subsequently, children were predicted to begin producing both physical and behavioral attributes earlier than shorebird names, and to consistently produce more correct forms of attribute information than correct forms of name information. This pattern was not predicted to hold for name comprehension. Receptive vocabulary typically is greater than productive vocabulary, and the comprehension test involved only three distractors. It therefore was predicted that the number of names that children correctly comprehended would be at least equal to the number of each type of attribute that they correctly produced.

Indirect tests of attribute knowledge. Concerning the two indirect tests of children's attribute knowledge, the triad task and the general sorting task, children were predicted to base almost all of their similarity decisions on overall morphological form at the beginning of the study. By the end of the study, children were predicted to attend more often to the attributional properties possessed by each of the shorebirds, as a consequence of their experience with the board game. During the final session, children were expected to be more likely to consider groups of shorebirds that shared correlated attributes to be "most like the same kind of thing" in both types of test.

Children's errors. Several questions relevant to the erroneous responses that children produced during both the board game and the interview session were investigated. One question concerned whether the children were more likely to make errors on name information or on attribute information. A related question concerned the number of birds for which children tried to produce a particular type of information, regardless of whether it was correct or incorrect. It was predicted, based on the expectation that attribute information would be more salient than name information, that children would be more likely in general to attempt to produce information about attributes than information about names. Children were predicted to attempt to comprehend names for at least as many shorebirds as the number of birds for which they attempted to produce attributes. Further questions were asked with regard to the content of children's errors. Specifically, when children displayed confusions in producing different types of information, did their confusions tend to involve particular shorebirds? In cases where children made errors either in producing or comprehending shorebird names or attributes, were these errors most likely to involve the bird that was similar to the target shorebird in terms of overall morphological form, the bird that was similar to the target in terms of shared correlated attributes, or a completly unrelated bird? Furthermore, when children produced incorrect behavioral attribute information, did they tend to produce a particular part of the attribute correctly more often than others?

<u>Performance on the pair justification task</u>. In the pair justification task, the number of justifications based on attributes of the whole shorebird was expected to be greater among pairs based on overall morphological form than among pairs based on shared correlated attributes. Members of the pairs based on overall morphological form generally shared "global" attributes that were predicted to be salient to children (e.g., color, size). Members of the pairs based on shared correlated attributes did not share an overall resemblance. Therefore, children were predicted to be more likely to focus on shared attribute properties when justifying these pairs. For the pairings based on shared correlated attributes that children correctly justified, the majority of these justifications was predicted to involve

physical attributes, since these often were visible in the pictures of the shorebird exemplars. For pairs based on correlated attributes that children correctly justified on the basis of a physical and/or a behavioral attribute, the majority of these pairs were predicted to involve two shorebirds for which the child had correctly produced that attribute(s) previously. Next most prevalent were predicted to be pairs for which the child had previously produced a correct attribute in reference to one member. Pairs containing two birds for which the child had never produced a correct attribute were predicted to be least likely to be correctly justified on the basis of that attribute.

Generalization of knowledge to novel shorebird exemplars. During the final session, children were tested on the generalizability of their previously acquired knowledge to a set of novel exemplars of the 14 target shorebirds. All children were predicted to generalize some of the domain-specific information that they had acquired during the first four sessions to novel exemplars. In general, children were expected to generalize to novel exemplars only those forms of information that had been produced correctly during an earlier session.

Relationship between PPVT-R scores and the acquisition of domain-specific information. Brighter children were predicted to comprehend and produce more correct types of information throughout both the board game and the interview session. Since the PPVT-R is positively correlated with existing tests of general intelligence, children with higher standard scores on the PPVT-R were predicted to be more likely to learn and produce more correct forms of information than children with lower standard scores.

CHAPTER 2

METHOD

Subjects

Sixteen girls ranging in age from 5;5 to 5;11 years participated in this study.[1] All subjects were native speakers of American English. Subjects whose vocabulary ages as measured by the PPVT-R were less than their chronological ages were excluded. On this basis, one additional girl was not included in the study.

Children were recruited from middle class neighborhoods in the vicinity of Amherst, Massachusetts through birth records maintained by the Psychology Department at the University of Massachusetts. Parents were contacted by telephone and provided with general information about the study. If parents agreed, times were then arranged for their child's participation.

Materials

Stimulus materials consisted of stimulus cards, a specially designed game board (modeled after the commercially available game Dinosaurs and Things), and accompanying game pieces.

Stimulus cards. Two general sets of stimulus cards were constructed. The two general sets differed only in that they pictured different exemplars for the 14 target shorebirds presented in the second column of Table 1.[2] The taxonomic levels of the target shorebirds and of the exemplars pictured on the stimulus cards are presented in the first and third columns, respectively. The specific exemplars pictured for each target are listed in the fourth and fifth columns. Monotypic species differed in terms of the exposure at which they were photographed (i.e., the species exemplar in one stimulus set was photographed at a low exposure and thus appeared quite dark, while the species exemplar in the other stimulus set was photographed at a high exposure). Cards in both general sets pictured realistic color drawings of male birds, presented in the same canonical orientation against a plain white background. Pictures of birds were extracted from field guides and reproduced on Ilford Cibachrome matte finish copy material through a direct-positive Ilford Cibachrome color copying process. All reproductions were mounted on 4 inch x 4 inch (10.16 cm x 10.16 cm) pieces of cardboard and then covered with transparent contact paper.

Eight groups of three stimulus cards were constructed for use as practice triads. The 24 cards were mounted on 4 inch x 5 inch (10.16 cm x 12.70 cm) pieces of cardboard and then laminated. Two of the practice triads contained differently colored geometric shapes, two contained differently colored abstract shape configurations, and the remaining four featured drawings of concrete objects. In half of the practice triads, color was correlated with the correct choice. For the four triads involving concrete objects, two of the figures were obviously more taxonomically related than a third. In two of these four triads, taxonomic relationship and overall morphology were correlated, and in two triads they were orthogonal.

Game board. The game board was drawn on a 21 inch x 21 inch (53.34 cm x 53.34 cm) piece of white paper, mounted on a piece of poster board, and then laminated. The game board was covered with the game route: a track of 80 spaces leading from a start to a finish point. The track consisted of 62 spaces, each displaying one of six colors (blue, green, orange, pink, red, or yellow). Fourteen identical circles were randomly positioned among the 62 colored spaces. Each of these circles was divided into six sections, with one of the six colors of the game track featured in each section. Four "message" spaces were randomly positioned along the track, detailing specific moves for players to make (e.g., Time to fly south - move ahead 4 spaces.). One "bridge" was positioned on the game track, intersecting an uninterrupted series of colored spaces.

Game pieces. Game pieces included two card trays, a colored die, and movable tokens.

The two card trays were constructed from white Fome-Cor and measured 29 inches x 5 inches (73.66 cm x 12.70 cm). Each contained two rows of seven compartments. Each compartment held two 4 inch x 4 inch (10.16 cm x 10.16 cm) stimulus cards.

The die and game tokens were the standard types used in children's games. The die had differently colored circles on each of its six sides. Each of the die's circles was one of the six colors used for the spaces on the game board. Four differently colored bird-shaped game tokens were available for players to choose from. An illustration of the game board and pieces is presented in Figure 1.

Procedure

All testing took place in children's homes. Each child participated individually in four one-hour sessions and a fifth half-hour session within a 17-day period. The first four sessions occured at intervals of 3 to 5 days, and the final session occurred within two days of the fourth session. All sessions were audiotaped. The first four sessions involved the playing of a specially designed board game called "Birdland." The game was played twice during each of these sessions except for the first. The fifth session involved a series of tests designed to investigate the child's ability to generalize the information she had learned about shorebirds to different exemplars of the same categories. In addition, the child's ability to verbally justify familiar shorebirds paired on the basis of either overall morphological form or shared correlated attributes was tested during session five.

Use of stimulus cards from the first and second general sets was counterbalanced across children. Half of the children used cards from the first general set throughout the first four sessions, and the other half of the children used cards from the second general set. During the final session, children used stimulus cards from the unfamiliar general set. That is, if a child had used stimulus cards from the first general set during sessions one through four, she used stimulus cards from the second general set during session five.

Session 1. During the first session, the experimenter spent some time talking to the child so that the child felt comfortable. Then the child completed the triad task. To ensure that the child understood this task, the eight practice triads were presented first. For each group of three cards, the child was asked to, "point to the two that are most like the same kind of thing." Feedback was given after each of the practice triads. Children were required to correctly solve at least six of the eight practice triads. The child was then asked to solve the 14 randomly ordered triads of shorebirds (listed in Table 2).[3] The shorebirds listed in the first and third columns are related by one of seven underlying feeding behaviors and their physical attribute correlates (as discussed in Ferguson-Lees, Willis, & Sharrock, 1986; Hayman, Marchant, & Prater, 1986; Johnsgard, 1981; Peterson, 1980; Robbins, Bruun, & Zim, 1983). Two types of shorebirds shared each of these seven sets of correlated attributes. The shorebirds listed in the first and second columns are similar in terms of overall morphological form. Drawings from the gallinule-coot-lapwing triad from the first general set of stimulus cards are presented in Figure 2. Verbal feedback was not given when children were solving the 14 triads involving target shorebirds.

After the triad task, children were asked to perform a general sorting task involving all 14 of the target shorebirds. Fourteen stimulus cards, each featuring one of the shorebirds, were placed in front of the child. The experimenter then said, "Now I'd like you to make some piles. Put the ones that are the same kind of thing together. Make as many piles as you want." After the child stopped sorting, the experimenter asked, "Are you all finished?". When the child agreed, the experimenter and the child played one game of Birdland, using a modified format unique to the first session (see below).

Following the Birdland game, the child was interviewed about each of the 14 shorebirds involved in the game (see below). The experimenter then administered the PPVT-R (Dunn & Dunn, 1981).

<u>Sessions 2 - 4</u>. During the next three sessions, two games of Birdland were played. A comprehension test was incorporated into one of the games played during each session, and a production test was incorporated into the other game (as described below). A test of children's knowledge of the physical attributes of each of the target shorebirds also was incorporated into one of the two games played each sesssion, while a test of children's knowledge of the behavioral attributes of each of the target

shorebirds was incorporated into the other game. Interview sessions were conducted after both games had been played.

The Birdland game. The experimenter and the child took turns tossing a multi-colored die and moving their tokens to the next space of that color on the game board. Simple instructions were given as the experimenter and child played the game, rather than before the game began. For example, the experimenter initiated the game by asking the child to pick out two game tokens, one for the child and one for the experimenter. Then the experimenter said, "Now we're going to play a game called Birdland. Here's a die. Throw this and see what color you get." After the child rolled the die, the experimenter asked, "What color did you get?" After the child responded (e.g., "blue"), the experimenter said, "That means you should move your piece to the first space where you see [color, e.g., blue]." Because the 14 colored circle spaces contained each of the die's six colors, both players had to land on each one before reaching the end of the game track.

Five spaces on the board automatically sent players who landed on them to specially designated locations. Four of these spaces contained messages, telling players to move either ahead or back a specified number of spaces (e.g., Time to feed baby bird. Move back one space). The game board included footprints starting from the original space and extending in the correct direction over the specified number of spaces. The provision of footprints alleviated any difficulties 5-year olds might have had in counting the correct number of spaces. The fifth space led directly to a "bridge;" players who landed on this space crossed immediately to get to another space farther along the game track on the opposite end of the bridge. The message spaces and bridge were positioned so that players could not skip over or land twice on any of the 14 colored circle spaces.

<u>Within-game tests of comprehension and production</u>. During each session, one of the rounds of the board game included a production test of the names of each of the 14 shorebirds, while the other round included a comprehension test for these names. Half of the children played the production test round first during each of sessions 2 through 4, while the remainder of the children played the comprehension round first.

Prior to each round, stimulus cards featuring the 14 target shorebirds were placed randomly on the 14 compartment bottoms of the child's card tray. The experimenter's card tray did not have any cards in it. After landing on a colored circle space and answering all of the relevant questions posed by the experimenter (see below), the child concluded her turn by placing her stimulus card in the compartment of her card tray that had in it the identical picture. This ensured that children had looked closely at the physical attributes of each of the 14 shorebirds. If the child put the stimulus card in an incorrect compartment, the experimenter said, "Look again carefully. Are those two birds exactly the same? Put your card in the hole with the bird that's exactly the same."

During the production test round of each session, each player had her own stack of 14 face-down stimulus cards, containing one card for each of the 14 target shorebirds. Each time the child landed on a colored circle space, the experimenter drew only the top card from the child's stack. The experimenter then asked, "Can you tell me what kind of bird this is?" Guessing was discouraged. If the child gave the correct answer, the experimenter responded positively and repeated the correct name. (e.g., "You're right! That's a gallinule.") The experimenter then continued on to the within-game test of attribute information (see below). If the child provided an answer that was incorrect, the experimenter responded, "Well, that's actually a [correct name]." and then continued on to the within-game test of attribute information. If the child indicated that she did not know, the experimenter provided the correct name and then continued on to the within-game test of attribute information. In the experimenter's response to the child's provision of name information, shorebird names listed in the second column of Table 1 that are longer than one word were shortened to one word (e.g., "lapwing" for "long-toed lapwing") and names that contain roots shared by more than one target were modified so that each name was unique (i.e., "black-fronted plover" and "golden plover" were called "blackfront" and "golder," respectively). When the experimenter landed on a colored-circle space during the production test round, she simply picked up the top card in her pile and immediately placed it in one of the empty compartments of her card tray.

During the comprehension round of each session, the child's stack of stimulus cards included 14 groups of four cards. Index cards were placed between the groups to separate them. One of the shorebirds within each of the 14 groups was the designated target (corresponding to each of the shorebirds listed in the second column of Table 1), while the remaining three were distractors. Two distractors in each group were similar in terms of overall morphological form to the target; the remaining distractor was similar to the target in terms of shared correlated attributes. The groups of cards within the child's stack were randomly ordered and positioned face-down so that the child could not see the pictures on their faces. The experimenter simply had a stack of 14 stimulus cards, as in the production test round. Each time the child landed on a colored circle space during this game, the experimenter drew the top group of four cards from the child's card stack and then placed the cards face up in a row in front of the child. The experimenter then asked her to point to the target shorebird in response to the question, "Do you see a(n) X?" Guessing was discouraged. If the child provided an incorrect response, the experimenter pointed to the appropriate picture and say "Well, this one is actually the [correct name].", and then continued on to the within-game test of attribute information (see below). If the child provided the correct response, the experimenter responded positively and repeated the correct name. The experimenter then continued on to the within-game test of attribute information. If the child indicated that she did not know, the experimenter pointed to the correct picture saying, "This is the [correct name].", and then continued on to the within-game test of attribute information. When the experimenter landed on a colored-circle space during the comprehension test round, she simply drew the top card from her stack and placed it in one of the empty compartments of her card tray.

Within-game tests of attribute knowledge. After being tested for either comprehension or production of the target shorebird's name, each child was provided with input relevant to one of the two types of attribute possessed by that shorebird and asked to provide its correlate. The order in which attribute types were tested was counterbalanced across children. Half of the children who played the production test round of the board game first and half of the children who played the comprehension test round first were provided with input relevant to physical attributes during the first round and input relevant to behavioral attributes during the second round. The remainder of the children were provided with information relevant to behavioral attributes during the first round and information relevant to physical attributes during the second round. After the particular type of attribute had been provided, the experimenter asked the child, "Can you tell me why?". If the child provided the correct correlated attribute, the experimenter said, "You're right!" and then repeated the correct correlated attribute. If the child provided a partially correct correlated attribute, the experimenter said, "Almost. That's really because...", and then continued on with the correct correlated attribute. If the child provided an incorrect correlated attribute, the experimenter said, "Well, that's really because...", and then continued on with the correct correlated attribute. If the child said that she did not know, the experimenter simply provided the correct correlated attribute. The attribute inputs shared by each of the seven correlated attribute-based pairs of target shorebirds are listed in Table 3. Only inputs in which the physical attribute was presented first are listed. After providing the appropriate attribute input, the experimenter pointed to the child's card tray and said, "Now put your card in with the other [shorebird name]."

Concluding the game. The game continued until the child reached the finish point. Since each child had to stop at all 14 of the colored circle spaces, she was ensured of seeing each of the 14 species of birds and hearing its attributes modeled exactly two times (once per game) and hearing its name exactly four times (twice per game).

Interview sessions. To further investigate the developmental processes involved in acquiring expertise, children were interviewed at the end of each session. The experimenter showed each child 14 stimulus cards individually, each featuring one of the target shorebirds and asked, "What can you tell me about this bird?" and "What is the name of this bird?" in reference to each one. The experimenter asked the former question first for seven randomly selected birds during each session, while the latter question was asked first in reference to the remaining seven birds. Children received a different random order of birds during each of the four sessions. The child was allowed to talk freely, although she was not permitted to hold the stimulus card throughout this task.

Birdland format during session 1. During the only game of Birdland played during the first session, children simply heard the relevant input for each shorebird. Both the child and the experimenter had her own stack of 14 stimulus cards, composed of one card for each of the 14 target shorebirds listed in the second column of Table 1. The child's card tray also contained one card for each of the 14 target shorebirds, while the experimenter's card tray was empty. When the child landed on a colored-circle space, the experimenter drew the top card from the child's stack and told her the name of the shorebird featured on that card. Then, she provided the child with one of the shorebird's correlated attributes, followed by, "And I'll tell you why."

Finally, she provided the child with the second correlated attribute. Half of the children were provided with the physical attribute for each shorebird first, while the other children were provided with the behavioral attribute first. The experimenter concluded the child's turn by pointing to the child's card tray and asking her to "Put that card in the hole with your [target shorebird name]." When the experimenter landed on a colored-circle space during the Session 1 Birdland game, she simply drew the top card from her stack of stimulus cards and placed it into an empty hole in her card tray.

Session five. During the final session, children were tested on their ability to generalize information that they had learned about the names and correlated attributes of each of the 14 target shorebirds to a set of novel exemplars of those shorebird categories. Children completed a triad task, an interview session, a comprehension test, and a general sort. All of these tasks were completed using stimulus cards from the unfamiliar general set. At the end of session five, children were asked to justify a series of pairings of shorebirds. Half of these pairings were based on overall morphological form similarity, and half were based on shared correlated attributes. These pair justifications were completed using stimulus cards from the familiar general set.

