

Infants' Use of Object Parts in Early Categorization

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Two experiments involving object-manipulation tasks were performed to examine whether 1- to 2-year-olds form superordinate-like categories by attending to object parts. In Study 1, 14-, 18-, and 22-month-olds were tested with contrasts of animals, furniture, insects, and vehicles. Fourteen- and 18-month-olds behaved systematically toward categories with different parts (legs or wheels) but not toward categories with matching parts (legs or legs). In Study 2, infants were tested with novel animals and vehicles generated by removing or attaching legs or wheels. In the absence of part differences, all three age groups failed to form superordinate categories. The two younger groups chose to categorize by parts (i.e., legs or wheels) rather than by category membership (animal or vehicle). The results suggest a perceptual basis for categorization whereby infants form dynamic categories, on-line, that are based on the characteristics of the input.

It is a common assumption that the categories formed in early childhood fall into one of the three hierarchical classes proposed by Rosch and her colleagues (e.g., Mervis & Rosch, 1981; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). According to Rosch, the categories that are developmentally primary are at the basic level, with categories developing subsequently at the more general, superordinate level. This developmental sequence is thought to occur because basic-level categories have a high level of within-category similarity and between-category dissimilarity, whereas superordinate categories have low within-category similarity. Thus, it is held that infants form categories of objects that are alike, such as dogs, cats, cars, and chairs, more easily than they form categories that include objects that vary in appearance, such as animals, vehicles, and furniture. Rosch (1978) referred to these categories as *taxonomies*, by which she meant that their members are the same kind of thing or are "related to one another by means of class inclusion" (p. 27).

A corollary for this assumption is that infants require knowledge beyond information given in the perceptual input to form

superordinate categories. The claim is that perceptual similarity cannot mediate categorization at the superordinate level because of the diversity of objects within a single category, and therefore conceptual understanding of some sort must direct behavior. On this view, non-perceptually based attributes lie at the core of superordinate representations or concepts. As Jones and Smith (1993) wrote in discussing the common view of concepts, "Our perceptual experiences as we encounter objects in the world are represented at the periphery of our concepts. At the center lies our nonperceptual knowledge: principally, beliefs about the origins and causes of category membership" (p. 114). It is not clear, however, whether this essentialist view applies to basic-level representations—in which perceptual similarity is a good predictor of category membership—or only to more perceptually dissimilar superordinate-level representations.

Mandler and her associates have challenged the view that basic-level categories develop before those at the superordinate level. In one study, Mandler and Bauer (1988) used the object-manipulation technique, in which infants' spontaneous sequential touching to objects is measured, to present 16- and 20-month-olds with basic-level contrasts from within the same superordinate domain (e.g., dogs and horses) and basic-level contrasts from different superordinate domains (e.g., dogs and cars). Infants were also presented with a contrast of two superordinate categories (animals and vehicles). The results showed that 16- and 20-month-old infants formed basic-level categories from different superordinates (e.g., dogs and cars) but not basic-level categories from the same superordinate (e.g., dogs and horses), and that 20-month-olds, but not 16-month-olds, formed superordinate-level categories. Mandler and Bauer claimed this behavior implies that basic-level categories are not the first categories to develop.

Support for this claim came from a later series of studies by Mandler, Bauer, and McDonough (1991), again using the object-manipulation task. In one experiment, 18-, 24-, and 30-month-olds were presented with different levels of contrast of basic-level categories drawn from the same superordinate. Thus, a low contrast of animal exemplars was dogs and horses, a moderate contrast was dogs and rabbits, and a high contrast was

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dogs and fish. In addition, the same infants were presented with a superordinate contrast of animals and vehicles. Mandler et al. found that 18-month-old infants distinguished the superordinate domains of animals and vehicles but did not distinguish basic-level contrasts within these domains when the contrast between the object sets was low or moderate (e.g., dogs vs. horses, dogs vs. rabbits). Although 24-month-olds' performance was superior to that of the 18-month-olds, they did not differentiate basic-level categories when the contrast between the two object sets was low (e.g., dogs vs. horses). Mandler et al. took this finding as confirmation that basic-level categories are not the first to develop in young infants. They claimed that superordinate categories, which were redefined as *global* categories because of the absence of basic-level classes nested within them, develop prior to those at the basic level. More important, Mandler et al. claimed that global categories are founded on conceptual knowledge of nonobvious properties (e.g., animacy, support), with properties perceptible in the immediate input playing only a subsidiary role. According to Mandler (1992), this conceptual format is derived from *perceptual analysis*, whereby the infant observes a particular aspect of the perceptual display and recodes it into a simpler, accessible form. The infant therefore has knowledge about the "kinds of things" objects are (Mandler & McDonough, 1993).

An informal analysis of the stimuli used by Mandler and Bauer (1988) and Mandler et al. (1991) suggested that alternative interpretations of their data cannot be eliminated. In the study by Mandler and Bauer, infants aged 16 and 20 months did not distinguish basic-level categories whose exemplars possessed the same parts (e.g., legs, in the case of dogs and horses), but they did distinguish basic-level categories whose exemplars possessed different parts (e.g., legs and wheels, in the case of dogs and cars). Likewise, in the study by Mandler et al., infants 18 and 24 months of age did not form categories when all the exemplars shared parts (e.g., legs in dogs and horses, wheels in cars and trucks), but they did form categories when exemplars within each domain possessed the same part that was not shared by the other domain (dogs and fish, cars and planes). Finally, in both studies, the exemplars within each superordinate category shared at least one part; that is, the animals possessed legs, and the vehicles possessed wheels.

The role of object parts in early taxonomic categorization was investigated initially by B. Tversky and Hemenway (1984). They found that when adults list features at the basic, superordinate, and subordinate levels, they associated a large number of parts at the basic level and few or nondefinitive parts at both the superordinate and the subordinate levels. B. Tversky and Hemenway interpreted this finding to mean that the primacy of the basic level results from its being the category at which objects share parts. In a later series of studies, B. Tversky (1989) found that not only do 5-year-old children make taxonomic groupings more readily when exemplars share parts but they also detect missing parts faster when they are external and affect shape (e.g., wheels) than when they do not affect shape (e.g., headlights). B. Tversky concluded that children and adults organize knowledge *partonomically*, by subdividing into parts, as well as taxonomically, by subdividing into kinds. Thus, she claimed that children use partonomic knowledge because "a partonomy can be established from a single instance or object,

whereas a taxonomy depends on comparison and contrast of several instances" (B. Tversky, 1989, p. 994).

Quinn and Eimas (1996b) disagreed with B. Tversky and Hemenway's (1984) claim that attention to object parts facilitates basic-level classification. Instead, they argued that attention to object parts should mean that the easiest categories to learn would be those in which parts are characteristic of category membership; for example, legs are characteristic parts of the category of mammals. B. Tversky and Hemenway, among others, would maintain that this description matches that normally assigned to the basic level (e.g., Markman, 1989; Rosch et al., 1976). However, it is evident that the attribute "legs" distinguishes animals from vehicles but does not distinguish dogs from cats or birds from spiders. In the same way, the feature "wheels" differentiates vehicles from numerous superordinates, but it does not distinguish cars from trucks or bicycles from buses. Thus the perceptual features that distinguish superordinate and global categories do not tend to distinguish basic-level categories.

Given the problems in interpreting the studies by Mandler and her colleagues (Mandler & Bauer, 1988; Mandler et al., 1991), can any conclusions be drawn about the nature of superordinate categorization by infants? There is little evidence in the developmental literature to suggest whether infants in the first years of life rely on obvious or nonobvious properties of objects to make taxonomic distinctions. For example, there are studies that suggest that infants in the first year are sensitive to the animacy of objects; however, these studies do not demonstrate that such properties act as a guide for categorization (e.g., Poulin-Dubois, Lepage, & Ferland, 1996). There are also a number of studies that detail the categories formed throughout the first few years of life (e.g., Eimas & Quinn, 1994; Mandler & McDonough, 1993; Mandler et al., 1991), although it was not until recently that researchers began to examine the input, or determinants, for these categories (e.g., Quinn & Eimas, 1996a).

