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INDUCTIVE CATEGORIZATION: A METHODOLOGY TO EXAMINE THE BASIS FOR CATEGORIZATION AND INDUCTION IN INFANCY

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ABSTRACT

Three experiments with a methodology called inductive categorization examined 12-16-, and 20-month-olds' categorization of animals and vehicles with and without functional parts as well as their inductive inferences about the motion properties of the objects in these classes. The experiments showed that infants at 12 months use object parts to categorize after a brief learning period, infants at 16 months attend spontaneously to object parts to categorize, and infants at 20 months use object parts and other features to categorize. The experiments also revealed that 12-month-olds have little knowledge about the motion properties of objects, 16-month-olds have associated specific object parts with those properties, and 20-month-olds have generalized from object parts to other features. Taken together, these experiments provide support for the domain-general approach to early concept development, and they are the first to show a relationship between inductive inference and categorization in infancy.

KEYWORDS: *infancy, induction, categorization, object features.*

INTRODUCTION

One of the key functions of concepts – mental representations of the object, entities, and events in the worlds—is to provide a basis for categorization and generalization. Only a fraction of the entities, objects, features, and events in the world can be experienced directly; therefore, we must rely on categorization and inductive inference to determine which things in the world belong together or are alike in some way and how to generalize a specific observation to other instances. For example, on encountering a novel mammal that barks and has fur

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one would conclude that it belongs to the category of "dog", that it is self-propelled, moves towards goals, and chases squirrels. As adults, we seamlessly and effortlessly accomplish these tasks—that is, we have carved nature accurately at its joints – yet how we reach this representational end-state currently remains unknown. The experiments in this paper were designed to address key, as yet unanswered, questions relating to the development of object concepts; namely, (1) what is the effect of high and low within-category part similarity on infants' categorization and induction?; and (2) what is the relationship between categorization and induction in infancy and is it informative about the content of infants' developing representations?

The last 20 years has witnessed a proliferation of research on the early development of categorization. One of the most fruitful avenues of this research has relied on the *sequential touching* or *object manipulation* procedure, in which the systematicity of infants' spontaneous successive touches to objects are interpreted as indicative of categorization. Using this paradigm, it was found that infants at 18 and 20 months categorize animals and vehicles as different (e.g., animals vs. vehicles) but not basic-level contrasts within these domains (e.g., dogs and horses) (Mandler & Bauer, 1988; Mandler, Bauer, & McDonough, 1991). According to Mandler and colleagues, these and similar data support the view that infants' categorization and induction are not based on surface features (see also Mandler & McDonough, 1996, 1998). They argued that exemplars within a superordinate domain (e.g., animals) share few surface properties and therefore categorization of such perceptually diverse stimuli must be based on conceptual categorization (e.g., animacy, movement abilities, or class relations), with properties perceptible in the input playing only a secondary role. A corollary of this view is that infants possess specialized processes, innate modules, or skeletal principles that facilitate rapid conceptual understanding and allow infants within the first year of life to learn about objects' surface properties as well as those that are sporadically available in the perceptual input (e.g. movement) (Gelman, 1990; Leslie, 1995; Mandler, 1992).

As an alternative to this perspective, a number of theorists suggested that general rather specific processes are sufficient to support early learning of objects' surface and less obvious properties (e.g., Jones & Smith, 1993; Oakes & Madole, 2003; Quinn & Eimas, 1997; Rakison & Lupyan, in press). According to this perspective, early concept development is a process of continuous representational augmentation that builds on a sensitive perceptual system in conjunction with associative learning and other such domain-general mechanisms. The specifics of the various theories differ but they have in common the idea that infants become sensitive to increasingly sophisticated and detailed levels of perceptual information – specifically, the surface features of objects - over developmental time. The representation that results from this process is an associative link between both static and dynamic perceptual cues that leads to an *expectation* on the part of the infant about how things move (e.g., things with legs move nonlinearly). It is these features and correlations among features that, according to this view, act as the basis for categorization and induction. The specifics of how such features are used in induction and categorization vary from theory to theory; however, they share many of the basic assumptions that are central to two well-known information-processing models of inductive inference, namely, the similarity-coverage model (Osherson, Smith, Wilkie, Lopez, & Shafir, 1990), and the feature-based induction model (Sloman, 1993). According to these models, induction relies on the featural similarity of an instance to a target and the category to which it belongs.