The child first completed the triad task. The triad task administered during session five had the same format as the session one triad task. However, the practice triads were not administered. Next, the child was interviewed to determine what she knew about each of the 14 shorebirds. The format of the interview session was identical to those administered during sessions one through four. Following the interview session, a comprehension test for the names of each of the 14 shorebirds was administered. The child was presented with 14 groups of four shorebirds. One of the shorebirds within each of the 14 groups was the designated target (corresponding to each of the shorebirds listed in the second column of Table 1), while the remaining three were distractors. One distractor shared the same correlated attributes with the target, while the remaining two were similar to the target in terms of overall morphological form. The experimenter asked the child to point to the target shorebird in reference to the question, "Is there a(n) X?" Guessing was discouraged. The experimenter responded "Okay." or "Thanks." after the child responded to each of the 14 groups. The child then completed the general sorting task. This task had a format identical to the general sorting task administered during session one.

Finally, the child completed the pair justification task. The experimenter presented the child with 14 pairs of shorebirds. In reference to each pair, the experimenter said to the child, "One time someone told me that these two birds were like the same kind of thing. Why do you think that she might have said that?" Seven of the pairs were similar in terms of overall morphological form. These corresponded to the groupings presented in the first and second columns of Table 2. The remainder of the pairs shared correlated attributes. These pairs corresponded to the groupings presented in the first and third columns of Table 2. Additional pairs were presented in the event that the child did not base all of her decisions in the session 5 triad task on either overall morphological form or correlated attributes (i.e., she paired the shorebird that was similar to the target in terms of overall morphological form with the shorebird that was similar to the target in terms of correlated attributes). These pairs were presented to the child after she had solved the first 14 pairs. After the child verbally justified each pair, the experimenter responded, "Okay." or "Good answer."

Subject rewards. Children were rewarded for their participation throughout the course of the study. At the end of the first session, each child was given a small blank notebook with her name on the cover to be used as an album for stickers. At the end of each of the five sessions, each child was asked to choose two stickers from a large bag of stickers to place in her sticker album. At the end of the final session, each child also received a book and parents were debriefed.

Coding System

The complete system used to code the verbal information produced during sessions one through five is presented in the Appendix. Below I present a summary of the systems used to code children's productions of name information, physical and behavioral attribute information, and information produced during the session five pair justification task.

Name production. Names produced during the game and interview sessions were coded as either correct, partially correct, or incorrect. Correct names included those that were produced in a form identical to that produced by the experimenter, as well as those produced with one phoneme added (e.g., "flapwing" for "lapwing"), deleted (e.g., "gold-" for "golder"), or replaced (e.g., "twerlew" for "curlew"). Partially correct names included forms that did not fit into the "correct" category, but were still recognizable as derived from the form produced by the experimenter (e.g., "winglap" for "lapwing"). (A list of all correct and partially correct forms is provided on pp. 137-138 of the Appendix.) Incorrect names consisted of forms derived from one of the 13 other target shorebird names, or forms that were completely underivable or nonsensical (e.g., hummingbird, nerk). If an incorrect name could be derived from one of the 13 other target shorebird names, it was coded as referring either to the shorebird that was matched to the target in terms of overall morphological form, the shorebird that was matched to the target in terms of shared correlated attributes, or to an unmatched shorebird.

Production of physical attributes. Each of the seven physical attributes was broken down into two components: a body part (e.g., toes) and a descriptor for that body part (e.g., very long). If both of these components were produced for a target shorebird in a form that was semantically equivalent to the input provided by the experimenter (see Table 3), the physical attribute was considered correct. If either or both of the components that were produced was not semantically equivalent to the input statement, the physical attribute was considered incorrect. Incorrect physical attributes or components of physical attributes that were semantically equivalent to one of the six other input statements (listed in Table 3) were further coded as either referring to the bird that was matched to the target in terms of overall morphological form or not.

All physical attributes for which both components were produced, whether correct or incorrect, were further coded along two dimensions. The first concerned whether or not the physical attribute was visible. Visible physical attributes included those that could be seen (e.g., bill that goes up at the end), while nonvisible attributes included those that could not be seen (e.g., strong legs). Second, all physical attributes that were visible were coded as either "true" or "not true." Determination of truth was made by looking at the relevant stimulus picture. For example, if a child said that a particular bird had a long bill, and the picture of a bird to which she was attending had a relatively short bill, that physical attribute was coded as "not true."

Production of behavioral attributes. Behavioral attributes were subdivided into three components: action (e.g., walks), location (e.g., on top of plants that float on the water), and goal (e.g., water bugs). Each component was coded as either correct, partially correct, or incorrect. Correct components were those that could be considered semantically equivalent to the input. Partially correct components were forms that were derivable from the original input provided by the experimenter, although they were not semantically equivalent to that input. (A list of all correct and partially correct components is presented on pp. 148-154 of the Appendix.) For a behavioral attribute to have been considered correct, it must have met one of three criteria: 1) all three components produced and correct; 2) all three components produced, two correct and one partially correct (e.g., for the gallinule/lapwing pair: "walk" (correct) "on top of plants" (partially correct) to find "water bugs" (correct) to eat); or 3) two components produced and correct, no other codable information produced (e.g., for the curlew/woodcock pair: "go" (not codable) "in the dark" to find "bugs" to eat).

For behavioral attributes that were not coded as correct and for which incorrect components were produced, those incorrect components were coded as either derivable from one of the other six input statements (listed in Table 3), or unrelated to any input provided in reference to the remaining pairs of shorebirds. For components that could be derived from one of the remaining six input statements, that component was coded as to whether it referred to the shorebird that was matched to the target in terms of overall morphology or not.

Production of physical and behavioral attributes during the interview session. Physical and behavioral attributes that were produced during the interview session were treated individually like those produced during the board game. However, when a child produced both a physical and a behavioral attribute in reference to a shorebird during the interview session, those attributes were coded as to whether they were correlated or not. In order for a pair of attributes to be coded along this dimension, the child had to have produced the two components of the physical attribute and at least the action component of the behavioral attribute. If a cause-and-effect relationship existed between the two attributes, the pair was coded as correlated (e.g, "long toes" to "walk on plants"). If the physical attribute was not necessary for the fulfillment of the behavioral attribute, the pair was coded as not correlated (e.g., "big eyes" to "walk on plants").

Information produced during the pair justification task. Children's productions during the session 5 pair justification task were first broken down into separate propositions, corresponding to the different reasons why the child thought that each pair was like the same kind of thing. Each proposition was then coded along two dimensions: the overall nature of the reason, and the content of the reason.

The overall nature of the reason was coded in three ways. First, the consistency with the input (or lack of input) that the child had received was considered. For pairs based on overall morphological form, reasons based on attributes of the whole bird (e.g., size, color) were considered consistent. Alternatively, for pairs based on shared correlated attributes, reasons based on attributes of a part of the bird or its corresponding behavioral function were consisdered consistent with the input. Second, each proposition was evaluated in terms of its correctness. To be considered correct, an adult (who knew all of the physical and behavioral attributes corresponding to each of the shorebirds) would have to agree with the reason produced by the child. Finally, the appropriateness of the means by which the child addressed the question was considered. Propositions produced when the child had apparently lost track of what the task was asking her to do were coded as invalid and excluded from further coding.

The content of each of the child's propositions was coded according to whether the reason produced by the child referred to an attribute of the whole shorebird or an attribute of a part of the shorebird. For reasons relevant to an attribute of the whole bird, the nature of that attribute was coded (e.g., did it refer to the bird's size, shape, color, or weight?). For reasons relevant to an attribute of a part of the bird, the reason was coded as to whether it referred to a physical attribute, a behavioral attribute, or both a physical and a behavioral attribute. Physical attributes were coded according to what part of the bird they referred to, whether they were visible or not, and whether they were semantically equivalent to one of the seven physical attribute input statements. For those physical attributes that were semantically equivalent to input statements provided by the experimenter, the reason was further coded as to whether one, both, or neither of the birds in the pair were actual possessors of the attribute, as dictated by the input statements. Behavioral attributes were coded according to which of the three components were produced, and whether they were semantically equivalent to one of the seven behavioral attribute input statements. As with the physical attributes, behavioral attributes that were semantically equivalent to input statements were then coded as to whether one, both, or neither of the birds in the pair were actual possessors of the attribute. Pairs for which both a physical and a behavioral attribute were produced were coded as to whether the attributes were correlated or not.

Table 1

Shorebirds Featured on Stimulus Cards

Taxonomic Level of Type	Shorebird	Exemplars on Stimulus Cards: Level of Exemplars	First General Set	Second General Set
Family	stone curlew	species	spotted dikkop	stone curlew
Genus	avocet	species	Andean	Pied
	coot	species	American	European
	gallinule	species	purple	common
	godwit	species	bar-tailed	black-tailed
	snipe	species	solitary	wood
	woodcock	species	Amami	dusky
Tribe	golden plover	species	American	Eurasian
Species	black-fronted plover	species	[monotypic]	
	long-toed lapwing	species	[monotypic]	
	northern phalarope	species	[monotypic]	
	ruddy turnstone	species	[monotypic]	
	terek sandpiper	species	breeding	nonbreeding
	wrybill	species	[monotypic]	

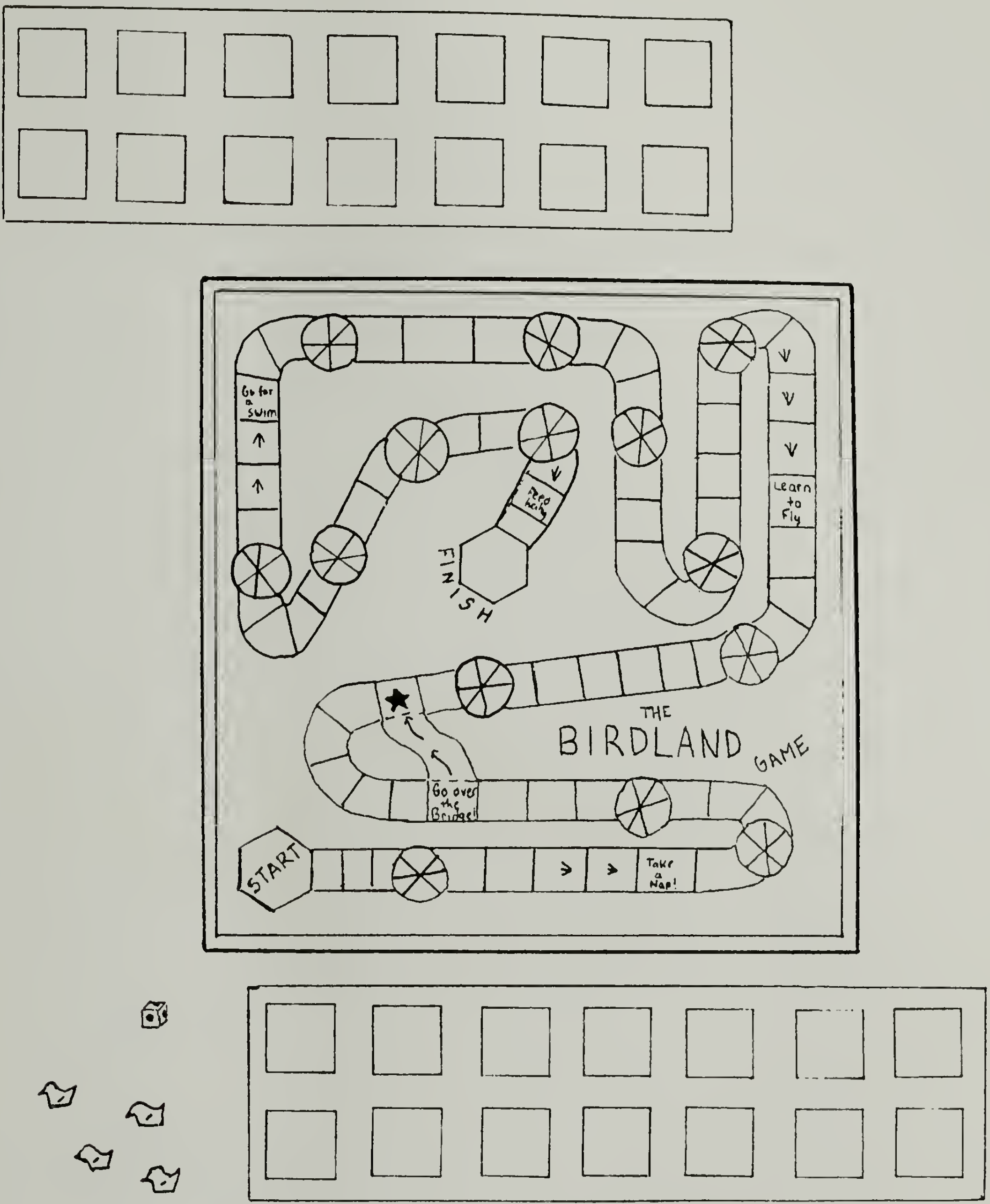
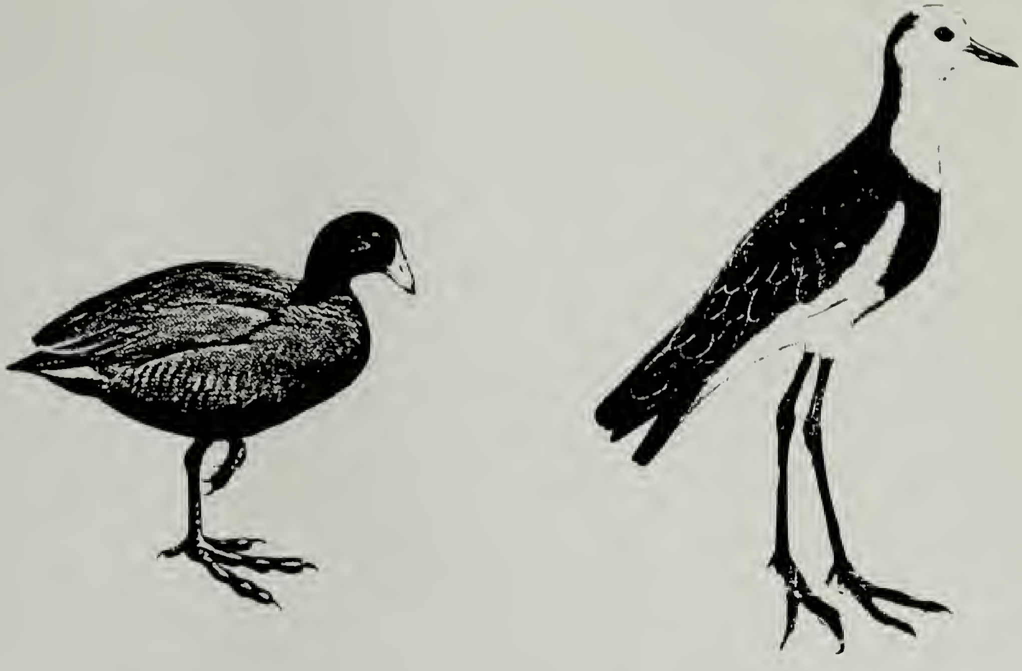


Figure 1. Game board and pieces.

Table 2

Triad Groupings

Target	Similar in Overall Morphological Form	Similar in Shared Correlated Attributes
avocet	long-toed lapwing	terek sandpiper
terek sandpiper	wrybill	avocet
black-fronted plover	ruddy turnstone	golden plover
golden plover	stone curlew	black-fronted plover
coot	gallinule	phalarope
phalarope	godwit	coot
gallinule	coot	long-toed lapwing
long-toed lapwing	avocet	gallinule
godwit	phalarope	snipe
snipe	woodcock	godwit
ruddy turnstone	black-fronted plover	wrybill
wrybill	terek sandpiper	ruddy turnstone
stone curlew	golden plover	woodcock
woodcock	snipe	stone curlew



COOT LAPWING

GALLINULE

Figure 2. Gallinule-coot-lapwing triad.

Table 3

Attribute Input

Shorebird Pair	Attribute Input
avocet terek sandpiper	That's an avocet/sandpiper. Its bill goes up at the end. You know why? That's so it can sweep its bill back and forth over the mud to find snails to eat.
black-fronted plover golden plover	That's a blackfront/golder. It has very strong legs. You know why? That's so it can tap its feet up and down on the ground to bring worms up to the surface to eat.
coot phalarope	That's a coot/phalarope. It has little bits of skin between its toes. You know why? That's so it can swim in the water to find water bugs to eat.
gallinule long-toed lapwing	That's a gallinule/lapwing. It has very long toes. You know why? That's so it can walk on plants that float in the water to find water bugs to eat.
godwit snipe	That's a godwit/snipe. It has a long straight bill. You know why? That's so it can push its bill up and down very fast in the mud to find worms to eat.
ruddy turnstone wrybill	That's a turnstone/wrybill. It has a very strong bill. You know why? That's so it can dig underneath rocks to find crabs to eat.
stone curlew woodcock	That's a curlew/woodcock. It has very big eyes. You know why? That's so it can see in the dark to find bugs to eat.

CHAPTER 3

RESULTS

The results are divided into eight general sections, corresponding to the hypotheses outlined in the Predictions section. The first section concerns children's demonstrations of their knowledge of shorebird names. This section is followed by a parallel discussion of the manifestation of children's knowledge of shorebird attributes. The third section addresses the relationship between children's knowledge of shorebird names and children's knowledge of shorebird attributes during the board game and the interview session. Next, children's performance on the two indirect tests of attribute knowledge, the triad task and the general sorting task, are considered. The fifth section addresses the errors in producing name and attribute information that children made during the board game and the interview session. The sixth and seventh sections concern children's performance during the final session. Section six addresses children's performance on the pair justification task, while section seven presents finding relevant to children's generalization of previously acquired knowledge to novel exemplars of the 14 target shorebirds. The final section discusses relationships between the standard scores that children obtained on the PPVT-R and performance during the board game and interview session.

The coding of all verbal information produced by children was performed by one person. A second person independently coded 12% of the name and attribute information produced during the board game, 12% of the name information produced during the interview session, 10% of the attribute information produced during the interview session, and 25% of the information produced during the pair justification task. Reliability on all data sets but one was 100%. Reliability on the data set containing behavioral attribute information produced during the interview session was 98%.