More perplexing, however, is an inconsistency in the age at which superordinate categorization is found first to occur. In recent studies, Behl-Chadha and colleagues (Behl-Chadha, 1996; Behl-Chadha, Eimas, & Quinn, 1995), using a paired-preference technique, have shown that 3- and 4-month-old infants can form categorical representations for mammals that exclude birds, fish, and furniture and that infants can form representations for furniture that exclude mammals. In a study with older infants, Ross (1980) found that 12-, 18-, and 24-month-olds habituated to superordinate-like categories, in which members varied considerably in perceptual appearance (e.g., food, furniture). In contrast, Roberts and Cuff (1989) found that 9- to 15-month-olds do not habituate to animals when presented with only three different kinds of animals and will only habituate at 15 months when six different kinds of animals are used in the learning procedure. Having been habituated, however, the 15-month-olds generalized habituation to novel mammals and a bird and dishabituated to a car. Poulin-Dubois and her colleagues (Poulin-Dubois, Graham, & Sippola, 1995; Poulin-Dubois & Sissons, 1992), using an object-manipulation task, found conflicting results from a cross-sectional and a longitudinal study: In the cross-sectional study, infants did not categorize at the superordinate level until 21 months, whereas in the longitudinal

study, infants categorized superordinate-level classes at 16 months. It remains to be seen whether these discrepancies may result from the level of contrast in the stimuli used, the different perceptual and cognitive processes tapped in different tasks, or the insensitivity of between-group designs in the study of category emergence. Nevertheless, the age at which infants form superordinate categories remains ambiguous.

The two experiments presented here were designed to assess whether infants in the second year form superordinate categories based on partonomic or taxonomic information. Experiment 1 studied 14-, 18-, and 22-month-old infants' categorizations of both object sets that shared a single part and object sets that differed with respect to a single part. The infants were presented with three contrasts between superordinate domains, in which all the exemplars had the same part (legs, in animal vs. furniture, animal vs. insect, and insect vs. furniture) and with three contrasts between superordinate domains in which the exemplars within each domain had different parts (wheels and legs in vehicle vs. animal, vehicle vs. furniture, and vehicle vs. insect). In Experiment 2, part relations were confounded by presenting infants with contrasts between animals and vehicles whose parts were modified. Infants were tested with a plain contrast of animals and vehicles, two contrasts in which there were no part differences among the animals and vehicles (all exemplars with legs and wheels; all exemplars without legs and wheels), and one contrast in which half of the animals had legs and half had wheels, and half of the vehicles had legs and half had wheels. As in similar recent studies on early taxonomic categorization, both experiments were conducted with the object-manipulation technique (e.g., Bauer, Dow, & Hertsgaard, 1995; Mandler et al., 1991).

Experiment 1

The aim of the study was to examine whether infants attend to the parts of objects to form taxonomic categories. Infants were presented with a number of contrasts of superordinate categories. Half the tasks contrasted two categories that shared a single part (legs), and half the tasks contrasted two categories that differed in respect to a single part (legs and wheels). It was reasoned that if infants attend to parts, they should distinguish objects that have different parts (e.g., animals with legs and vehicles with wheels) more easily than they distinguish objects that have the same parts (e.g., animals with legs and furniture with legs).

Method

Participants. Forty-eight infants participated in the experiment, 16 with a mean age of 13 months 21 days (range = 13 months 13 days to 14 months 15 days), 16 with a mean age of 18 months 8 days (range = 17 months 21 days to 18 months 18 days), and 16 with a mean age of 22 months 7 days (range = 21 months 18 days to 22 months 19 days). In the 14-month-old group, there were 9 girls and 7 boys. In the 18-month-old group, there were 9 boys and 7 girls. There were equal numbers of boys and girls in the 22-month-old group. The majority of infants were White and of middle-class socioeconomic status. Seven other infants were tested but were not included in the study: 4 infants because of fussiness or crying, 2 infants for not engaging in the tasks (touching less than three objects), and 1 infant as a result of experi-

menter error. Infants were drawn from two sources: 36 of the infants were recruited from a pool of volunteer parents who had responded to an advertisement for an unrelated experiment, and 12 of the infants, 4 in each age group, were recruited at the university crèche facility. Parents were contacted initially by letter and then by telephone.

Stimuli. There were four types of stimuli: animals, vehicles, furniture, and insects. All the exemplars were three-dimensional realistic scale models and ranged in size between 4 cm to 6 cm in length and 2 cm to 4 cm in height. The animals were a cow, a dog, a goose, and a walrus, and the vehicles were an all-terrain vehicle, a train, a bus, and a motorbike. It should be noted that, with three exceptions (motorbike instead of ambulance, walrus instead of seal, dog instead of turtle), the stimuli were similar to those in Mandler et al. (1991). The parts of the exemplars within each category varied in form and number (e.g., a goose has two legs, and a walrus has four flippers). The "insects" were a fly, a centipede, a beetle, and a spider. Although spiders and centipedes are not insects—spiders are arachnids, centipedes are arthropods—they were chosen to provide variety in the number and the style of legs among the "insect" exemplars. Although insects might be thought of as nested below the superordinate of animals, there is certainly a superordinate-basic-subordinate hierarchy within the insect domain. Thus, insects are at the superordinate level, spiders, beetles, and ants are categories at the basic level, and tarantulas and black widows form categories at the subordinate level. The furniture exemplars were a chair, a table, a bed, and a cabinet. As with the other categories used, the furniture exemplars varied in the number and style of legs that they possessed. The animals, insects, and furniture were made from rubber or plastic and had no moving parts. The vehicles were made from metal and had moving parts (the wheels).

There were six object-manipulation tasks generated from combinations of the four superordinate categories. Each child participated in all six tasks. Three tasks contrasted objects with the same parts (all legs), and three tasks contrasted objects with different parts (legs and wheels). Thus, the tasks were animals versus vehicles, animals versus insects, animals versus furniture, vehicles versus insects, vehicles versus furniture, and insects versus furniture. Because of the number of tasks (six), it was not possible to completely counterbalance the order of task presentation. The order was therefore determined by two 3×3 Latin squares presented twice forward and backward.

Procedure. Infants were tested individually in their own home or at the university crèche, in the presence of a parent, guardian, or crèche-assistant. The infants were seated on their parent's lap or on a chair or in a high chair, and a table of the appropriate height was placed in front of them. For each object-manipulation task, the relevant eight objects were placed randomly on the table in front of the infants. The experimenter encouraged the infants to manipulate the objects with such statements as "Here, these are for you to play with" and "Look at all this stuff." The experimenter then left the room in order not to inhibit object manipulation. The infants were given 2 min to manipulate the objects. Parents were instructed that if an object was dropped from the table or was put out of reach, they were to unobtrusively replace it within touching distance. If no object manipulation occurred for 30 s or if the child manipulated only one object for 30 s, the parent, the caretaker, or the crèche assistant were instructed to encourage the infant to play with the whole set by passing a hand over all the objects and saying, "What can you do with all of these?" or words to that effect. Apart from these instances, there was no feedback, labeling, or pointing from the experimenter or from the parent, the guardian, or the crèche assistant. All six tasks were videotaped for later analysis.