Support for this similarity-based domain-general position was generated from a number of studies also with the sequential touching procedure. Rakison and Butterworth (1998a, 1998b; see also Oakes, Coppage, & Dingel, 1997) reasoned that if surface features - such as object parts – and not abstract concepts act as the basis for categorization, infants' ability to classify would be significantly affected by the presence, absence, and structure of such features. Consistent with this idea, they found that 14- and 18-month-olds more readily group objects in different-parts contrasts (e.g., animals vs. vehicles) than same-parts contrasts (e.g., animals vs. furniture), and that they fail to categorize animals as different from vehicles when the stimuli had matching parts (animals and vehicles with legs and wheels) or possessed no such parts (legs or wheels removed) (see Rakison & Cohen, 1999, for similar findings for infants' categorization of basic-level classes). Additional support for the importance of surface features was garnered from research by Rakison (2005) with the *inductive generalization* procedure that showed that 18-month-olds do not generalize linear and non-linear motions to objects on the basis of category membership but rather to objects on the basis of parts (e.g., wheels and legs). Thus, perceptual similarity – and in particular the presence of shared functional features - has been shown to act as the basis for categorization and induction in the first years of life.

Although these findings are consistent with the general learning mechanism view of early concept and category development, a number of important issues remain. First, the findings of Rakison and Butterworth (1998a, 1998b) have been questioned by those who suggest that infants' behavior with adapted stimuli (e.g., animals without legs) may not reflect how they respond to real-world, unmodified category exemplars (Mandler, 2000, 2003). According to this view, infants' come to the laboratory with prior knowledge about which objects belong to which category, and they express this knowledge in the sequential touching task by touching in succession those objects they know are "the same kind of thing". According to the perspective argued here, however, infants may arrive at the task with little or no knowledge about category relations or even about animals or vehicles; that is, infants may have no representations for these objects or, if they do, the represented information involves only the characteristic features of certain objects (e.g., there are things with legs in the world). Their performance in the sequential touching task, therefore, is either guided by a tendency to touch objects that are perceptually alike in some way (e.g., shared parts, shape, or color) or to touch object in succession that share features that they have learned are frequently found in the environment. Given the debate over these issues, it is important to show that infants attend to object parts in a categorization context and that they do so with unmodified stimuli.

Second, it remains to be seen when and how infants learn that different object kinds move in different ways. Research by Rakison (2005), which was described above, showed younger infants generalize land motions on the basis of surface features and that older infants – those at 22 months of age - generalize linear and nonlinear motion to appropriate category members with and without such large parts. It is as yet unknown how, and precisely when, this representational transition occurs.

Third, the relationship between categorization and induction remains opaque. Previous empirical work has examined separately infants' categorization – grouping discriminable objects together—or their inductive inference – generalizing to novel exemplars based on experience with one exemplar (e.g., Mandler et al., 1991; Mandler & McDonough, 1996; Rakison, 2005; Rakison & Butterworth, 1998a). It is implicitly assumed by many theorists that both of these processes rely on the same underlying representations. There is reason to hypothesize, therefore, that there is a connection between the ability to categorize and make inductive inferences in infancy (and beyond); when infants learn a property about a single exemplar they would not only generalize this information to other, similar exemplars but also their categorization of such exemplars would be facilitated. Indeed, recent formulations of concepts within the adult cognition literature have stressed the notion that the specific concepts that humans possess are those that maximize inductive potential (Anderson, 1991; Heit, 2000). It is unlikely, however, that infants' inductive ability will necessarily mirror their categorization ability; infants at 3 months can categorize cats as different from dogs but know little, if anything, about the properties of either category (Quinn & Eimas, 1997). It is nonetheless possible that by considerably later in developmental time – around the 2nd year of life – when infants learn a property for an object (e.g., this thing moves non-linearly) they are more likely successfully to categorize objects that share surface features with that object. This issue has not yet been addressed from a developmental perspective, however.

The three experiments reported here were designed to address these issues by using an adaptation of two previously employed methodologies – the sequential touching and inductive generalization paradigms – which I labelled the *inductive categorization* procedure (see Oakes & Plumert, 2002, and Mareschal & Tan, 2007, for other variations of the sequential touching paradigm). As in the inductive generalization procedure, an experimenter performed one of two actions with two exemplars: in *Model* events, infants were shown an animal or vehicle that was moved in a category appropriate way; that is, the animal was moved nonlinearly and the vehicle was moved linearly. In *No-Model* events, infants were shown the same exemplars but they were not moved in any way. Infants were then presented with a typical sequential touching task with eight objects drawn from two superordinate domains (animals and vehicles) and the effect of this manipulation on infants' categorization and induction was assessed.

EXPERIMENT 1

In this experiment, 16- and 20-month-old infants' categorization and induction of animals and vehicles was tested following either a simple modeling event of a linear or non-linear motion or without such a modeling event. The model exemplars were a prototypical animal that possessed legs (i.e., a dog) or a prototypical vehicle that possessed wheels (i.e., a car), and the test stimuli within each category possessed the appropriate parts for the motions (i.e., legs or wheels) or possessed no such large functional parts.

