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The Wheels on the Bus Go Round and Round: Infants' Use of Functional Parts
in Basic-Like Categorization

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Submitted 7/23/98

Abstract

Three experiments with the object-manipulation technique investigated the role of large, functional object parts on 1- to 2-year-old infants' ability to form basic-like categories. In the first two experiments, infants were tested with novel objects that were made by removing or attaching large functional object parts. In Experiment 1, 14-, 18-, and 22-month-olds were tested with contrasts of cows and cars. In Experiment 2, the same age groups were tested with contrasts of cows and birds. The results of the two experiments revealed that infants attend to large functional object parts to form basic-like classes under specific within- and between-category similarity conditions. Analyses of functional responses revealed that 14- and 18-month-olds associate different large object parts with different kinds of movement (e.g., objects with wheels "roll"). By 22 months, infants associate different objects with different kinds of movement. Experiment 3 tested infants' categorization of object parts independent of the whole object. The results indicate that perceptible attributes are sufficient for infants to form specific basic-like classes. It is suggested that attention to correlations between object parts and functions may provide the foundation for conceptual knowledge in certain domains.

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Introduction

Of the three hierarchical category levels defined by Rosch and her colleagues -- that is, basic, superordinate, and subordinate -- it is the basic level (e.g., dogs, trucks) that is considered to be "psychologically privileged" (e.g., Rosch, 1978; Mervis & Rosch, 1981; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). This unique status results from, among other things, the fact that the basic level maximizes within-category perceptual similarity as well as between-category perceptual dissimilarity. Thus, exemplars from a single basic-level category are often alike in many ways (e.g., form, function, structure) and very different from other basic-level category types. In comparison, instances from within a single superordinate domain (e.g., animals, vehicles) are often quite dissimilar, and instances from within a subordinate category (e.g., Rottweilers, Pick up truck) provide little additional category membership information from that given at the basic level (Tversky & Hemenway, 1984).

Rosch, among others, claimed that the basic level is not only psychologically fundamental, but it is also developmentally prime (e.g., Markman, 1989; Mervis, 1987; Mervis & Rosch, 1981; Rosch et al., 1976). Thus, according to this view, the first categories that infants form are thought to be at the basic level, with superordinate and subordinate distinctions following later in development. Considerable evidence in the literature supports this claim. It has been shown in vocabulary acquisition studies, for example, that the first 50 or so words that infants learn are at the basic level (Anglin, 1977; Clark, 1973), and there is a greater frequency of basic-level terms than superordinate terms in children's and adults' speech (Rosch et al., 1976). Finally, children between 2 and 4 years of age who were taught artificial

categories at different hierarchical levels more easily learned terms at the basic level than any other level (Mervis and Crisafi, 1982).

If basic-level categories are formed early in childhood, or even in infancy, does this mean that they are based on perceptual information alone? Or is it that infants' basic-level categories are conceptual categories in that they are based on information beyond external appearances and hence grounded in "what something is" (Mandler, 1998)? Although Rosch did not address this issue directly, the putative view until recently was that the earliest basic level categories are formed on the basis of information available in the perceptual input. It has been pointed out that this is hardly surprising because categories at the basic level tend to have similar shapes, similar functions, and many features in common (Rosch et al., 1976; Tversky, 1989). As Markman (1989) stated: "At the basic and subordinate levels category members are quite similar to each other, and justification for considering them the same is readily apparent" (p.78). And indeed, there is evidence that young infants can form complex "basic-like" representations by attending, presumably, just to perceptual information. For instance, using the familiarization technique it was found that infants as young as 3 months can form categorical representations for cats that exclude dogs, for horses that exclude cats and zebras, and for cats that exclude horses and tigers, but not female lions (Eimas & Quinn, 1994; Quinn, Eimas, & Rosenkrantz, 1993). In addition, there is evidence that 3- to 4-month-olds can form a basic-like category of cats that excludes dogs on the basis of facial information alone (Quinn & Eimas, 1996a). Hence, information available in the perceptual input is sufficient for infants to form basic-like categories.

The developmental primacy of the basic-level, and the perceptual basis for certain aspects of early categorization, have been disputed recently by Mandler and her colleagues (e.g., Mandler, 1992, 1993, 1998; Mandler & Bauer, 1988; Mandler, Bauer, & McDonough,

1991). The empirical evidence for Mandler's claims came, in part, from a series of studies using the object-manipulation technique in which spontaneous sequential touching to toys from the same category is taken as evidence of classification. Mandler and Bauer (1988) found that 16- and 20-month-old infants categorized basic-level domains from different superordinates -- for example, dogs versus cars -- but not basic-level domains within a single superordinate; for example, dogs versus horses. In a later study, again with the object-manipulation technique, Mandler et al. (1991) found that 18-month-olds categorized the superordinate domains of animals and vehicles but not basic-level contrasts within these domains when the contrast between object sets was low or moderate; for example, dogs versus horses or dogs versus rabbits. According to Mandler et al. (1991; see also Mandler, 1998), the only within-domain distinctions evidenced by infants were between animals that move on land, sea, and air and between vehicles that move on land and in the air; for example, dogs versus fish and cars versus planes.

Based on these, and other results drawn from studies using different experimental techniques (e.g., Mandler & McDonough, 1993, 1996), Mandler made a number of claims about early categorization that have since been highly influential in the developmental literature. First, she rejected the primacy of the basic-level and proposed instead that the first categories to be formed are at the superordinate, or global, level. (Mandler redefined superordinate categories as global because of the absence of basic-level classes nested within them.) Second, Mandler argued that infants' ability to make distinctions at the global but not at the basic level reflects that they form conceptual, rather than perceptual, categories. The claim is that infants have developed a conceptual format that embodies abstract properties such as the differences between self-moving, animate objects and inanimate objects (Mandler, 1992). The conceptual format is thought to emerge from a process of perceptual analysis in which the infant recodes a

certain aspect of the perceptual input into a more generalized, accessible form. According to Mandler, conceptual knowledge -- for instance, a distinction between animate and inanimate things - provides the basis for young infants to categorize objects from different global domains; for example, animals versus vehicles. However, the same conceptual knowledge would not be sufficient to categorize objects within one global domain; for example, dogs versus horses because both are animate. The only distinctions within a global domain are thought to occur when there are conceptual differences between exemplars in terms of their domain of movement. Thus, infants categorize cars and planes because cars move on land and planes move in the air, but they do not categorize cars and trucks because they both move on land.

In general terms, Mandler's theory has led to a new framework for conceptual development. For example, there is now considerable evidence from studies with infants and connectionist models to suggest that global-like domains are formed prior to those at the basic level (e.g., Behl-Chadha, 1996; Behl-Chadha, Eimas, & Quinn, 1995; Quinn & Johnson, 1997). Nonetheless, there is at present little direct evidence to support the theories of perceptual analysis or conceptual primitives. In addition, Rakison (1998; Rakison & Butterworth, 1998, in press) has pointed out that in many cases there are alternative, perceptually oriented, interpretations of the results of Mandler's studies. Rakison argued that in a number of object-manipulation tasks designed by Mandler and her colleagues (e.g., Mandler & Bauer, 1988; Mandler et al., 1991), infants categorized when object sets had different parts -- for example, legs and wheels in animals and vehicles -- but not when object sets shared parts; for example, legs in horses and dogs. To test infants' attention to object parts in categorization, Rakison and Butterworth (1998, Experiment 2) presented 14-, 18-, and 22-month-olds with novel versions of animals and vehicles that were created by removing or attaching legs and wheels. There were four conditions in the experiment: In one task the stimuli were unmodified; in a second task, all

the stimuli had the same parts (legs and wheels); in a third task, the stimuli had parts removed (no legs or wheels); and in a fourth task, half the stimuli had legs and half the stimuli had wheels (e.g., two animals with wheels and two with legs). The results revealed that 14- to 22-month-old infants categorized animals and vehicles that were unmodified, but they failed to categorize in the conditions in which the stimuli had the same parts or had parts removed. The authors interpreted this behavior to mean that object parts are sufficient, and in some cases necessary, for infants' superordinate-like categorization. This view was supported by the fourth task in which infants were given a "choice" to categorize on the basis of objects parts or category relations: The 14- and 18-month-olds classified on the basis of the former ("objects with legs" and "objects with wheels") rather than the latter (animals and vehicles). The 22-month-olds in the same task did not categorize on either basis, however.

Based on this evidence, Rakison (1998; Rakison & Butterworth, 1998, in press) argued that infants in the first half of the second year do not form conceptual categories, rather they attend to object parts to form superordinate-like categories. Support for the claim came from a later study by Rakison and Butterworth (in press) that showed that 1- to 2-year-old infants are sensitive not only to object parts but also to the structural aspects of objects given by those parts. In one experiment, for example, 14- to 22-month-olds were presented with animals and vehicles, the parts of half of which were either altered in orientation but not configuration -- for example, legs were moved as a unit onto an object's back and pointing upward -- or in orientation and configuration; for example, legs were divided into four individual units and then each leg was placed tangentially to the host object. The results showed that 14- to 22-month-olds group together objects with the same parts if their configurational structures are equivalent -- for example, legs that are in the same configuration but not the same orientation -- but not if their configurational structures differ. Furthermore, the results revealed that 22-month-olds, but

not younger infants, tended to invert stimuli so that legs or wheels were in a correct orientation. Infants engaged in this behavior even though this meant that the remainder of the object was in a novel orientation, that is, upside-down. Rakison (1998; Rakison & Butterworth, in press) interpreted infants' responses to mean that they develop "expectations" about the orientation, and possibly the function, of certain object parts. It was hypothesized that infants notice the association between different parts and part structures and "conceptual" aspects of the object such as mode of locomotion; for example, walking or rolling. Once the association is learned, the presence of a certain object part (e.g., wheels) would prime infants to "expect" that an object moves in a particular way; for example, objects with wheels "roll".

This theory is consistent with the work of Madole, Oakes, and Cohen (1993) who used an object-examination technique to examine infants' attention to the relationship between form and function. Infants at 10, 14, and 18 months were familiarized with a number of objects whose form and function (e.g., rolling, shaking) were either correlated or uncorrelated and then tested with a novel object that did not embody the properties of the training exemplars. The results showed that 10-month-olds attend to form, 14-month-olds attend to form and function as independent properties, and 18-month-olds attend to the relation between an object's form and its function. In a later study by Madole and Cohen (1995) that also used the object-manipulation technique, it was shown that 18-month-olds attend only to form-function correlations that are compatible with those found in the real world; that is, when the form of an object part predicts its function. Likewise, Tversky (1984; Tversky and Hemenway, 1984) argued that parts support children's and adults' inferences from surface appearance to function. Thus, object parts are "simultaneously natural units of perception and natural units of function" (Tversky, 1989, p.983).