Knowledge of Names

To test the predictions that children's production and comprehension of shorebird names would increase over time, and that comprehension would consistently exceed production, a two-factor (information type x session) repeated measures analysis of variance was performed comparing the number of shorebird names that children correctly produced during the board game with the number of shorebird names that children correctly comprehended during the board game. Both predictions were confirmed. The mean numbers of correct names produced and comprehended during each session are presented in Table 4. The main effect of information type was significant [$F(1,30) = 211.20$, $p<.0001$], indicating that across all sessions, the number of names comprehended correctly was significantly greater than the number of names produced correctly. In tests of comprehension, children simply needed to recognize the correct shorebird from an array of three distractors, whereas in production tests, children were provided with no such cues. The main effect of session also was significant [F(2,30) = 30.69, p<.0001]. The interaction between information type and session was not significant. Across sessions, both the number of shorebird names that children produced correctly and the number of shorebird names that children comprehended correctly increased significantly.

A parallel two-factor repeated measures analysis of variance was performed on the proportions of names correctly comprehended and produced (out of the total number of shorebirds for which children attempted to produce or comprehended names, regardless of whether they were correct or incorrect). The mean proportions of correct names produced and comprehended during each session are listed in Table 5. Again, there were significant main effects of both information type [F(1,30) = 8.39, p<.05] and session [F(2,30) = 15.55, p<.0001]. A significantly higher proportion of names was comprehended correctly than produced correctly, although both the proportion of names comprehended correctly and the proportion of names produced correctly increased significantly over time. Again, the information type x session interaction was not significant.

To test the prediction that children would produce a significantly greater number of correct names during the interview session than during the board game, a two-factor (test type x session) repeated measures analysis of variance was performed, comparing the number of correct names children produced during the board game with the number of correct names children produced during the interview across sessions two through four. The mean numbers of correct names that children produced during each of these test mediums are presented in Table 4. Main effects of both test type [$F(1,30) = 28.33$, $p<.001$] and session [$F\ (2,30) = 36.02$, $p<.0001$] were significant. There also was a significant interaction between test type and session [$F(2,30) = 4.21$, $p<.05$]. The numbers of correct names that children produced during both the board game and the interview session increased significantly over time. Children produced a significantly greater number of correct names during the interview session than during the board game, presumably since the interview session occurred at the end of each test session. Correct name production also increased at a significantly greater rate during the interview session. Children tended to benefit a great deal from simply hearing the correct names produced two additional times prior to the interview session.

A parallel analysis was performed on the proportions of correct names produced during the board game and the interview session, the means of which are presented in Table 5. Again, a significantly higher proportion of correct names was produced during the interview session than during the board game [$F(1,30) = 12.65$, $p<.01$]. There also was a significant main effect of session [F(2,30) = 12.81, p<.001], indicating that the proportion of correct names produced increased significantly over time for both the board game and the interview session. The test type x session interaction was not significant.

Order effects. Correct information produced during the board game could have been influenced by an order effect. For example, children who were tested for comprehension during the second round of the board game may have performed better than children who were tested for comprehension during the first, simply because the former had heard each of the 14 shorebirds labeled correctly twice during the first round. Half of the children played the comprehension test round first, while the other half played the production test. Two separate two-factor (round tested x session) repeated measures analyses of variance were conducted on the correct forms of information that children produced. The first analysis compared the numbers of names correctly comprehended by children who were tested for comprehension during round one versus the numbers of names correctly comprehended by children who were tested on comprehension during round two. The second analysis compared the numbers of names correctly produced by the same two groups of children. Neither analysis revealed a significant main effect of round tested at the p=.05 level, indicating that there was no effect of test order on the number of correct names that children comprehended or produced.

Knowledge of Attributes

Children were predicted to consistently produce more correct physical attributes than behavioral attributes, since the relevant body parts of the physical attributes were always recognizable in the pictures of the shorebird exemplars. Only the descriptors for the body parts needed to be recalled in the production of correct physical attributes, whereas all three components of the correct behavioral attributes needed to be actively recalled. Furthermore, the numbers of correct physical and behavioral attributes that children produced were predicted to increase over time. To test these predictions, the numbers of correct physical and behavioral attributes that children produced during the board games of sessions two through four were analyzed in a two-factor (attribute type x session) analysis of variance. A parallel analysis was conducted on the correct attribute information produced during the interviews of sessions one through four. The mean numbers of correct attributes produced during both the board game and the interview sessions are presented in Table 4. For the board game data, there were significant main effects of both attribute type [$F(1,30) = 44.57$, $p<.0001$] and session [$F(2,30) = 32.92$, $p<.0001$]. The interaction between attribute type and session also was significant [$F(2,30) = 5.67$, $p<.01$]. Both the prediction that children would consistently produce more correct physical attributes than behavioral attributes and the prediction that the number of correct productions of both types of attribute would increase over time were confirmed. The production of correct physical attributes also increased at a significantly greater rate than the production of correct behavioral attributes. When this analysis was repeated, using the proportions of correct attributes produced during the board game (the means of which are presented in Table 5), there again were significant main effects of both attribute type [$F(1,30) = 13.07$, $p<.01$] and session [$F(2,30) = 17.97$, $p<.0001$]. The attribute type x session interaction, however, was not significant.

The numbers of correct attributes produced during the interviews of sessions one through four were analyzed in a parallel fashion. The main effects of both attribute type [$F(1,45) = 14.43$, $p<.01$] and session [$F(3,45) = 10.72$, $p<.0001$], and the interaction between attribute type and session [$F(3,45) = 4.63$, $p<.01$] were significant. Children produced a significantly greater number of correct physical attributes than behavioral attributes during the interview sessions. The number of correct productions of both types of attribute increased significantly over time, although the number of correct physical attributes produced increased at a significantly greater rate than the number of correct behavioral attributes. This analysis was repeated on the proportions of correct attributes produced during the interviews of sessions one through four. The mean proportions of correct attributes are listed in Table 5.

Only the main effect of session was significant [$\underline{F}(3,45) = 5.20$, $\underline{p}<.01$]. The proportions of correct attributes produced increased significantly over time for both physical and behavioral attributes. However, contrary to initial predictions, children did not produce higher proportions of correct physical attributes during the interview session.[4]

To test the prediction that children would produce more correct physical and behavioral attributes during the board game than during the interview session, two separate two-factor (test type x session) repeated measures analyses of variance were performed. One analysis compared the numbers of correct physical attributes produced during the board game with the numbers of correct physical attributes produced during sessions two through four of the interview. The other compared the numbers of correct behavioral attributes produced during the board game with those produced during the interview session. Each of the two analyses was then repeated, using the proportions of correct attributes produced out of the number of birds that children provided with that particular type of attribute.

When the numbers of correct physical attributes produced during the board game were compared with the numbers of correct physical attributes produced during the interview session, there were significant main effects of both test type [$\underline{F}(1,30) = 9.49$, $\underline{p}<.01$] and session [$\underline{F}(2,30) = 26.75$, $\underline{p}<.0001$], and a significant interaction between test type and session [$\underline{F}(2,30) = 8.70$, $\underline{p}<.01$]. As predicted, children produced a significantly greater number of correct physical attributes during the board game than during the interview. The number of correct physical attributes produced during the board game also increased at a significantly greater rate than the number of correct physical attributes produced during the interview session. When this analysis was repeated, using the proportions of correct physical attributes listed in Table 5, there again were significant main effects of both test type [$F(1,30) = 5.24$, $p<.05$] and session [$F(2,30) = 16.86$, $p<.0001$]. The test type x session interaction, however, was not significant. Children produced a significantly higher proportion of correct physical attributes during the board game than during the interview session. In general, children's production of physical attributes was greatly enhanced during the board game by the provision of correlated behavioral attributes. Furthermore, the benefit of the behavioral attribute correlate appeared to outweigh the benefit of hearing the requested information provided an additional time. By the interview session, children had heard the correct physical attribute produced twice. Despite this additional exposure to the correct information, children still were more likely to produce the correct physical attribute during the board game.

In comparing the numbers of correct behavioral attributes produced during the board game with those produced during the interviews of sessions two through four, there were significant main effects of both test type [$F(1,30) = 26.52$, $p<.001$] and session [$F(2,30) = 16.03$, $p<.0001$], and a significant interaction between test type and session [$F(2,30) = 5.90$, $p<.01$]. As predicted, children produced a greater number of correct behavioral attributes during the board game than during the interview session. Furthermore, the number of correct behavioral attributes produced during the board game increased at a significantly greater rate than the number of correct behavioral attributes produced during the interview session. Once again, productions of correct behavioral attributes were better facilitated by the provision of a physical attribute correlate than by simply hearing the requested behavioral attribute information an additional time.

When this analysis was repeated using the proportions of correct behavioral attributes produced, there were no significant effects. Children did not produce a significantly higher proportion of correct behavioral attributes during the board game than during the interview session. When children did produce behavioral attributes during the interview session, the attributes were as likely to be correct as those produced during the board game.

Order effects. As with correct name information, correct attribute information produced during the board game could have been influenced by an order effect. Half of the children were asked to provide physical attributes during the first round of the board game, while the remainder of the children were asked to provide behavioral attributes. Children who were asked to provide a particular type of attribute during the first round may have performed significantly worse than children who were asked to provide that attribute type during the second round, since the latter group of children would already have heard the correct attribute during round one. Two separate two-factor (round tested x session) repeated measures analyses of variance were conducted on the numbers of correct types of attribute (either physical or behavioral) produced by children who were tested on that attribute type during round one versus the numbers of correct types of attribute produced by children who were tested on that type of attribute during round two. No significant main effects of round tested were found at the $p=.05$ level, indicating that there was no effect of test order on the numbers of correct attribtes that children produced.

Relationship Between Knowledge of Names and Knowledge of Attributes

It initially was predicted that attribute information in general would be more salient to children than information about shorebird names. Children were predicted to produce significantly greater numbers of correct physical and behavioral attributes than correct shorebird names during both the board game and the interview session. A parallel prediction was made for the proportions of correct name and attribute information produced (out of the total number of birds that children provided with that type of information). However, the number of birds for which children correctly comprehended names was predicted to be equal to or greater than the number of birds for which each type of attribute was correctly produced. To test these predictions, two separate pairs of two-factor (information type x session) repeated measures analyses of variance were conducted. The first pair involved all types of information produced during the board game, while the second pair involved all types of information produced during the interview session. Within each pair, the first analysis involved numbers of correct types of information, while the second analysis involved proportions of correct types of information. The mean numbers of each type of information produced are presented in Table 4, while the mean proportions of each correct type of information produced are listed in Table 5. Separate two-factor (information type x session) repeated measures analyses of variance were then conducted across pairs of information types produced within the two test mediums.

<u>Board game</u>. The numbers and proportions of correct types of information elicited from children during the board game were analyzed separately. First, the numbers of names correctly comprehended and produced and the numbers of physical and behavioral attributes produced were analyzed in a two-factor (information type x session) repeated measures analyses of variance. The main effects of both information

type [$F(3,90) = 51.73$, $p<.0001$] and session [$F(2,90) = 64.48$, $p<.0001$] were significant, as well as the interaction between information type and session [$F(6,90) = 2.22$, $p<.05$]. The proportions of correct information elicited during the board game were analyzed in a parallel fashion. There again were significant main effects of both information type [$F(3,90) = 6.15$, $p<.01$] and session [$F(2,90) = 29.29$, $p<.0001$]. However, the interaction between information type and session was not significant. In general, children produced significantly more correct forms of all information types over time, although some forms tended to be produced more frequently than others.

To test for differences among pairs of information types, a series of two-factor (information type x session) repeated measures analyses of variance was conducted. First, the numbers and proportions of names comprehended correctly were compared with the numbers and proportions of each type of attribute correctly produced. Then, the numbers and proportions of children's correct productions of shorebird names were compared with the numbers and proportions of children's correct productions of physical and behavioral attributes.

In the first set of analyses, correct names comprehended during the board game were compared with correct physical attributes produced. The main effects of both information type [$F(1,30) = 10.05$, $p<.01$] and session [$F(2,30) = 53.22$, $p<.0001$] were significant, indicating that children comprehended significantly more shorebird names than they produced correct physical attributes during the board game. The information type x session interaction was not significant. In repeating this analysis for the proportions of correct information, only the main effect of session was significant [$\underline{F}(2,30) = 26.34$, $\underline{p}<.0001$]. The difference between the proportions of names comprehended correctly and the proportion of physical attributes produced correctly was not significant.

The second set of analyses compared the correct comprehension of shorebird names during the board game with the correct production of behavioral attributes. In comparing the numbers of each type of information, there were significant main effects of both information type [$\underline{F}(1,30) = 85.28$, $\underline{p}<.0001$] and session [$\underline{F}(2,30) = 26.98$, $\underline{p}<.0001$]. The interaction between information type and session was not significant. Children comprehended significantly more correct names than they produced correct behavioral attributes. When this analysis was repeated using the proportions of correct information produced, there again were significant main effects of both information type [$\underline{F}(1,30) = 7.46$, $\underline{p}<.05$] and session [$\underline{F}(2,30) = 13.19$, $\underline{p}<.001$]. The information type x session interaction was not significant. These sets of findings are all in accordance with the initial prediction that correct comprehension of shorebird names would be equal to or greater than correct production of both types of attributes.

The third set of analyses compared the productions of correct names during the board game with the productions of correct physical attributes. When number of correct types of information was used as the dependent variable, both the main effect of information type [$F(1,30) = 31.90$, $p<.0001$] and the main effect of session [$F(2,30) = 54.17$, $p<.0001$] were significant, as well as the interaction between information type and session [$F(2,30) = 3.59$, $p<.05$]. As predicted, children produced significantly greater numbers of correct physical attributes during the board game than correct names. Furthermore, the production of correct physical attributes increased at a significantly greater rate than the production of correct names. When this analysis was repeated for the proportions of correct physical attributes and names that children produced during the board game, there again were significant main effects of both information type [$F(1,30) = 7.80$, $p<.05$] and session [$F(2,30) = 13.94$, $p<.001$]. Children produced a significantly higher proportion of correct physical attributes than correct names. The interaction between information type and session was not significant.

In the fourth set of analyses, correct productions of names during the board game were compared to correct productions of behavioral attributes. In comparing the numbers of correct types of information, there were significant main effects of both information type [$F(1,30) = 13.65$, $p<.01$] and session [$F(2,30) = 35.24$, $p<.0001$].

Children produced significantly greater numbers of correct behavioral attributes than correct names. The interaction between information type and session was not significant. When proportion of correct information was used as the dependent variable, only the main effect of session was significant [F(2,30) = 9.76, p<.001]. Children did not produce a significantly higher proportion of correct physical attributes during the board game than correct names. The prediction that children would correctly produce greater numbers of both types of attributes than shorebird names was confirmed by these sets of analyses. However, the prediction that children would correctly produce higher proportions of attributes than names was not confirmed for behavioral attributes. The difference between the proportions of behavioral attributes correctly produced and the proportions of shorbird names correctly produced was not significant.

Interview session. Productions of correct names and correct physical and behavioral attributes during sessions one through four of the interview were analyzed in a two-factor (information type x session) repeated measures analysis of variance. As with the numbers of correct types of information produced during the board game, there again were significant main effects of both information type [F(2,90) = 8.97, p<.001] and session [F(3,90) = 33.75, p<.0001]. The information type x session interaction also was significant [F(6,90) = 8.22, p<.0001]. A repetition of this analysis for the proportions of correct information produced during the interview session revealed only a significant effect of session [$F(2,90) = 18.47$, $p<.0001$]. In general, children produced significantly more correct forms of all types of information over time, although some forms tended to be produced more frequently than others. Two separate sets of two-factor (information type x session) repeated measures analyses of variance were performed to determine significant differences among pairs of correct types of information. The first set compares the productions of correct names with the productions of correct physical attributes, while the second set compares the productions of correct names with the productions of correct behavioral attributes. In both sets, the first analysis compares the numbers of correct types of information produced, while the second compares the proportions of correct types of information produced.

A comparison of the numbers of correct names produced during the interview sessions with the numbers of correct physical attributes produced indicated a significant main effect of session [$F(3,45) = 34.44$, $p<.0001$] and a significant interaction between information type and session [$F(3,45) = 4.26$, $p<.01$]. The main effect of information type was not significant. Contrary to the initial prediction, children did not produce a significantly greater number of correct physical attributes than shorebird names. When this analysis was repeated for the proportions of correct names and physical attributes produced, only the main effect of session was significant [$F(3,45) = 20.41$, $p<.0001$]. Again, children failed to produce a significantly higher proportion of correct physical attributes than names during the interview session.

When the numbers of correct names that children produced during the interview session were compared to the numbers of correct behavioral attributes, there were significant main effects of both information type [$F(1,45) = 13.70$, $p<.01$] and session [$F(3,45) = 37.51$, $p<.0001$]. The interaction between information type and session also was significant [$F(3,45) = 14.91$, $p<.0001$]. Children produced significantly greater numbers of correct names than correct behavioral attributes during the interview session. Furthermore, the number of correct names that children produced increased at a significantly greater rate across sessions than the number of correct behavioral attributes that children produced. In repeating this analysis for the proportions of correct names and behavioral attributes that children produced, there was a significant main effect of session [$F(3,45) = 15.06$, $p<.0001$]. Neither the main effect of information type nor the information type x session interaction were significant.

During the board game, when children were provided with the correlate to the type of attribute they were asked to produce, children tended to produce greater numbers and proportions of attribute information than name information.

When such cues were removed during the interview sessions, the difference between correct names produced and correct physical attributes produced became nonsignificant. Furthermore, children actually were less likely to produce correct behavioral attributes than correct names.

Children's attribute productions during the interview sessions likely were affected by the phrasing of the interview question. The interview consisted of two questions: one referring to the shorebird name and one referring to the shorebird attributes. In response to the second question, "What can you tell me about this bird?" children tended to produce only one form of attribute. To provide a direct test of children's correct responses to each of the two questions, an additional pair of analyses was performed. In the first, the number of birds for which names were produced correctly and the number of birds for which at least one type of attribute was produced correctly were compared in a two-factor (information type x session) repeated measures analysis of variance. The main effects of both information type [$F(1,45) = 4.10$, $p<.06$] and session [$F(3,45) = 38.28$, $p<.0001$] were significant, as well as the interaction between information type and session [$F(3,45) = 3.17$, $p<.05$]. Children produced more attributes than names at the beginning of the study. However, during the later sessions the rate at which children acquired correct names eventually surpassed the rate at which correct attributes were acquired. The main effect of information type was replicated through an additional sign test. When the total number of birds that were correctly named across all sessions was compared with the total number of birds for which at least one attribute was correctly produced, children produced significantly more attributes than names ($p<.05$).