Coding and scoring. Coding focused on the infants' sequential touching of objects. Thus, every object contacted by an infant, either by hand or with another object, and the order in which the objects were contacted were coded. The idea behind this scoring system is that if infants sequentially touch the objects within a category more often than

would be expected by chance, this must be because they perceive them to be categorically related (Mandler, Fivush, & Reznick, 1987). In coding, the following rules, defined by Poulin-Dubois et al. (1995), were observed: (a) If 10 s passed between touches, a break in the sequence of touches was coded, (b) a touch was not considered part of a sequence if the attention of the infant was drawn to an object by the parent or the experimenter or if two objects from two different categories were touched simultaneously, (c) a single touch was coded when the same object was touched in succession or when the infant touched two objects from the same category simultaneously, and (d) if the infant was holding an object and touched other objects with it, the touches were counted as part of the sequence as long as the infant's attention was not restricted to the object being held.

Two judges independently coded 25% of the tasks (4 infants from each age group), and interrater reliability was obtained by two measures: (a) calculating Pearson correlation coefficients between the run lengths scored by the two independent coders, and (b) 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 $r = .90$, and percentage reliability for objects touched by the infants was 91%. The first judge, who was not naive to the experimental hypothesis, coded the remaining tasks. The coding made by the first judge for the initial 25% of the tasks was used in the final analysis.

Procedures for analyzing sequential touching were taken from those developed by Mandler et al. (1987), which have been used subsequently in a number of categorizing studies (e.g., Bauer et al., 1995; Mandler & Bauer, 1988; Mandler et al., 1991; Poulin-Dubois et al., 1995). The first measure determined whether sequential touching by groups of infants differed significantly from chance performance. The mean length of successive touches to the objects of each category was calculated for each child on each task and compared with the run length expected by chance (1.75) if items from two sets of four objects were chosen at random. The mean run length analysis indicates whether infants sequentially touched objects from each category, but it does not provide detailed information about the type of touching that was made. For instance, the measure does not reveal whether infants attended to objects from one or both of the available categories or whether they touched some or all of the objects from a category. For this reason, and to determine whether touching runs of three or four objects from the same category occurred by chance, a second measure of run length was carried out. In accordance with the analyses used in previous categorizing studies, infants who systematically touched objects from one category were termed *single* categorizers, and infants who systematically touched objects from both categories were termed *dual* categorizers.¹ The criterion for a categorizing run was the same as that used in previous research (e.g., Mandler et al., 1991; Starkey, 1981; Sugarman, 1983). A Monte Carlo program was used to determine the probability of occurrence of single and dual categorizing runs 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 that was repeated 10,000 times, as a function of the number of touches made. Touches to the same object (i.e., repetitions) were allowed only if another object was touched between two touches to the same item and as long as there were at least three or four unique items in the categorizing run. As in previous studies, a cutoff point of $p < .10$ was used for the Monte Carlo analysis (e.g., Mandler & Bauer, 1988; Mandler et al., 1987).

Results

Run length analysis. Preliminary analyses revealed no significant statistical difference between mean run lengths for gender or place of testing (home or crèche) at any age on any of the six manipulation tasks. The run length values for each gender and each place of testing were therefore collapsed into a single

run length score. The first analysis compared the mean run lengths for the six tasks to the run length expected by chance (1.75). The mean run lengths for all the tasks and their associated one-tailed related t test values are shown in Table 1.

The data show that the level of sequential touching on the three tasks that contrasted object sets with different parts was significantly greater than chance across all three age groups. Hence, each age group behaved systematically on a contrast of vehicles and animals, vehicles and insects, and vehicles and furniture. On the three tasks that contrasted objects with the same parts, it can be seen that the 14- and 18-month-olds generated run lengths at chance level. That is, they failed to behave systematically to contrasts of animals and insects, animals and furniture, and insects and furniture. The run lengths of the 22-month-old group exceeded chance on the animal and furniture contrast and the insect and furniture contrast; however, they performed at chance level on the task contrasting animals and insects.

The run length analysis shows whether infants behaved systematically to the object sets—that is, whether they tended sequentially to touch related objects—but it does not allow direct comparison of performance across tasks and age groups. The run lengths were therefore investigated further with two-way mixed design analyses of variance (ANOVAs). A first question was whether the performance on the same-parts contrasts significantly differed from that on the different-parts contrasts. A two-way mixed-design ANOVA was performed, with three levels of age as a between-subjects variable (14, 18, 22 months) and two levels of task (same-parts, different-parts) as a within-subjects variable. The effect of task was found to be significant, $F(1, 45) = 10.00, p < .005$. Thus, run lengths on tasks contrasting same-parts categories ($M = 1.98$) were significantly lower than run lengths on tasks contrasting different-parts categories ($M = 2.40$). This shows that infants more readily categorized when there were part differences among objects than when there were no part differences among objects. The effect of age and the interaction of the two variables were not significant.

A second question was whether there were any differences in performance across the six tasks. The main design had age (14, 18, 22 months) as a between-subjects variable and task (animals vs. vehicles, animals vs. insects, animals vs. furniture, vehicles vs. furniture, vehicles vs. insects, and insects vs. furniture) as a within-subjects variable. The only reliable effect was of Task, $F(5, 225) = 3.23, p < .01$. Tukey's honestly significant difference (HSD; $p < .05$) showed that run lengths on the animal and vehicle contrast (2.64) were significantly longer than on the animal and insect contrast (1.80).

Monte Carlo analysis. Because the run length analysis does not indicate either which category was touched or how many objects within any given category were touched, the number of infants in each age group who made categorizing runs of three

¹ Mandler and her colleagues (e.g., Mandler & Bauer, 1988; Mandler et al., 1991; Mandler et al., 1987) referred to infants who systematically touched objects from both categories as *exhaustive* categorizers. However, the term *dual* is preferred here over *exhaustive* because the latter implies contact with every available object.

² Originally devised by Gary Cottrell, a version of the Monte Carlo program was developed for this work by David Hitchin.

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

Manipulation task	Age group					
	14 months		18 months		22 months	
	<i>M</i>	<i>t</i>	<i>M</i>	<i>t</i>	<i>M</i>	<i>t</i>
Different-parts contrasts						
Vehicles vs. animals	3.16	2.91***	2.52	1.91*	2.24	1.93*
Vehicles vs. insects	2.30	2.20**	2.07	2.07*	2.26	1.84*
Vehicles vs. furniture	2.08	1.89*	2.53	2.77***	2.64	3.39***
Same-parts contrasts						
Animals vs. insects	1.98	0.49	1.63	-1.26	1.76	0.13
Animals vs. furniture	2.18	1.46	1.67	-0.82	2.42	1.84*
Insects vs. furniture	1.86	0.63	1.97	1.55	2.32	2.55**

Note. One-tailed *t*-test values are of comparison to run length 1.75, with *df* = 15.
 * *p* < .05. ** *p* < .025. *** *p* < .01.

or four touches to different objects from an object set was calculated. As discussed previously under the *Coding and scoring* section, a Monte Carlo program was used to compare the number of infants who made categorizing runs of three or four touches with that expected at chance level. Table 2 shows the percentage of infants classified as single (a minimum of three or four sequential touches to items from only one category) or dual categorizers (a minimum of three or four sequential touches to items from each category) and the mean length of any categorizing runs made. Because the infants' mean run lengths tended to be considerably longer than the minimum of three touches, the means of the probabilities of such categorizing arising by chance were less than .05 for each age and task.

Overall, across all the tasks and all the age groups, there were a similar number of categorizers on the tasks contrasting objects with different parts (59%) as on the tasks contrasting objects with the same parts (58%). The mean percentage of single categorizers was slightly higher across all age groups on the same-parts tasks (50%) than on the different-parts tasks (43%). However, the percentage of dual categorizers was higher across all the age groups on the different-parts contrasts (16%) than on the same-parts tasks (8%). Thus, infants were more likely to touch instances from both categories when objects possessed different parts than when they possessed matching parts.