The notion that infants attend to the relationship between function and form is also consistent with the large database of evidence that suggests that naïve theories underlie certain aspects of children's and adults' categorization (e.g., Barrett, Abdi, Murphy, & McCarthy, 1993; Keil, 1989; Krascum & Andrews, 1998; Murphy & Medin, 1985; Wisniewski, 1995). The claim, first advanced by Murphy and Medin (1985), is that perceptual similarity alone is insufficient to account for categorization because the salience of attributes along which similarity is measured varies depending on context-specific aims and goals. According to Murphy and Medin (1985), it is naïve theories that provide coherence for correlated clusters of properties among category members. Consistent with these claims, there is evidence that distinctive functions or behavior are seen as the product of fundamental, nonobvious properties in the case of living things (Keil, 1989) or from the collective response of multiple attributes (Medin, Wattenmaker, & Hampson, 1987). A recent study revealed that 4- to 5-year-olds categorize better when they are given a theory to explain the existence of correlated attributes than when were given no theory or when they are presented with unrelated functions for the attributes (Krascum & Andrews, 1998). There is also evidence from studies with novel artifacts (e.g., Wisniewski, 1995) that adults are confident in their generalizations of category membership if the object in question possesses an attribute that is crucial to function. Thus, according to Wisniewski (1995), function acts as an intermediary between perceptual properties and what something is, as defined by the category name.

There is, therefore, considerable evidence concerning infants' attention to object parts in superordinate-like categorization, and their sensitivity to correlations of form and function (e.g., Madole & Cohen, 1995; Madole, Oakes, & Cohen, 1993; Rakison & Butterworth, 1998, in press). There is also evidence that adults and 4- to 5-year-old children rely on theories about the relationship between form and functional properties -- theories that often encapsulate

causal reasoning -- to form categories of real world objects. As yet, however, there has been little research to test whether infants attend to objects' parts, and the functional properties of those parts, to form categories at the basic-like level.

The goals of the three experiments presented here were twofold: First, the experiments were designed to ascertain whether infants attend to parts to form basic-like categories or whether they rely on certain kinds of conceptual knowledge to do so. Mandler (1992, 1998; Mandler et al., 1991) has intimated that the only basic-level distinctions that can be made by infants are those based on conceptual information; for example, land vehicles versus air vehicles. However, this conclusion relies on the premise that infants form conceptual global categories -- a premise that recently has been questioned in the literature by evidence that infants form superordinate-like categories on the basis of object parts (e.g., Rakison & Butterworth, 1998, in press). If infants are capable of grouping together perceptually dissimilar objects on the basis of a single part, why should they not do the same for perceptually similar objects? One reason might be the level of between-category similarity. At the superordinate-level, for example, low between- and within-category similarity might engender heightened salience for certain object parts -- for example legs, wheels -- that consequently act as the basis for categorization. On the other hand, two basic-level categories within a single domain -- for example, horses and dogs -- often have high a level of between-category similarity, and it is quite common for certain object parts to be possessed by members of both categories. The three experiments presented here were designed to test whether the level of within- and between-category perceptual similarity among category members, and the presence of large, functional object parts, determine infants' ability to form basic-like classes.

Second, the studies presented here were designed to test how infants develop the ontological principles, often referred to as conceptual knowledge, that come to organize basic-

like, and presumably superordinate-like, domains. One such principle refers to the distinction between animate and inanimate objects, one of the components of which is the different kinds of movement of different objects (Mandler, 1992; Premack, 1990). Rakison & Butterworth (in press) hypothesized that the development of knowledge or “expectations” about objects’ locomotion results from attention to large, moving object parts. They claimed further that such an explanation might provide the foundation for the transition from perceptual to conceptual or theory-based associations, for which a sufficient explanation is currently absent from the developmental literature (Mandler, 1998; Mandler et al., 1991; Quinn & Eimas, 1986). Mandler (1992, 1998), on the other hand, posited that infants’ knowledge about the movement of objects is encapsulated in conceptual primitives that allows inductive generalizations across category members.

In order to examine these issues, the experiments made use of the novel version of the object manipulation task developed by Rakison and Butterworth (1998, Experiment 2). Thus, infants were presented with category exemplars that were modified by attaching or removing certain large functional parts. In the first experiment, 14-, 18-, and 22-month-olds were presented with basic-level exemplars from different superordinate; that is, cows versus cars. In the second experiment, the same three age groups were presented with basic-level exemplars from within the same superordinate; that is, cows versus birds. In the third experiment, infants were tested with contrasts of large parts alone; that is, legs versus wheels and legs versus wings. To test whether infants’ attend to the movement of large object parts, the three experiments include an analysis of infants’ functional responses -- that is, “rolling”, “jumping”, “walking” or “flying” -- with the toys in each task. Clearly, the movements made by infants with toy animals and vehicles will not match the movements made by real world objects. The wheels of a car, for example, were designed for reasons other than for infants to roll them.

Nonetheless, infants' responses can be taken as indicative of their expectation, or knowledge, about the movement of different objects or object parts.

Experiment 1

The aim of the study was to examine the role of parts in infants' categorization of basic-level domains from different superordinates. Infants were presented with four contrasts of cows and cars that matched in design the four tasks used by Rakison and Butterworth (1998, Experiment 2). In addition to a task with unmodified cows and unmodified cars, there were three tasks in which the parts of stimuli were modified across- and within- the category domains. The cow and the car exemplars were altered so that they all shared, partly shared, or did not share at all certain parts; that is, legs and wheels. It was reasoned that if infants attend to parts to categorize, they should find it difficult to classify cows and cars in the absence of part differences among the stimuli. Given the high level of within-category similarity and between-category dissimilarity, it was not clear whether infants would attend to object parts to categorize when parts were shared across the two object sets; that is, when half the cows and cars had legs and half the cows and cars had wheels.

Method

Participants. Forty-eight infants participated in the experiment, 16 with a mean age of 14 months, 1 day (range = 13 months 17 days to 14 months 13 days), 16 with a mean age of 17 months, 24 days (range = 17 months 16 days to 18 months 6 days), and 16 with a mean age of 22 months, 0 days (range = 21 months 18 days to 22 months 14 days). Eight boys and 8 girls were tested in each age group. The majority of infants were of White middle socioeconomic status. Seven further infants were tested but were not included in the study: four infants because of fussiness or crying, two infants for not engaging in the tasks (touching less than three objects), and one infant as a result of experimenter error. Infants' names were obtained

through birth announcements published in the local newspaper. Parents were contacted by letter and later by telephone.

Stimuli. Four object-manipulation tasks were used in the study. Each task consisted of a contrast of cows and cars. The stimuli were 3-dimensional, realistic scale models and ranged in size from 4 cm to 6 cm in length and 2 cm to 4 cm in height. Every cow was a different breed and color (black, tan, black and white, and white car), and every car was a different model and color (sedan, sports, family, and estate car). The wheels of the cars were glued so that they could not move. One task was a straightforward contrast between normal cow and car exemplars. In the other three tasks, the parts of objects were systematically modified within and across the categories. The control task consisted of four unmodified cows and four unmodified cars. There were two tasks in which parts were equivalent, or matched, across the two categories. In the first of these contrasts, the cows and cars were modified by adding legs to the cars and wheels to the cows. Thus, every cow and car exemplar possessed both legs and wheels. The legs were taken from scale model cows and the wheels were taken from scale model cars. In the second matched-parts contrast, the cows and cars were modified by removing the legs from the cows and the wheels from the cars. These tasks reduced the part contrast between the two categories. In other words, there were no differences between the category exemplars due to wheels or legs.

Insert Table 1 about here

In the final task, the across-category confound, cows and cars were modified by removing the legs of two cows and replacing them with wheels, and by removing the wheels of two cars and replacing them with legs. This task was designed to provide a confound across the object sets by allowing infants to classify on the basis of category membership -- that is, cows versus cars -- or on the basis of part relations; that is, "objects with wheels" versus "objects with legs". As in previous studies with this task design (i.e., Rakison & Butterworth, 1998, in press), it could be argued that eight stimuli represented the leg-wheel distinction and only four represented the true cow-car distinction. This might bias infants to respond on the basis of parts. However, whether infants categorized by attending to parts or to category membership required them sequentially to touch two modified objects and two unmodified objects.

Task 1 will be referred to hereafter as the "control" task, Task 2 will be referred to as the "matched-parts task", Task 3 will be referred to as the "no-parts task", and Task 4 will be referred to as the "across-category confound task". Each child participated in all four object-manipulation tasks. A Latin square determined the order in which the tasks were presented.

Procedure. Infants were tested individually in the laboratory. Each infant was seated on their parent's lap in front of a table of the appropriate height. For each object-manipulation task, the relevant eight objects were placed randomly on the table in front of the infant and the experimenter encouraged the infant to manipulate the objects with such statements as "Here, these are for you to play with." and "Look at all these things." The experimenter then left the room. Each task lasted two minutes, and the infant was allowed to manipulate the objects in any way they wished. Parents were instructed that if an object was dropped from the table or put out of reach, they were to unobtrusively replace it within touching distance. Parents were also instructed to encourage the infant to play with the stimuli by passing a hand over all the objects and saying "What can you do with these things?", or words to that effect if no object

manipulation occurred for 20 seconds or if the infant manipulated only one object for 20 seconds. There was no other feedback, labeling, or pointing from the experimenter or from the parents. All four tasks were videotaped.

Coding and scoring. Coding focused on infants' sequential touching of objects. Every object contacted by an infant, both by hand or with another object, and the order in which the objects were contacted, were coded. The idea behind this coding system is that if sequential touches to objects within a category occur more often than would be expected by chance, this must be because infants apply a basis for categorization (Mandler, Fivush, & Reznick, 1987). The rules used to code the infants' behavior were those defined by Poulin-Dubois, Graham, and Sippola (1995; see also Rakison & Butterworth, 1998). In addition, coders noted the number of functional responses made by infants to the stimuli. The functional behaviors coded were "rolling" and "jumping". Rolling was defined as an action in which an object in the appropriate orientation was moved horizontally in a smooth motion on the table surface. Jumping was defined as an action in which an object in the appropriate orientation was moved horizontally and vertically in a "hopping" motion during which contact was made with the table surface at the end of the vertical motion. Infants could be coded as jumping or rolling both cars and cows.

Two judges coded independently 25% of the tasks (four infants from each age group), and interrater reliability was obtained by two measures: (1) by calculating Pearson correlation coefficients between the run lengths scored by the two independent coders, and (2) by calculating a percentage agreement between the different objects scored as touched by the two coders. Overall coder reliability for the run lengths made by the infants was $r = .92$, and percentage reliability for objects touched by the infants was 91%. Once interrater reliability was established, each judge coded half of the tasks. The judges were not naïve to the rationale of the experiment.