Individual differences. To determine whether any of the children exhibited a pattern of acquiring name and attribute information that was markedly different from that described for the board game and interview session, two additional analyses were performed. First, for information produced during the board game, the number of correct names produced were subtracted each from the number of correct physical attributes produced and the number of correct behavioral attributes produced. If a child consistently produced more correct attributes than correct names, the resulting differences would be positive across all sessions, whereas if names were produced correctly more often than attributes, the resulting differences would be negative across all sessions. During the board game, one child consistently produced correct names more often than correct physical attributes. That same child also consistently produced more correct names than correct behavioral attributes. The remaining 15 children consistently produced more correct physical attributes than correct names. Likewise, more correct behavioral attributes were produced than correct names. A sign test indicated that this effect was significant at $p<.005$. During the interview, three children consistently produced more correct names than correct physical attributes, and eight children consistently produced more correct names than behavioral attributes. However, as described above, when the number of birds correctly named were compared with the number of birds for which at least one attribute was correctly produced, attributes again were produced more frequently than names. In general, attribute information appeared to be more learnable than name information. However, this pattern cannot be interpreted as universal; a few children demonstrated orthogonal patterns of acquisition of domain-specific information.

Earliest correct forms of information. Several predictions were made in reference to the order in which correct forms of information would emerge. Names were predicted to be correctly comprehended before they were produced. Furthermore, both physical and behavioral attributes were predicted to be produced earlier than names. These predictions have been addressed by the repeated measures analyses of variance described above. However, they also may be considered by examining the earliest form of correct information that children produced in reference to each of the target shorebirds.

Across children, the first correct form of information (either name comprehension, name production, physical attribute production, or behavioral attribute production) provided in reference to each of the 14 shorebirds was recorded. Thirteen of the 16 subjects eventually provided a correct form of information in reference to all 14 birds. Two of the remaining three subjects eventually provided a correct form of information in reference to 13 of the shorebirds, and the remaining child eventually provided a correct form of information in reference to 11 shorebirds. The proportions of birds for which each type of information was first provided (out of the number of birds for which correct information eventually was provided) are presented in Table 6. On average, the first form of correct information for 50% of the shorebirds was comprehension of the name. Nine of the sixteen children first comprehended names correctly in reference to at least half of the birds for which information was ever correctly provided. The first form of correct information for 36% of the shorebirds was production of physical attributes. For 10% of the shorebirds, behavioral attributes were the first form of correct information. Finally, the first form of correct information for 4% of the shorebirds was production of the name. These findings are in accordance with the initial predictions. A one-way repeated measures analysis of variance was conducted on the numbers of birds for which each child first produced correctly a physical attribute, a behavioral attribute, or a name. The exclusion of comprehension data rendered the three remaining categories more similar in terms of type of knowledge elicited. Only productive (rather than receptive) knowledge of the domain was considered. The main effect of information type was significant [$F(2,30) = 21.88$, $p<.0001$]. Bonferroni t-tests performed on the set of three means revealed that the number of birds for which physical attributes were first produced ($M = 4.91$) was significantly greater than both the number of birds for which behavioral attributes were first produced ($M = 1.41$) and the number of birds for which names were first produced ($M = .56$) ($p<.05$). The difference between the number of birds for which behavioral attributes were first produced and the number of birds for which names were first produced was not significant.

Indirect Tests of Attribute Knowledge

Children's knowledge of the shorebirds' correlated physical and behavioral attributes was tested indirectly twice, once during the first session and once during the fifth session. Shorebird exemplars used in the fifth session were unfamiliar. Two indirect tests of attributes were used: the triad task and the general sorting task. In both of these tests, children were expected to base the majority of their session one solutions on overall similarity of morphological form. By the fifth session, children were predicted to attend more to attributional properties of the shorebirds, and therefore be more inclined to base their solutions on attributes shared among various types of shorebirds.

Triad task. One analysis was peformed to compare the number of times that children paired the target shorebird with the shorebird that was similar to it in terms of shared correlated attributes during session one versus the number of times that children solved the triads in this manner during the final session. All children solved three triads or fewer on the basis of shared correlated attributes during session one (M=1.25). As predicted, the number of triads solved on this basis was significantly greater during session five (M = 2.69), $t(15)$ = 3.29, $p<.01$. Children were slightly more inclined by the end of the study to attend to attributional properties of shorebirds in their triad task solutions. However, the majority of the triad solutions at both the beginning and the end of the study were based upon similarity of overall morphological form.

General sorting task. In the general sorting task, children were permitted to form as many piles as they wanted, as long as they put the birds that were "most like the same kind of thing" together in the same pile. The numbers of piles that children formed ranged from 3 to 7 in session one and from 4 to 7 in session five. The difference between the numbers of piles formed in sessions one and five was not significant, as measured by a paired-samples t-test. To test the prediction that more piles would be based upon shared attributes during session five than during session one, a two-factor (attribute type x session) repeated measures analysis of variance was conducted, comparing for both sessions the numbers of pairs based on overall morphology that were retained within the same pile at the end of the pile sort with the numbers of pairs based on shared correlated attributes that were similarly retained. The mean numbers of retained pairs based on overall morphology were 3.25 during session one and 4.19 during session five, while the mean numbers of retained pairs based on shared correlated attributes were .94 during session one and .69 during session five. There was a significant main effect of attribute type [$F(1,15) = 65.16$, $p<.0001$], indicating that children tended during both sessions to retain in their piles more pairs based on overall morphology than pairs based on shared correlated attributes. The main effect of session and the attribute type x session interaction were not significant. Contrary to the initial prediction, children were not more likely to base their pile sorting on shared attributes during the session five general pile sort than during the session one pile sort.

Children's Errors

The incorrect information that children produced during both the board game and the interview session was analyzed in three different ways. First, the numbers of incorrect types of information produced were compared both across test mediums (game vs interview), and within the same test medium to determine whether particular forms of errors tended to be produced more frequently than others. Second, the content of children's errors was analyzed more closely.

Specifically, when children produced an incorrect piece of information in reference to a particular shorebird, did that type of information tend to refer to the bird with which the target was matched in terms of overall morphology, the bird with which the target was matched in terms of shared correlated attributes, or an unrelated bird? Another issue relevant to the content of children's errors was considered for behavioral attribute production only. Specifically, when a child produced a behavioral attribute that was not coded as correct, did she tend to produce one of the three attribute components (either the action, location, or goal) correctly more often than the others? Finally, an issue related to error production was considered. To determine whether children demonstrated a proclivity to produce particular forms of information, regardless of whether they were correct or incorrect, the numbers of birds for which children provided particular types of information were compared both within and across test mediums.

<u>Numbers of incorrect forms of information produced</u>. In order to compare the numbers of incorrect forms of information produced, two separate two-factor (information type x session) repeated measures analyses of variance were conducted. The first compared incorrect information types produced during the board game, and the second compared incorrect information types produced during the interview session. Separate series of two-factor (information type x session) repeated measures analyses of variance were then

conducted within each of the two test mediums to determine significant differences among pairs of information types. The mean numbers of incorrect forms of information produced across sessions are presented in Table 7.[5]

For the board game, the number of incorrect names comprehended and produced and the numbers of incorrect attributes produced were compared across sessions two through four. A two-factor (information type x session) repeated measures analysis of variance revealed significant main effects of both information type [$F(3,90) = 7.42$, $p<.001$] and session [$F(2,90) = 9.15$, $p<.001$], as well as a significant interaction between information type and session [$F(6,90) = 3.42$, $p<.01$]. Children produced significantly fewer forms of incorrect information over time. A series of two-factor (information type x session) repeated measures analyses of variance were conducted to determine differences among pairs of incorrect information types. Only significant main effects of information type are reported. Children made a significantly greater number of comprehension errors than production errors [$F(1,30) = 29.61$, $p<.001$]. The number of comprehension errors also was significantly greater than the number of errors made in producing physical attributes [$F(1,30) = 7.63$, $p<.001$]. The number of errors involving behavioral attributes was significantly greater than the number of production errors that children made [$F(1,30) = 5.61$, $p<.05$]. Children were least likely to make production errors. In sum, the order of prevalence of error types produced during the board game was as follows: comprehension, behavioral attributes, physical attributes, production. Only the differences between comprehension and production, comprehension and physical attributes, and between behavioral attributes and production were significant.

Within the interview session, the number of incorrect name productions and attribute productions were compared across sessions one through four in a two-factor (information type x session) repeated measures analysis of variance. The main effect of session [$F(3,90) = 6.03$, $p<.01$] and the interaction between information type and session [$F(6,90) = 2.54$, $p <.05$] were significant. Separate two-factor repeated measures analyses of variance performed on pairs of information types revealed that children produced a significantly greater number of errors involving physical attributes than production errors [$F(1,45) = 7.93$, $p<.05$]. In general, the errors that children were most likely to make during the interview were considerably more varied than those made during the board game. However, in both test mediums, children were least likely to make errors involving production of shorebird names.

A series of three two-factor (test medium x session) analyses of variance also were conducted in order to compare productions of incorrect types of information across the two test mediums. Children were more likely to produce behavioral attribute errors during the board game than during the interview session [_F_(1,30) = 32.08, _p_<.0001]. This was attributable to the fact that children produced relatively few behavioral attributes during the interview session. Those that were produced tended to be correct about as often as those produced during the board game. The differences between the numbers of production errors and the numbers of errors involving physical attributes produced during the board game and the interview session were not significant.

The content of children's errors. When children made errors in producing or comprehending shorebird names, they could provide the name of the shorebird with which the target was matched in terms of overall morphological form, the name of the shorebird with which the target was matched in terms of shared correlated attributes, the name of an unrelated shorebird, or the name of a bird that was not included in the set of 14 shorebirds. Similarly, when children made errors in producing physical and behavioral attributes, they could produce an attribute possessed by the shorebird that was matched to the target in terms of overall morphological form, an attribute possessed by an unrelated shorebird, or an attribute not possessed by any of the shorebird pairs. Errors involving name comprehension, name production, and physical attribute production are each considered separately. Errors involving behavioral attribute production were not included in the present set of analyses due to the relative infrequency of analyzable errors. Only 24% of the behavioral attribute errors produced during the board game and 17% of those produced during the interview session involved cases where the child produced a behavioral attribute that was possessed by another of the target shorebirds. A number of the incorrect behavioral attributes produced during the board game and the interview session involved cases where children produced one or more correct or partially correct components (either the action, the location, or the goal), but the overall behavioral attribute was not coded as correct. At the end of this section, the content of incorrect behavioral attribute productions is analyzed more closely. Specifically, for behavioral attributes that were coded as incorrect, the liklihood of an individual component being produced correctly is addressed.

During the comprehension test, children were presented with four choices: the target shorebird, the shorebird paired with the target in terms of overall morphological form, the shorebird paired with the target in terms of shared correlated attributes, and a distractor that was moderately similar to the target in terms of overall morphological form. The numbers of times that children selected the shorebird in each of the three nontarget categories were compared across sessions two through four in a two-factor (session x error type) repeated measures analysis of variance. Only the main effect of session was significant [$\underline{F}(2,60) = 8.62$, $\underline{p}<.01$]; children tended to produce fewer errors over time. There was no tendency for children to choose a particular type of distractor when making comprehension errors.

Among production errors, the numbers of times that children produced the name (or a derivation of the name) of the shorebird with which the target was matched in terms of overall morphological form were compared with both the numbers of times that children produced the name (or a derivation of the name) of the shorebird with which the target was matched in terms of shared correlated attributes, and the numbers of times that children produced a correct or derived form of another of the 11 target shorebird names. The proportion of each error type (out of the total number of the above set of errors) was then calculated for each child. The probability that each type of error would occur by chance was then subtracted from each of these proportions (1/13 [.075] for both the overall morphological form and the shared correlated attribute matches; 11/13 [.85] for unrelated shorebirds). The adjusted proportions were then analyzed in a two-factor (session x error type) repeated measures analysis of variance. Separate two-factor repeated measures analyses of variance were conducted for the production errors produced during the board game and the production errors produced during the interview session. The means for these sets of adjusted proportions are presented in Table 8. In comparing the errors produced during the board game, only the main effect of error type was significant [$F(2,60) = 4.59$, $p<.05$]. Two-factor (error type x session) repeated measures analyses of variance conducted across pairs of error types revealed that across all sessions, children produced the name of the shorebird matched to the target in terms of overall morphological form most frequently. Children were next most likely to produce the name of a shorebird unrelated to the target, and least likely to produce the name of the shorebird matched to the target in terms of shared correlated attributes. The proportion of times that children produced the name of a shorebird unrelated to the target did not differ significantly from either the proportion of times that children produced the name of the shorebird matched to the target in terms of overall morphological form or the proportion of times that children produced the name of the shorebird matched to the target in terms of shared correlated attributes. However, the difference between the proportion of times that children produced the name of the morphological form-matched shorebird and the proportion of times that children produced the name of the correlated attribute-matched shorebird was significant [$F(1,30) = 6.45$, $p<.05$].

In comparing the proportions of production error types produced during the interview session, there again was only a significant main effect of error type [$F(2,90) = 13.28$, $p<.001$]. Two-factor (error type x session) repeated measures analyses of variance conducted across pairs of error types revealed that the proportion of times that children produced the name of the shorebird that was matched to the target in terms of overall morphological form was significantly higher than both the proportion of times that children produced the name of the shorebird matched to the target in terms of shared correlated attributes [$F(1,45) = 21.10$, $p<.001$], and the proportion of times that children produced the name of a shorebird that was unrelated to the target [$F(1,45) = 7.79$, $p<.05$]. The proportion of times that children produced the name of a shorebird unrelated to the target also was significantly higher than the proportion of times that children produced the name of the shorebird matched to the target in terms of shared correlated attributes [$F(1,45) = 13.36$, $p<.01$]. The majority of children's erroneous productions of shorebird names during the interview session again involved the shorebird matched to the target in terms of overall morphological form. Children were next most likely to produce the name of a shorebird unrelated to the target, and least likely to produce the name of the shorebird matched to the target in terms of shared correlated attributes.

For errors involving productions of physical attributes, children could produce a physical attribute possessed by the shorebird matched to the target in terms of overall morphological form, a physical attribute possessed by one of the five other pairs of shorebirds, or a physical attribute not semantically equivalent to one of the seven physical attributes listed in Table 3. Only cases in which children produced one physical attribute that was semantically equivalent to one of the seven unique physical attributes were considered in the present error analyses. These cases involved 64% of the physical attribute errors produced during the Birdland game and 31% of the errors produced during the interview session. The proportions of each error type (morphological form-matched shorebird vs. unrelated shorebird) out of the number of analyzed errors were computed for both the game and the interview session. The probability that each error would occur by chance (1/6 [17%] for the morphological form-matched shorebird, 5/6 [83%] for an unrelated shorebird) was then subtracted from each of these proportions. The means for these adjusted proportions are presented in Table 8. For the board game, a two-factor (session x error type) repeated measures analysis of variance revealed no significant effect of error type. The difference between the proportion of times children produced the physical attribute possessed by the shorebird matched to the target in terms of overall morphological form similarity did not differ significantly from the proportion of times that children produced a physical attribute possessed by an unrelated shorebird. Among the interview session physical attribute errors, however, there was a significant main effect of error type [$\underline{F}(1,45) = 17.68$, $\underline{p}<.001$]. Across sessions, the proportion of physical attribute errors involving the shorebird matched to the target in terms of overall morphological form was significantly higher than the proportion of physical attribute errors involving shorebirds unrelated to the target.

Overall, significant effects of error type emerged only when errors involving name production and physical attribute production were considered. When children produced incorrect forms of these types of information, they tended to produce the form possessed by the shorebird that was most similar to the target in terms of overall morphological form. Presumably this result obtained because of confusions created by the overall perceptual similarity between the target and the shorebird matched to it in terms of overall morphological form.

Behavioral attribute errors. For productions of incorrect behavioral attributes, it was of interest whether children tended to produce a particular part of the attribute correctly, even though the attribute as a whole was coded as incorrect. Each of the behavioral attributes consisted of three components: an "action" corresponding to what the shorebird was doing, a "location" corresponding to where the action was being performed, and a "goal" corresponding to the food that the bird acquired by performing the action. Across sessions, the proportions of correct forms of each of the three types of components out of the total number of incorrect behavioral attributes produced were recorded. Partially correct forms of components were excluded. These proportions were analyzed in two separate two-factor (session x component type) repeated measures analyses of variance; one relevant to information produced during the board game and one relevant to information produced during the interview session. For incorrect behavioral attributes produced during the board game, there was a significant main effect of component type [$F(2,60) = 5.74$, $p<.01$]. The means for the proportions of correct components are presented in Figure 3. Two-factor (component type x session) repeated measures analyses of variance conducted across pairs of component types revealed that children produced the goal component correctly significantly more frequently than both the action component [$F(1,30) = 7.85$, $p<.05$] and the location component [$F(1,30) = 7.72$, $p<.05$]. The difference between the proportion of times that children produced the correct action component and the proportion of times that children produced the correct location component was not significant. For incorrect behavioral attributes produced during the interview session, the main effect of component type was not significant. Children were more variable in the correct components that they tended to produce during the interview session.

Numbers of birds for which children attempt to provide information. To detect whether children displayed a tendency to produce particular forms of information, regardless of whether they were correct or incorrect, the numbers of birds provided with particular forms of information during the board game and during the interview session were analyzed in two separate two-factor (information type x session) repeated measures analyses of variance. The mean numbers of birds provided with each form of information are presented in Table 9.

Among all forms of information produced during the board game, there were significant main effects of both information type [$F(3,90) = 42.83$, $p<.0001$] and session [$F(2,90) = 8.84$, $p<.01$], as well as a significant interaction between information type and session [$F(6,90) = 2.16$, $p<.05$]. Separate two-factor (information type x session) repeated measures analyses of variance performed on pairs of information types revealed that children were most likely to attempt to comprehend names for shorebirds. The number of shorebirds for which children attempted to comprehend names was significantly greater than the number of shorebirds for which children produced physical attributes [$F(1,30) = 23.07$, $p<.001$], behavioral attributes [$F(1,30) = 38.82$, $p<.0001$], or names [$F(1,30) = 209.81$, $p<.0001$]. Children were next most likely to produce physical attributes. The number of birds for which children produced physical attributes was significantly greater than both the number of birds for which children produced behavioral attributes [$F(1,30) = 18.84$, $p<.001$] and the number of birds for which children produced names [$F(1,30) = 28.27$, $p<.001$]. After physical attributes, children were next most likely to produce behavioral attributes. Children produced behavioral attributes in reference to significantly more birds than they produced names [$F(1,30) = 11.44$, $p<.01$]. Children were least likely to produce names in reference to shorebirds.

