Studies in Inductive Inference in Infancy

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Imitation of events was used to explore the inductive generalizations that 14-month-olds have made about animals, vehicles, and household artifacts. In Experiment 1 infants generalized domain-specific properties such as drinking to animals but not to vehicles, whereas they generalized domain-neutral properties such as going into a building to exemplars from both domains. The next four experiments showed that infants tend to interpret animal events very broadly, for example, construing a dog merely as a land animal rather than as a differentiated kind in its own right. Infants were somewhat more selective in their construals of vehicles. Experiment 6 showed that 14-month-olds also generalize “basic-level properties” very broadly. For example, they chose a pan to demonstrate drinking almost as often as a cup and fed a bone to a bird as often as to a dog. By 20 months, their selections narrowed appropriately for artifacts, but were still overgeneralized for natural kinds. The experiments indicate that infants tend to generalize their early experiences broadly across domains, often across exemplars that have a variety of different surface characteristics. The data suggest that it is the conceptual meaning of objects, rather than their physical features, that controls early associative learning.

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In our explorations of concept formation in infancy we have found that between the ages of 7 and 11 months, infants form global concepts of animals, vehicles, furniture, plants, and utensils (Mandler, 1998; Mandler & McDonough, 1993; 1998). However, little is yet known about the content or limits of these concepts. About the most we can say is that many of them...
seem relatively undifferentiated. For example, on the various categorization and inferencing tasks we use, infants rarely make distinctions among different kinds of land animals or among different kinds of furniture, utensils, and plants (Mandler, 1998; Mandler, Bauer, & McDonough, 1991; Mandler & McDonough, 1996). The one exception is that on some (but not all) tasks, infants distinguish not only cars and airplanes, but also make a distinction between cars and motorcycles (Mandler et al., 1991; Mandler & McDonough, 1993).

We know that infants can distinguish the perceptual differences among subclasses of animals and furniture. Eimas and Quinn (1994) and Quinn, Eimas, & Rosenkrantz (1993) found that when 3-month-olds are shown pictures of horses, they rapidly form a perceptual category that distinguishes them from zebras and giraffes, and when shown pictures of cats they form a perceptual category that distinguishes them from dogs and tigers. In a similar fashion, Behl-Chadha (1996) has shown that 3-month-olds can perceptually categorize tables and chairs. It is assumed that at this young age this kind of categorization takes place solely on the basis of schematizing of visual patterns and does not imply that infants have formed concepts of horses or tables in the sense of having a notion of what a horse is or how tables are used. Other kinds of evidence are needed to show conceptual differentiation above and beyond seeing the difference in appearance of different kinds.

Our initial studies of the growth of conceptualization used two categorization tasks. One is the object-examination task (Mandler & McDonough, 1993; Oakes, Madole, & Cohen, 1991). In this task infants are familiarized one at a time with little models of real-world objects from one category and then given a dishabituation test in which amount of time spent examining an item from a new category is measured. The other is the sequential-touching task (Mandler et al., 1991; Sugarman, 1983) in which a number of models of real-world objects from two categories are presented simultaneously to infants. Although before about 2 years of age infants do not spontaneously sort such objects, the extent to which they respond categorically can be assessed by comparing runs of touches to items from the same category to chance levels of responding. On both of these tasks, when domain-level (superordinate) contrasts such as animals and vehicles are used, perceptual appearance of the exemplars varies so much that we have assumed that the reason infants categorize them is more apt to be due to some conceptual notion of likeness than to physical likeness. For example, 7- to 11-month-olds categorize animals as different from vehicles even when the animals consist of a varied collection of land, air, and sea creatures and the vehicles vary widely as well. Similarly, infants also differentiate birds and airplanes

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1 We use the term "domain" to refer to large superordinate categories, such as animals, plants, vehicles, and furniture, because if infants do not differentiate them the term superordinate category does not seem appropriate.
when all the exemplars have outstretched wings and a high degree of percep-
tual similarity (Mandler & McDonough, 1993).

However, it is difficult to rule out completely the possibility that the basis
for the categorization is not a conceptual notion of likeness, but instead re-
sponse to some surface perceptual differences. For example, Behl-Chadha
(1996) found that 3-month-olds categorized pictures of mammals as different
from birds, although she did not test the wider range of animals that we have
used, and the infants in her study did not clearly differentiate mammals from
either fish or furniture (p. 129). Nevertheless, her data suggest that there
are some common parts or surface characteristics among mammals (perhaps
mouths or fur) that infants could be using to categorize them. Similarly, Van
der Walle, Spelke, and Carey (1997) showed that 8-month-olds are respon-
sive to the curvilinear vs rectilinear differences that tend to characterize ani-
imals vs artifacts, suggesting that within some still unknown limits perceptual
solutions can be found for some fairly broad categories. If this is the case,
then the categorical behavior could be accounted for without regard to mean-
ing. It seems desirable, therefore, to have other tests of early concept forma-
tion.