Based on previous findings, it was predicted that 16-month-olds would categorize animals and vehicles as different only when they possessed legs and wheels and that they would demonstrate more appropriate actions – that is, rolling and walking – in the model condition than in the no-model condition when the stimuli possessed the appropriate parts than when they did not. It was also predicted that 20-month-olds would categorize animals and vehicles as different regardless of their parts, and that following the modeling of the linear and nonlinear motions they would demonstrate those motions both with the objects that possessed and did not possess the appropriate parts (i.e., legs and wheels).

METHOD

Participants. Eighty infants participated in the experiment, 40 with a mean age of 16 months, 3 days (range = 15;17 to 16;14) and 40 with a mean age of 20 months, 2 days (range = 19;13 to 20;15). There were an equal numbers of boys and girls in both age groups. Ten further infants (5 in each age group) were tested but excluded from the final sample, five because of fussiness, three because of experimenter error, and two for refusing to engage in the task. Infants were recruited through birth lists acquired from a private company, and they were given a small gift for their participation. In this experiment, and the others reported here, the majority of infants were White and of middle socioeconomic status.

Stimuli and motions tested. 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. The model animal exemplar was a dog and the model vehicle exemplar was a car. There were two test stimulus sets in total: animals with legs versus vehicles with wheels (*Same-Parts* set) and animals without legs versus vehicles without wheels (*No-Parts* set). Note that these labels do not describe in their entirety the nature of the stimuli; for example, the stimuli within each category in the Same-Parts condition did not share all parts and the stimuli within each category for the No-Parts set shared some parts (e.g., facial features for the animals). The animals with legs were a cat, a donkey, a seal, and a parrot (in a standing position with legs exposed), and the vehicles were a fire truck, a motorcycle, a plane (with clearly defined wheels), and a tractor. The animals without legs were a snake, an eagle (in a flying position with no legs exposed), a whale, and a snail, and the vehicles without wheels were a boat, a snowmobile, a tank, and a rocket. Movable object parts (e.g., wheels) were glued to minimize any extraneous salience resulting from their movement.

There were also two simple motions that were performed with the model exemplars by the experimenter. The motions were identical to those used by Rakison (2005). Thus, the nonlinear motion for the cat was a curvilinear up-and-down movement as it traveled horizontally, and the linear motion for the car was a straight line (with no up-and-down movement) as it traveled horizontally. Each event was accompanied by a non-verbal vocalization by the experimenter: "Whoop" for the nonlinear motion, and "Wee" for the linear motion.

Procedure. Participants were tested in a small, quiet room. Each infant sat on their parent's lap across the table from the experimenter. The parent was instructed not to guide their infant's behavior or to comment in any way. Each infant's behavior was tested with the two stimulus sets; that is, animals with legs versus vehicles with wheels as well as animals without legs versus vehicles without wheels. For the No-Model trial, the experimenter would draw the infant's attention to the two static model exemplars by pointing at them and saying "Look at this"; however, the stimuli were not moved in any way. For the Model trial, the experimenter attracted the infant's attention to one model exemplar by saying, "Look at this," and then would perform the appropriate simple motion described above from right to left and left to right. This procedure was repeated for the second model exemplar with a different initial direction (i.e., left to right followed by right to left). The same two stimuli (the dog and the car) were used as example objects for the Model and No-model trials. The direction of the two motions was counterbalanced across the infants within each age group.

After this initial phase, the model exemplars were withdrawn from view and the relevant eight test stimuli were placed randomly on a tray in front of the infant. 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 infant was then allowed to manipulate the objects in any way for 2 minutes or until no further manipulation occurred. There was no feedback, labeling, or pointing from the experimenter or from the parent. Each infant was involved in two such tasks, a Model and a No-Model trial. Infants were tested with the Same-Parts stimuli in a Model trial and the No-Parts stimuli in a No-Model or the Same-Parts stimuli in a No-Model trial and the No-Parts stimuli in a Model trial. The order of the two tasks was counterbalanced across infants in each age group. All the tasks were videotaped for later analysis.

Scoring. Coding and scoring were similar to that in previous studies with the sequential touching and inductive generalization technique (e.g., Mandler et al., 1991; Rakison & Butterworth, 1998a, 1998b; Rakison, 2005). Coders recorded every object contacted by the infant, by hand or with another object, and the order in which each object was touched (for details of the rules used for coding, see

Rakison & Butterworth, 1998a). Coders also recorded whether infants demonstrated the linear or nonlinear motions with the appropriate stimuli. Infants were coded as having demonstrated successfully the nonlinear motion if they moved an object up-and-down in an arc at least once while making contact with the tray or table. A linear motion was coded if an infant moved an object in a straight line along one of the available surfaces (see Rakison, 2005).