For birds provided with various forms of information during the interview session, there also were significant main effects of both information type [$F(2,90) = 6.12$, $p<.01$] and session [$F(3,90) = 5.67$, $p<.01$], as well as a significant interaction between information type and session [$F(6,90) = 6.62$, $p<.0001$]. A series of separate two-factor (information type x session) repeated measures analyses of variance performed on pairs of information types revealed that children produced physical attributes in reference to significantly more birds than they produced either behavioral attributes [$F(1,45) = 6.76$, $p<.05$] or names [$F(1,45) = 8.51$, $p<.05$]. The number of birds provided with behavioral attributes during the interview session did not differ significantly from the number of birds provided with names.

In comparing the numbers of birds provided with particular forms of information during both the board game and sessions two through four of the interview, separate two-factor (test medium x session) repeated measures analyses of variance were performed. Only the difference pertaining to the numbers of birds provided with behavioral attributes was significant [$F(1,30) = 39.25$, $p<.0001$].

Children produced behavioral attributes in reference to a significantly greater number of birds during the board game than during the interview session.

In general, children displayed a tendency to produce attribute information during both the game and the interview session. During the board game, children were most likely to attempt to comprehend the names of shorebirds. This was due in part to the fact that children were asked only to point to the appropriate shorebird during the comprehension task. Most children tended to make some sort of response during each of the 14 trials of the comprehension task. Children were next most likely to produce physical and then behavioral attributes. Names were least likely to be produced. During the interview session, physical attributes were most likely to be produced. Children were next most likely to produce behavioral attributes. Again, names were least likely to be produced, although the difference between name production and behavioral attribute production was not significant.

Pair Justification Task

In the pair justification task, children were asked to tell the experimenter why the birds in seven pairs based on overall morphological form and in seven pairs based on shared correlated attributes were like the same kind of thing. Children's responses were broken down into a series of propositions, each of which corresponded to a particular reason why the child thought two birds were like the same kind of thing. The number of propositions that children produced in reference to pairs based on overall morphological form (M = 9.69) was significantly greater than the number of propositions that children produced in reference to pairs based on shared correlated attributes (M = 6.88), t(15) = 2.96, $p<.01$. For the remainder of the analyses performed on information produced during the pair justification task, only data from the first proposition that each child produced in reference to a particular pair of shorebirds were used.

To evaluate whether children tended to justify correctly a particular type of shorebird pairing, the number of times that children's propositions were correct were compared across both pair types in a paired-samples t-test. The difference in number of correct justifications between pairs based on overall morphological form (M = 4.94) and pairs based on shared correlated attributes (M = 4.75) was not significant at the $p=.05$ level. Children were not more likely to correctly justify a particular type of pair. The attribute knowledge gained throughout the first four sessions enabled children to successfully justify pairs based on shared correlated attributes just as often as pairs based on overall morphological form. Therefore, the attribute information that children possessed appeared to be just as salient as information about perceptual similarity for verbal justifications of pairings of shorebirds.

To test the prediction that children would produce a greater number of justifications based on attributes of the whole shorebird (e.g., size, color) in reference to pairs based on overall morphological form similarity than in reference to pairs based on shared correlated attributes, the numbers of justifications based on an attribute of the whole shorebird were compared across both pair types. The numbers and proportions of types of bases for these justifications are presented at the top of Table 10. Children produced an average of 2.81 such 'whole bird' justifications in reference to pairs based on overall morphological form similarity, and an average of 1.63 such justifications in reference to pairs based on shared correlated attributes. The difference between the two pair types was significant, $\underline{t}(15) = 2.54$, $\underline{p}<.05$, confirming the initial prediction.

The majority of the justifications across both pair types were based on an attribute relevant to a specific part of the shorebird. Children produced an average of 3.50 such justifications in reference to pairs based on overall morphological form and an average of 3.94 such justifications in reference to pairs based on shared correlated attributes. The difference between the two pair types was not significant. The numbers and proportions of types of bases for these 'bird part' justifications are presented at the bottom of Table 10.

It also was predicted that the majority of correct justifications of pairings based on shared correlated attributes would involve physical attributes. This prediction was confirmed. Physical attributes were the basis for 97% of the correct justifications of pairs based on shared correlated attributes. Behavioral attributes were the basis for the remaining 3%. Children never produced both correlated attributes as basis for their justifications.

A final prediction was that for correct justifications of pairs based on shared correlated attributes, children would be most likely to have previously produced that correct attribute in reference to both members of the pair during at least one earlier session. This result occurred in 90% of the cases. In the remaining 10% of all cases, children never correctly justified shared correlated attribute-based pairs for which neither pair member had ever received a correct physical or behavioral attribute. The child produced the correct attribute in reference to one of the two pair members during an earlier session.

Generalization of Knowledge to Novel Shorebird Exemplars

By the end of the study, children were predicted to be able to generalize some of the information that they had learned about shorebirds to novel exemplars of those shorebirds. This prediction was confirmed; all children generalized at least one correct form of information to a novel exemplar. Across those children who did produce at least one correct form of a particular type of information during the final session, at least a third of the information acquired throughout sessions one through four was generalized appropriately to novel exemplars. In general, children were not predicted to comprehend or produce correct forms of information during the final session in reference to shorebirds for which they had never before correctly comprehended or produced that form of information. This expectation also was confirmed. Across children who produced at least one correct form of a particular type of information during session five, the vast majority of the correct information produced in reference to novel exemplars had been previously produced in reference to a familiar exemplar. However, this was not always the case. A small number of children did produce information in reference to a novel exemplar after never before producing that information in reference to a familiar exemplar. Children's correct comprehension and production of names, and correct production of physical and behavioral attributes are each considered separately.

<u>Name comprehension</u>. Children comprehended an average of 8.13 names correctly in reference to novel exemplars during session five. The number of names that children comprehended correctly during session five was significantly lower than the total number of familiar shorebird exemplars for which children had correctly comprehended names during sessions two through four (<u>M</u> = 12.19), <u>t</u>(15) = 6.83,

$p < .0001$. Out of the total names comprehended correctly throughout the first four sessions, an average of 61% of these names were also comprehended correctly in reference to the unfamililar exemplars of session five. Therefore, the vast majority of cases fit with the initial prediction that children would tend to comprehend names correctly during session five for the shorebirds that they had previously comprehended correct names. In a small number of cases, children comprehended a shorebird name correctly in reference to a novel exemplar, when they had never before comprehended that name correctly in reference to a familiar exemplar of the target shorebird. Across children, an average of 8% of names correctly comprehended during session five were not correctly comprehended during any of the previous four sessions. This finding may have been attributable to chance performance; children had a 25% chance of selecting the correct shorebird during each of the 14 trials.

Name production. During the final session, children produced an average of 3.06 names correctly in reference to novel exemplars of the target shorebirds. The number of names that children produced correctly during session five was significantly lower than the total number of shorebirds for which names had ever been correctly produced ($M = 5.75$), $t(15) = 7.43$, $p < .0001$. Across the 15 children who produced at least one correct name during session five, an average of 49% of the names ever produced correctly in reference to familiar exemplars also were produced correctly in reference to novel exemplars. It also was predicted that children would tend to produce names correctly during the final session in reference to shorebirds for which they had produced correct names during the previous four sessions. This prediction was confirmed. Across the 15 children who produced at least one correct name during the final session, an average of 89% of the shorebirds correctly named during this session had been correctly named during an earlier session.

Production of physical attributes. Children produced an average of 3.44 correct physical attributes in reference to novel exemplars of the target shorebirds during session five. The number of novel shorebird exemplars for which children produced a correct physical attribute was significantly lower than the total number of familiar shorebird exemplars for which children produced a correct physical attribute during one of the interviews of sessions one through four (M=6.44), $t(15) = 4.56$, $p<.0001$. Only data from the interviews were considered because attribute correlates were not provided during session five. Therefore, a comparison between interview sessions provided a more conservative estimate of children's physical attribute generalization. Across the 14 children who produced at least one correct physical attribute during session five, an average of 37% of the physical attributes ever produced correctly during sessions one through four also were produced correctly in reference to novel shorebird exemplars. The prediction that children would tend to generalize to novel exemplars only physical attributes that had been previously produced correctly also was confirmed. Across the 14 children who produced at least one correct physical attribute in reference to a novel exemplar, an average of 97% of the physical attributes produced correctly during the final session had been previously correctly produced in reference to familiar exemplars.

Production of behavioral attributes. During the final session, children produced an average of 1.13 correct behavioral attributes in reference to novel exemplars. The number of correct behavioral attributes produced during session five was significantly lower than the total number of familiar shorebird exemplars for which children ever produced correct behavioral attributes during the interviews of sessions one through four ($M=2.56$), $t(15) = 3.82$, $p<.01$. As with the correct physical attribute productions, only the correct behavioral attributes produced during the interview sessions of sessions one through four were considered in order to provide a more conservative estimate of children's behavioral attribute generalization. Across the eight children who produced at least one correct behavioral attribute during the final session, an average of 37% of the correct behavioral attributes produced during the first four sessions were generalized to novel exemplars during session five. Furthermore, in accordance with initial predictions, children tended to generalize to novel exemplars only those behavioral attributes that had been produced correctly during an earlier session. Across the eight children who produced at least one correct behavioral attribute during session five, an average of 94% of the correct behavioral attributes produced during that session previously had been produced correctly in reference to familiar exemplars.

Relationship Between Vocabulary Age and Knowledge of Shorebird Information

To test whether a positive association existed between standard scores that children obtained on the PPVT-R, and amounts of correct information produced during the game and interview session, two Pearson *r* correlation coefficients were calculated. The first measured the strength of the association between children's standard scores on the PPVT-R and the total number of correct forms of information produced during the board game (including names comprehended, names produced, physical attributes produced, and behavioral attributes produced). The mean PPVT-R standard score was 111.31, and the mean number of correct forms of information produced during the board game was 57.13. The correlation between standard scores and the numbers of correct forms of information produced was .62 ($p<.01$), indicating that there was a significant positive association between mental age and the number of correct pieces of information that children produced. A replication of this analysis was carried out for the number of correct forms of information that children produced during the interview session (including productions of names, physical attributes, and behavioral attributes). The mean number of correct pieces of information that children produced during the interview was 27.44, and when correlated with PPVT-R standard scores, $r=.64$ ($p<.01$). Again, children with higher mental ages tended to produce more correct pieces of information during the interview session. These findings support the prediction that brighter children would tend to comprehend and produce more correct information throughout the study than children who were less bright.

Discussion

Below, novel findings from this study that are relevant to research on expertise are summarized and discussed. Implications for these findings are presented in the General Discussion chapter.

Facilitation of children's productions of correct name and attribute information. The relative frequencies of correct name and attribute information tended to vary according to the medium in which that information was elicited. Although brighter children consistently tended to produce more correct information than children who were less bright, more correct names generally were produced during the interview session than during the board game. In contrast, more correct attributes tended to be produced during the board game than during the interview session. The differential effect of test medium could be attributed to two possible factors. First, productions of name information and productions of attribute information benefited from different sources. In producing correct names, children benefited a great deal from simply hearing the correct names modeled two additional times prior to the interview session. In producing correct attributes, this repetition benefit was largely outweighed by the provision of an attribute correlate. The provision of a physical or a behavioral attribute during the board game likely provided a scaffold for children's recall of the relevant correlate. This finding suggests that correlated attribute information is extremely useful to children. The emphasis on correlations that exist among attributes is expected to be facilitative of both children's storage and subsequent retrieval of attribute information. The second factor that probably contributed to the differences between children's attribute productions during the board game and children's attribute productions during the interview was the format of the interview session. Children were presented with a picture of each of the target shorebirds and asked "What can you tell me about this bird?" Children tended to produce only one of the two types of attribute in response to this question, and due to the presence of pictures, these tended to be physical attributes. Perhaps if children had been queried further during the interview session, their attribute productions might have been more comparable to those produced during the board game. Because of the probable influence of this second factor, information produced during the board game was relied upon more heavily in formulating conclusions about children's acquisition of expertise on shorebirds.

<u>Relationship between direct and indirect tests of attribute knowledge</u>. Performances on direct tests of attribute knowledge revealed that children were capable of acquiring impressive quantities of physical and behavioral attribute information within a relatively short period of time. However, these developments were not strictly quantitative. Chlildren were able to use the attribute information that they had learned to verbally justify particular pairings of shorebirds. In addition, children were able to generalize their attribute knowledge to novel subspecies of the target exemplars. Despite these significant increases in domain-specific competence by the end of the study, children did not consistently use their attribute knowledge as the basis for their solutions to the sorting tasks. In both the triad task and the general sorting task, the vast majority of children's solutions were based on overall morphological similarity.

In providing an explanation for these conflicting patterns of behavior, it is useful to return to the notions of quantitative and qualitative changes inherent in the acquisition of expertise. Those who are more expert differ quantitatively from novices in that they possess a greater amount of domain-specific information. In the present study, children's performance during the later sessions differed quantitatively from their performance during the earlier sessions in that greater numbers of both name and attribute information were produced. Acquiring expertise also has been argued to involve qualitative changes (e.g., Carey, 1985; Chi, et al., 1981; Gobbo & Chi, 1986). Those who are more expert organize their domain-specific information differently from those who are less expert. In the present study there was a significant increase in the number of triads solved on the basis of shared correlated attributes between the first and fifth sessions. In general, however, qualitative differences evidenced by differences in performance on the two sorting tasks were not manifest by the end of the study. The majority of children's solutions continued to be driven by the knowledge that they possessed relevant to perceptual similarities existing among objects. Although by the end of the study children possessed a greater quantity of attribute information that could be generalized and used to correctly justify pairings of shorebirds, children did not consider this information the most obvious basis for solving the triad and general sorting tasks. Thus, quantitative change preceded qualitative change.

Qualitative change might have obtained by the end of the study if certain variables had been manipulated. First, if children had participated for a longer period of time, perhaps until correct physical and behavioral attributes were consistently produced in reference to each of the target shorebirds, qualitative changes might have been more likely to emerge. Children's increased familiarity with the attributes possessed by each shorebird would have resulted in the use of those attributes as criteria for decisions of similarity in the triad and general sorting tasks. Second, if children had possessed large quantities of knowledge relevant to other kinds of birds prior to the onset of the study, qualitative change also might have been more likely to obtain. Evidence for this prediction stems from data generated by one of the pilot subjects for this study. This child had been interested in all kinds of birds from a very young age and consequently knew a great deal about them. Although he was unfamiliar with all but three of the target shorebirds, he was able to rapidly assimilate the information about each of the unfamiliar birds into his preexisting bird-relevant knowledge base. At the beginning of the study, this child solved 10 of the 14 triads on the basis of overall morphological similarity. The remaining four were solved on the basis of shared correlated attributes. (The general sorting task was not given to this child during the first session since the complete design of the study had not yet been finalized.) At the end of the study, 11 triads were solved on the basis of shared correlated attributes and the remaining three were solved on the basis of overall morphological similarity. Even more impressively, this child solved the general sorting task at the end of the study by forming seven piles, each of which contained two species paired on the basis of shared correlated attributes. This child's qualitative change in sorting behavior appeared to have been greatly facilitated by his possession of a relatively large quantity of bird-relevant knowledge at the onset of the study. Levels of domain-relevant background knowledge should be evaluated and controlled in future research on expertise.

Relationship between knowledge of names and knowledge of attributes. The central issue of the thesis concerned the relationship between children's knowledge of names and children's knowledge of attributes throughout the earliest stages of acquiring expertise. The board game proved to be an extremely fruitful medium for examining this relationship. In general, children comprehended more correct names than they produced correct forms of any other type of information. Children's correct productions of attributes also tended to begin earlier and consistently exceed their correct productions of names. Correct physical attributes were produced more often than correct behavioral attributes. This finding was partially attributable to children's ability to recognize a portion of the correct physical attribute information in pictures of the shorebird exemplars. Furthermore, children may have found information about what unique attribute each shorebird possessed more salient than information about what the possession of that attribute enabled the shorebird to do. Names were the least likely type of information to be produced, despite the fact that they were modeled twice as frequently as either physical or behavioral attributes in reference to each of the target shorebirds. This same pattern of findings was replicated when the proportions of birds for which each type of information was produced first were considered. Evaluations of children's productions generally indicated that attribute information appeared to be more salient to children than information about shorebird names.

Additional evidence in support of the prediction for attribute saliency came from considering the number of birds for which a type of information was produced, regardless of whether it was correct or incorrect. Children were most likely to attempt to comprehend shorebird names. This finding was partially attributable to a ceiling effect; children tended to point to one member of the set of four shorebirds on each of the comprehension test trials. Children were next most likely to produce physical attribute information. After physical attributes, behavioral attributes were most likely to be produced. Children were least likely to produce name information. Regardless of whether it was correct or not, children tended to produce attribute information more frequently than information about shorebird names.

The relatively low frequency of shorebird name production across both test mediums could be attributed to two possible factors. First, children may have been inherently disposed to attend more to attribute information than information about names. Information about what a particular thing can do as a result of possessing a certain attribute may simply be more interesting to children than information about what that thing is called. Second, this predisposition may have been exacerbated by children's capacity to refer to each of the shorebirds as "bird" from the beginning of the study. "Bird" was most likely a basic level category for children; it is the most general level at which members share both similar overall shapes (forms) and similar characteristic behaviors (functions), and the most general level at which the cluster of relevant correlated attributes associated with the category is large (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). For example, all birds have feathers and wings, and almost all birds are able to fly. The 14 target shorebirds belonged to categories subsumed under the basic level "bird;" that is, each of the target shorebirds belonged to different subordinate level categories. Subordinates contained under the same basic level category possess few differences in attribute structure relative to the attributes that are shared (Mervis & Crisafi, 1982; Rosch, et al., 1976). Tversky and Hemenway (1984) also have argued that coordinate subordinate level categories share parts and differ in terms of the attributes of those parts. For example, both a curlew and a lapwing have eyes and toes. However, the eyes of the curlew are large relative to the lapwing's eyes and the toes of the lapwing are long relative to the curlew's toes. Not suprisingly, children have been found to have difficulty acquiring subordinate level categories (e.g., Mervis & Crisafi, 1982; Nelson, 1985). Because it is relatively difficult to learn a new name without having an attribute basis for that name, it is not suprising that children in the present study tended to concentrate first on the attribute information presented in reference to each shorebird. As a result, names were the least likely form of information to be produced.