Analyses of object salience. The Monte Carlo analysis revealed that in most cases, the majority of infants were single rather than dual categorizers. Although the effect of category salience for perceptually diverse object sets should not be as significant as it is for identical objects, it is possible that single or dual categorizing behavior could have been the result of the greater salience of one or more objects or of a category as a whole. Consequently, several analyses of salience were performed. According to the format developed by Mandler and her associates, the most salient category was defined as (a) the object set most often categorized by the single categorizers or (b) the object set touched first by the dual categorizers. Chi-square tests were used to examine the number of infants who

selected each category within each task and revealed no preference across the age groups for any category. As a second test of salience, related *t* tests were used to analyze the number of touches to each category in each task at every age level. The 14-month-olds made more touches to the vehicles (*M* = 4.9) than to the insects (*M* = 2.9), *t*(16) = 2.57, *p* < .025, and the 22-month-olds made more touches to the furniture (*M* = 7.0) than to the animals (*M* = 4.9), *t*(16) = 2.22, *p* < .05. The 22-month-olds also made more touches to the animals (*M* = 7.5) than to the insects (*M* = 5.0), *t*(16) = 2.70, *p* < .05. There were no other significant effects. Finally, one-way ANOVAs were conducted to examine the number of touches made by the infants to each object within each object set. The analyses showed that the number of touches to each item within an object set was equally distributed. On the basis of these analyses, it was concluded that categorizing was not determined by the most attention worthy or salient items or by the greater salience of a category as a whole.

Discussion

The results suggest that both 14- and 18-month-old infants may attend to the perceptible parts of objects to make category membership decisions. Infants between 14 and 22 months readily distinguished classes of objects that differed with respect to a particular part (i.e., legs and wheels); however, 14- and 18-month-old infants failed to distinguish classes of objects that possessed the same part. By 22 months, infants differentiated certain categories whose exemplars shared a single part (animals and furniture, insects and furniture) but not other categories (animals and insects). This suggests that toward the end of the second year, infants no longer attend solely to a single part as the basis for categorization.

The finding that infants attend to parts may support B. Tversky's (1989) theory that children categorize by forming partonomies—that is, by grouping objects that share parts. Although the children in this study are considerably younger than those

Table 2
Experiment 1: Percentage of Categorizers and Mean Categorizing Run Lengths

Infant classification	Age group					
	14 months		18 months		22 months	
	%	<i>M</i>	%	<i>M</i>	%	<i>M</i>
Animals vs. vehicles						
Single	50	6.0	31	4.4	50	6.0
Dual	6	5.0	25	4.3	13	4.5
Total	56		56		63	
Insects vs. vehicles						
Single	25	4.4	56	4.3	56	4.8
Dual	19	3.5	13	5.3	6	3.5
Total	44		69		62	
Furniture vs. vehicles						
Single	44	4.4	50	6.1	25	11.5
Dual	6	3.0	19	3.3	37	4.6
Total	50		69		62	
Animals vs. insects						
Single	31	4.4	37	3.9	25	4.8
Dual	6	4.0	6	3.5	13	3.5
Total	37		43		38	
Animals vs. furniture						
Single	56	4.3	63	3.3	63	5.2
Dual	0	0	6	3.5	13	3.8
Total	56		69		76	
Insects vs. furniture						
Single	50	3.3	75	3.7	50	3.9
Dual	13	4.7	0	0	13	5.4
Total	63		75		63	

in B. Tversky's study, the data suggest that infants' earliest categories of perceptually diverse object domains may be based on attribute relations. This claim is substantiated by the age at which superordinate-like categorization was found to occur in the present study. Previous studies with the object-manipulation technique found that infants did not differentiate animals and vehicles until 16 months (Mandler & Bauer, 1988; Poulin-Dubois & Sissons, 1992) and would not do so at that age when there were no shared parts among category members (Rakison, 1996a). However, in this study, when the exemplars within each category shared the same part, infants as young as 14 months distinguished animals and vehicles. It is conceivable that this behavior was a function of the specific objects used here; for instance, the toy vehicles chosen for this study might be easily distinguished from other toys. However, there are data to show that under certain conditions, 14- and 18-month-olds do not categorize the animals and vehicles used here, and they will categorize quite different toy animals and toy vehicles (Rakison, 1996a, 1996b).

The 22-month-old infants differentiated the animals and furniture and the insects and furniture, but not the animals and in-

sects. This suggests that by 22 months, infants no longer attend to a single attribute as the basis for categorization. It remains to be seen, however, why the 22-month-old infants sorted the animals and the insects from the furniture but not the animals from the insects. Moreover, there are a number of perceptible properties that might account for the infants' behavior in the present study. For example, the vehicle exemplars were fashioned from metal and had moving parts, whereas the animal, insect, and furniture exemplars were made from rubber or plastic and had no moving parts. For this reason, it is important to be cautious about claims concerning the importance of object parts in early categorization. Further, to examine this issue, in Experiment 2 manipulations of attribute relations among category members were made. The aim was to test whether the presence or the absence of parts affected infants' categorization.

Experiment 2

Although the sequential touching technique has been used extensively, it does not readily allow alternative explanations for the actual patterns of touching to be discriminated. For example, it fails to reveal whether infants sequentially touch objects from different categories because of some unpredicted basis on which relations between objects is established. In such a case, infants' sequential touching of categorically unrelated objects might actually be based on the same processes as are used to give apparently taxonomic grouping under the normal circumstances in which sequentially touching analyses have been applied. As a solution to this problem, and as a way independently of altering part relations among objects, a novel version of the object-manipulation task, termed a *confound* task, was created. Confound tasks provide infants with more than one basis for categorizing by creating novel stimuli from two categories that share across-category similarities. As such, the tasks give infants the choice to categorize by, for example, taxonomic relations or part relations and provide the means to analyze both types of behavior.

Given infants' difficulty in distinguishing categories of objects with the same parts, in Experiment 2, infants were presented with a number of contrasts of animals and vehicles. In addition to a task with unmodified exemplars, infants were also tested with exemplars that were confounded across and within the category domains. The animal and vehicle exemplars were altered so that they either all shared, partly shared, or did not share at all certain parts (i.e., legs and wheels). If infants' categorization is mediated by attention to parts, they should have difficulty in discriminating animals and vehicles when there are no part differences among the exemplars. Likewise, they would be expected to make categorizing decisions on the basis of part relations rather than of superordinate membership, when parts are shared across the categories—that is, half the animals with legs and half with wheels and half the vehicles with legs and half with wheels.

Method

Participants. Forty-eight infants participated in the experiment, 16 with a mean age of 14 months 10 days (range = 13 months 21 days to 14 months 18 days), 16 with a mean age of 18 months 16 days (range

= 17 months 25 days to 18 months 25 days), and 16 with a mean age of 21 months 27 days (range = 21 months 14 days to 22 months 12 days). There were equal numbers of boys and girls in the 14- and 18-month-old groups and unequal numbers in the 22-month-old group (9 boys and 7 girls). Five other infants were tested but were not included in the study: 3 infants because of fussiness or crying and 2 infants because they did not engage in the tasks. The infants in Experiment 2 were not the same as those tested in Experiment 1. Thirty-six infants were recruited from a pool of volunteer parents who had responded to an advertisement for an unrelated experiment. Twelve infants, 4 in each age group, were recruited at the university crèche. Parents were contacted initially by letter and later by telephone.

Stimuli. As in Experiment 1, each manipulation task consisted of three-dimensional realistic scale models of various real-world objects that were fairly consistent in scale within and between category sets. The animal and vehicle stimuli were the same as those used in Experiment 1. Thus, the four animals were a cow, a dog, a goose, and a walrus, and the four vehicles were a bus, an all-terrain vehicle, a train, and a motorbike. A list of the stimuli and the manipulation tasks is presented in Table 3.