Two judges, who were blind to the experimental hypotheses and to the modeling condition, independently coded 25% of the tasks (10 infants from each age group). Interrater reliability was obtained by calculating a percentage agreement of the two independent coders' scores for the objects that infants touched as well as the movements that were demonstrated with those objects. Percentage reliability for all the experiments reported here for objects touched by the infants and for actions performed by the infants was >93%.

RESULTS

Initial analyses for this experiment, and the others reported here, revealed that there were no effects for the order in which infants received the stimulus set (e.g., Same-parts before No-parts) or the modeling (e.g., Model before No-Model trials).

Sequential touching behavior. As a first analysis of categorization behavior, two-tailed paired *t*-tests were used to compare infants' mean run lengths (MRL) to the run length expected by chance (1.75). The MRL for each task and their associated two-tailed *t*-test values are shown in Table 1. It can be seen that the MRL of both age groups on the Same-Parts trials were significantly greater than that expected by chance. In other words, infants at 16 and 20 months of age categorized the animals with legs as different from the vehicles with wheels. It can also be seen that the 16-month-old infants' MRL on the No-Parts stimuli for both the Model and No-Model trials were at chance level, which indicated that they did not categorize the animals without legs as different from the vehicles without wheels. However, the 20-month-olds MRL for the No-Parts stimuli were significantly greater than chance for the Model trial but not for the No-Model trial.

Table 1.
Mean run lengths and standard deviations and associated t-test values for Experiment 1

Task	*16 months*		*20 months*	
	No-Model	*Model*	*No-Model*	*Model*
Same-Parts	*2.25 (0.73)***	*2.20 (0.84)**	*2.45 (0.89)***	*2.71 (2.00)**
No-Parts	*1.92 (0.69)*	*1.73 (0.46)*	*1.90 (0.49)*	*2.21 (0.88)**

Note.- Two-tailed t-values are of comparison to run length (1.75), with df = 19.
** p < .05. ** p < .01.*

Actions performed: The dependent measure for the action performed was the number of appropriate motions made by each infant on each trial with any of the eight objects. Preliminary analyses revealed that infants demonstrated an equivalent number of motions with the animals and the vehicles so the scores were collapsed across the two categories. In addition, initial analyses for this experiment and the other two reported here showed no effects for the order in which infants received the stimulus set (e.g., Same-parts before No-parts) or the modeling trials (e.g., Model before No-Model).

Because of the design of the experiment, it was necessary to analyses separately infants' behavior with the Same-Parts stimuli and their behavior with the No-parts stimuli. Infants' actions with the Same-parts stimuli were analyzed with a two-way ANOVA with age (16 months vs. 20 months) and Trial (Model vs. No-Model) as between-subjects factors. The data are presented in Figure 1. The analysis revealed a marginally significant effect for Age, $F(1, 76) = 3.38$, $p=.07$, which indicated that older infants tended to perform more actions ($M = 1.83$, $SD = 1.33$) than younger infants ($M = 1.40$, $SD = 1.17$). The analysis also revealed a significant effect for Trial, $F(1, 76) = 54.12$, $p<.001$, which showed that across the two age groups infants performed more actions in the Model trials ($M = 2.43$, $SD = 1.15$) than the No-Model trials ($M = 0.83$, $SD = 0.78$). There was no significant interaction between Trial and Age, $p>.4$.

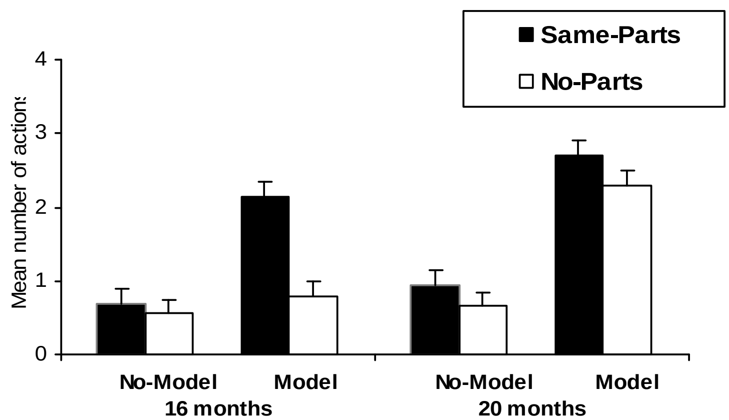

Figure 1.
Mean number (and SE) of appropriate actions performed by 16- and 20-month-olds in Experiment 1.