In sum, children exhibited a number of quantitative changes over the course of acquiring expertise on shorebirds. However, qualitative changes in triad task sorts were minimal by the end of the study. Attribute information was correctly produced earlier and more frequently than name information, even though names were modeled twice as often as attributes in reference to each shorebird. This result may have been attributable either to the inherent saliency of attribute information, or to the fact that children had difficulty learning subordinate level category names. Finally, levels of general intelligence and of domain-relevant background knowledge had a significant influence on the rate at which expertise was acquired.

Table 4

Mean Numbers of Correct Types of Information

Board Game

	Session 2	Session 3	Session 4
Name Comprehension	5.94	8.13	10.19
Name Production	.44	1.63	3.13
Physical Attribute	3.69	5.75	8.19
Behavioral Attribute	2.06	3.56	4.44

Interview Session

	Session 1	Session 2	Session 3	Session 4
Name Production	.25	1.31	2.94	5.19
Physical Attribute	1.88	3.06	3.81	4.75
Behavioral Attribute	.38	1.13	1.38	1.38

Table 5

Mean Proportions of Correct Types of Information

Board Game

	Session 2	Session 3	Session 4
Name Comprehension	.47	.58	.73
Name Production	.25	.43	.57
Physical Attribute	.37	.72	.78
Behavioral Attribute	.35	.53	.53

Interview Session

	Session 1	Session 2	Session 3	Session 4
Name Production	.17	.33	.59	.74
Physical Attribute	.30	.38	.52	.62
Behavioral Attribute	.17	.36	.40	.41
Both Physical and Behavioral Attribute[a]	.08	.30	.29	.42

[a] Not mutually exclusive with "physical attribute" and "behavioral attribute" means.

Table 6

Proportion of Shorebirds for Which Each Type of Information Was First Provided

Subject	Comprehension	Physical Attribute	Behavioral Attribute	Production
1	.54	.46	.00	.00
2	.64	.29	.07	.00
3	.36	.57	.07	.00
4	.57	.36	.07	.00
5	.55	.09	.27	.09
6	.71	.21	.07	.00
7	.57	.36	.07	.00
8	.29	.43	.21	.07
9	.43	.50	.07	.00
10	.14	.79	.00	.07
11	.43	.43	.00	.14
12	.43	.50	.00	.07
13	.64	.07	.21	.07
14	.71	.00	.21	.07
15	.62	.31	.00	.08
16	.36	.43	.21	.00
Mean:	.50	.36	.10	.04

Table 7

Mean Numbers of Incorrect Types of Information

Board Game

	Session 2	Session 3	Session 4
Name Comprehension	6.81	5.81	3.69
Name Production	1.94	2.00	2.56
Physical Attribute	5.25	2.63	2.31
Behavioral Attribute	5.13	3.63	3.69

Interview Session

	Session 1	Session 2	Session 3	Session 4
Name Production	1.06	2.31	1.56	1.75
Physical Attribute	5.38	4.06	2.94	2.31
Behavioral Attribute	3.00	2.25	1.44	1.56

Table 8

Adjusted Mean Proportions of Error Types

Production of Names

Board Game

Session 2			Session 3			Session 4		
m	a	u	m	a	u	m	a	u
.07	.01	.02	.07	.04	.05	.22	.00	.05

Interview Session

Session 1			Session 2			Session 3			Session 4		
m	a	u	m	a	u	m	a	u	m	a	u
.06	.00	.04	.24	.00	.04	.17	.01	.05	.15	.00	.06

Production of Physical Attributes

Board Game

Session 2		Session 3		Session 4	
m	u	m	u	m	u
.07	.07	.14	.06	.15	.05

Interview Session

Session 1		Session 2		Session 3		Session 4	
m	u	m	u	m	u	m	u
.17	.04	.15	.03	.31	.02	.29	.04

Note. m = shorebird matched to target in terms of overall morphology
a = shorebird matched to target in terms of correlated attributes
u = unrelated shorebird

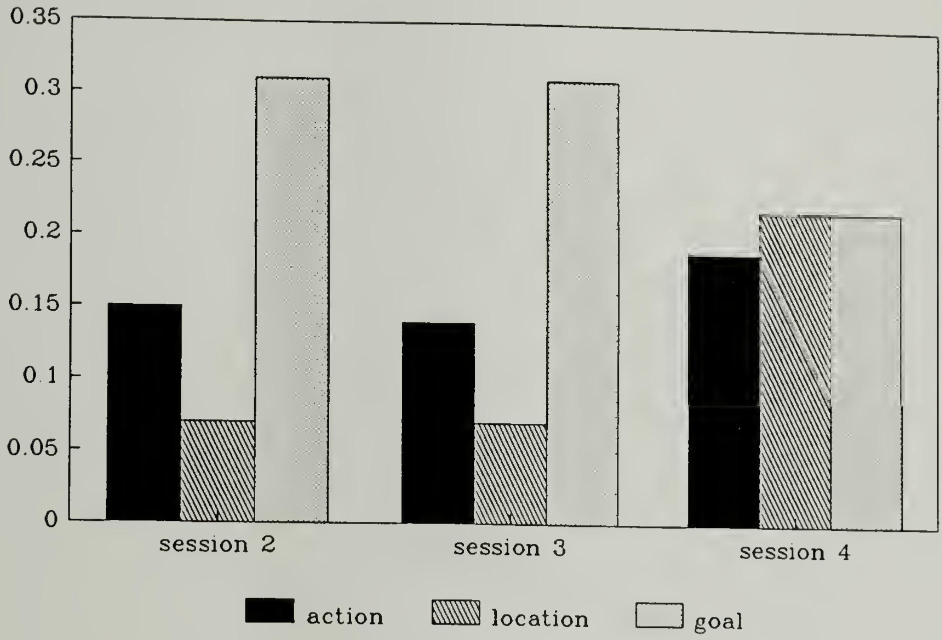


Figure 3. Mean proportions of correct behavioral attribute components produced during board game.

Table 9

Mean Numbers of Birds for Which Information is Produced

Board Game

	Session 2	Session 3	Session 4
Name Comprehension	12.75	13.94	13.88
Name Production	2.38	3.63	5.69
Physical Attribute	8.94	8.38	10.50
Behavioral Attribute	7.19	7.19	8.13

Interview Session

	Session 1	Session 2	Session 3	Session 4
Name Production	1.31	3.63	4.56	6.94
Physical Attribute	7.25	7.13	6.75	7.06
Behavioral Attribute	3.38	3.38	2.81	2.94

Table 10

Numbers and Proportions of Types of Bases for Pair Justifications

Justifications Based on Attribute of Whole Bird:

Justification Basis	Pair Type Overall Morphological Form	Shared Correlated Attributes	Total
overall size	21 (.47)	12 (.48)	33 (.47)
color	8 (.18)	8 (.32)	16 (.23)
pattern	6 (.13)	1 (.04)	7 (.10)
weight	2 (.04)	1 (.04)	3 (.04)
shape	3 (.07)	0 (.00)	3 (.04)
possession of body part	1 (.02)	0 (.00)	1 (.02)
unspecified	4 (.09)	3 (.12)	7 (.10)

Justifications Based on Attribute Relevant to Part of Bird:

Justification Basis	Pair Type Overall Morphological Form	Shared Correlated Attributes	Total
bill	26 (.50)	25 (.41)	51 (.45)
eyes	6 (.12)	12 (.19)	18 (.16)
toes	8 (.15)	14 (.23)	22 (.19)
legs	6 (.12)	6 (.10)	12 (.11)
stomach	0 (.00)	2 (.03)	2 (.02)
feet	2 (.04)	1 (.02)	3 (.03)
wings	1 (.02)	1 (.02)	2 (.02)
tail	1 (.02)	0 (.00)	1 (.01)
head	1 (.02)	0 (.00)	1 (.01)
unspecified	1 (.02)	0 (.00)	1 (.01)

Note. Mean proportions are presented in parentheses.

CHAPTER 4

GENERAL DISCUSSION

In this chapter, implications of the results from the present study are discussed. Three major issues are addressed. First, novel aspects of the expertise continuum that were revealed by the results of the present study are described. The second issue concerns possible applications of this model to the development of children's educational materials. Finally, implications of findings from the present study for past and future empirical investigations of expertise are discussed.

Analysis of the Expertise Continuum

The board game was an extremely useful medium for investigating the earliest transitional stages involved in acquiring expertise. The limitation of input to information about the names and correlated attributes relevant to feeding facilitated the examination of the relationship between these two types of knowledge during the acquisition of domain-specific knowledge. The information that children produced during the interview session was less revealing. Children tended to interpret the question, "What can you tell me about this bird?" as a request for only one attribute. Since pictures were present during the interview session, the attribute provided in the response tended to be a physical attribute. Perhaps if children had been queried further (e.g., "Can you tell me why?"), their responses would have been more similar to those elicited during the board game. In general, information elicited during the interview session was considered a less complete index of children's shorebird knowledge than information produced during the board game. Subsequently, information obtained through the board game was relied upon more heavily in the formulation of general conclusions about the process of acquiring expertise.

First, conclusions relevant to quantitative change are presented. Then, conclusions relevant to qualitative change and its relationship to quantitative change are presented and discussed. Finally, individual differences in acquiring expertise are examined.

Quantitative change. The results from the present study revealed much information relevant to quantitative changes that occurred as children acquired information relevant to shorebird names and attributes. Correct comprehension and production of names, and correct productions of physical and behavioral attributes all increased significantly over time. Children also were capable of generalizing a portion of this name and attribute information to novel exemplars of the target shorebirds at a relatively early point along the continuum of acquiring expertise. Level of intelligence appeared to play a role in the rate at which quantitative change obtained. A significant positive relationship existed between children's levels of general intelligence, as estimated by the PPVT-R, and the rate at which expertise on shorebirds was acquired.

Specifically, brighter children tended to produce more correct information during both the board game and the interview session than children who were less bright.

A closer analysis of quantitative changes revealed that children generally began to produce attribute information earlier than name information, and attributes were consistently produced more often than names. Names, however, were correctly comprehended more often than any type of information was correctly produced. It is particularly striking that children produced names later and less often than attributes since correct names were modeled twice as often as attributes in reference to each shorebird during the board game. It appears that attribute information may be easier for children to learn than name information during the acquisition of expertise.

Further research is needed to expand our understanding of the saliency of attribute information. It initially was predicted that during the earliest stages of acquiring expertise, children would find information about attributes more interesting than information about shorebird names. As mentioned previously, this prediction was based on two possibilities. First, children could simply be more interested in what attribute a thing has or what that thing can do than in what that thing is called. Second, because children possessed an adequate label at the basic level for each of the unfamiliar types of shorebird (in this case, "bird"), they had no need to acquire a new label in order to refer to the birds. Therefore, attentional resources were available for learning attribute information. In order to differentiate between these two possibilities, an additional experiment must be conducted. Children should be systematically exposed to information about names and information about attributes relevant to two classes of referents. Referents in the first class must belong to categories for which the child is able to comprehend and produce a label at the basic level while referents in the second class must belong to categories for which the child is not able to either comprehend or produce such a label. If children consistently produce more correct attribute information than name information for referents in both classes, support will be acquired for the notion that attribute information is inherently salient. However, if children tend to produce more attribute information only in reference to the class of objects for which the basic level is known, support for the idea that children initially focus on acquiring a label for a particular referent will be obtained.

Qualitative change. It is clear from the present study that a substantial quantitative increase in domain-specific knowledge is necessary before qualitative change obtains. Although children had accumulated a significant amount of domain-specific information by the end of the study, they did not consistently use this information in their solutions to the triad and general sorting tasks. Despite a significant increase in the number of triad solutions based on shared correlated attributes by the final session, the majority of children’s solutions consistently were based on overall morphological similarity. A detailed analysis of the qualitative changes inherent in acquiring expertise was beyond the scope of this study. More than four sessions are needed to instill such changes, and in order to maintain children’s attention, the board game would most likely have required supplementation by similar media (e.g., a "lotto-type" game involving pictures of the shorebird exemplars; books featuring pictures or photographs of shorebirds, or a clue game, such as that used by Chi and Koeske [1983]).

Further longitudinal research is needed to determine when in the process of acquiring information children’s restructuring of their domain-specific knowledge occurs. The triad task used in the present study placed perceptual and conceptual bases for similarity in direct competition. Similar triad tasks could be utilized to evaluate factors that contribute to the ultimate supression of perceptual bases by competing conceptual bases. For example, the length of time that children are exposed to information about shorebirds could be substantially increased until children no longer based their solutions on perceptual similarity. Furthermore, the verbal prompts that children are given as they solve the triad task also may be manipulated. For example, children may be prone to sort on the basis of shared correlated attributes at an earlier point along the continuum of expertise if they are asked a more specific question than, "Which two are most like the same kind of thing?" Perhaps children would be more sensitive to these types of similarities if they were asked, "Which birds can do the same kinds of things?" or, "Which birds have the same types of parts?" Alternatively, children at a point much further along the continuum might be able to sort on the basis of shared correlated attributes even when pictures of shorebirds are not available (e.g., "Which bird is most like the gallinule: the lapwing or the coot?").

The rate at which qualitative change emerges during the acquisition of expertise is likely affected by the amount of information relevant to the domain that the child initially possesses. In the present study, one pilot subject, who initially knew a great deal about other kinds of birds, succeeded in demonstrating dramatic quantitative and qualitative changes in shorebird knowledge. During the fourth session, this child produced correct names in reference to 13 of the 14 shorebirds and comprehended correct names in reference each of the 14 shorebirds. Both physical and behavioral attributes also were produced correctly in reference to each of the 14 target shorebirds. In the fifth session, this child demonstrated a dramatic increase in the number of triads solved on the basis of shared correlated attributes. Even more impressively, this child solved the final general sorting task by forming seven piles, each of which contained the two birds that shared the same correlated attribute structure. It is clear that for this child, the possession of information about other kinds of birds facilitated the acquisition of correlated attribute information within the domain of shorebirds. This background knowledge succeeded in enabling the child's conceptual bases for similarity to override competing perceptual bases. Further research is needed to assess the effects of relevant background knowledge on the acquisition of expertise by both children and adults.

Within the realm of name learning, qualitative changes also followed changes that were quantitative. As discussed earlier, children most likely considered each of the target shorebirds to belong to coordinate subordinate level categories. Therefore, one quantitative development that occurred over the course of the study was that children learned more subordinate level categories over time. Although not addressed by the present investigation, it is predicted that after a significant number of subordinate level categories have been acquired and their respective attribute structures learned, a shift in the level of categories should obtain. Carey (1985) proposed that one form of restructuring that occurs along the transition from novice to expert involves a shift in the basic level of concepts. That is, categories that were formerly at the subordinate level become basic level categories, while categories that were formerly at the basic level shift upwards to become intermediate level categories. If the present study had continued for a longer period of time, target shorebird categories (e.g., gallinule) presumably would have become basic level categories for children whereas the basic level category (i.e., bird) would have become an intermediate level category. Again, further longitudinal research is needed to determine when along the continuum this type of shift occurs.

Individual differences. Relatively few developmental processes relevant to learning appear to be universal. Constraints, or the universal factors by which children's development may be governed, are probably limited to behaviors that are highly canalized (e.g., language, sensorimotor development). The existence of individual differences among children in the present study indicated that the acquisition of expertise does not appear to be governed by universal constraints. A small number of children did not fit with the general pattern predicted by the sets of analyses. For example, although 15 of the 16 children consistently demonstrated a bias to produce more correct attribute information during the board game than name information, one child appeared more attuned to name information. One means of explaining the individual differences among children in the present study is through the notion of equifinality that has been discussed entensively by Horowitz (1987). In contrast to machines, biological organisms are "open systems" in which the same endpoint may be reached through a number of different developmental routes. The principle of equifinality refers to this notion that similar outcomes may be achieved by different paths leading from the same point of origin. In acquiring expertise, there may be a particular route along which the majority of children may travel. However, the existence of this "heavily weighted" route does not rule out the possibility that some children may develop along alternate routes. What remains to be addressed is why particular routes are traveled as expertise is acquired. Horowitz (1987) would maintain that this may be determined only by examining the combinatorial roles of the structures inherent in the child and external environmental factors.

Applications for the Design of Educational Materials

Some findings from the present study could be readily applied to the development of educational materials for the instruction of biological science to young children. The board game was extremely beneficial to children's acquisition of information relevant to the shorebird domain. Prior to their child's participation, parents often were quite skeptical of their daughter's ability to acquire information about such seemingly esoteric species of birds. By the end of the study, parents generally were very impressed by the number of birds for which their child could provide names and information relevant to feeding. Children seemed to really enjoy playing the board game and often requested to continue playing at the end of the session.

Learning about the shorebirds was incidental to the larger goal of playing (and, often winning) the game. Similarly designed games might be useful in helping children to learn about other biological domains (e.g., insects, reptiles, plants).

In the present study, children also were quite sensitive to the cause-and-effect relationships that existed among certain groups of attributes. When the correlate of a particular attribute was provided during the board game, children were more likely to produce a correct physical or behavioral attribute than during the interview (when no attribute information was provided). This suggests that in designing curricula for the presentation of biological topics, teachers should emphasize the cause-and-effect relationships that exist among attributes. It is more informative to children to be told _why_ something possesses a particular type of attribute than to simply be told that something _does_ possess that attribute.

Particular means of instructing children about the names of subordinate level categories may be more helpful to children than others. In the present study, children were taught the names of each of the target shorebirds at the same time as the particular correlated attributes possessed by that shorebird were taught. As mentioned in the first chapter, this is one of the most informative means by which subordinate categories may be introduced. Less informative means include purely ostensive labeling and the provision of the shorebird name along with only one of the two types of attribute possessed by that bird (Banigan & Mervis, 1988). For some birds, a still more informative device than the one employed in the present study would be to make use of meanings which are sometimes inherent in the structure of the word used to refer to particular subordinate level categories. (e.g., "This is called a blackfront because it has black on its front."; "This is called a turnstone because it turns over stones as it hunts for its food.") Tactics such as these also could easily be incorporated into educational curricula.