The study comprised four object-manipulation tasks. Each task consisted of a contrast of two sets of four objects and was based around the animal and vehicle superordinate domains. There was a straightforward contrast between animal and vehicle exemplars and three tasks that systematically confounded parts within and across the object categories. The control task consisted of four animals (cow, dog, goose, and walrus) and four vehicles (bus, all-terrain vehicles, train, and motorbike). There were two tasks in which parts were equivalent across the two categories. In one matched-parts contrast, the animals and vehicles were confounded by attaching legs to the vehicles and wheels to the animals. In this case, every animal and vehicle exemplar possessed both legs and wheels. The legs were taken from scale models of cows, and the wheels were of the

kind usually found on small scale model "Matchbox" cars. In the second matched-parts tasks, the animals and vehicles were confounded by removing the legs from the animals and the wheels from the vehicles. These confound tasks minimized the part contrast between the two object sets; that is, there were no differences between the category exemplars because of wheels or legs.

In the across-category confound task, the animals and vehicles were confounded by removing the legs of two animals (cow and dog) and replacing them with wheels, and by removing the wheels of two vehicles (train and all-terrain vehicle) and replacing them with legs. An example of two confounded stimuli is shown in Figure 1. The wheels were taken from scale model "Matchbox" cars; one set of legs was taken from a toy dog, and the other set was taken from a toy cow. As shown in Table 3, this task provided a complete confound across the object sets by allowing categorization to occur on the basis of taxonomic membership (i.e., animals and vehicles) or on the basis of part relations (i.e., "objects with wheels" and "objects with legs"). It could be argued that the task design meant that eight stimuli represented the leg-wheel distinction, and only four stimuli represented the true animal-vehicle distinction. In other words, the across-category confound may encourage infants to respond partonomically rather than taxonomically because of the greater statistical likelihood of touching objects on the basis of parts rather than on the basis of category membership. This fact will be borne in mind in considering the data from this task. However, it is also worth pointing out that for infants to respond partonomically or taxonomically, they need sequentially to touch two modified objects and two unmodified objects.

It should be noted that the number and form of parts shared by items was not identical. Thus, for infants to treat "objects with legs" equivalently, they were required to group stimuli with four legs (e.g., train, ATV), two legs (e.g., goose), and four flippers (e.g., walrus). The cow, dog, ATV, and train were chosen to be confounded, as this

Table 3
Object-Manipulation Tasks and Exemplars in Experiment 2

Manipulation task	Exemplar	
	Animals	Vehicles
Control task		
Animals vs. vehicles	Cow, dog, goose, walrus	ATV, train, bus, motorbike
Matched-parts confound tasks		
Animals with wheels and legs vs. vehicles with wheels and legs	Cow with wheels and legs, dog with wheels and legs, goose with wheels and legs, walrus with wheels and legs	ATV with wheels and legs, train with wheels and legs, bus with wheels and legs, motorbike with wheels and legs
Animals without legs vs. vehicles without wheels	Cow without legs, dog without legs, goose without legs, walrus without legs	ATV without wheels, train without wheels, bus without wheels, motorbike without wheels
Across-category confound task		
Animals, 2 with legs and 2 with wheels vs. vehicles, 2 with legs and 2 with wheels	Cow with wheels and without legs, dog with wheels and without legs, goose, walrus	ATV with legs and without wheels, train with legs and without wheels, bus, motorbike
Object with wheels vs. objects with legs	ATV with legs and without wheels, train with legs and without wheels, goose, walrus	Cow with wheels and without legs, dog with wheels and without legs, bus, motorbike

Note. ATV = all-terrain vehicle.

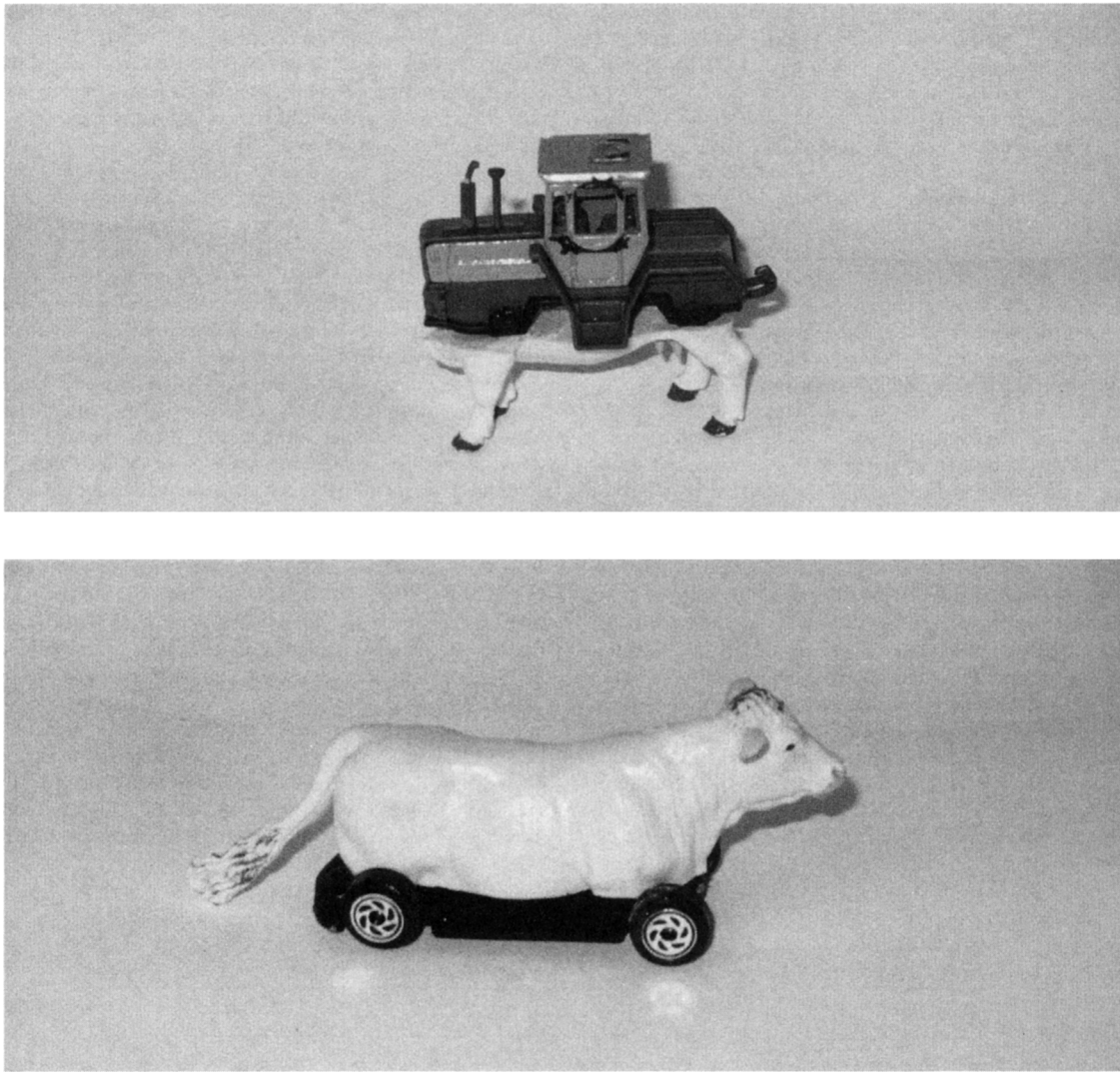


Figure 1. Stimuli used in the across-category confound: All-terrain vehicle with legs (top) and cow with wheels (bottom).

allowed quadrupartite legs or wheels—that is, attributes consisting of four parts—to be replaced with parts of the same number and configuration. Thus, the legs of the cow were replaced with four wheels in approximately the same position and configuration. An attempt to provide a task in which the parts of the other exemplars were confounded (e.g., goose, motorbike) was unsuccessful because it proved difficult to exchange only two legs and wheels and maintain analogous relations between the parts and the whole of objects.