Infants' actions with the No-parts stimuli were also analyzed with a two-way ANOVA with age (16 months vs. 20 months) and Trial (Model vs. No-Model) as between-subjects factors. The analysis produced significant main effects for Age, $F(1, 76) = 25.01$, $p<.001$, and Trial, $F(1, 76) = 35.26$, $p<.001$. These main effects were mediated by a significant interaction between Age and Trial, $F(1, 76) = 19.15$, $p<.001$. Additional analyses revealed that the number of actions by the younger age group were equivalent on the Model ($M = 0.80$, $SD = 0.77$) and No-

Model (*M* = 0.55, *SD* = 0.80) trials, $F(1, 38) = 1.31$, $p>.2$. However, the older age group performed significantly more actions in the Model trials (*M* = 2.30, *SD* = 0.80) than the No-Model trials (*M* = 0.65, *SD* = 0.67), $F(1, 38) = 49.86$, $p<.001$.

DISCUSSION

The aim of Experiment 1 was to examine the effect of modeling a simple motion on 16- and 20-month-olds' categorization and induction of objects with and without shared functional parts. The data revealed that infants at 16 months of age categorized animals as different from vehicles when exemplars within each category shared a single part (i.e., legs or wheels) but they did not categorize animals as different from vehicles when such parts were not present. This finding is consistent with previous research which showed that object parts act as the basis for superordinate-like categorization at 14 and 18 months of age (Rakison & Butterworth, 1998a). It also extends this earlier work because it involves a direct comparison of infants' performance with the same superordinate contrasts (i.e., animals vs. vehicles) in the presence or absence of parts.

In contrast to the 16-month-olds, the 20-month-olds categorized the animals without legs as different from the vehicles without wheels in the Model trial but did not do so in the No-Model trial. This suggests that the dynamic modeling phase facilitated infants' categorization by triggering their representations about the relations between object features and motion events. The data suggest that for 20-month-olds, but not 16-month-olds, the activated representations include objects with the parts typically associated with specific motions as well as other, as yet unspecified features.

An important question that remains unanswered is when and how do younger infants learn that animals without legs belong in the same category and move nonlinearly and that vehicles without wheels belong in the same category and move linearly. If infants observe a snake moving nonlinearly and a boat moving linearly, for instance, would they learn that these motions are not inherently associated with parts such as legs or wheels but are also associated with other object features (e.g., eyes, rectilinear shapes)? Experiment 2 was designed to test this issue.

EXPERIMENT 2

The current experiment examined whether 16- and 20-month-olds' categorization of objects without legs and wheels is facilitated when they observe a model exemplar that does not possess legs move nonlinearly and a model exemplar that does not possess wheels move linearly. Thus, the design of this experiment was identical to that of Experiment 1 except that the model exemplars did not have legs or wheels.

METHOD

Participants. Eighty infants participated in the experiment, 40 with a mean age of 16 months, 5 days (range = 15;19 to 16;16) and 40 with a mean age of 20 months, 3 days (range = 19;15 to 20;13). There were an equal numbers of boys and girls in the 16-month-old age group and 21 boys and 19 girls in the 20-month-old age group. Fourteen additional infants (8 at 16 months and 6 at 20 months) were tested but excluded from the final analyses, seven because of fussiness, two because of experimenter error, and five for refusing to engage in the task. Infants were recruited in the same way as in Experiment 1 and were given a small gift for their participation.

Stimuli and motions tested, Procedure, and Scoring. The stimuli and motions were identical to those in Experiment 1 with one exception; the model animal exemplar was a shark and the model vehicle exemplar was a jet-ski. All aspects of the procedure were the same as the first experiment. Coding and scoring were the same as in Experiment 1.

RESULTS

Sequential touching behavior. Table 2 presents the MRL for each task and their associated two-tailed *t*-test values. Consistent with the results of Experiment 1 and with previous research, the 16- and 20-month-old infants' MRL on the Same-Parts trials were significantly greater than that expected by chance. Thus, infants in both age groups categorized the animals with legs as different from the vehicles with wheels. However, although the 16-month-olds' MRL on the No-Parts task in the No-Model trial were not reliably different from chance, their MRL on the No-Parts task in the Model trial were significantly higher than that expected by change. This suggests that observing two static exemplars prior to the task did not facilitate 16-month-olds' ability to categorize the No-Parts stimulus sets; yet observing two simple motion events modeled with those exemplars did improve overall categorization performance. In contrast, infants at 20 months of age generated MRL significantly greater than chance for the No-Parts stimulus sets in both the No-Model and Model trial. This suggests that observing two static exemplars prior to the task facilitated 20-month-olds' ability to categorize.

Table 2.
Mean run lengths and standard deviations and associated *t*-test values for Experiment 2

Task	16 months		20 months	
	No-Model	Model	No-Model	Model
Same-Parts	2.41 (1.00)**	2.67 (1.18)**	2.52 (0.88)**	2.69 (0.84)**
No-Parts	1.86 (0.43)	2.42 (1.21)*	2.26 (0.59)**	2.47 (0.99)**

Note.- Two-tailed t-values are of comparison to run length (1.75), with df = 19.
* $p < .05$. ** $p < .01$.