Some measures also could be taken by teachers to encourage children to categorize on the basis of flexible criteria. In the present study, children consistently tended to base their decisions of similarity on the overall morphological characteristics of shorebirds. By explicitly demonstrating to children that two things could be alike either because they look the same, or because they can do the same kind of thing or possess the same kind of attribute, children may subsequently become more flexible in their categorizations. This type of instruction may lay the groundwork for future qualitative shifts in the acquisition of expertise.

Implications for Past and Future Empirical Investigations of Expertise

The results obtained from the present study are useful for reexamining some findings from earlier investigations of children's expertise, and for providing direction for future research.

Dinosaur studies revisited. Perhaps the most troubling question that remains regarding earlier research on children's dinosaur expertise is whether the children who were considered experts had actually acquired significant levels of expertise. The child studied by Chi and Koeske (1983) almost certainly was expert relative to his peers. His mother reinforced his natural interest in dinosaurs by reading him relevant books and providing him with dinosaur models. This child also was knowledgeable about a large number of dinosaurs and prehistoric mammals, and their respective physical and behavioral properties. However, the children considered experts by Gobbo and Chi (1986) may not necessarily have acquired very high levels of expertise on dinosaurs. As illustrated in the present study, the relationship between knowledge of names and knowledge of physical and behavioral attributes is quite complex. The pretests that Gobbo and Chi used as a criterion for expertise were heavily biased towards children's knowledge of dinosaur names. Only 5 of the 20 pretest questions tapped children's knowledge of behavioral functions. Therefore, at least some of the children considered experts by Gobbo and Chi may have been unaware of the attribute structures affiliated with the dinosaurs that they named. Ensuring that child experts are knowledgeable about both names and attributes results in a richer criterion for expertise. Children who meet this criterion may be considered truly knowledgeable of the <u>categories</u> included in the domain, in that both the names of those categories and their corresponding attribute structures are present in the knowledge base.

One variable that typically has been ignored in previous research on expertise is intelligence. In the present study, brighter children tended to comprehend and produce more correct forms of information than children who were less bright. In the study conducted by Gobbo and Chi (1986), children considered novices were not matched to children considered experts in terms of mental age. Neglecting to do this may have resulted in a confound between expertise and intelligence. If children who were more bright tended to meet the criterion set for expertise more often than children who were less bright, then the differences observed between the group of novices and the group of experts were partially attributable to differences in intelligence. It is essential that future research on expertise take into account levels of general intelligence possessed by experts and novices.

One of the most prevalent means of assessing differences in knowledge base structure among novices and experts has been the general pile sorting task (e.g., Chi, Feltovich, & Glaser, 1981; Chi & Rees, 1983; Gobbo & Chi, 1986). It was suggested in the Introduction chapter that younger children might be overwhelmed by such a task. At the end of the present study, the triad task revealed a slight trend towards solutions based on shared correlated attributes, whereas the general sorting task did not. Therefore, the triad task appears to be a slightly more sensitive measure for qualitative changes inherent in the acquisition of expertise than the general sorting task. If a triad task had been used in the study conducted by Gobbo and Chi (1986), perhaps a slightly different pattern of results would have obtained. At a minimum, both types of tasks should be employed in further empirical work on expertise.

Considerations for future research. As mentioned above, future research on expertise must concentrate heavily on developing better measures for determining which subjects are truly expert. Levels of intelligence must be considered when contrasting the behaviors of experts and novices, and care should be taken when choosing the sorting tasks on which those behaviors are measured. In addition, two other issues should be considered seriously in designing future studies on the acquisition of expertise.

First, the influence of knowledge outside the narrow domain in which expertise is being acquired must be investigated. As mentioned in the Results chapter, one pilot subject did demonstrate a qualitative change in his sorting behavior by the end of the study. This most likely was due to his knowing a great deal about other kinds of birds prior to his participation. Indeed, knowing a great deal about an area related to a particular domain could very well have a powerful influence on the acquisition of knowledge within that domain. For example, knowing a great deal about birds (e.g., taxonomic organization, reproductive behaviors, migration patterns, feeding behaviors) could serve as a scaffold for the acquisition of expertise within another biological domain (e.g., fish, insects). Knowing about one domain may allow you to "know what to know" about a related domain. Future studies should attempt to contrast the acquisition of expertise by two types of novice: one who has acquired expertise in a related domain and one who has not. Furthermore, levels of relevant background knowledge should be controlled when contrasting the behaviors of groups of experts and novices.

Another area that requires further investigation is the effects of development on the process by which expertise is acquired. The present study specifically addressed the relationship between knowing names and knowing attributes among 5-year olds progressing through the earliest stages of acquiring expertise. Still to be addressed is the question of whether the findings from this study are specific to 5-year olds, or whether they are generalizable to older children and adults. For example, Waters (1989) recently has provided evidence that child and adult experts may differ in terms of strategy use, although the contents of their domain-specific knowledge may be quite similar. Future research should attempt to formulate relatively stable developmental models of the processes by which expertise is acquired.

Finally, research on the acquisition of expertise may be facilitated by further analysis of what it means to become expert. For example, researchers must determine where along the continuum of expertise acquisition an individual may be considered to have attained expertise. Certainly a 5-year old who is able to name six shorebirds and recognize their correlated attributes relevant to feeding would not be considered an expert on shorebirds. However, that child is certainly more expert than another child who is completely unfamiliar with the shorebird domain. Similarly, a typical 5-year old who is completely unfamiliar with shorebirds could not be considered a true novice. Such a child is probably aware of the names and attributes possessed by a number of other birds. For example, the child would probably know that ducks, penguins, owls, and robins are all birds and that some or all of these birds can swim, fly, eat worms, and lay eggs. Furthermore, the child might realize that birds are animals that can breathe, eat, and have babies. This knowledge would be quite useful in facilitating the acquisition of knowledge relevant to shorebirds.

One solution to the problem of providing such definitions is to consider the states of "being a novice" and "being an expert" as relative points along a continuum of increasing competence.[6] From birth, children are continually acquiring competence in understanding the nature of the things in their world. When this competence is domain-specific, the potential for being an expert within that domain is maximized. At any point along the continuum of acquiring competence within a particular domain, a person may be considered a relative expert if the level of his or her knowledge is great relative to the level of domain-specific knowledge possessed by his or her peers. Within particular domains (e.g., chess), the realm of peers may be extended across both adults and children. As Chi (1978) has demonstrated, child experts are capable of surpassing the performance of adult novices.

Conclusion

By far the most important conclusion that can be drawn from the present study is the paramount importance of longitudinal research in the future investigation of expertise. The stages that children and adults must go through in the process of acquiring expertise must be further delineated and individual differences explained. The present study was useful in examining the relationship between two specific variables in a controlled examination of the early acquisition of expertise on shorebirds. Quantitative changes were found to precede changes that were qualitative, and children were capable of both generalizing information to novel exemplars and using their attribute knowledge to justify pairings of shorebirds at a relatively early point during the process of acquiring expertise.

Attribute information was produced earlier and more frequently than name information, despite the fact that names were modeled more often than attributes. Furthermore, the rate at which expertise was acquired seemed to be affected both by domain-relevant background knowledge and by levels of general intelligence. These findings are a preliminary step in investigating the continuum of expertise. Further insights into the nature of the continuum may be gained through analyses of data generated by the additional studies that have been proposed. Researchers now know a great deal about the differences that exist between individuals at relatively early and at much later points along the continuum of expertise acquisition. Investigators must now strive to understand better the nature of the many processes which interact to create movement along this continuum.

APPENDIX

CODING MANUAL

The coding manual is broken down into three parts. The first deals with name information produced during both the board game and the interview session. The second deals with attribute information. The final part addresses the data produced during the pair justification task.

I. NAME PRODUCTION

Names produced during the board game and the interview session may be coded as either correct, partially correct, or incorrect.

Correct

C - Correct (form identical to input)

The following are the 14 correct forms of shorebird names:

AVOCET
BLACKFRONT
COOT
CURLEW
GALLINULE
GODWIT
GOLDER
LAPWING
PHALAROPE
SANDPIPER
SNIPE
TURNSTONE
WOODCOCK
WRYBILL

Partially Correct

1[1] - variation of correct form; 1 syllable missing, added, or replaced

2 - variation of correct form; doesn't fit into '1' code

See Table below to determine whether form should be coded as either '1' or '2':

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[1] "1" codes were considered correct for purposes of name production analyses

Partially Correct Name Productions

Shorebird	'1' Code	'2 Code'
AVOCET		it has a kind of 'set' in its name- a 'set' in the middle
BLACKFRONT		blackchest blackeye blackstomach blacktummy blackwich blackwing black...whatever frontblack something black
COOT	cook hoot	
CURLEW	twerlew	
GALLINULE		
GODWIT	godwich	
GOLDER	gold- goldener goldie	goldminder
LAPWING	flapwing	blackwing darkflap darkwing flackwing lapeeole something about wing winglap
PHALAROPE	allathrope	a rope thing laprope rope bird
SANDPIPER		cornpipe piper snap turnpipe turnpiper
SNIPE		something snare

TURNSTONE	it has a rock in it some kind of rock some kind of stone stone something whatever stone wrystone
WOODCOCK	cockeye something with wood wooder wood...front
WRYBILL	

Incorrect

3 - morphological form-matched shorebird name; correct pronunciation

4 - morphological form-matched shorebird name; variation of correct pronunciation

5 - correlated attribute-matched shorebird name; correct pronunciation

6 - correlated attribute-matched shorebird name; variation of correct pronunciation

7 - unmatched shorebird name; correct pronunciation

8 - unmatched shorebird name; variation of correct pronunciation

9 - non-shorebird name (e.g., robin, hummingbird)

0 - non-bird/"nonsense" (e.g., nerk, something tape recorder)

X - attributional name (e.g., Little long legs)

To determine whether the incorrect name is possessed by the shorebird that is matched to the target in terms of either morphological form or correlated attributes, use the following table:

Target Shorebird	Shorebird Matched by Morphological Form	Shorebird Matched by Correlated Attributes
avocet	lapwing	sandpiper
blackfront	turnstone	golder
coot	gallinule	phalarope
curlew	golder	woodcock
gallinule	coot	lapwing
godwit	phalarope	snipe
golder	curlew	blackfront
lapwing	avocet	gallinule
phalarope	godwit	coot
sandpiper	wrybill	avocet
snipe	woodcock	godwit
turnstone	blackfront	wrybill
woodcock	snipe	curlew
wrybill	sandpiper	turnstone

II. ATTRIBUTE INFORMATION

The following sets of codes concern non-name information produced in reference to each shorebird. In general, this information consists of two types of attributes; one in reference to a specific physical attribute possessed by the shorebird (hereafter, "physical attribute") and one in reference to a particular function relevant to feeding behavior that the possession of the correlated physical attribute enables the shorebird to do (hereafter, behavioral attribute).

The same coding system is used for both information produced during the board game and for information produced during the interview session. However, due to the nature of the interview, some of the codes presented below will not be used, while others may be added. During the board game, physical attribute information was elicited from children by presenting them with a behavioral attribute and then asking them, "Can you tell me why?" Similarly, behavioral attribute information was elicited by presenting children with the correlated physical attribute. During the interview session, all information that children produce was spontaneous. Therefore, codes "5" and "6" listed under physical attribute code 2 column 1 will not be used for information produced during the interview session.

One additional code will be added for use with the interview session. This code concerns whether the attributes that the child produced during the interview session appear to be correlated. It is described at the end of the coding manual.

Production of Physical Attributes

Each correct physical attribute code may be subdivided into two components: a descriptor for a body part and the body part itself. The table below lists the two correct components for each of the seven pairs of birds that possess them.

Shorebird Pair	Descriptor	Body Part
avocet/sandpiper	goes up at the end	bill
blackfront/golder	strong	legs
coot/phalarope	little bits of skin between	toes
curlew/woodcock	very big	eyes
gallinule/lapwing	very long	toes
godwit/snipe	long straight	bill
turnstone/wrybill	very strong	bill

Overview of Physical Attribute Codes

Production of physical attribute information is coded through three major codes. The first two codes are three-column codes. The third code is a one-column code. Code 1 considers the portions of the child's utterance that are correct. The first column addresses which components are correct, column 2 is concerned with whether the referents of these portions are visible or not visible and column 3 addresses whether the visible portions are "true" or "not true." Code 2 considers the portions of the child's utterance that are incorrect. Again, the first column concerns which components are incorrect, column 2 addresses whether the referents of these portions are visible or not visible, and the third column concerns whether the incorrect visible portions are "true" or "not true." Code 3 is relevant only to the portions of the child's utterance that are incorrect. Code 3 indicates whether or not the incorrect physical attributes that were produced are possessed by any of the other target shorebirds.

Determination of "correctness". In general, for a physical attribute or a component of a physical attribute to be coded as correct, it must be semantically equivalent to the correct physical attribute input presented in the table above. The following types of utterances are to be considered correct:

Utterance Type	*Examples*
a) substitution of "synonomous" words	*beak* for *bill*; *nose* for *bill*; *large* for *big*; *curved* for *goes up at the end*
b) gestural substitutions for portions of attribute information	Cause it goes up at the end. (C is pointing at her nose)
c) addition or deletion of magnitude modifiers	long toes for very long toes; *bits of skin between its toes* for *little bits of skin*...; either *long bill*, *straight bill*, *very long bill*, or *long, long bill* for *long, straight bill*
d) substitution of prepositions	*skin inside its toes* for *skin between its toes*

Determination of "visibility". This codes for whether the attribute information produced by the child could be visibly apparent or not. If one could tell whether or not the child was correct by looking at a picture of the shorebird, then the child's utterance should be coded as visible. If the response of the child can not be verified by simply looking at a picture (e.g., strong legs), then the child's utterance would be coded as not visible.

Examples of Visible and Not Visible Physical Attributes

Visible	*Not Visible*
bill that goes up at the end	strong legs
little bits of skin between its toes	strong bill
very big eyes	strong feet
very long toes	sharp eyes
long, straight bill	bright eyes
long legs	

Determination of "truth". This codes for whether the attribute information produced by the child is "true" according to the picture of the shorebird to which she was attending. Determination of truth can only be made for physical attributes coded as "visible" (described above).

Code 1

Column 1

0 - nothing is correct

1 - both components (descriptor of body part and body part) are correct

2 - only descriptor of body part is correct

3 - only body part is correct

Column 2

0 - column 1 does not equal "1"

1 - column 1 = 1; physical attribute is visible

2 - column 1 = 1; physical attribute is not visible

Column 3

0 - column 1 does not equal "1"

1 - column 1 = 1; physical attribute is visible and true

2 - column 1 = 1; physical attribute is visible and not true

3 - column 1 = 1; physical attribute is not visible

Code 2

Column 1

0 - no incorrect information produced

1 - incorrect complete physical attribute produced (both descriptor for body part and body part are produced and both are incorrect) (Note: Utterances referring to an aspect of the entire bird (e.g., It's purple.) should get coded as having both the descriptor for the body part and the body part produced. In these cases, the body "part" is considered the whole bird, or a large portion of the whole bird.)

2 - only incorrect descriptor for body part produced

3 - only incorrect body part produced

4 - more than one incorrect physical attribute produced (incorrect descriptor for body part and body part are produced in addition to one or more incorrect component(s))

5 - repetition of behavioral attribute or portion of behavioral attribute possessed by the target shorebird
e.g., "walks on plants in the water" in reference to gallinule

6 - provision of behavioral attribute or portion of behavioral attribute not possessed by target
e.g., "to sweep his bill back and forth" in reference to gallinule

7 - more than one incorrect descriptor for body part produced; no incorrect body part produced

8 - more than one incorrect body part produced; no incorrect descriptor for body part produced

9 - incorrect/other
e.g., "because he likes to"

Column 2

0 - column 1 does not equal "1"

1 - column 1 = 1; physical attribute is visible

2 - column 1 = 1; physical attribute is not visible

Column 3

0 - column 1 does not equal "1"

1 - column 1 = 1; physical attribute is visible and true

2 - column 1 = 1; physical attribute is visible and not true

3 - column 1 = 1; physical attribute is not visible

Code 3

0 - no incorrect components of a physical attribute were produced (code 2 = "000")

If code 2 does not equal "000," use one of the following codes:

1 - incorrect component(s) of physical attribute are possessed by the shorebird which is matched to the target in terms of overall morphological similarity

2 - incorrect component(s) of physical attribute are possessed by a pair of shorebirds, neither of which is matched to the target in terms of overall morphological similarity

3 - incorrect component(s) of physical attribute are not included in the input relevant to any of the 14 target shorebirds

4 - incorrect component is possessed by more than one pair of shorebirds, one member of which is the shorebird that is matched to the target in terms of overall morphological similarity

5 - incorrect component is possessed by more than one pair of shorebirds, neither of which include the shorebird that is matched to the target in terms of overall morphological similarity

6 - multiple incorrect physical attributes are produced (both incorrect components of one physical attribute are produced in addition to one or more components of an additional incorrect physical attribute)

7 - multiple incorrect components are produced (e.g., "long, straight bill that goes up at the end" for wrybill)

X - other (code 2, column 1 = 5, 6, or 9)

Use the table on p. 139 when determining for code 3 whether incorrect physical attribute components are possessed by morphologically-matched shorebird.

Production of Behavioral Attributes

Each correct behavioral attribute code may be subdivided into three components; an action, a location, and a goal. The table below lists the three correct components for each of the seven pairs of birds that possess them.

Shorebird Pair	Action	Location	Goal
avocet sandpiper	to sweep its bill back and forth	over the mud	snails
blackfront golder	to tap its feet up and down	on the ground	bring worms up to the surface
coot phalarope	to swim	in the water	water bugs
curlew woodcock	to see	in the dark	bugs
gallinule lapwing	to walk	on top of plants that float in the water	water bugs
godwit snipe	to push its bill up and down... very fast	in the mud	worms
turnstone wrybill	to dig	underneath rocks	crabs

Overview of Behavioral Attribute Code

There are three behavioral attribute codes, each containing three components. The three components of each of the three codes correspond to the three components outlined above for each of the seven pairs of shorebirds: action, location, and goal.

Code 1 - deals with portions of utterance that are correct/semantically equivalent to input

Code 2 - deals with portions of utterance that are incorrect

Code 3 - addresses whether or not incorrect portions of utterance (that are actual inputs for some shorebirds) are possessed by shorebird that is paired to the target in terms of overall morphology)

Each of codes 1,2, and 3 are broken down into three components corresponding to the three components in the input statement: action, location, and goal.