Procedures for analyzing sequential touching were taken from those developed by Mandler et al. (1987) and used in a number of subsequent categorizing studies (e.g., Dubois et al., 1995; Mandler & Bauer, 1988; Mandler et al., 1991; Rakison & Butterworth, 1998). The first analysis determined whether infants' sequential touching differed significantly from chance performance. The mean length of successive touches to the objects of each category was calculated for each infant on each task. This value was compared with the run length expected by chance if items from two sets of four objects were chosen at random (1.75). The mean run length measure indicates whether infants touched sequentially objects from each category, but it is not informative about the type of touching that was made. For instance, it does not reveal whether infants touched objects from one or from both of the available categories. For this reason, and to ascertain whether touching runs of three or four objects from the same category occurred by chance, a second analysis of run length was carried out. As in Rakison and Butterworth (1998), infants who touched systematically objects from one category were classified as single categorizers and infants who touched systematically objects from both categories were classified as dual categorizers.¹ The categorizing run criterion was the same as that used in previous research (e.g., Mandler et al., 1991; Sugarman, 1983). A Monte Carlo program was used to determine the probability of single and dual categorizing runs occurring in 10,000 random draws.² The program computed the number of categorizing runs of three or four items that would occur in a random draw repeated 10,000 times as a function of the number of touches (cf., Dixon, Woodard, & Merry, in press). Touches to the same object (i.e., repetitions) were allowed only if another object was touched between two touches to the same item and there were at least three or four unique items in the categorizing run. As with previous studies involving the Monte Carlo analysis, a cut-off point of $p < .10$ was used (e.g., Mandler & Bauer, 1988; Rakison & Butterworth, 1998).

Results

Run length analysis. Initial statistical analyses on the data revealed no significant difference between mean run lengths for gender at any age on any of the manipulation tasks. The run length values for each gender were therefore collapsed into a single run length score. One-tailed related t -tests were used to compare the infants' mean run lengths to the run length expected by chance (1.75). Because there were two ways for infants to categorize on the across-category confound task (cows and cars or "objects with wheels" and "objects with legs"), the run lengths for each of the alternative groupings were also calculated. The mean run lengths for all the tasks and their associated one-tailed t -test values are shown in Table 2.

Insert Table 2 about here

It can be seen that the mean run lengths of the three age groups on the control task of unmodified cows and unmodified cars were significantly greater than that expected by chance. In other words, infants at 14, 18, and 22 months behaved systematically to the cows and to the cars. The different age groups were more variable in their behavior on the two tasks in which part differences across the categories were minimized. On the no-parts task, it was not until 18 months that infants generated mean run lengths significantly greater than chance. However, on the matched-parts task it was not until 22 months that infants made mean run lengths that significantly exceeded chance level. Thus, infants behaved systematically to objects that did not share parts before they behaved systematically to objects that shared parts. In other words, they categorized more easily object sets that shared fewer large parts -- that is, objects without legs and wheels -- than object sets that shared more large parts; that is, objects with both legs

and wheels. On the across-category confound, the 14-, 18-, and 22-month-olds generated run lengths significantly greater than chance level to objects as cows and cars. Conversely, all three age groups made mean run lengths at chance level to stimuli in terms of “objects with wheels” and “objects with legs”.

The run length analysis indicates whether infants responded systematically or otherwise to the object sets, but it does not analyze infants’ performances across tasks and age groups. Accordingly, the run lengths were investigated further using a two-way mixed design ANOVA with a multivariate approach for within-subject effects (Pillai’s Trace). The main analysis had three levels of Age (14, 18, 22 months) as a between-subjects factor and five types of Task (control, no-parts, matched-parts, across-category [cows and cars], across-category [objects with wheels and objects with legs]) as a within-subjects factor. The analysis revealed that there was a significant main effect for Age, $F(2,45) = 4.42$, $p < .025$. Pairwise comparisons ($p < .05$) among the means indicated that the 22-month-olds ($M = 2.87$) generated significantly higher run lengths than the 14-month-olds ($M = 2.13$). There were no other significant differences among the run lengths of the age groups. The main effect for Task was also significant, $F(4,42) = 3.52$, $p < .025$. Two-way related t -tests revealed that infants generated significantly longer mean run lengths in the control task ($M = 2.90$) than in the matched-parts ($M = 2.10$), $t(47) = 2.86$, $p < .01$, and the across-category confound task (cows and cars) ($M = 2.10$), $t(47) = 2.35$, $p < .025$. Infants also made significantly longer run lengths in the no-parts tasks ($M = 2.75$) than in the matched-parts task ($M = 2.10$), $t(47) = 2.47$, $p < .025$. There were no further significant effects. The Task \times Age interaction was not statistically significant.

Monte Carlo analysis. A Monte Carlo analysis was conducted to assess whether infants touched one or both of the available categories and to provide a measure of how many objects in each category were touched. Table 3 shows the percentage of infants classified as

single or dual categorizers and the mean lengths of any categorizing runs made. For each age and task the means of the probabilities of this categorizing behavior occurring by chance were less than .05. The data indicated that 14-month-olds tended to be single categorizers; that is, they made categorizing runs to only one of the two available categories. On the other hand, approximately half of the 18- and the 22-month-olds were classified as single categorizers and half were classified as dual categorizers. The exception to this behavior was the high number of 18-month-olds on the matched-parts task classified as single categorizers (56%) in comparison to the number classified as dual categorizers (12%). This difference is reflected in the run length analysis that showed that the 18-month-olds failed to categorize successfully on the matched-parts task. It is possible, therefore, that infants' attention to both objects sets rather than one is indicative of the ability to categorize.

Insert Table 3 about here

The mean run lengths of those infants classed as categorizers appear to be equally predictive of categorization. The mean run lengths of the 14-month-olds on the two tasks in which they failed to categorize (according to the run length analysis) were fairly low (\underline{M} =4.5). The mean run lengths of the 18-month-olds was comparable to this score on the task in which they failed to categorize (matched-parts task: \underline{M} =4.0) but it was higher on the task in which they categorized successfully (no-parts: \underline{M} =5.4). Note that the mean run lengths were well above the minimum of three even on those tasks in which infants, as a group, failed to categorize. This suggests that those infants classified as categorizers were behaving

systematically toward the object sets. Note also that relatively few infants were classed as categorizers of “objects with legs” and “objects with wheels” on the across-category confound. This is not to say, however, that infants overlooked parts as a basis for categorization. For example, the same number of infants was classified as single categorizers for objects on the basis of parts (legs, wheels) as on the basis of category (cow, car).

Analysis of functional behavior. Three analyses were performed to examine infants’ functional responses -- that is, rolling and jumping -- toward the stimuli (see Procedure, coding, and scoring section). As a first analysis, a Chi-square goodness of fit test was used to examine the number of infants across the three age groups who made an appropriate functional response to the stimuli on the control task. Infants were coded as having “jumped” cows, “rolled” cars, or performed both actions. The test was significant, $\chi^2(2) = 25.17, p < .001$, indicating that the functional responses made by the infants were not equally distributed across the stimuli. Examination of the data revealed that the number of infants (26) who “rolled” cars was considerably higher than the number of infants who “jumped” cows or who made both responses (3 and 7 respectively).

As a second analysis, a two-way mixed design ANOVA with a multivariate approach for within-subject effects (Pillai’s Trace) was used to compare the number of appropriate functional responses to unmodified objects to the number of appropriate functional responses to objects without parts across the age groups. For each infant, a functional behavior score was calculated by dividing the total number of appropriate functional responses (“rolling” objects with wheels [cars] or “jumping” objects with legs [cows]) by the total number of touches made. The main analysis had three levels of Age (14, 18, 22 months) as a between-subjects factor and two types of Task (control, no-parts) as a within-subjects factor. The analysis revealed a main effect for Age, $F(2,45) = 3.54, p < .0001$, and a significant Task \times Age interaction, $F(2,45) =$

5.10, $p < .01$. Two-way related t -tests revealed that the 14-month-olds (parts $\underline{M} = 0.23$; no-parts $\underline{M} = 0.05$; $t(15) = 2.28$, $p < .025$) and the 18-month-olds (parts $\underline{M} = 0.33$; no-parts $\underline{M} = 0.20$; $t(15) = 2.57$, $p < .025$) generated considerably higher functional behavior scores on the task in which objects had parts than in the task where objects were without parts. No significant difference was found in the number of functional responses made by the 22-month-old age group to objects with ($\underline{M} = .13$) and without parts ($\underline{M} = 0.22$).

As a third analysis, a two-way mixed design ANOVA was used to examine infants' functional responses in the across-category confound. It was possible for infants in the task to make functional responses to the confounded objects -- that is, cars with legs and cows with wheels -- in one of two ways. First, infants could make functional responses on the basis of the part -- legs or wheels -- possessed by the object; for example, "jumping" a car with legs. Second, infants could make functional responses on the basis of the category -- cow or car -- to which the object belongs; for example, "rolling" a car with legs. (It should be noted that responses that appear to be based on inductions about properties of category members could also be explained by attention to perceptible attributes other than legs or wheels such as facial features or overall shape.)

Because of the different responses that infants could make to the stimuli, the total number of part appropriate responses and the total number of category appropriate responses were coded for each infant on the across-category confound task. The main analysis had three levels of Age (14, 18, 22 months) as a between-subjects factor and two types of Response (parts, category) as a within-subjects factor. The analysis revealed a main effect for Response, $F(1,45) = 18.89$, $p < .0001$. Examination of the data revealed that infants made significantly more responses to object on the basis of parts ($\underline{M} = 0.98$) than on the basis of category membership ($\underline{M} = 0.27$). The effect of Age and the interaction of Age and Response were not

statistically significant. To summarize, the functional analyses revealed: (1) infants were more likely to “roll” cars than they were to “jump” cows; (2) infants made functional responses to objects with parts more than they did to objects without parts; and (3) infants made functional responses to objects on the basis of parts rather than on the basis of category membership or other object properties (e.g., curvilinearity vs. rectilinearity).

Analyses of object salience. The Monte Carlo analysis indicated that infants in a number of tasks were more likely to be single categorizers than to be dual categorizers. In other words, infants tended to make a categorizing run to only one of the two available object sets. The Monte Carlo analysis does not, however, provide any information about which object set was touched by the single categorizers or whether infants’ touching behavior in general was affected by an especially salient object or category. A number of analyses of infants’ sequential touching behavior were performed to assess these two issues. Following the guidelines developed by Mandler and her associates (Mandler et al., 1987), the most salient category was defined as (a) the object set most often categorized by single categorizers, or (b) the object set touched first by dual categorizers.