Task 1 will be referred to as the “control” task, Task 2 and Task 3 will be referred to as the “matched-parts confound” tasks, and Task 4 will be referred to as the “across-category confound.” Each child participated in all four object-manipulation tasks. A Latin square determined 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 that in Experiment 1. Overall coder reliability for the run lengths made by the infants was $r = .89$, and percentage reliability for objects touched by the infants was 92%. One judge, who was naive to

the experimental hypothesis, coded the remaining tasks. The judge was not the same one who was the primary coder in Experiment 1.

Results

Run length analysis. Initial statistical analyses on the data revealed no significant difference between mean run lengths for gender or place of testing (home or crèche) at any age on any of the four manipulation tasks. The run length values for each gender and each place of testing were consequently collapsed into a single run length score. The mean run lengths for each age on each task were calculated and compared with one-tailed related t tests to the run length expected by chance (1.75). Because the across-category confound task could be categorized in two ways—that is, animals and vehicles 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 4.

The level of sequential touching across the three age groups on the control task of unmodified animals and vehicles was significantly greater than that expected by chance. Thus, as observed in the previous experiment, infants as young as 14 months behaved systematically to the animal and vehicle object sets. In contrast, on the two matched-parts tasks, all three age groups generated run lengths that did not exceed chance level. Thus, the infants did not behave systematically either to the animal and vehicle exemplars that possessed both legs and wheels or to the animal and vehicle exemplars that possessed neither legs nor wheels.

On the across-category confound, the 14-, 18-, and 22-month-olds generated run lengths at chance level to objects as animals and vehicles. However, the level of sequential touching by the 14- and 18-month-old infants to the "objects with wheels" and "objects with legs" significantly exceeded chance level. Hence, in contrast to their behavior on the control task, the two younger age groups behaved systematically to objects on the basis of part relations and not on the basis of taxonomic relations. The 22-month-old infants generated run lengths at chance level for the objects related by parts. This suggests that a single attribute was not sufficient as a basis for categorization by this age. However, the confound disrupted the 22-month-old infants' categorizing in that they did not entirely disregard part relations among the objects and sort by taxonomic-like membership.

The run length analysis reveals whether the infants responded systematically or otherwise to the object sets; that is, whether they sequentially touched related objects. However, it does not analyze the performance of infants across the different tasks and age groups. Consequently, the run lengths were investigated further with a two-way mixed design ANOVA. The main analysis had three levels of age (14, 18, and 22 months) as a between-subjects variable and five types of task (control, within-category confound [legs and wheels], within-category confound [no legs or wheels], across-category confound [animals and vehicles], across-category confound [objects with wheels and objects with

legs]) as a within-subjects variable. The analysis revealed that there was a significant main effect for age, $F(2, 45) = 3.35, p < .05$. Tukey's HSD ($p < .05$) among the means indicated that the 14-month-old group ($M = 2.58$) generated significantly greater run lengths than the 22-month-old group ($M = 2.05$) but not the 18-month-old group ($M = 2.16$). The run lengths of the two older age groups were not significantly different. The analysis also revealed that run lengths were significantly different across the tasks, $F(4, 180) = 13.18, p < .0001$. Tukey's HSD showed that the run lengths for the control task ($M = 2.76$) and the across-category confound task in terms of part relations ($M = 3.12$) were significantly greater than the run lengths on the matched-parts tasks (legs and wheels, $M = 1.77$; no legs or wheels, $M = 1.78$) and the across-category task in terms of animals and vehicles ($M = 1.88$). Hence, run lengths were lower when there were no part differences among the stimuli than when there was a part difference among the object sets. The run lengths for the control task and the across-category confound task, in terms of part relations, were not significantly different. The Task \times Age interaction was not statistically significant.

Monte Carlo analysis. Because the run length analysis indicates neither which category was touched nor how many objects within any given category were touched, a Monte Carlo analysis was conducted. Table 5 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. Across all the age groups, the mean percentage of categorizers (single and dual) on the task contrasting unmodified animals and vehicles (78%) was higher than on the contrasts in which there were no part differences between the object sets (legs and wheels, 58%; no legs or wheels, 62%). This trend is reflected in the mean run lengths across the age groups for the three tasks, with longer run lengths made on the control task than on the matched-parts tasks (control task, $M = 4.6$; legs and wheels, $M = 4.2$; no legs or wheels, $M = 4.1$). Hence, the number of 14-, 18-, and 22-month-old infants who

Table 4
Experiment 2: Mean Run Lengths and Associated *t*-Test Values for Five Object-Manipulation Tasks

Manipulation task and object grouping	Age group					
	14 months		18 months		22 months	
	<i>M</i>	<i>t</i>	<i>M</i>	<i>t</i>	<i>M</i>	<i>t</i>
Control task						
Animals vs. vehicles	2.71	2.53*	2.94	2.65**	2.64	3.69**
Matched-parts confounds						
Animals with wheels and legs vs. vehicles with wheels and legs	1.75	-0.04	1.66	-0.90	1.90	1.27
Animals without legs vs. vehicles without wheels	1.78	0.19	1.85	0.92	1.73	-0.13
Across-category confound						
Animals (2 with wheels, 2 with legs) vs. vehicles (2 with wheels, 2 with legs)	1.86	0.33	1.98	0.76	1.82	0.55
Objects with wheels vs. objects with legs	4.88	4.20****	2.35	3.49****	2.12	0.90

Note. One-tailed *t*-test values are of comparison to run length (1.75), with $df = 15$.
* $p < .05$. ** $p < .025$. **** $p < .005$.

Table 5
 Experiment 2: Percentage of Categorizers and Mean
 Categorizing Run Lengths

Infant classification	Age group					
	14 months		18 months		22 months	
	%	<i>M</i>	%	<i>M</i>	%	<i>M</i>
Animals vs. vehicles						
Single	58	5.4	75	4.6	58	4.1
Dual	0	0	17	4.3	25	3.4
Total	58		92		83	
Animals with legs and wheels vs. vehicles with legs and wheels						
Single	58	4.4	25	3.3	50	4.9
Dual	0	0	17	4.0	25	3.8
Total	58		42		75	
Animals without legs vs. vehicles without wheels						
Single	58	4.1	50	4.4	42	3.9
Dual	0	0	8	4.5	0	0
Total	58		58		42	
Animals (2 with legs, 2 with wheels) vs. vehicles (2 with legs, 2 with wheels)						
Single	42	3.2	50	5.2	42	4.0
Dual	8	3.0	0	0	25	3.3
Total	50		50		67	
Objects with legs vs. objects with wheels						
Single	25	10	50	4.8	25	3.7
Dual	50	4.8	0	0	0	0
Total	75		50		25	

made categorizing runs, and the length of those runs, was considerably lower when animals and vehicles shared the same parts (i.e., legs and wheels) or did not possess these parts than when animals possessed legs and the vehicles possessed wheels.

The infants' tendency to make short categorizing runs, or not make them at all, was also evident on the across-category confound task. The run lengths and mean percentages of categorizers to objects as animals and vehicles were considerably lower on the across-category confound (% = 56, *M* = 4.0) than on the control task (% = 78, *M* = 4.6). Further analysis indicated that the lower scores on the across-category confound resulted from infants' attention to part relations (% = 50, *M* = 5.7). However, this effect was found to be more pronounced for the performance of the 14- (% = 75, *M* = 7.4) and 18-month-olds (% = 50, *M* = 4.8) than for that of the 22-month-olds (% = 25, *M* = 3.7). It is worth noting that the number of infants classified as single or dual categorizers on the across-category confound task (for the two possible groupings) was comparable to that on the control task and to that found in Experiment 1 on tasks in which categorizing was found to be above chance level. These data suggest that infants included both confounded and unmodified objects in their categorizing runs.

Analyses of object salience. Three analyses of salience that were identical to those used in Experiment 1 were performed

to assess whether infants' touching was the result of an especially salient object or category. Chi-square tests revealed no differences in the number of infants who selected each category within a task, and related *t* tests revealed a reasonable distribution in the number of touches to each category on each task. Finally, one-way ANOVAs used to compare the number of touches made by all the infants to the four animals and vehicles on the four different tasks revealed that the number of touches were equally distributed across the four tasks and the objects within those tasks.