Component 1 - action
Component 2 - location
Component 3 - goal

Using the Behavioral Attribute Information Codes

Code 1: Correct Information

________________ ________________ ________________
action location goal

For each of the three components, one of the following codes may apply:

1 - component is produced and is semantically equivalent to input

P - only part of component is produced; this part is semantically equivalent to input

2 - two components produced; one is correct and one is partially correct

0 - component is not produced

(See table on pp. 148 to 154 to determine whether component should be considered correct or partially correct)

Note: The words "go" and "find" (as in "goes in the water to find water bugs to eat" and "finds crabs") are not to be considered ACTION information. Code the action column as "0" in the event that these forms are produced. Similarly, the word "things" should not be considered either LOCATION or GOAL information. Code the relevant columns as "0."

Code 2: Incorrect Information

________________ ________________ ________________
action location goal

For each of the three components, one of the following codes may apply:

1 - incorrect component is produced; component is semantically equivalent to input relevant to another shorebird

P - only part of incorrect component is produced; this part is semantically equivalent to input relevant to another shorebird

2 - component does not exist in input relevant to any other shorebird

3 - more than one incorrect exemplar[a] of component produced, all exemplars are semantically equivalent to input relevant to another shorebird

4 - more than one incorrect exemplar of component produced, at least one exemplar does not exist in input relevant to another shorebird

5 - repetition of physical attribute or portion of physical attribute possessed by target shorebird (code all relevant components as "5")

6 - provision of physical attribute or portion of physical attribute that is not possessed by target but is possessed by one of the 6 other pairs of shorebirds (code all relevant components as "6")

7 - other (e.g., because he likes to) (code all three components as "7")

8 - incorrect component is produced that receives a '1' under one pair and a 'P' under a second pair. (Note: Do not use this code with utterances of "bugs" or water bugs." Code these forms based on only the word that the child produces.)

0 - incorrect component is not produced

[a] An exemplar in this sense refers to a distinct example of a type of component. For example, if a child says "...to find snails and worms to eat," she would be providing two exemplars of a goal component.

(See table on pp. 148 to 154 to determine whether component should be considered correct or partially correct)

Definitions of Correct and Partially Correct Components

Use the following table in determining whether a particular component should be coded as a '1' (correct or semantically equivalent to input) or a 'P' (partially correct) (Note: actual input statements are presented in capital letters). When coding a particular utterance, look first at the list under the pair to which the target shorebird belongs. Only if the utterance is not on this list, look at the other lists.

Note: When coding utterances produced during the interview session, the body part (e.g., "sweeps its bill back and forth") need not be included in the action component if that body part was mentioned in the accompanying physical attribute utterance (e.g., bill that goes up at the end). Therefore, an action component of "sweeps" would receive a code of "1" (wholly correct) in the interview session if the child had already mentioned the bill in the physical attribute statement.

Correct and Partially Correct Behavioral Attribute Components

Shorebird Pair	Code	
	'1'	'p'
AVOCET/SANDPIPER		
action:	SWEEP ITS BILL BACK AND FORTH	scoops its bill
	wave its beak back and forth	sweeps
	move its beak back and forth	sweep um- thingie
	to go like this (C moves her head from side to side) to sweep its bill up and down	to go like this (C sweeps her head back and forth) to dig
	swish his bill back and forth	to go sweep, sweep sweep
	sweep its bill up and down	to help it sweep, swap
	push its beak back and forth	go sweep sweep sweep sweep sweep sweep sweep
	sweep its beak	sweep...very fast
	wind his beak back and forth	sweep back and forth
	to (C sweeps her head back and forth	
location:	OVER THE MUD	underneath the mud
	in the mud	under the mud
	on the mud	
	the mud (action = sweep)	

Shorebird Pair	'1'	'p'
goal:	SNAILS little snail to get snails up	snails up to the surface
BLACKFRONT/GOLDER		
action:	TAP ITS FEET UP AND DOWN to (C stomps her feet up and down on the floor) (if correct, Location = '1' too) tap its feet tap its foot up and down tap its feet up and down fast tap up and down tap its foot go tap (C stomps her feet up and down on the floor) (If correct, Location = '1' too) flap its feet up and down stomps its foot..very fast go (C stomps her feet up and down on the floor) (If correct, Location = '1' too) pound its foot up and down very fast	tap pound...very fast to stomp...very fast to tap tap tap tap tap tap tap stomps his feet

Shorebird Pair	'l'	'p'
location:	ON THE GROUND	underneath the ground
	the ground	through the ground
	on the surface	
goal:	BRING WORMS UP TO THE SURFACE	to get worms
	get worms up to the surface	worms
		get worms very fast
	to get worms up	bring little worms to eat
	to bring worms up	little worms
	to bring worms up from the surface	find worms
	find worms to bring up to the surface	bring bugs up to the surface very fast
	get worms from out of the ground	bring snails up to the surface
COOT/PHALAROPE		
action:	SWIM	
	paddle	
location:	IN THE WATER	by the water
	on the water	
	on top of water	
	across the water	
	through the water	

Shorebird Pair	'l'	'p'
goal:	WATER BUGS	bugs
	little water bugs	
CURLEW/WOODCOCK		
action:	SEE	
	look [for bugs]	
location:	in the dark	
	in the night	
	at night	
	through the dark	
goal:	BUGS	water bugs
	little bugs	dead bugs
	dry bugs	
	insects	
	large bugs	
GALLINULE/LAPWING		
action:	WALK	to float
	step	stand(s)
		grab [onto]

Shorebird Pair	'1'	'P'
location:	ON TOP OF PLANTS THAT FLOAT IN THE WATER on water plants on the plants in the water on plants in water on top of plants in the water across plants in the water on top of plants floating in the water onto plants in the water on top of plants that float on plants in the water that float on top of plants that live in the water on plants that float up to the surface in the water on top of plants that go in the water	on top of plants over plants on top of the water on the plants on a plant across the top on water in flowers in the water onto plants
goal:	WATER BUGS	bugs

Shorebird Pair	'1'	'p'
GODWIT/SNIPE		
action:	PUSH ITS BILL UP AND DOWN...VERY FAST move its beak up and down push its bill back and forth like this (C is bobbing her head up and down) push its bill up and down to go like this (C is bobbing her head up and down)	to push under to tap its bill push its beak..very fast push its beak back and forth..very fast push its bill back and forth push his beak back and forth flap its beak up and down sweep its bill up and down... very fast push its beak push (only if location does not equal 'rocks") push...very fast (only if location does not equal 'rocks' tap its beak up and down tap its beak dig holes (in the sand) push up (only if location does not equal 'rocks') dig up and down
location:	IN THE MUD	on the mud mud

Shorebird Pair	’l’	’p’
goal:	WORMS	bring worms up from the surface
	little worms	bring worms up to the surface
		get worms up to the surface
TURNSTONE/WRYBILL		
action:	DIG	lift up
	pick up (only if location = ’rocks’)	dig up and down
	push up (only if location = ’rocks’)	look for (crabs under rocks)
	push (only if location = ’rocks’)	bring up (crabs to eat under rocks)
	dig...real fast	
location:	UNDERNEATH ROCKS	on the rocks
	rocks (only with action=’pick up’ or ’push up’)	rocks (only if action is not ’pick up’ or ’push up’)
	under rocks	
	between rocks	
	under rock	
goal:	CRABS	get crabs up to the surface
	bring up crabs	

Code 3: Possessors of Incorrect Information

__________ action   __________ location   __________ goal

If no incorrect components were produced, place a 0 in each component.

If an incorrect component was produced, but it did not receive a code of either a "1" or a "P," place an X in the relevant component.

Only components that received a "1" or a "P" in code 2 may receive one of the following codes:

1 - component possessed by the pair containing the one shorebird that is matched to the target in terms of overall morphology

2 - component possessed by more than one pair of shorebirds, one member of which is matched to the target in terms of overall morphology

3 - component possessed only by one pair of shorebirds, neither of which is matched to the target in terms of overall morphology

4 - component possessed by more than one pair of shorebirds, none of which are matched to the target in terms of overall morphology

5 - code 2 = '8'; one of the pairs contains the shorebird that is matched to the target in terms of overall morphology

6 - code 2 = '8'; neither of the pairs contains the shorebird that is matched to the target in terms of overall morphology

To determine whether incorrect component is possessed by shorebird matched in terms of overall morphology, use the table on p. 139.

Additional Correlated Attribute Information Code for Interview Session

In addition to coding whether the attribute components produced during the interview session are correct or incorrect, the correlation existing between those attributes must be considered. This code can only be used if the child produces both components of a particular physical attribute and the "action" component of a particular behavioral attribute in reference to a shorebird. (The location and goal components of a behavioral attribute may or may not be present.) A correlation is considered to be a type of cause-and-effect relationship. In order for a correlation to exist, there must be a causal link between the possession of a particular physical attribute and the ability to perform a particular behavioral attribute. For example, the possession of long toes allows a bird to walk on top of water plants. Therefore "long toes" and "walk on top of water plants" are considered to be correlated attributes. On the other hand, big eyes are not necessary for walking on top of water plants. Therefore, "big eyes" and "walk on top of water plants" are not correlated attributes.

When recording this code, place it out to the right of the behavioral attribute information codes.

0 - the child does not produce both a physical attribute (both the descriptor and the body part components) and at least the action component of a behavioral attribute in reference to the shorebird

1 - both types of attribute are produced and a cause-and-effect relationship exists between them

2 - both types of attribute are produced and a cause-and-effect relationship does not exist between them

III. PAIR JUSTIFICATION DATA

The child's utterance must first be broken down into separate sentences or propositions, corresponding to the different reasons why the child thinks that each pair are like the same kind of thing. Each sentence or proposition must then be coded individually. Each will be numbered according to the order in which it was produced.

Examples of breaking down children's utterances into propositions:

C: "They have the same legs and feet."

proposition 1: same legs
proposition 2: same feet

C: "Their heads and necks are red."

proposition 1: heads are red
proposition 2: necks are red

For each reason (proposition), specify the following:

I. The Overall Nature of the Reason.

This is a three column code that addresses the nature (rather than the content) of the child's reason. First, the reason is evaluated in terms of its consistency with the type of input that the child has received relevant to that particular pair of shorebirds. Second, it is considered in terms of whether an adult would agree or disagree with the child's utterance. Finally, the child's apparent understanding of the question is evaluated.

Column 1. Is it consistent with the input (or lack of input) that the child has received? That is, for pairs based on overall morphology, did the child provide reasons relevant to the bird as a whole? For pairs based on shared correlated attributes, did the child mention attributes (either physical or behavioral) as the basis for similarity?

1 = consistent
2 = inconsistent

Column 2. Is it correct? Would an adult agree with the reason provided by the child? (If the child produces a physical attribute that is not visible (e.g., "they both have strong legs") or a behavioral attribute, assume that the adult knows the appropriate input statements for physical and behavioral information. If the child produces a physical or a behavioral attribute that is contained in the input statement of only one member of the pair, code as if the adult agrees with the child (column 2 = 1).

1 = adult would agree that what child says is true

2 = adult would not agree that what child says is true

3 = unclear, due to lack of clarity in the child's utterance (use this code only if column 3 = 2 or physical attribute column 2 = 3 or 4)

Column 3. Does the child appear to lose track of what the question is asking? (e.g., "Well, these are alike because this has X and this has Y." instead of "...this has X and this has X."

1 = child answers question appropriately
2 = child does not answer question appropriately

If column 3 is coded as 2 (i.e., the child is not answering the question appropriately) stop coding here and move on to the next proposition.

II. The Content of the Reason.

This group of codes addresses the specific nature of the child's reason.

1. Attribute of Whole vs. Attribute of Part.

This code concerns whether the child's reason is referring to an attribute of the whole bird (e.g., its size, color, or shape) or an attribute of a specific part of the bird (e.g., something about its wings, bill, eyes, or toes).

For attributes of the whole bird, use one of the following codes to determine the basis for the child's proposition:

1 = size/height (e.g., big/little)
2 = weight (e.g, fat/skinny)
3 = color
4 = shape (e.g., fluffy, long)
5 = pattern of colors (e.g., they're both black and white; they both have black in the front)
B = possession of whole body parts (e.g., they both have wings)
6 = unspecified (e.g., everything's the same; they both look like coots)

(Note: Reasons relevant to a particular bird's body (e.g., "Their bodies are both long.") will be considered attributes of the whole bird.)

For attributes of a part of the bird, use one of the following codes to specify the nature of the attribute(s):

7 = physical attribute
8 = behavioral attribute
9 = physical + behavioral attribute, correlated
0 = physical + behavioral attribute, uncorrelated

(Note: to determine whether two attributes are correlated or not, see pp. 129-130 of the coding manual)

If child provides a reason referring to an attribute of the whole bird (i.e., code 1 = 1, 2, 3, 4, 5, or 6), or code 1 = X, stop coding that particular proposition here and begin coding the next proposition. If the child produces a reason referring to an attribute of a part of the bird, continue coding the nature of that attribute, using the following system:

If the child produces a PHYSICAL ATTRIBUTE (i.e., code 1 = 7, 9, or 0), code the following four columns:

column 1: What part of the bird does physical attribute refer to?

1 = bill/beak/nose
2 = eyes
3 = toes
4 = legs
5 = stomach/tummy
N = neck
F = feet
6 = wings
7 = tail
8 = back
H = head
9 = unspecified (e.g., "thingie")

column 2: Is the child's reason identical (or semantically equivalent) to an input statements relevant to physical attributes possessed by one of the seven pairs of shorebirds?

1 = whole utterance is equivalent to one of the inputs in the physical attribute table

(Note: The addition of a modifier to an otherwise semantically equivalent utterance (e.g., kind of long beaks) makes the utterance NOT semantically equivalent to the input statement. Code such utterances as "2.")

2 = whole utterance is not equivalent to one of the inputs in the physical attribute table, but contains one clear body part and one clear descriptor for body part

3 = whole utterance is not equivalent to one of the inputs in the physical attribute table, and does not contain any clear descriptor for part (e.g., same eyes; same beaks; same way of the feet; same length of toes)

4 = whole utterance is not equivalent to one of the inputs in the physical attribute table, and contains an unspecified or nonsensical descriptor for body part and/or body part (e.g., unspecified descriptor: the legs might be the right sizes; nonsensical descriptor: they both have little bumbles going down their backs; the thingies are the same)

column 3: Which of the 14 shorebirds possess that attribute? For utterances that are equivalent to one of the inputs in the physical attribute table, code for which of the 14 shorebirds possess that attribute.

X = whole utterance is not equivalent to one of the inputs in the physical attribute table

1 = physical attribute possessed by both birds in the pair

2 = physical attribute possessed by only one of the birds in the pair

3 = physical attribute possessed by neither of the birds in the pair, but is possessed by one of the birds with which one or the other is matched in terms of overall morphology

4 = physical attribute possessed by neither of the birds in the pair, but is possessed by one of the birds with which one or the other is matched in terms of shared correlated attributes

5 = physical attribute possessed by neither of the birds in the pair, nor by one of the birds with which they are matched in terms of overall morphology or correlated attributes

column 4: Is the physical attribute that the child produces visible or nonvisible? (Consider it visible if you could verify whether or not the child was correct by looking at a picture of the shorebird; otherwise consider it not visible.)

1 = visible

2 = not visible

If the child produces a BEHAVIORAL ATTRIBUTE (i.e., code 1 = 8, 9, or 0), code the following three columns:

column 1: What parts of the behavioral attribute were produced?

1 = action only

2 = location only

3 = goal only

4 = action and location

5 = action and goal

6 = location and goal

7 = action, location, and goal

column 2: Are the parts of the behavioral attribute that were produced identical (or semantically equivalent) to one of the seven behavioral attribute input statements?

1 = all parts that were produced are equivalent to input in the behavioral attribute table

2 = at least one part that was produced is not equivalent to input in the behavioral attribute table

column 3: Which of the 14 shorebirds possess that attribute? (Only code utterances for which column 2 = 1.)

X = column 2 does not = 1.

Attribute Possessed by:

1 = both birds in the pair

2 = one of the birds in the pair

3 = neither of the birds in the pair; one of the birds with which one or the other is matched in terms of overall morphology

4 = neither of the birds in the pair, one of the birds with which one or the other is matched in terms of shared correlated attributes

5 = neither of the birds in the pair, nor by one of the birds with which they are matched in terms of overall morphology or correlated attributes

ENDNOTES

[1] In piloting this study, girls tended to be less distractable than boys. Furthermore, girls tended to enjoy playing the board game more than boys, and often requested to continue playing the board game at the end of each session. For these reasons, only girls participated as subjects.

[2] All of the shorebirds listed in Table 1 are included in the order _charadriiformes_, except for the coot and the gallinule, which are included in the order _gruiformes_.

[3] To verify that naive children would select the shorebirds listed in the first and second columns as being most like the same kind of thing, a separate group of 6-year olds was tested on each of the 14 triads. On the basis of these data, the stimulus cards featuring the bar-tailed godwit and the black-tailed godwit were modified slightly to increase their overall morphological similarity to the northern phalarope. Each of the godwit bills was shortened by 25%.

[4] To test whether the difference between physical and behavioral attribute productions was simply due to physical attributes possessing fewer components than behavioral attributes, a parallel set of analyses was performed. In this set, the numbers and proportions of correct attributes produced during the board game and the numbers and proportions of correct attributes produced during the interview again were compared. However, a weaker criterion for correct behavioral attribute productions was employed: if either the action or the location component was correctly produced, the entire behavioral attribute was coded as correct. Even when this less stringent criterion for correct behavioral attributes was employed, the results reported above for numbers of correct information produced were replicated. The result reported for proportions of correct information produced during the interview also was replicated. However, in comparing the proportions of correct attribute information produced during the board game, the main effect of information type was not significant in the revised analysis, whereas it was significant ($\underline{p}<.01$) in the analysis reported above. In general, however, it appears that the difference between correct physical and behavioral attribute productions is not simply attributable to differences in the numbers of components needed to be recalled.

[5] Proportions of incorrect information (out of the number of birds for which a particular type of information was produced) are not addressed here, since these proportions are the exact complements of the proportions of correct information reported in Table 5. The significant

differences among information types for proportions of incorrect information are identical to those reported for proportions of correct information.

[6] The notion of a continuum of increasing competence was originally proposed by Aleeta Zietsman.

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