In the first analysis, Chi-square tests were used to examine the number of infants who chose each object group (category) within each task. Across all three age groups, more infants made categorizing run to cows than to the cars on the control task, $\chi^2(1) = 4.90, p < .01$. There were no significant preferences for either category on any of the tasks. As a second test of salience, two-tailed related t-tests were used to analyze the number of touches to cows and cars in the four tasks and at every age level (14, 18, 22 months). The tests revealed that the number of touches made by the 14-month-olds to the cows ($M = 4.9$) and cars ($M = 7.0$) on the across-category confound approached significance, $t(16) = 2.13, p = .051$. The results also revealed that the 18-month-olds made significantly more touches to the cars than to the cows on the

control task (car \underline{M} = 7.7, cow \underline{M} = 4.8, $t(16) = 2.86$, $p < .025$) and on the across-category confound (car \underline{M} = 6.8; cow \underline{M} = 4.3; $t(16) = 2.38$, $p < .05$). In addition, 22-month-olds made significantly more touches to cars (\underline{M} = 8.4) than to cows (\underline{M} = 5.5) on the control task, $t(16) = 2.24$, $p < .05$. There were no other significant effects on any task or at any age level. Hence, infants found cars more salient than cows on a number of individual tasks. This is consistent with the findings of Rakison and Butterworth (in press) who found that infants often preferred vehicles to animals in object manipulation tasks. In addition, infants' preference for cars in some tasks may explain why they made more "rolling" responses than "jumping" responses.

As a third test of salience, two-way repeated-measures ANOVA were used to compare the number of touches made by infants to each of the stimuli on the different tasks. The aim of the test was to investigate whether infants' categorization was influenced by a particularly salient stimulus, or whether confounded stimuli were more salient than normal stimuli. The main design contrasted four types of Task (control, matched-parts, no-parts, across-category) and four types of Object. Separate analyses were performed for the animal and for the vehicle stimuli. The analysis for the car stimuli revealed that the number of touches to the different exemplars was not uniformly distributed, $F(3, 141) = 2.97$, $p < .05$. Pairwise comparisons ($p < .05$) on the number of touches showed that significantly fewer touches were made to the family car (\underline{M} = 1.43) than the sedan car (\underline{M} = 1.79), the estate car (\underline{M} = 1.83), and the sports car (\underline{M} = 1.91). There were no other differences between the number of touches to the different car exemplars. There was also no main effect for Task and no significant Object \times Task interaction. The analysis for the cow stimuli revealed no significant effects. To summarize, although the cars were found to be more salient in certain tasks and one car was touched less than the other car exemplars, there is no evidence that the choice of stimuli that were confounded affected

categorization. The salience effects revealed by the data suggest that certain objects were more salient on the four tasks, however, there was no consistent effect of age, category, or task.

Discussion

The results of this experiment suggest that 14- to 22-month-old infants' categorization at the basic-like level is affected considerably by certain object parts. The results also suggest, however, that there is a developmental trend whereby infants attend to other, as yet unknown, properties as the basis for categorization in the absence of helpful object part distinctions. Consistent with Mandler et al. (1987), infants in all three age groups categorized unmodified objects as cows (legs) and cars (wheels). However, 14-month-old infants failed to categorize when objects had parts removed (no-parts task) and when objects had the same parts (matched-parts task). In other words, 14-month-olds found no basis for categorization in the absence of large part differences. By 18 months, infants categorized the cars from the cows when there were no parts present (no-parts task), but they did not categorize the cars from the cows when the objects shared parts (matched-parts). Thus, in the absence of parts such as legs and wheels, 18-month-olds are able to attend to other, as yet unknown, properties as the basis for categorization. However, they still treat objects with the same parts -- in this case, legs and wheels -- as equivalent. This suggests that shared large object parts -- that is, legs and wheels -- are sufficient to interfere with 18-month-old infants' ability to attend to other bases for categorization. Alternatively, it may be that 18-month-olds treat equivalently -- that is, group together -- objects that share the same large object parts. By 22 months, infants categorize not only objects without parts -- that is, cars without wheels from cows without legs -- but also objects that share the same parts; that is, cars with legs and wheels from cows with legs and wheels.

Infants' performances on the across-category confound appear initially to contradict the notion that object parts are crucial to basic-like categorization. In Rakison and Butterworth (1998), for example, when animals and vehicles were used in an across-category confound design, infants attended to object parts to form categories of "objects with legs" and "objects with wheels". In the present study, however, infants categorized objects as cars and cows rather than as "objects with wheels" and "objects with legs". One explanation for this difference in performance is that the across-category confound task in this study differed from that in Rakison and Butterworth (1998) in the level of within-category similarity; for instance, cars are more alike to other cars than vehicles are to other vehicles. Thus, it is possible that large object parts play a more significant role in categorization when within-category similarity is low than when it is high. In other words, when category members are perceptually different - - as in the case of vehicles or animals -- they are still likely to have large, functional parts in common. On the other hand, when category members are perceptually similar -- as in the case of cows and cars -- infants can attend to any number of large or small object parts to classify; for example, windshields, doors, heads, facial features, and so on. It remains to be seen at this point, however, whether the role of object parts in early categorization is affected by between-category similarity.

The functional analysis suggests that infants' attention to parts such as legs and wheels is not arbitrary. Rather, infants have "expectations" about the functions -- here rolling and jumping - of certain parts independent of category membership. For example, infants are more likely to make functional responses to objects with parts -- that is, legs or wheels -- than to objects without parts. Moreover, infants make functional responses on the basis of object parts rather than on the basis of category membership (e.g., cows "walk") or smaller parts (e.g., objects with facial features "walk"). This suggests, as hypothesized by Rakison and

Butterworth (in press), that infants associate certain parts with certain kinds of movement. It is not clear, however, whether it is parts per se or whether infants' knowledge of functional attributes that act as the basis for categorization. In other words, do infants attend to object parts to categorize because of their functional properties? Or is it that object parts provide a perceptual distinction between objects? It is possible, for example, that legs and wheels are salient because they are relatively large in size in comparison to other parts, because they are in contact with the ground, or because they move (on real world objects at least).

These data are consistent with the findings of Rakison and Butterworth (1998) that showed that 14- to 22-month-old infants attend to parts to categorize superordinate-like domains. However, the object sets used in this study were drawn not only from different basic-level categories (cow and cars) but also from different superordinate categories (animals and vehicles). Although Rakison and Butterworth (1998) argued that infants' attention to parts suggests that they do not categorize objects in terms of their category membership (e.g., the "superordinate-level"), it is conceivable that infants' performances in this experiment were guided by the superordinate category membership of the stimuli. In addition, the basic level categories of cars and cows have high within-category similarity and low between-category similarity. It is unclear what effect these factors may have had on infants' categorization. The next experiment was designed further to examine these issues.

Experiment 2

In the second experiment, infants' responses to two basic-level categories drawn from a single superordinate were tested. Cows and birds were chosen because they have a high level of between-category similarity relative to cows and cars; that is, they are both members of the superordinate category of animals. In addition, cows and birds were chosen because they differ with respect to a large functional part -- that is, cows have four legs and birds have wings -- and

because they have different modes of locomotion; that is, cows move on land and birds move in the air. According to Mandler (1998; Mandler et al., 1991), by 18 months of age infants should be able to categorize these different basic-like classes because they have conceptual knowledge of the distinct movement domains. Infants were presented with four tasks -- one control task and three task in which parts were modified -- that matched in design those used in Experiment 1 and in Rakison and Butterworth (1998, Experiment 2).

Method

Participants. Forty-eight infants participated in the experiment, 16 with a mean age of 14 months, 6 days (range = 13 months 20 days to 14 months 13 days), 16 with a mean age of 18 months, 4 days (range = 17 months 23 days to 18 months 15 days), and 16 with a mean age of 22 months, 2 days (range = 21 months 19 days to 22 months 14 days). There were seven boys and nine girls in the 14-month-old group, and an equal number of boys and girls in the 14- and 22-month-old groups. Fifteen additional infants were tested but were not included in the study: eight infants because of fussiness or crying, five infants for not engaging in the tasks, and two infants as a result of experimenter error. Infants' names were obtained through birth announcements published in the local newspaper. Parents were contacted by letter and later by telephone.

Stimuli. The stimuli were four cows and four birds. The cows all possessed legs and were all of different breeds and different colors (black, tan, black and white, and white). The birds were an ostrich, a pelican, a chicken, and a goose. Because all of the birds did not possess outstretched wings, it was necessary to attach wings to the ostrich, pelican, and chicken in certain tasks. (The wings that were originally part of these stimuli were considered not to be obvious wings; that is, they were painted on or were so small as not to be seen as wings.) It was also necessary to remove legs from two of the toy birds - the ostrich and the pelican. All

the exemplars were 3-dimensional plastic scale models and ranged in size between 3 cm to 5 cm in length and 3 cm to 5 cm in height.

The experiment comprised four tasks that were the same in design as Experiment 1. Thus, there was a control task and three tasks in which the parts of objects were systematically modified within and across the categories. The control task consisted of four unmodified cows and four unmodified birds. In the matched-parts contrast, the cows and the birds were modified by attaching wings to the cows and legs to the birds. Thus, every cow and bird exemplar possessed both legs and wings. The legs were taken from scale model cows and the wings were taken from scale model birds. In the no-parts contrast, the legs were removed from the cows and the wings were removed from the birds. Thus, in the matched- and no-parts tasks there were no differences between the category exemplars due to legs or wings. In the across-category confound task the cows and birds were confounded by removing the legs of two cows and replacing them with outstretched wings, and by removing the wings of two birds and replacing them with legs. The design of the task allowed infants to classify on the basis of category membership -- that is, cows and birds -- or on the basis of part relations; that is, "objects with legs" and "objects with wings". For ease of discussion, Task 1 will be hereafter be referred to as the "control" task, Task 2 will be hereafter referred to as the "matched-parts task", Task 3 will be referred to as the "no-parts task", and Task 4 will be referred to as the "across-category confound task". Each infant participated in all four object-manipulation tasks, and a Latin square was used to determine the order in which the tasks were presented.

Procedure, coding and scoring. The procedure was the same as that in Experiment 1. All tasks were videotaped and scored in the same format as in Experiment 1. In contrast to Experiment 1, however, "flying" was included in addition to "jumping" as one of the possible functional responses that infants could make to the toys. Flying was defined as when an object

was moved horizontally or vertically without repeated contacts on the table surface. Infants could be coded as “jumping” or “flying” both cows and birds. Overall coder reliability for the run lengths made by the infants was $r = .94$, and percentage reliability for objects touched by the infants was 91%. As in Experiment 1, the judges were not naïve to the rationale of the experiment.

Results

Run length analysis. Initial statistical analyses on the data revealed that the 22-month-old girls ($M = 2.0$) made significantly longer run lengths than the 22-month-old boys ($M = 1.4$) on the no-parts task, $t(14) = 2.51$, $p < .025$. There were no other significant effects for gender at any age on any of the four manipulation tasks. The run length values were therefore collapsed into a single run length score. One-tailed related t tests were used to compare the mean run lengths for each age on each task with to the run length expected by chance (1.75). Table 4 shows the mean run lengths for all the tasks and their associated one-tailed t -test values.