One of the most important functions of concepts is their use in making
inferences. All people, whether adults or infants, can make only a limited
number of observations of events in the world. From these observations they
must make generalizations about which things are the same kinds and
whether various properties they observe in these samples are generalizable
or not. It seemed to us, therefore, that the breadth of the inferences that
infants have made about different kinds of things would provide the best
evidence for the kinds of concepts they have formed. For example, if infants
have formed a global concept of animals that differs from vehicles, they
should attribute properties and behaviors to animals that are different from
those they attribute to vehicles. Furthermore, if the inferences are conceptu-
ally based they should assign these properties to all animals, rather than
just to those that are perceptually similar to the exemplars upon which the
inferences were initially made.

Furthermore, at any age perceptual factors may be used to categorize objects, especially
if these factors are emphasized and/or meaning is deemphasized. For example, Waxman &
Markow (1995) used the same object-examination test we used in Mandler & McDonough
(1993) and found that 12-month-old infants categorized cows as different from dinosaurs but
were not responsive to the differences between animals and vehicles. However, they gave
only half the number of familiarization trials we used. Since other investigators have confirmed
our finding of categorization of animals and vehicles on the object-examination task before
12 months of age (Oakes, Coppage, & Dingel, 1997) we suspect the different performance
of the infants in Waxman and Markow (1995) was due to this change in technique. Giving
only four exemplars of a category, as they did, should be sufficient to allow perceptual categori-
ization of highly perceptually similar items (such as cows), but apparently is insufficient for
the more challenging task of understanding that items with a variety of different surface charac-
teristics are all members of a domain-level (superordinate) category.
The technique we have been using to explore inductive generalizations in infancy is imitation. We model an event, such as giving a little model of a dog a drink from a cup. We then give the infant the cup but instead of the dog we give the infant two new objects, such as a bird and an airplane. Then we see which of these items the infant uses to imitate drinking. This technique, which we call generalized imitation, allows us to vary the contrasts provided and thus test different levels of generality of knowledge. For example, after showing a dog drinking, we might provide the infant with a different dog and a cat instead of a bird and a plane to see if infants would also respect this finer distinction when they generalize.

The imitation technique relies on two facts about infant behavior. First, infants imitate spontaneously and do not need instructions to do so. Second, their imitations are determined by what they have understood from their observations. For example, they will not imitate everything a model does, even when capable of performing the actions; in particular they do not imitate events they do not understand or think are incorrect (Killen & Uzgiris, 1981; Mandler & McDonough, 1996). At the same time, if they do imitate the model they tend to match the model’s behavior. For example, Bauer and Dow (1994) found that toddlers would generalize from one object to a related one when imitating an event, but when given a choice they preferred to use the original object that had been used by the model. Therefore, if we provide various objects, the ones infants choose to carry out their imitations give us information about how they have interpreted the modeled event. Thus, in addition to enabling an assessment of the generalizations infants have made about different domains and their subclasses, imitation provides a way for preverbal infants to communicate how they have construed the events they observe.

Since generalized imitation is a relatively new technique, it is worthwhile illustrating this point in detail by outlining some hypothetical contrasts and possible responses to them. For example, assume that infants watch us give a dog a drink. We then provide the infants with another dog and a cat. If they choose the dog over the cat, they are telling us they have watched a dog being given a drink. If, on the other hand, they equally often choose the cat as the dog, they are telling us they have watched an animal being given a drink or perhaps a land animal being given a drink. Assume further that we repeat the experiment but this time we provide the infants with another dog and a bird. Now if the infants give the bird a drink as often as the dog, they are telling us they have watched an animal being given a drink. On the other hand, if they now tend to prefer the dog over the bird, they are telling

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3 It may be noted that when familiar events such as drinking are used this technique assesses knowledge infants have already acquired rather than induction on the spot. We assume, however, that the acquisition of such knowledge, whether in or out of the lab, takes place on the basis of inductive generalization from the observations infants have made.
us they have watched a land animal being given a drink. In this way it is possible to home in on how infants have construed the modeled event: as a dog drinking, as a land animal drinking, or more generally still, as an animal drinking. (We leave open here how infants might define any of these categories, but return to this issue in the discussion. Here we are mainly concerned with the breadth of the categories that infants are using to interpret the events they observe.)