Actions performed: The dependent measure for the action performed was the number of appropriate motions made by each infant on each trial with any of the eight objects. As in Experiment 1, preliminary analyses showed no difference in the number of motions that infants demonstrated with the animals and the vehicles and consequently the scores were collapsed across the two categories.

The data were analyzed in the same way as the first experiment. Infants' actions with the Same-parts stimuli were submitted to a two-way ANOVA with age (16 months vs. 20 months) and Trial (Model vs. No-Model) as between-subjects factors. The data are presented in Figure 2. The analysis revealed a significant effect for Trial, $F(1, 76) = 39.10$, $p<.001$, which indicated that across the age groups infants performed fewer actions in the No-Model trials ($M = 0.87$, $SD = 0.82$) than in the Model trials ($M = 2.48$, $SD = 1.38$). There was no significant effect for age, $p>.4$, and no significant interaction between Trial and Age, $p>.8$.

Infants' actions with the No-parts stimuli were also submitted to a two-way ANOVA with age (16 months vs. 20 months) and Trial (Model vs. No-Model) as between-subjects factors. The analysis revealed that infants in the No-parts trials produced significantly more actions in the Model trials ($M = 2.28$, $SD = 1.22$) than the No-Model trials ($M = 0.95$, $SD = 0.78$), $F(1, 76) = 33.10$, $p<.001$. There were no other significant effects, all p's >.4.

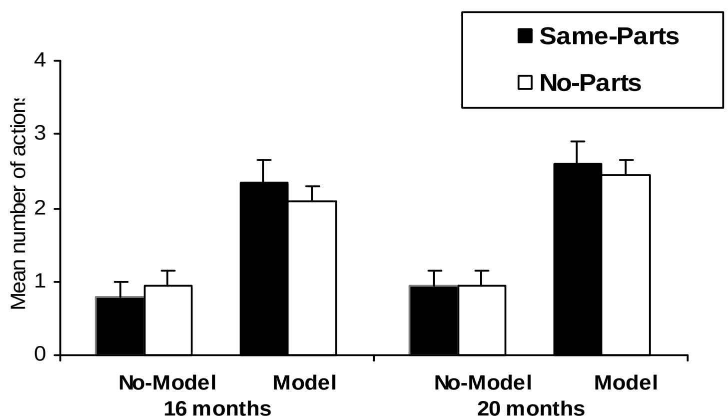

Figure 2.
Mean number (and SE) of appropriate actions performed by 16- and 20-month-olds in Experiment 2.

DISCUSSION

The aim of Experiment 2 was to examine the effect of modeling a simple event with an exemplar without appropriate parts for a motion (e.g., legs or wheels for linear and nonlinear trajectories) on 16- and 20-month-olds' categorization and induction. As in Experiment 1, infants at 16 and 20 months of age categorized animals with legs as different from vehicles with wheels in the no-Model trial, and infants at 20 months of age categorized animals without legs as different from vehicles without wheels in the Model trial.

There were, however, two significant differences between the behavior of infants in the first experiment and those in Experiment 2. A first finding of note was that infants at 16 months in the Model trial categorized animals without legs as different from vehicles without wheels whereas those in Experiment 1 did not. This suggests that the action of highlighting two moving exemplars without functional parts – one from each category – may have caused 16-month-olds to learn that animals without legs can move nonlinearly and that vehicles without wheels can move linearly. One plausible explanation for this finding is that the act of moving the stimuli in the Model trial helped to attract infants' attention to the two exemplars, which caused them to encode their appearance more than infants in the No-Model trial. Thus, the modeling phase may have highlighted the relationship between motions and facial features or curvilinear shape and that these cues were used as the basis for categorization and induction. A second finding of note is that infants at 20 months in the No-Model trial categorized the animals without legs as different from the vehicles without wheels. This suggests that the same process described above may operate for 20-month-old infants, but they do not need the attention grabbing motion of the exemplars to hold their attention on them.

As in Experiment 1, the linear and nonlinear motions demonstrated by the infants tended to reflect their categorization behavior. However, as can be seen in Figure 2 an unexpected result given the categorization data was that infants at 20 months did not demonstrate motions with the No-Parts stimulus set in the No-Model trial. This implies that infants at 20 months have not yet learned that animals without legs tend to move nonlinearly and that vehicles without wheels tend to move linearly. This interpretation is consistent with previous research that showed that it is not until 22 months that infants generalize nonlinear motion to animals such as snakes and linear motion to vehicles such as snowmobiles (Rakison, 2005). In conjunction, these results suggest that this knowledge is acquired at some point between 20 and 22 months.