Insert Table 4 about here

It can be seen that 14- and 18-month-old infants produced run lengths at chance level and 22-month-old infants generated run lengths significantly higher than chance on the control task. Thus 22-month-old infants, but not 14- and 18-month-olds, behaved systematically to cows (legs) and to birds (wings). On the two tasks where parts were equivalent across the categories, all three age groups produced run lengths at chance level. In other words, infants did not behave systematically toward cows without legs versus birds without wings, and they did

not behave systematically to cows with legs and wings versus birds with legs and wings. On the across-category confound, the 14-, 18-, and 22-month-olds failed to generate run lengths significantly above chance level to objects as cows and birds. Thus, infants did not touch sequentially objects from the same category with different parts, for example, a cow with legs and a cow with wings. However, the level of sequential touching by the 14-month-old infants to the “objects with legs” and the “objects with wings” significantly exceeded chance level. Thus, the youngest age group behaved systematically to objects from different categories but with the same parts; for example, a cow with wings and a bird with wings.

Two-way mixed ANOVA with a multivariate approach for within-subject effects (Pillai’s Trace) was used to examine infants’ performances across the different tasks and to compare the performance of the different age groups. The main analysis had three levels of Age (14, 18, 22 months) as a between-subjects factor and five types of Task (control, matched-parts, no-parts, across-category confound [cows and birds], across-category confound [objects with legs and objects with wings]) as a within-subjects factor. The analysis revealed that there was no main effect for Age, Task, and no significant Task x Age interaction.

Monte Carlo analysis. Table 5 shows the percentage of infants classified as single or dual categorizers and the mean lengths of any categorizing runs made. The data reveal that few infants made categorizing runs. For instance, the highest percentage of infants classified as categorizers (single and dual) on any task was 76% (on two tasks), whereas in Experiment 1, 94% of infants were classified as categorizers in three tasks. In addition, on 10 of the 15 conditions (three age groups in five tasks), less than 60% of infants were classified as categorizers. In contrast, in Experiment 1, less than 60% of infants were classified as categorizers on only 5 out of 15 tasks. Infants’ difficulty in generating sequential touches to three or more unique objects from a category is reflected further in the high number of single

categorizers and the low number of dual categorizers. This is highlighted by the fact that there were more single categorizers than there were dual categorizers in every condition. By comparison, in Experiment 1, there were more dual categorizers than there were single categorizers in 7 of the 15 conditions.

Insert Table 5 about here

The mean categorizing run lengths provided further evidence that infants found it difficult to classify on the five tasks. The data show that although a number of the mean categorizing run lengths were above the minimum of 3, in the majority of tasks infants produced mean run lengths that approached this figure. That is, 18 of 28 mean categorizing run lengths were 4 or lower, and of the 18 that were 4 or below, 10 were 3.5 or lower. These mean run lengths are considerably lower than those found in Experiment 1, which suggests that infants did not explore in detail relations among objects. The number of infants classified as categorizers was found to change across the age groups. In accordance with previous studies using similar stimuli (e.g., Rakison & Butterworth, 1998, in press), the most obvious differences in performances were between the 22-month-olds and the two younger age groups. Thus the average percentage of infants classified as categorizers (single and dual) across the five tasks was identical for the 14- and for the 18-month-olds (49%) and considerably higher for the 22-month-olds (62%). The same trend was not found in the mean categorizing run lengths. For example, among the single categorizers, the average run length of the 14-month-olds ($\underline{M} = 4.7$) was higher than the 18- and the 22-month-olds ($\underline{M} = 3.8$ and $\underline{M} = 4.1$ respectively). Overall,

infants failure to attend to both of the available categories, combined with their general difficulty in generating categorizing runs, suggests that contrasts of birds and cows whereas a particularly difficult one for them.

Analysis of functional behavior. In line with Experiment 1, two analyses were performed to examine infants' functional responses -- that is, jumping and flying -- toward the stimuli (see Procedure, coding, and scoring section). Note that infants made considerably less functional responses in Experiment 2 than in Experiment 1. One explanation for the disparity is that infants in Experiment 2 did not exhibit "flying" as a functional response for any bird on any task whereas in Experiment 1 they exhibited both "jumping" and "rolling" for cows and cars respectively. It should be pointed out that infants did not display "jumping" for birds. As a first test, Chi-square goodness of fit test was used to examine the number of infants across the three age groups who made an appropriate functional response to the stimuli on the control task; that is, those who made cows "jump", or birds "fly". The test revealed that infants were significantly more likely to make "jumping" responses with cows (12) than "flying" responses with birds (0), $\chi^2(1) = 12.00, p < .001$. Thus, in contrast to Experiment 1 where infants made fewer functional responses to objects with legs than to objects with wheels, in Experiment 2 infants made more functional responses to objects with legs than to objects with wings.

For the second analysis, a functional behavior score was calculated for each infant on the control task and on the no-parts task by dividing the total number of appropriate functional responses by the total number of touches made. The analysis used a two-way mixed design ANOVA with a multivariate approach for within-subject effects (Pillai's Trace) to examine the number of appropriate functional responses on the control task and on the no-parts task across the three age groups. The main analysis had three levels of Age (14, 18, 22 months) as a between-subjects factor and two types of Task (control, no-parts) as a within-subjects factor.

The analysis revealed a significant Task \times Age interaction, $F(2,45) = 6.82$, $p < .005$. Two-way related t -tests revealed that the 18-month-olds made significantly more functional responses to objects with parts ($M = 0.06$) than to objects without parts ($M = 0.01$), $t(15) = 2.41$, $p < .05$. In contrast, the 22-month-old age group made more functional responses to objects without parts ($M = 0.10$) than ($M = 0.03$) to objects with parts ($M = 0.03$), $t(15) = 2.25$, $p < .05$. The 14-month-olds made an equivalent number of functional responses to objects with parts ($M = 0.03$) and to objects without parts ($M = 0.01$). Again, note that the mean number of functional responses in the cow-bird tasks were considerably lower than in the cow-car tasks in Experiment 1. There was no main effect of Age or Task.

The third analysis used a two-way mixed design ANOVA to examine infants' behavior in the across-category confound task. As in Experiment 1, the total number of part appropriate responses and the total number of category appropriate responses were scored for each infant. The main analysis had three levels of Age (14, 18, 22 months) as a between-subjects factor and two types of Response (parts, category) as a within-subjects factor. The analysis revealed a significant main effect for Response, $F(1,45) = 5.47$, $p < .025$. Exploration of the data revealed that, as in Experiment 1, infants made significantly more part appropriate responses ($M = 0.27$) than category appropriate responses ($M = 0.06$). As noted earlier, these figures are considerably below those observed with cow and car exemplars in Experiment 1. The effect of Age and the interaction of Age and Response were not statistically significant.

Analyses of object salience. As in Experiment 1, several analyses of salience were carried out. First, Chi-square tests were used to examine the number of infants who chose each category within each task. The results revealed that across all three age groups there was no preference for cows or birds on any task. There was, however, a preference for legs over wings on the across-category confound task, $\chi^2(1) = 8.17$, $p < .01$. Second, two-tailed related t -tests

were used to examine the number of touches to the object sets in each task for all three ages (14, 18, 22 months). No reliable effects were found on any task or at any age.

Third, two-way repeated-measures ANOVA were used to compare the number of touches made by infants to the cows and birds on the four different tasks. The main design contrasted four types of Task (control, matched-parts, no-parts, and across-category confound) and four types of Object. Separate analyses were performed for the cows and for the birds. The analysis for the cow stimuli revealed that the number of touches to the different exemplars was not uniformly distributed, $F(3,141) = 26.34$, $p < .001$. Pairwise comparisons ($p < .05$) on the number of touches indicated that infants made significantly more touches to the brown cow ($M = 1.56$) and the white cow ($M = 1.40$) than to the tan cow ($M = 0.92$) and the black and white cow ($M = 0.85$). There were no further reliable differences among the touches to the various cows. There was no main effect for Task and no significant Object by Task interaction. The analysis for the birds revealed a significant Object \times Task interaction, $F(9, 423) = 1.94$, $p < .05$. Examination of the data indicated that an equivalent number of touches were made to each bird on the control task. However, more touches were made to the Chicken ($M = 1.44$) than the other three birds on the no-parts task (Ostrich $M = 1.14$; Pelican $M = 1.08$; Goose $M = 1.15$), and more touches were made to the Ostrich ($M = 1.40$) than to the Pelican ($M = 0.94$) on the matched-parts task. Finally, on the across-category confound, more touches were made to the Goose ($M = 1.60$) than to the Pelican ($M = 0.85$). The effects of Task and of Object were not significant.

Discussion

The pattern of results in Experiment 2 is compatible with the notion that object parts play an important role in early categorization at the basic-like level. In addition, the data indicate that infants' attention to object parts is affected considerably by between- and within-

category similarity. In contrast to the behavior observed in Experiment 1 with unmodified cows and unmodified cars, the 14- and 18-month-old infants failed to categorize cows and birds in the control task. This finding is consistent with the notion that infants make distinctions at the global-like level prior to the basic-like level (e.g., Mandler, 1992; Mandler et al., 1991). It also suggests that single large object part differences -- that is, legs versus wings - are insufficient for infants to form basic-like categories when between-category similarity is high. Presumably, the within-category similarity of cows and birds is comparable to that of cows and cars. Thus, other perceptible similarities among birds and cows -- for example, facial features, curvilinearity, possessing a head and a body -- may interfere with the salience of a single large part difference. All three age groups failed to categorize on the matched-parts and no-parts tasks. The implications of this behavior are ambiguous for the two younger age groups in light of their inability to categorize on the control task. However, the 22-month-old infants categorized successfully on the control task but failed on the matched-parts and no-parts task. At 22 months, therefore, infants categorize perceptually similar objects when there are large object part differences between members of distinct categories -- for instance, legs in cows and wings in birds -- but not when there are no large part differences between members of different categories; for example, cows and birds with legs and wings. This suggests, in concordance with the findings of Rakison and Butterworth (1998), that large object parts continue to influence 22-month-olds' categorization of objects.

Although the 14-month-olds did not categorize on the control task, they did categorize objects as "objects with legs" and "objects with wings" on the across-category confound task. On the surface this result appears to be quite surprising: Why should 14-month-old infants form a category based on object parts in one task but not in another, possibly easier task? One feasible explanation is that confounding stimuli increases the salience of parts because it

highlights paired cusps that provide a basis for parsing (Hoffman & Richards, 1985). That is, attaching legs, wheels, or wings to objects highlights the presence of a distinct part. A second explanation is that infants were unable to categorize cows from birds and instead “dropped down” to a lower, or less complex, level of processing (Cohen, 1998). In other words, categorizing objects by a single object part may be considered a lower level of processing than categorizing on the basis of overall similarity or category membership.