Because only a few contrasts can be provided in any one experiment, to answer these kinds of questions requires an extensive program of research. In our first set of experiments using this method (Mandler & McDonough, 1996) we began by asking how broadly 14-month-olds have generalized the common animal properties of drinking and sleeping and the common vehicle properties of being keyed and providing transportation. We asked this question first because almost nothing was known about what 1-year-olds think animals and vehicles are or how broad or narrow their generalizations might be. For example, 1-year-olds have seen people sleep and perhaps a dog or cat sleep as well. How far have they generalized these properties? Similarly, 1-year-olds have seen keys used to open and start cars and are familiar with being carried about in cars. How far have they generalized these characteristics of automobiles?

The traditional story about infants’ inductive generalizations is that they are determined solely by perceptual similarity; what Quine (1977) termed an animal sense of similarity and Keil (1991) referred to as original sim. Infants see a dog drink and generalize that association to all dogs because dogs look alike. Thus, the stop rule for the generalization is either the boundary of the dog category or a similarity gradient around the particular dog seen. That is, things looking like the dog will be assumed to drink, but as things become perceptually less similar the inference will become less certain or not be made at all. Gradually with experience, infants observe cats and other animals (and of course people) drink and so eventually make the less perceptually bound and therefore more difficult inductive leap of assuming that all animals drink. According to this view, the very concept of animal is assumed to be created by the accumulation of these associative inferences (e.g., Eimas, 1994). However, this assumption does not make clear why infants should stop at the boundary of the animal domain. Because surface similarity to dogs lessens steadily as one moves through the animal domain from mammals to birds and fish, if one has no other idea of what an animal is but that it drinks, there is no principled basis to say when surface similarity is no longer enough to allow the generalization to be made; one might stop making the generalization too soon and assume that birds do not drink or one might generalize too broadly and assume that any never-before-encountered object will drink.

When we began our studies on this topic, there were almost no data to assess this traditional view. However, it did not seem to fit well with our
categorization work, especially in the animal domain. On our object-examination tests infants between ages 7 and 11 months categorized animals as different from vehicles, but did not treat dogs differently from other mammals (Mandler & McDonough, 1993). Even in the second year we found no distinctions being made between dogs and horses or rabbits. It seemed to us that infants knew that animals differed from vehicles but were not certain that, let alone how, one kind of animal differed from another. This suggested that they might generalize more broadly than at the level of dog or cat.

In our first three experiments (Mandler & McDonough, 1996) we used the generalized imitation technique to assess the boundaries of the concepts of animals and vehicles that infants have formed. We found that no distinctions were being made within either the animal or the vehicle domains. When we modeled drinking or sleeping on a dog, infants generalized these behaviors to other mammals as well as to fish and birds, and when we modeled keying a car or giving a ride, infants generalized these behaviors to motorcycles and airplanes. They showed the same generalization regardless of the extent to which the test exemplar physically resembled the model. For example, even though dogs look more like rabbits than like birds, when we modeled giving a dog a drink infants just as often gave a bird or a fish a drink as a cat or a rabbit. When we modeled keying a car, infants just as often keyed a motorcycle or an airplane as a truck. At the same time they rarely gave a vehicle a drink or put a key to an animal. Thus, no matter what exemplars we provided, infants demonstrated the relevant action on any other exemplar of the correct domain and stopped at the domain boundary. This was true even for associations that infants would only have observed with the modeled “basic-level” class. For example, in the realm of vehicles infants have only seen cars being opened or started with keys, but they generalized keying to all vehicles, including motorcycles and airplanes. In a second experiment, we found that infants showed the same pattern of generalization when tested with exemplars they had never seen before, such as an anteater and a forklift. Drinking was generalized to anteaters but not to forklifts, and keying was generalized to forklifts but not to anteaters. In a third experiment, we used a more stringent test by modeling actions on inappropriate exemplars (e.g., giving a car a drink). We found that even when encouraged to imitate inappropriate behavior infants did not do so.