Discussion

The results of this study support the conclusion that infants under 22 months attend to the parts of objects to make category membership decisions. Infants between 14 and 22 months differentiated the animal and the vehicle domains when the animals had legs and the vehicles had wheels, but they did not distinguish these domains when all the exemplars possessed the same parts (i.e., legs and wheels) or shared no salient parts (i.e., no legs or wheels). This suggests that 14- to 22-month-olds form categories only when there are between-category-part differences and within-category-part similarities to act as the basis for classification. More important, the 14- and 18-month-old infants categorized by attending to parts rather than to category membership when such a choice was available. Thus, they grouped exemplars from different taxonomic classes that shared the same single attribute. By 22 months, however, a single part was no longer sufficient as the basis for categorization, although infants at this age could not disregard part differences and categorize by taxonomic relations alone. It is important to remember that the younger infants' categorizing responses on the basis of parts in the across-category confound may have resulted from the design bias of the task (see *Method* section). However, it should also be taken into account that the infants' behavior on the across-category confound corresponds not only to that found in the other confound tasks but also to that found in Experiment 1.

It is possible that the younger infants' performance on the confound tasks was a function of the unusual nature of certain objects: It could be argued, for example, that a "cow with wheels" is simply no longer a cow. However, there are three aspects of the data that suggest that this explanation is not compelling. First, infants' partonomic bias in categorizing in Experiment 1—that is, when all the objects were unmodified—reflected that found in Experiment 2; in other words, sequential touching was more systematic when there were part differences among the stimuli than when there were no part differences. Second, infants made a similar number of touches to the confounded objects as they did to the "normal" objects, suggesting that the former were not especially salient. Third, the number of infants classified as single or dual categorizers on the across-category confound task (for the two possible groupings) was comparable to that on the control task; on the across-category confound, infants included at least one of the confounded objects and one of the unmodified objects in their categorizing runs. Together, these findings suggest that the confounded objects were not too novel to influence infants' category membership decisions, an effect that might have been observed had

infants found the confounded objects "bizarre" or "weird." Rather, it appears that by attempting to find some basis by which to categorize them, infants might have dealt with the confounded objects as they would any other object never before encountered.

A related issue that needs to be addressed concerns the structure of the confounded objects. It is possible that moving the parts of objects made infants more sensitive to partonomic distinctions by making those attributes "stand out." However, a series of studies by Rakison (1996b) showed that moving the parts of objects into a novel orientation or configuration does not promote partonomic categorizing *per se*. For example, in one study, 14- and 18-month-old infants categorized partonomically when the parts of objects were in an uncommon orientation and common configuration, but they did not categorize partonomically when the parts of objects were in an uncommon configuration and an uncommon orientation.

General Discussion

A common assumption in the literature is that superordinate categorization is evidence of a knowledge- or theory-based understanding that category members are "the same kind of thing." A corollary for this assumption is the traditional view that basic-level categories are developmentally prime, although recent research has suggested that the earliest conceptual categories might be global in nature (Mandler & Bauer, 1988; Mandler et al., 1991; Mandler & McDonough, 1993). The results of the two studies presented here indicate that infants 14 and 18 months of age can form superordinate-like categories and will do so on the basis of partonomic information—that is, by a subdivision of objects into parts—rather than on the basis of category membership, that is, by a subdivision of objects into kinds. Across a number of tasks, 14- and 18-month-old infants more readily categorized when object sets differed with respect to a single part—that is, when animals had legs and vehicles had wheels—than when there were no part differences between object sets. More compelling, perhaps, infants under 22 months attended to attribute relations and not to taxonomic category relations (animals vs. vehicles) when presented with a task that allowed them to categorize on either basis. This behavior suggests that early categorization initially conforms to the classical view that certain attributes are necessary and sufficient for category membership (e.g., legs).

Infants' attention to attribute relations implies that they may not categorize objects on the basis of knowledge about the nonobvious properties of objects such as animacy (Mandler, 1992, 1993) or of knowledge of deeper nonobvious properties, such as "living being," "has a brain," "man-made" (e.g., Keil, 1989; Massey & Gelman, 1988). Hence, the view that superordinate relations, and possibly basic-level ones, are conceptually defined needs to be reassessed. There is now evidence that infants as young as 3 and 4 months can form superordinate-like representations (Behl-Chadha, 1996; Behl-Chadha et al., 1995). It seems quite unlikely that by this age, infants have developed knowledge about superordinate or basic-level relations. Rather, these findings support the notion that perceptual information may be at the core of categorical representation, as suggested by Jones and Smith (1993). Indeed, the evidence presented here suggests that even in the second year, infants

may form superordinate-like categories based on information available in the perceptual input.

More important, perhaps, just as Mandler et al. (1991) argued that it is wrong to claim that infants have developed superordinate categories when they "do not necessarily include well-differentiated, basic-level subclasses nested within them" (p. 290), so it may be equally incorrect to assert that 1- to 2-year-old infants have developed global, superordinate, or basic-level categories when there is little evidence that a knowledge-based understanding of category relations exists. In other words, if infants form a category of animals or vehicles on the basis of attribute relations alone, should those categories be considered taxonomic or partonomic? Unfortunately, the developmental literature is not forthcoming in a solution to this problem. Mandler (1992) claimed that infants' categorization of these superordinate domains means that they conceptually understand "what kind of thing an animal or vehicle is" (p. 588), whereas Rosch (1978) argued that a taxonomic category is based on some shared common attributes among category members. Moreover, clarifying this issue is made more troublesome by two contingencies that cannot be precluded in an account of early categorization: First, infants may possess a deeper, conceptual understanding about the relatedness of category members even if their behavior appears to be driven by attribute relations; second, infants may already have and use knowledge about the functional or causal significance of certain attributes that goes beyond what is perceptible; for example, they may know that things with wheels roll and that things with legs jump.³ It seems, therefore, that both a clarification of the terminology used to describe infants' categorization and a reassessment of their basis for behavior in previous studies are called for.

The finding that 14- and 18-month-old infants attend to parts to form categories does not necessarily reaffirm the developmental primacy of the basic level. As Quinn and Eimas (1996b) argued, attention to object parts implies that the easiest categories to learn would be those at the superordinate or global level: Infants' attention to legs and wheels would facilitate the categorization of animals from vehicles but not of dogs from cats or of cars from trucks. It is questionable, however, whether infants in the second year attend to object prototypicality. A recent study by Bauer et al. (1995) found that 16- and 20-month-olds categorized successfully on a prototypical contrast of animals and vehicles but failed to do so on a nonprototypical contrast of those domains. Nevertheless, an analysis of the stimuli used in the study revealed that the prototypical animals and vehicles had common within-category parts, whereas the nonprototypical animals and vehicles had no common within-category parts.

The basis for 22-month-old infants' categorizing is not so straightforward to interpret as that of younger infants. Unlike the 14- and 18-month-olds, in Experiment 1, the 22-month-olds discriminated certain object sets with the same parts (animals and furniture, insects and furniture) but not others (animals and insects). However, in Experiment 2, infants in the 22-month-old

³ There is evidence that 18-month-olds attend to correlations between the form and the function of objects and do so only to normal form and function relationships (Madole & Cohen, 1995; Madole, Oakes, & Cohen, 1993). However, it is equivocal whether they use the functional or causal aspects of parts to form categories.

group failed to categorize, in the absence of parts, differences between the object sets. This suggests that infants approaching the third year of life are still influenced by single attribute relations, although other properties of objects also play a role in classification. This view is supported by the 22-month-olds' refusal to use a single part as a basis for categorization. That is, by 22 months, a single attribute is not sufficient for objects to be treated equivalently; rather, additional attribute relations are necessary for category membership.