A third explanation, and one consistent with the findings here and elsewhere (e.g., Rakison & Butterworth, 1998, in press), is that the level of within-category similarity was lower in the across-category confound task than in the control task. When infants are presented with unmodified cows and birds, both within- and between-category similarity is high. However, when infants are presented with modified cows and birds, as in the across-category confound, between-category similarity remains high but within-category similarity is lowered. For example, if infants group objects by category -- that is, cows and birds -- they must group together objects with different parts. On the other hand, if infants group objects by parts -- that is, legs and wings -- they must group together two cows and two birds. The data suggest that when presented with a “choice” of this nature, and given the low within-category similarity of the stimuli at hand, 14-month-olds categorize on the basis of parts rather than category membership. It could be argued that this result has little to do with categorization in the real world because basic-level classes, by definition, maximize within-category similarity. And indeed, the basic level exemplars used in many object-manipulation studies tend to be perceptually similar; for example, members of the cow category tend to vary mainly in color and posture. However, it is also true that many basic-level classes consist of exemplars with great perceptual variation.

Two questions that arise from this explanation concern why the infants did not categorize by parts in the across-category confound in Experiment 1, and why the two younger age groups did not categorize by parts -- thereby forming classes of cows and birds -- in the control task in Experiment 2? Although the level of within-category similarity of the cars and cows was lowered in the across-category confound task in comparison to the control task, between-category similarity remained low in both tasks. Thus, cows with legs are perceptually different from cars with wheels or cars with legs, and the data suggest that this difference is significant enough to override the effect of any partonomic bias that infants may have. With respect to performance on the control task in Experiment 2, it is likely that high within- and between-category perceptual similarity made this task particularly difficult for the younger infants. When within-category similarity was relatively low, as it was in the across-category confound, infants were compelled to search for a common attribute among the stimuli, and legs and wings were the most salient of those available.

As in Experiment 1, the functional analysis revealed that infants are sensitive to the movements associated with certain object parts. Infants in all three age groups made more functional responses to objects with parts than objects without parts. In general, however, the number of functional responses made to the cows and birds was lower than the number made to the cows and the cars in Experiment 1. The most likely explanation for this is that infants were observed both "rolling" cars and "jumping" cows in Experiment 1 and 2, but they were not observed "flying" birds. This implies that infants may have learned the association between certain land-based objects' parts and their type of movement -- for example, objects with wheels "roll" -- but they have not yet learned the relationship between wings (or birds) and flying. Note that the 14- and 18-month-olds' failure to categorize the birds and cows suggests that they are unable to make distinctions between objects on the basis of their domain of

movement; that is, land animals versus air animals. This finding is incongruous with Mandler's (1998; Mandler et al., 1991) claim that infants in the second year form basic-level distinctions of classes that are conceptually distinct; for example, planes and cars or birds and dogs.

The combined results of the first two experiments suggest that, depending on the level of within- and between-category similarity, infants attend to objects' functional parts to form basic-like categories. The evidence also suggests that infants have knowledge about the types of movement of certain parts -- namely, legs and wheels -- but not others, namely wings. It remains unclear whether functional parts are themselves sufficient for infants to form basic-like categories. Many attributes contribute to the level of within- and between-category similarity, and the effect of functional parts in the determination of these levels is not known. It also remains an open question whether infants make more functional responses on the basis of legs, wheels, and wings alone. The data in Experiment 1 and 2 suggest that the younger infants made functional responses on the basis of object parts; however, parts have yet to be presented in isolation to infants in sequential touching tasks. Experiment 3 was designed to investigate these issues.

Experiment 3

The no-parts tasks used in the first two experiments and in previous studies (i.e., Rakison & Butterworth, 1998) provide a means, in conjunction with the control tasks, to determine whether certain object parts are necessary for categorization. If infants categorize successfully on a control task -- for example, unmodified cars and unmodified cows -- but not on a no-parts task, it can be assumed that the part absent in the no-parts task plays an important role in category membership decisions. This design, coupled with the other tasks presented to infants, has been successful in determining infants' basis for categorization for superordinate-like and basic-like domains (e.g., Rakison & Butterworth, 1998). However, it has

not yet been tested whether certain object parts -- and in particular the ones confounded in Experiment 1 and 2 - can act independently as a guide for early categorization. Consequently, in the third experiment 14- to 22-month-old infants were presented with two tasks that contrasted parts alone: In one task infants were tested with legs versus wheels, and in a second task infants were tested with legs versus wings. The rationale was to determine whether object parts alone are sufficient for categorization and to ascertain the extent to which object parts affect between- and within-category similarity. Finally, the tasks were designed to allow infants' functional responses to different object parts directly to be compared. It was predicted, based upon the results of the first two studies, that infants would make more functional responses to legs and wheels than to legs and wings.

Method

Participants. There were forty-eight infants in the experiment, 16 with a mean age of 14 months, 2 days (range = 13 months 14 days to 14 months 15 days), 16 with a mean age of 17 months, 28 days (range = 17 months 19 days to 18 months 13 days), and 16 with a mean age of 22 months, 4 days (range = 21 months 24 days to 22 months 10 days). Nine girls and seven boys were in the 14-month-old group, and seven girls and nine boys were in the 18- and 22-month-old groups. Thirteen additional infants were tested but were not included in the study: six because of fussiness, five because of experimenter error, and two for not engaging in the task. All of the infants also participated in an additional object-manipulation task prior to their inclusion in the present experiment. Infants' names were obtained through birth announcements in the local newspaper. Parents were contacted by letter and later by telephone.

Stimuli, procedure, coding and scoring. There were two object-manipulation tasks. In the first task, infants were presented with the legs from four cows and the wheels from four cars. The legs and the wheels were taken from identical scale models to those used in

Experiment 1. Each set of legs was attached to a small portion of the underside of the cow, and each set of wheels was attached to the base of a car. As in Experiment 1, the wheels were glued so that they could not roll. The bases of the wheels and the legs of the cows were painted so that they were all of different colors, and the colors approximated those found in the real world; that is, black, brown, white, and tan. In the second task, infants were presented with the legs of four cows and the wings of four birds. The legs were the same as those used in the first task, and the wings were taken from identical scale models to those used in Experiment 1. The wings were attached to a small portion of the body of the bird from which they were originally taken. The wings were painted so that they were different colors. Each infant took part in both tasks, and the order of presentation was counterbalanced. The procedure, coding, and scoring were the same as in Experiment 1. Overall coder reliability for the run lengths was $r = .93$, and percentage reliability for objects touched by the infants was 90%.

Results

Mean run length values were calculated for the two tasks and these values were compared with the run length expected by chance (1.75). Table 6 displays the means and their associated t values. The data reveal that the 14-month-olds generated mean run lengths at chance level on the contrast of legs and wheels, and they generated mean run lengths significantly above chance level on the contrast of legs and wings. It can also be seen that the 18- and 22-month-old infants generated run lengths that were significantly greater than chance on the contrast of legs and wheels and on the contrast of legs and wings. To examine whether infants' performed differently on the two tasks (legs vs. wheels, legs vs. wings) or across the three age groups (14, 18, 22 months), a two-way mixed design ANOVA was performed with a multivariate approach for within-subject effects (Pillai's Trace). The analysis revealed no significant effect of Age or of Task, and no significant interaction of the two variables.

Insert Table 6 about here

Table 7 shows the percentage of infants who were classified as single or as dual categorizers by the Monte Carlo analysis. The data are consistent with the analysis of the mean run lengths in terms of the number of infants classified as single or dual categorizers. Thus, 82% of the 14-month-olds were classified as categorizers on the contrast of legs and wings but only 69% were similarly classified on the contrast of legs and wheels. Conversely, the number of 22-month-old infants classified as categorizers (88%), and particularly as dual categorizers (25%) on the leg and wing contrast, was considerably lower than on the leg and wheel contrast (76% total, 6% dual).

Insert Table 7 about here

Three tests were performed on the functional responses made by the infants. A Chi-square goodness of fit test revealed that an equivalent number of infants made “jumping” and “rolling” responses to the legs and wheels respectively. (A second Chi-square goodness of fit test was not performed because the number of infants who made functional responses to legs and wings fell below criterion.). For the second analysis, a functional behavior score was calculated for each infant on each task, and a two-way mixed design ANOVA was performed with Task (legs vs. wheels, legs vs. wings) as a within-subjects variable and Age (14, 18, 22 months) as a between-subject variable. The analysis revealed no main effect of Age or of Task

and no significant Age \times Task interaction. Examination of the data revealed that a majority of infants failed to make any functional response on either task. Consequently, a second analysis was performed using a two-tailed Wilcoxon Signed Ranks Test. The test revealed that across the three age groups, infants made significantly more functional responses in the contrast of legs and wheels than on the contrast of legs and wings, $z = 2.01$, $N = 19$, $p < .05$. Analyses of salience revealed that more infants made categorizing runs to wheels (29) than to legs (12), $\chi^2(1) = 7.05$, $p < .01$. In addition, 22-month-olds made more touches to the wheels ($M = 8.3$) than to the legs ($M = 4.8$), $t(15) = 2.99$, $p < .005$, and they made more touches to the wings ($M = 6.1$) than to the legs ($M = 3.6$), $t(15) = 2.32$, $p < .025$. The number of touches to the different legs, wheels, and wings were equally distributed.

Discussion

The results from the present experiment help to explain infants' performances in the first two experiments, and in particular in Experiment 2. The results indicate that infants behaved systematically to the legs and to the wings; in other words, legs and wings alone are sufficient for 14-, 18-, and 22-month-olds to form partonomic categories. This suggests that 14- and 18-month-olds' failure to categorize unmodified cows and unmodified birds, as in the control task in Experiment 2, resulted from the level of between-category similarity generated by object properties other than legs and wings. In other words, legs and wings may well have been sufficient for infants to categorize birds and cows, but other shared object properties -- for example, facial features or shared curvilinearity -- diminished the distinguishing role of large parts. The behavior of the 14-month-olds on the contrast of wings and legs is consistent also with the 14-month-olds' performance on the across-category confound in Experiment 2 where they categorized on the basis of parts rather than category membership. Thus, infants will attend to legs and wings when within- and between-category similarity conditions allow them

to do so; for example, when between-category similarity is relatively low or when within-category dissimilarity is relatively high.

In contrast to the two older age groups, the 14-month-old infants failed to categorize the legs from the wheels. This suggests that legs and wheels alone are insufficient as the basis for categorization, which is a conclusion that appears initially to contradict the findings of Experiment 1 and of Rakison and Butterworth (1998). One possible explanation for this result is that unlike legs and wings, legs and wheels share structural configuration. That is, legs and wheels, presented independently as they were here, have relatively similar part structures in that they have a central base with one of four parts in each corner of that base. On the other hand, legs and wings are structurally quite different in that wings have a much smaller central base with only one of two parts protruding from each side. Support for this explanation comes from evidence that showed that 14- and 18-month-old infants group together objects with matching part configurations but not those with different part configurations (Rakison & Butterworth, in press). Thus, young infants attend to structural properties as well as part similarities, and the role of part structure may be increased considerably in the absence of cues normally present in the categorization of real world objects.