EXPERIMENT 3

A final question addressed here relates to the age at which infants use object parts to categorize and whether modeling a motion serves to facilitate categorization in infants younger than 16 months. This issue was addressed in the present experiment by testing 12-month-olds with the same basic design as that used in Experiments 1 and 2. Infants were tested with only the Same-Parts stimulus set in a Model or No-Model trial because Experiment 1 showed that 16-month-olds did not categorize the No-Parts stimulus set.

METHOD

Participants. Forty infants with a mean age of 12 months, 1 day (range = 11;14 to 12;14) were the participants in the experiment. There were an equal numbers of boys and girls. Seven additional infants were excluded from the final analyses, three because of fussiness, and four for refusing to engage in the task. Infants were recruited in the same way as the previous experiments and were given a small gift for their participation.

Stimuli and motions tested, Procedure, and Scoring. The stimuli were the animals and vehicles from the Same-Parts set that were used in Experiment 1. Twenty infants were randomly assigned to one of two conditions, the Model or No-Model trial. All aspects of the procedure were the same Experiment 1. Coding and scoring were the same as Experiment 1.

RESULTS

Table 3 presents MRL for each task and their associated two-tailed *t*-test values. It can be seen that infants' MRL were significantly higher than chance in the Model condition but not in the No-Model condition. Thus, infants at 12 months categorized the animals with legs as different from the vehicles with wheels after they observed moving model exemplars prior to the task but not when they observed static model exemplars. An analysis of the number of linear and nonlinear motions demonstrated by each participant revealed that infants were more likely to demonstrate actions in the Model condition (M = 1.10, SD = 0.67) than the No-Model (M = 0.55, SD = 0.60) condition, $t(38) = 2.44$, $p<.025$. However, the overall number of motions demonstrated in both conditions was low.

Table 3.
Mean run lengths and standard deviations and associated *t*-test values for Experiment 3

Task	12 months	
	No-Model	Model
Same-Parts	1.97 (0.72)	2.39 (1.36)*

Note. Two-tailed *t*-values are of comparison to run length (1.75), with df = 19.
* $p < .05$.

DISCUSSION

The data from Experiment 3 suggest that 12-month-olds categorize animals with legs as different from vehicles with wheels, but they do not do so without some form of facilitating cue. In contrast to the 16-month-olds in Experiment 1 and 2, infants at 12 months did not categorize animals and vehicles in a regular sequential touching task; that is, after they saw two static exemplars. However, infants in the Model condition categorized the animals as different from the vehicles which suggests that the modeling phase facilitated infants' categorization. This finding supports the idea that the movement of the model exemplars may have caused infants to attend to those exemplars, and it may have highlighted that there were two different kinds of objects or features.

GENERAL DISCUSSION

The three experiments reported here were designed to investigate two issues. First, the experiments examined systematically the role of object parts as the basis for categorization by comparing infants' behavior toward contrasts of animals and vehicles with high and low within-category part similarity. Second, the experiments investigated the effect of modeling an action on early categorization and induction by testing infants in conditions in which an experimenter either displayed two static model exemplars or two moving model exemplars. To examine these issues, the experiments employed a relatively novel methodology that combined the inductive generalization and sequential touching procedures.

The findings of the three experiments support the notion that infants in the second year of life attend to object parts such as legs and wheels to form superordinate-like categories. Previous research showed that infants at 14 and 18 months rely on parts such as legs and wheels to categorize superordinate domains such as animals, vehicles, furniture, and insects (Rakison & Butterworth, 1998a) as well as basic level classes (e.g., cows and cars) within these domains (Rakison & Cohen, 1999). This past work has been criticized by some researchers who claim that infants may behave differently in tasks with modified stimuli – that is, those with parts added or removed—than with unmodified ones (e.g., Mandler, 2000, 2003). The present experiments addressed this concern because they involved a direct comparison of infants' performance with a stimulus set with shared parts to a stimulus set without shared parts. The experiments reported here also extend previous work by showing that infants at 12 months of age do not categorize animals with legs as different from vehicles with wheels within the sequential touching task. This suggests that infants' attention to object parts as the basis for categorization emerges between 12 and 14 months of age.