What might account for the developmental difference in behavior between 18 and 22 months? One possibility is that categorization is advanced by the development of language and, in particular, by the "naming explosion" that occurs between 18 and 22 months of age. A number of studies have shown that improved categorization in the second part of the second year corresponds chronologically with a faster rate of vocabulary development (e.g., Gopnik & Meltzoff, 1987, 1992; Rescorla, 1980). It remains to be seen, however, whether these correlations in development result from overall advances in cognitive ability or whether particular relations between capacities are causal. It is clear that infants' naming accelerates at the same time that they start to form spatial groups of related objects, although the emergence of these abilities could result from the development of, for instance, conceptual knowledge. The acquisition of object labels in itself suggests that infants may be developing linguistically coded representations of objects; however, whether these representations lead to advances in categorization remains unanswered. An alternative and novel explanation is that the development of categorization skills expedites the acquisition of language. For example, it is possible that category formation allows infants' processing resources to be redirected toward language acquisition or that successfully grouping things together encourages them to form a label for the new category. Although admittedly speculative, these explanations cannot be eliminated for the existing data that point to only a correlation between vocabulary growth and categorization and not to a causal agent among them (e.g., Gopnik & Meltzoff, 1987, 1992).

A further theory to explain 22-month-old infants' categorization is that they may infer the properties of objects from parts and part-whole relations. Mandler (1992, 1993) and Lakoff (1987) have suggested that infants in the first year of life develop image-schemas representing the movements of objects, among other things, and they use these image-schemas to discriminate between self-instigated motion and caused motion (see also Premack, 1990). In support of this view, there is evidence that infants in the first year can discriminate self-starting, biological motion from caused, nonbiological motion (e.g., Bertenthal, 1992; Leslie, 1984; Poulin-Dubois et al., 1996). However, as argued earlier, there is little evidence that such properties guide taxonomic categorization. Indeed, if knowledge of nonobvious properties is in place early in infancy, as Mandler (1992, 1993) argued, it follows that objects related by movement (e.g., self-starting) should be grouped whether or not they share the same parts. The infant should know, for example, that all animals travel through space in a similar way, that they are self-starting and do not move linearly, and that vehicles move in a different manner. However, even though some of the 22-month-old infants' made the animals "jump" or "cat" or made the appropriate vehicle noises, the behavior of

the 22-month-olds as a group suggested that their categorization was not based on the nonobvious properties of the objects. Rather, it was driven by the readily perceptible attributes that allowed a partition of objects to be made.

The 14- and 18-month-olds' tendency to form novel categories that cross typical taxonomic borders suggests that they may form dynamic, mutable categories *on-line*, as suggested by Jones and Smith (1993; see also Thelen & Smith, 1994). For example, in the control task, 14- and 18-month-old infants treated animals and vehicles as different kinds of things. However, when parts were confounded across the two categories, infants treated equivalently those animals and vehicles that shared the same part. It is unlikely that the infants had experienced previously such categories; rather, it appears that they formed novel object sets on the basis of salient attributes. This interpretation is consistent with Ward's *attribute-availability theory*, which holds that real-world category learning is facilitated by children's tendencies to process selectively one or more attributes that are characteristic of a category (Ward, Becker, Hass, & Vela, 1991; Ward, Vela, & Hass, 1990). Thus, children "seek out particular component properties of the objects that will allow correct decisions to be made regarding membership in those suggested categories" (Ward et al., 1991, p. 145). In other words, the categories that infants form may be dynamic, mutable entities that match adults' taxonomic categories by virtue of shared attributes among related objects. It is important that infants' touches to the stimuli within each novel category (e.g., objects with wheels) were equally distributed, which indicates that they had no preference for confounded objects or objects with the same type of parts (e.g., quadrupeds).

It remains to be seen, however, whether infants attend solely to parts or whether, as hypothesized by A. Tversky (1977) and Ward et al. (1990), the critical feature for categorization varies within any particular context. For instance, it was found in this study that having the features "legs" and "wheels" will distinguish animals from vehicles and that having the features "eyes," "mouth," and "head" will not distinguish them, as in the task in which legs and wheels were removed. In contrast, however, a recent study involving a paired-preference technique found that 3- and 4-month-olds will distinguish cats from dogs on the basis of facial information alone (Quinn & Eimas, 1996a). It is unclear whether this distinction might result from the nature of the stimuli in the two types of studies (pictures and scale models) or whether there is a qualitative difference in the categories formed during habituation studies and object-manipulation studies (see Oakes, Madole, & Cohen, 1991). A further explanation for infants' attention to salient object parts—that is, legs and wheels—is that it might mark the beginnings of the process of discovering the attributes that come to identify the category. Thus, legs and wheels are attribute differences that tend to distinguish the category of animals and the category of vehicles, and, with the accrual of other attributes (e.g., overall shape, movement), the infant should be able to distinguish more finely defined domains.

An important issue concerning the stimuli used in this and in other studies involving the object-manipulation technique is whether infants consider toys as representations of real objects (e.g., Mandler, 1993; Soja, Carey, & Spelke, 1991). A corollary is that object-manipulation tasks measure attention to relations

among scale models and not to the relations among real-world objects. In response to this problem, it has been argued that children and adults use the same term to refer to a mechanical animal, a stuffed animal, and a real animal, even though they know that the objects have different nonobvious properties (e.g., Jones & Smith, 1993). Few studies, however, have directly addressed this issue. Mandler (1992) noted that 1- to 2-year-olds who were engaged in playing with animal and vehicle exemplars tended to move or roll vehicles in a straight line, whereas they tended to "hop" or "bounce" animals. Likewise, in the present studies, the 22-month-old infants sometimes attributed toys with a nonobvious property of the object that they represent; for example, they made animals "eat" or made the engine noise of a vehicle or they referred to toy animals and toy vehicles as if they were real animals and real vehicles—saying "hello doggy." (These behaviors were not systematic among the infants and were therefore not analyzed, merely observed.) More important, perhaps, infants in all three age groups tested here managed to find some basis for categorization. Thus, even the youngest infants formed categories of objects that resemble those made by adults—for instance, they grouped animals, vehicles, and furniture, and so on. As discussed earlier, the nature of these categories—that is, whether they are paronomies or taxonomies—is at present ambiguous. Likewise, because some infants attributed toys with the properties of real objects yet were affected in categorizing by perceptible attributes, it must remain a moot point whether the scale models in these studies were merely perceived as objects or as iconic representations of real objects. Thus, infants' behavior in object-manipulation tasks, whether guided by attention to parts or by knowledge of nonobvious properties, can tell us something about the mutable basis for early categorization but not necessarily about the conceptual status of the stimuli.

In any case, the data presented here indicate that there is a perceptual basis for early superordinate categorization. It can no longer be assumed that perceptually dissimilar categories are conceptual categories; rather, it has been shown that a single attribute is sufficient for infants to form categories comprising diverse objects. It appears that infants, particularly those under 22 months, may form categories on-line without referring to knowledge or beliefs about the origins and causes of category membership or to the nonobvious properties to which Mandler (1992, 1993) suggested they might attend. The use of confound object-manipulation tasks in future studies may help us further to understand this perceptual basis for early categorization. Independent manipulation of perceptible attributes may lead us to discover the different (possibly invariant) features that underlie different superordinate-like categories. It remains to be seen whether this information becomes conceptually realized as knowledge of the kinds of things animals are (Mandler, 1992) or as beliefs underlying the causes of category membership (Jones & Smith, 1993). Ultimately, the answer to this issue may lie in a greater understanding of the infants' basis for categorization. As Quinn (in press) pointed out, "Insight into how early, perceptually driven categories develop into higher level conceptual structures . . . is not likely to be understood unless the input—the content and organization of the infants' mental structures—at the time the transition begins is known" (p. 4).

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