As predicted, infants made more functional responses in the contrast of legs and wheels than in the contrast of legs and wings. This suggests that infants have not yet associated wings with a particular kind of movement, namely flying. Also, note that infants made considerably fewer functional responses in Experiment 3 in comparison to the first two experiments. It remains to be seen whether this resulted from the absence of animals' trunks and facial features and the absence of cars' bodies. It may be, for example, that the legs, wheels, and wings were hard to grip in such a way that would allow infants to make a functional response.

General Discussion

There is at present considerable debate about the nature of the categories formed by infants. At the focus of this debate lies the distinction between perceptual categorization -- that is, grouping objects because of the way that they look -- and conceptual categorization; that is, grouping objects because of what they are. The arena for this debate has been the study of what Rosch (1978, Rosch et al., 1976) called the basic and the superordinate level. Until recently it was assumed that basic-level categories, because of their high-level of within-category similarity and between-category dissimilarity, are formed primarily on the basis of perceptual similarity (e.g., Markman, 1989; Rosch et al., 1976). As a corollary, it was also assumed that infants form basic-level categories before superordinate and subordinate categories. Recent work by Mandler (e.g., Mandler et al., 1991; Bauer, 1988) suggested not only that basic-level classes are formed after those at the global level but also that infants form categories at the global and basic level only when they have knowledge that provides a conceptual distinction between kinds of object. For example, Mandler claimed that infants classify cars from planes because they make a distinction between objects that move on land and objects that move in the air. Recent work by Rakison and Butterworth (1998) suggested an alternative explanation of infants' behavior in many of the sequential touching tasks used by Mandler and her colleagues (e.g., Mandler et al., 1991; Mandler & Bauer, 1988). They provided evidence that infants do not rely on conceptual knowledge of "what something is" to form global categories; Rather, infants attend to large object parts to form superordinate-like categories (Rakison & Butterworth, 1998, in press).

The three experiments presented here were designed to test whether infants form basic-like categories also by attending to large object parts. The experiments were also designed to test whether infants' functional responses -- for example, jumping or rolling objects -- were based on category membership or on object parts. Finally, the experiments were designed to

examine whether infants have developed expectations about the kinds of movement associated with different objects or with different object parts. The results of Experiment 1 and 2 provide support for the notion that large, functional object parts play an important role in infants' basic-like category formation. In Experiment 1, infants were presented with contrasts of two object sets (cars and cows) with a high level of within-category similarity and between-category dissimilarity. The tasks can be viewed also as contrasts of two basic-level classes from two different superordinate domains (Mandler & Bauer, 1988). Consistent with the results of previous studies (e.g., Mandler & Bauer, 1988; Mandler et al., 1991), infants in all three age groups categorized unmodified cars from unmodified cows. However, 14-month-olds failed to categorize the cows from the cars when the legs and the wheels were removed from each stimulus, and 14- and 18-month-olds failed to categorize the cows from the cars when legs and wheels were possessed by each exemplar. By 22 months, infants categorized successfully on all three tasks. Infants' performances on the across-category confound appears initially to conflict with these results; that is, all three age groups categorized objects as cows and cars and not by parts. However, this finding suggests that infants' partonomic bias is influenced greatly by high levels of between-category dissimilarity. In conjunction, these results suggest that 14- and 18-month-olds do not form a conceptual category, as has been argued by Mandler (1992, 1993, 1998), when they classify basic-like objects from different "superordinate" domains; for example, cows and cars. The results also imply, at least initially, that 14-month-olds do not attend to object properties other than large functional parts to categorize. Furthermore, even 18-month-olds do not attend to alternative bases for categorization when objects share the same large parts - that is legs and wheels -- even though they do so when large object parts are missing. This suggests that at least until 18 months, certain object parts are sufficient -- and

possibly necessary -- for categorization under particular within- and between-category similarity conditions.

Experiment 2 provided further evidence in support of the role of parts in the formation of basic-like classes. In addition, it goes some way to dispel the notion that the basic-like categories formed by infants are conceptual categories. The 14- and 18-month-olds' failure to categorize when birds and cows were normal, as well as when they had parts removed (no-parts) and parts attached (matched-parts), suggests that high between-category similarity may be primarily responsible for infants' failure to classify two basic-level domains within a single superordinate. According to Mandler (1992; Mandler et al., 1991), by 18 months infants should be able to categorize basic-level classes that differ with respect to particular conceptual properties. In one study, for example, 18-month-olds were found to categorize two basic-level classes from different domains of movement -- for instance, dogs from fish and cars from planes - but they did not categorize basic-level sets from the same movement domains; for instance, dogs from horses or cars from trucks. The fact that the two younger age groups in Experiment 2 were unable to make the distinction between cows and birds implies that they have not yet acquired the kind of conceptual knowledge to which Mandler refers. Indeed, the 14-month-olds revealed a preference to categorize by parts rather than category membership or movement domain when given a choice to do so. Furthermore, even though the 22-month-olds categorized the normal cows from the normal birds, they too failed to categorize on the contrast in which the stimuli had parts removed and the contrast in which stimuli shared parts. This behavior suggests that object parts continue to play a role in category membership decisions at the end of the second year.

These results, in conjunction with those of Rakison and Butterworth (1998), suggest that infants' basis for categorization may be determined by the level of within- and between-

category similarity of the objects at hand. When there is sufficiently high within-category similarity and between-category dissimilarity, as in the case of two basic-level classes from different superordinates, large functional object parts play a less significant role in categorization. This is because there are a considerable number of similarities among category members - of which large object parts are one - that together may act as the basis for categorization. On the other hand, when the level of within-category similarity is high but the level of between-category dissimilarity is low, as it is in a contrast of two basic-level classes within a single superordinate, a single object part may come to define category membership. This effect, however, may be masked when the exemplars in question have many properties in common, as they often do in object-manipulation tasks that contrast basic level classes from within a single superordinate (e.g., Mandler & Bauer, 1988; Mandler et al., 1991). Finally, when the level of within-category and between-category similarity is low, as it is for different superordinate domains, the role of object parts may be maximized (see Rakison & Butterworth, 1998, in press). This analysis goes some way to explain why the superordinate-like or global-like level appears to be the first category to be formed in infancy (e.g., Mandler et al., 1991; Mandler & Bauer, 1988). That is, infants are more likely to categorize exemplars from different superordinate domains -- assuming of course that the exemplars drawn from each domain share at least one large object part -- than exemplars from two basic-level classes within the same superordinate - which often have many object parts in common.

Infants' tendency to make functional responses to the toys in each study --- in the manner of imitating objects' movement -- suggests that they have expectations or knowledge about certain objects. Crucially, in the first half of the second year, these expectation are not grounded in the category membership of the objects but in the parts that they possess. This was demonstrated by the high number of functional responses made by the 14- and 18-month-olds

to the objects with parts in comparison to the number of functional responses made to the objects without parts. Furthermore, on the across-category confound tasks, infants made functional responses on the basis of parts rather than category membership; for example, “rolling” a cow with wheels. The evidence also suggests that infants expect that objects with wheels roll and objects with legs walk and jump but not that objects with wings fly. This conclusion is bolstered by the behavior of infants in Experiment 3 in which significantly more functional responses were made during the contrast of legs and wheels than during the contrast of legs and wings. Indeed, this finding is perhaps not surprising because infants have greater experience of objects that move on land than objects that move through the air. They are more likely, for example, to observe the motion of real world land-based objects -- and in particular the movement of object parts -- at close range than they are air-based objects. It is possible that the younger infants’ failure to categorize cows from cars stems from the fact that they have not yet learned the association between wings and flying. Such an explanation would be consistent with that presented by Mandler (1992, 1998). However, there is little evidence here that form-function correlations drive infants’ categorizing responses.

Support for the role of functional object parts in category membership decisions at the basic level came from a recent study by Rakison & Koenig (1998). In the study, 3-year-olds and adults were presented with a single across-category confound either with cows and cars, cows and birds, or animals and vehicles. Children and adults were asked to form two groups of four objects in any way, and they were then asked for the rationale behind the grouping. The results matched in general those found here and in Rakison & Butterworth (1998; see also Tversky, 1989). That is, 3-year-olds classified by category membership when presented with a contrast of confounded cows and cars, but they categorized by object parts when presented with a contrast of confounded animals and vehicles and a contrast of confounded cows and

birds. Similarly, adults categorized cows and cars by category membership, cows and birds by parts, and animals and vehicles either by category membership or by object parts. Furthermore, the rationale for a partonomic grouping tended to be related to the function of the objects; for example, “these things walk” and “these thing fly”. Thus, there is a bias to categorize partonomically under certain within- and between-category similarity conditions that extends beyond the second year and even into adulthood.

These results are consistent with the theory posited by Rakison (e.g., 1998; Rakison & Butterworth, 1998, in press) that infants acquire knowledge of some properties that are commonly thought of as conceptual -- for example, animate versus inanimate motion -- via the association of object properties and functional actions presented in the perceptual input. For instance, in the case of different types of locomotion, infants may notice the correlation between the type of movement -- for example, smooth versus gaited motion -- and the object parts that concurrently are in motion.² It may be that this form-function correlation is among the first to be learned and subsequently plays a primary role in children’s animate-inanimate distinction. Evidence to support this claim is found in a study by Richards and Siegler (1986) with 5- to 6-year-old children. When presented with computer displays of novel moving objects, the children made inferences about animacy on the basis of large object parts -- for example, legs and wheels -- and not on the basis of the way that the objects started to move; for example, self-starting versus pushed by a person.

According to Mandler (1992, 1993, 1998), infants form global- and basic-like categories on the basis of properties other than perceptual similarity; that is, infants form conceptual categories. Thus, infants rely on knowledge of the distinction between, for example, animate and inanimate objects to categorize animals from vehicles. Mandler posits a process of perceptual analysis that recodes perceptible information into a more abstract conceptual

schema. However, it is not clear how this process occurs. There is considerable evidence that perceptual information is sufficient for infants to form basic- and superordinate-like categories (e.g., Behl-Chadha, 1995; Eimas & Quinn, 1994; Rakison & Butterworth, 1998, in press). Thus, 3- to 4-month-old infants make the distinction between cats and dogs on the basis of facial features (Quinn & Eimas, 1996a) and 14- and 18-month-olds categorize animals from vehicles on the basis of legs and wheels (Rakison & Butterworth, 1998). The findings of the three experiments presented here not only add support to these studies, but they also suggest that infants' attention to correlations between large object parts and their functions may provide for the transition -- at least in some domains -- from perceptual to conceptual categorization (see also Rakison, 1998; Rakison & Butterworth, in press). There is considerable evidence that around 14 months of age, infants have begun to develop sensitivity to correlations between an object's form and its function (Madole & Cohen, 1995; Madole, Oakes, & Cohen, 1993). This was apparent in Experiment 1 and 2 in the way that 14- and 18-month-old infants' functional responses were dependent on the parts of objects. Moreover, that the 22-month-olds made a comparable number of functional responses to cows and cars without parts as to cows and cars with parts suggests they may have begun to associate different kinds of type of movement with whole objects and not solely with large functional parts. This new association may ultimately provide infants with the basis to make inductive inferences across category exemplars and not just to objects with the same parts. Indeed, such a mechanism may provide the foundation for the causal theories behind categorization that are evident among older children and adults (Krascum & Andrews, 1998; Murphy & Medin, 1985; Wisniewski, 1995).