The data corroborate and extend previous work showing that initially infants associate specific motion characteristics with specific object parts (Rakison, 2005; Rakison & Cohen, 1999). In the current experiments, when infants were shown linear and nonlinear motions demonstrated with exemplars that possessed appropriate parts, 16-month-olds generalized the motions only to objects that possessed those parts whereas 20-month-olds generalized the motions to animals and vehicles regardless of whether they possessed large functional parts. It is not clear, based on these data alone, whether infants learned on-line during the modeling phase how objects with specific parts move or whether they brought such knowledge to the laboratory. However, there are two reasons to reject the former interpretation in favor of the latter. First, previous research by Rakison (2005) has shown that infants at 18 months generalize linear and nonlinear motions to objects with the appropriate parts (e.g., nonlinear motion to a cat and a table) even when an ambiguous exemplar was the model; that is, when no information was provided about the identity of objects that move linearly or nonlinearly. Second, the 16-month-olds demonstrated the linear and nonlinear motions with the objects with legs and wheels regardless of whether the model exemplar possessed those features or not; however, they generalized the motions to objects without legs and wheels only when the model exemplars also did not have those features. This suggests that the 16-month-olds had associated legs with nonlinear motion and wheels with linear motion based on their experience prior to coming to the task.

How might the modeling phase contribute to infants' enhanced categorization performance? The present data suggest that modeling may first serve to attract infants' attention to the objects, highlight that there are two different things displayed, and then induce categorization of other objects that are similar in surface appearance. Thus when an adult displays to infants a moving (or static) dog and car, infants may interpret this act in terms of "These are things that are different" and take this as a cue to seek out other objects that are similar to them. Waxman (2003) has proposed a similar process involving labels whereby they serve as invitations to form new categories and concepts. Likewise, the claim here is that the act of emphasizing two discriminable objects to infants may encourage infants to search for two different categories. I also suggest, however, that presenting two exemplars may be a more powerful cue to categorize than labels because infants are provided with perceptual information about the basis for categorization. Labels do not, in and of themselves, provide any information about the basis for categorization whereas example category members do. Regardless, the current experiments show that there is a relationship between induction and categorization in infancy, and as such they support the notion that even by the 2nd year of life infants' concepts may start to provide – though not necessarily maximize - inductive potential (Anderson, 1991; Heit, 2000).

More broadly, the data reported here support the view that infants' concepts for animals and vehicles are grounded on surface features and relations between those features and particular motion characteristics (Rakison, 2003, 2005; Quinn & Eimas, 1997). Infants at 16 months of age grouped together animals and vehicles when the exemplars of each category shared parts, but they did not group together animals without such shared parts; that is, they did not treat animals without legs or vehicles without wheels as "same kind of thing". These findings are inconsistent with the view that specialized processes, mechanisms, or modules allow infants in the first year of life develop concepts that include abstract qualities of objects' motion – such as agency, path of motion, and self-propulsion—that are unrelated to their surface appearance (Gelman, 1990; Mandler, 1992, 2003).

According to these views, infants' perception of surface features cues conceptual knowledge about the category membership and properties of an object, and it is this conceptual knowledge that acts as the basis for categorization and induction. However, if infants did possess such abstract concepts of animacy or inanimacy they would have been expected to group together, and perform appropriate inductive inferences for, animals and vehicles regardless of their appearance. This was not the case in the current experiments. Researchers who adopt this perspective (e.g., Mandler, 2003) could argue that the categories without shared parts were sufficiently unprototypical as to not trigger the appropriate conceptual knowledge. This argument cannot be refuted given the current data. Nonetheless, the animal stimuli without shared parts, for example, possessed many features typical of animals (e.g., facial features, wings, curvilinear body); from my perspective, the onus is on these researchers to specify which features are crucial and which are not and to provide a justification for why certain features would not cue the appropriate conceptual knowledge.

Finally, it is worth noting that the methodology employed may prove fruitful in future studies on infants' categorization and induction. Previous research with the sequential touching paradigm has provided insight into infants' spontaneous categorization for thematic, taxonomic, and even gender-based domains (e.g., Levy, 1999; Mandler et al., 1991; Oakes et al., 1997. Rakison & Butterworth, 1998a, 1998b): Research with the more recently developed inductive generalization paradigm has presented evidence on infants' production of actions and motions (Mandler & McDonough, 1996; Rakison, 2005). The experimental procedure used here, which combines these two methodologies, has the potential to be applied to equally important areas of early concept and category development. It allows researchers simultaneously to investigate infants' categorization of a variety of domains as well as their ability to learn about the properties of objects within those domains. The experiments reported here are the first to show that categorization and induction in infancy are based on the same mental representations and that there is a strong relation between these processes.

In summary, the three experiments reported here used a novel methodology to show that functional object parts act as the basis for categorization and induction at 16 months of age and even as young as 12 months of age. The experiments also reveal that 12-month-olds have little knowledge about the motion properties of objects, 16-month-olds have associated specific object parts with those properties, and 20-month-olds have generalized from object parts to other, as yet unspecified, features. The experiments support the view that early concepts of objects and entities that involve motion properties are grounded in surface features rather than an abstract notion of animacy or inanimacy. As such, they are consistent with the view that domain-general associative learning, rather than specialized processes, can account for how early object concepts are formed.

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