It has been pointed out that infants' attention to perceptual attributes in categorization is consistent with the notion that the global- or superordinate-like levels are the first to be formed (Quinn & Eimas, 1996b; Rakison & Butterworth, 1998). For example, attention to

wheels would help infants to categorize vehicles from animals but not cars from trucks or motorcycles from trains. Within the perceptual framework, one issue that remains open is how infants develop the ability to categorize at the basic level. Is it that they develop finer levels of analysis of object properties? Or, maybe they attend to other object properties such as, for example, overall shape? It is certainly conceivable that infants make finer category distinctions by attending to perceptible properties specific to different basic-level classes. For example, infants as young as 3 to 4 months form categories of cats that exclude dogs on the basis of the whole objects or even just facial information (Quinn & Eimas, 1996a). However, this account fails to provide the mechanism by which children develop theories about causal relations among object attributes and category members. Likewise, there is a great deal of evidence for the role of shape in categorization in the third year of life (Jones & Smith, 1993; Jones, Smith, & Landau, 1991), but it is not clear how this might facilitate the development of hierarchically structured categories or adult-like theory-driven knowledge.

Perhaps a more compelling notion to explain the emergence of categorization at the basic-like level -- and in addition, the development of knowledge that embodies hierarchical and causal relations -- is that infants and young children attend to ever more detailed correlations between object parts and their functions. Presumably, perceptual similarity continues to play a role in categorization in those cases where objects possess distinctive properties. For example, tigers and leopards have unique colorings that allow them to be differentiated from other big cats. However, in many cases, particularly among artifacts, objects do not have these kinds of unique properties. Rather, as argued by Wisniewski (1985), it is the relation of part configuration and function that determines an attribute's importance and thus its relevance to category membership. It is most likely that relations among large parts and important functions will be acquired prior to those among small parts and less important functions (Tversky, 1989).

Support for this view also comes from Krascum and Andrews (1998) who speculated that attention to functional associations between features would allow children to form generic categories for living things. For example, many animals with long legs and a lightweight body run quickly whereas those with short legs and a large body run slowly. The authors argue that attention to more specific or even unique functions -- for example, an elephant's trunk -- would allow children to make finer and finer distinctions. The data presented here do not clarify whether the processes underlying infants' categorization follow such a trend. However, they do go some way to support the notion that around 14 months, infants are sensitive to form-function correlations that can support a broad distinction between objects with different kinds of movement.

In conclusion, the three experiments presented here provide evidence that perceptual information -- namely, object parts - is sufficient for 1- to 2-year-old infants to form basic-like categories under certain within- and between-category similarity conditions. Infants are most likely to attend to object parts when between- and within-category similarity is low, as in the case of superordinate contrasts (see Rakison & Butterworth, 1998). They are also likely, though less so, to attend to large object parts when between-category and within-category similarity is high, as in the case of two basic-level classes from the same superordinate. The evidence suggests that infants do not make basic-like distinctions only when they possess conceptual knowledge about the kinds of things that objects are (Mandler, 1992, 1998; Mandler & McDonough, 1993). Rather, infants form basic-like classes when perceptual differences between different categories' exemplars are sufficient (e.g., cars and cows), and they do not categorize in the absence of sufficient perceptual dissimilarity (e.g., cows and birds). It remains to be seen, however, at what point infants are capable of attending to information that is

adequately specific to allow distinctions of highly similar objects, as well as to which information they attend at that point.

The analyses of functional responses provided a novel method to investigate infants' expectations of the movement of different kinds of objects. The analyses indicated that infants develop knowledge about the different kinds of locomotion of land-moving objects by attending to the correlation between characteristic features of motion -- for example, walking -- and large, moving parts (e.g., legs). It is possible that this knowledge is the foundation for what is later to become conceptual knowledge about object kinds that encompasses, for example, the distinction between animate and inanimate things. It remains to be seen, however, whether children beyond infancy continue to use perceptible attributes independently to form categories, or whether they come to rely primarily on the relationship between form and function. Barrett et al. (1993) suggested that the importance of form and function in categorization cannot be understated: "Correlations between structural properties and functional attributes are likely to be intimately connected with the set of principles that organize the domain" (p.1597). The evidence presented here suggests that a focus on infants' attention to large object parts, as well as on the functional interactions in which infants engage, may prove fruitful in discovering exactly what these principles are.

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Author Notes

The work reported here was supported in part by Grant HD-23397 to the second author from the National Institute of Child Health and Human Development. The results of the first experiment in this manuscript were presented by the first author at the 11th Biennial International Conference on Infant Studies, Atlanta, GA, 1998. Many thanks to Melissa Koenig for her comments on an earlier draft, and to Cara Cashon, Lindsay Knox, Lisa McLaughlin, Brett Parmenter, and Tamara Perera for their help in testing and coding.

Footnotes

1 The Monte Carlo program used here was developed by David Hitchin.

2 It is true that parts other than the ones necessary for movement may also be in motion during locomotion, for example, the tail of a cow or the arms of a human. However, the movement of these parts would not be highly correlated with the locomotion of the object in question; that is, tails and arms move at times other than during locomotion.

Table 1

Object Manipulation Tasks and Exemplars in Experiment One

Classification Task	Stimuli	
Control	Four unmodified cows	Four unmodified cars
Matched-parts	Four cows with wheels and legs	Four cars with wheels and legs
No-parts	Four cows without legs	Four cars without wheels
Across-category confound task	Two cows with wheels and two cows with legs	Two cars with wheels and two cars with legs

Table 2
Experiment 1: Mean Run Lengths and Associated t-Test Values for Five Manipulation Tasks

Classification Task	14 months	18 months	22 months
Control			
Cows versus cars	2.63 (1.77)*	2.79 (3.53)***	3.27 (3.69)***
Matched-parts			
Cows with wheels and legs versus Cars with wheels and legs	1.92 (0.63)	1.76 (0.96)	2.62 (3.95)***
No-parts			
Cows without legs Versus Cars without wheels	1.98 (0.84)	2.94 (2.20)**	3.34 (3.11)***
Across-category confound			
Cows (2 with wheels, 2 with legs) Versus Cars (2 with wheels, 2 with legs)	2.44 (2.12)*	2.81 (1.87)*	2.43 (3.07)***
Objects with wheels Versus Objects with legs	1.70 (0.50)	1.90 (0.52)	2.68 (1.08)

Note.- One tailed t -values are of comparison to run length (1.75), with $df = 15$.

* $p < .05$. ** $p < .025$. *** $p < .005$.

Table 3
Experiment 1: Percentage of Categorizers and Mean Categorizing Run Lengths

Classification task	14 months		18 months		22 months	
	%	<u>M</u>	%	<u>M</u>	%	<u>M</u>
Cows versus Cars						
Single	50	5.5	31	5.5	44	5.3
Dual	6	4	44	4.5	50	5.4
Total	56		75		94	
Cows with legs and wheels versus Cars with legs and wheels						
Single	44	4.6	56	4.1	44	5.0
Dual	0	0	13	3.8	50	4.1
Total	44		69		75	
Cows without legs versus Cars without wheels						
Single	56	4.0	31	7.1	38	7.2
Dual	13	4.9	44	3.6	56	5.3
Total	69		75		94	
Cows (2 with legs, 2 with wheels) versus Cars (2 with legs, 2 with wheels)						
Single	38	4.2	50	5.4	44	3.6
Dual	31	5.1	31	4.2	50	4.8
Total	69		81		94	
Objects with legs versus Objects with wheels						
Single	38	5.2	12	5.5	31	3.2
Dual	0	0	25	3.8	25	3.6
Total	38		37		56	

Table 4

Experiment 2: Mean Run Lengths and Associated t-Test Values for Five Manipulation Tasks

Classification Task	14 months	18 months	22 months
Control			
Cows versus birds	1.72 (-0.18)	1.74 (-0.71)	2.11 (1.78)*
Matched-parts task			
Cows with wings and legs Versus Birds with wings and legs	1.82 (0.23)	1.65 (-0.47)	1.78 (-0.54)
No-parts task			
Cows without legs Versus Birds without wings	2.00 (0.83)	1.87 (0.59)	1.67 (0.32)
Across-category confound task			
Cows (2 with wings, 2 with legs) Versus Birds (2 with wings, 2 with legs)	1.50 (-1.60)	1.56 (-2.56)	2.31 (1.33)
Objects with wings Versus Objects with legs	2.18 (1.80)*	1.64 (-0.77)	2.02 (0.99)

Note.- One tailed t -values are of comparison to run length (1.75), with $df = 15$.

* $p < .05$.

Table 5

Experiment 2: Percentage of Categorizers and Mean Categorizing Run Lengths

Classification Task	14 months		18 months		22 months	
	%	<u>M</u>	%	<u>M</u>	%	<u>M</u>
Cows versus Birds						
Single	63	3.7	44	3.3	50	5.1
Dual	13	3.3	6	4.5	19	3.9
Total	76		50		69	
Cows with legs and wings versus Birds with legs and wings						
Single	25	8.0	44	4.0	38	3.5
Dual	6	3	13	4.3	13	3.8
Total	31		57		51	
Cows without legs versus Birds without wings						
Single	25	4.0	56	4.3	38	3.7
Dual	25	4.3	6	3.5	19	3.3
Total	50		62		57	
Cows (2 with legs, 2 with wings) versus Birds (2 with legs, 2 with wings)						
Single	13	3.0	38	3.5	69	3.8
Dual	6	3.0	0	0	6	3.0
Total	19		38		75	
Objects with legs versus Objects with wings						
Single	50	4.6	25	4.0	56	4.5
Dual	19	5.5	13	4.5	0	0
Total	69		38		56	

Table 6

Experiment 3: Mean Run Lengths and Associated t-Test Values for Two Manipulation Tasks

Classification Task	14 months	18 months	22 months
Legs versus Wheels	2.07 (1.13)	2.51 (3.31)***	2.62 (3.09)***
Legs versus Wings	2.04 (1.87)*	2.49 (2.40)**	2.70 (1.79)*

Note.- One tailed t -values are of comparison to run length (1.75), with $df = 15$.

* $p < .05$. ** $p < .025$. *** $p < .005$.

Table 7

Experiment 3: Percentage of Categorizers and Mean Categorizing Run Lengths

Classification Task	14 months		18 months		22 months	
	%	<u>M</u>	%	<u>M</u>	%	<u>M</u>
Legs versus Wheels						
Single	50	5.3	38	4.3	63	6.0
Dual	19	3.4	38	3.7	25	4.3
Total	69		76		88	
Legs versus Wings						
Single	63	4.3	25	3.6	69	5.1
Dual	19	3.3	44	4.0	6	4.0
Total	82		69		76	