These results, along with similar findings for 9- and 11-month-olds (McDonough & Mandler, 1998), suggest that infants are generalizing observed properties across entire domains. It appears that when infants see a dog eat, they make an association not just between dogs and eating but between animals and eating. Or, when infants see a car being keyed, they make an associ-

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4 The only clear-cut differentiation we have found before 11 months is the life-form distinction between dogs and birds (Mandler & McDonough, 1998).
ation not just between cars and keys but between vehicles and keys. This finding is the opposite of what has traditionally been assumed, and so it seems worthy of further test, in particular, to investigate whether there are other category boundaries that affect generalization as well as domain-level (superordinate) ones. The present article reports a number of such tests.

In the first experiment, we ask whether 14-month-old infants always restrict their generalizations to the domain to which the modeled object belongs. It is possible that no matter what we modeled, infants would have chosen an exemplar from the same domain for their imitations. If so, they might not be demonstrating knowledge of domain-specific properties, such as eating, but instead would merely be demonstrating a limitation on imitative behavior itself. Although limiting imitative behavior to the modeled domain would show categorical knowledge, it is not the same as recognizing the domain-specific appropriateness of the modeled actions. Therefore in Experiment 1, we tested both domain-specific and domain-neutral properties on the same objects. By domain-neutral, we refer to properties appropriate for both animals and vehicles, such as going into a building. This experiment also allowed a different test from that used in Mandler and McDonough (1996) to show that infants are not merely following the lead of the experimenter but are treating the little models as representations of real-world objects. If infants treat the same objects differently depending on whether they are acting out a domain-specific or domain-neutral property, that tells us they are not merely mimicking whatever the experimenter does, but are expressing knowledge they have learned about the world.

Following this experiment we report four experiments designed to assess further the generality of the concepts 14-month-olds are using to construe the modeling events. In these experiments we model events appropriate to animals using a dog and provide infants different choices in different experiments, but all from the animal domain. In each experiment another dog is provided with either a cat, rabbit, bird, anteater, or muskox. We also model events appropriate to vehicles using a car and provide infants different choices in different experiments, but all from the vehicle domain. In each experiment another car is provided, with either a truck, motorcycle, airplane, forklift, or shovel. As discussed above, infants’ first choice of object to use for their imitations provides information as to how they have construed a modeled event. We can also examine their second choices, which tells us whether they are willing to generalize further the property in question. In these four experiments all the test exemplars come from the same domain and so the demonstrated properties are appropriate for all the objects used. However, depending on their construal, infants might restrict their generalizations to the same subcategory as the one used by the experimenter, or freely generalize to other exemplars from the same domain. Thus, these experiments begin to map out the boundaries of the concepts of animals and
vehicles that 14-month-olds are using when they interpret events such as those we model.

All the properties we examined in these experiments are appropriate either to an entire domain or to more than one domain. Experiment 6 turns to the issue of whether infants restrict any of their associations to “basic-level” classes when it is actually appropriate to do so. For example, when do infants learn the specialized uses of particular kinds of furniture, such as that beds but not bathtubs are used for sleeping, or behavior specific to particular animals, such as that dogs but not birds chew on bones? If we are correct that the earliest concepts are global in nature, infants might well overgeneralize the properties specific to particular subclasses to other members of the domain in the same way that we have seen they generalize more widespread properties such as drinking. We made this prediction in part on the basis of finding that infants overgeneralize keying to airplanes and forklifts even though they have not observed these vehicles being keyed (Mandler & McDonough, 1996). If they make this kind of overgeneralization then we might expect to find the same overgeneralization of properties that are specific to particular subclasses.

EXPERIMENT 1

In our first experiments on inductive generalization (Mandler & McDonough, 1996), we found that when infants were given a choice of objects to use to imitate a model, they generalized to all exemplars from within a domain, even unfamiliar ones, but did not generalize to exemplars from another domain. Furthermore, when we modeled inappropriate behavior for a given domain such as giving a car a drink, infants would not imitate us even when we gave them the exact object that was used in the modeled event (Mandler & McDonough, 1996). We took these findings to mean that infants based their imitations on their conceptualizations of the world. The failure to imitate inappropriate behavior in particular is not amenable to a perceptual explanation because if the infants were only attempting to match the modeled behavior as closely as possible, they should have been willing to imitate when the identical object was provided. The present experiment was conducted to demonstrate the conceptual basis of inductive generalization in another way, namely by using the same animals and vehicles to test imitation of behavior that is appropriate either for only one domain or appropriate for both. If infants generalize one kind of behavior to both a horse and a train...
engine but restrict another kind of behavior only to the horse, it is difficult
to account for this differential performance in terms of a train engine not
looking like a horse.

Therefore, we tested 14-month-olds’ knowledge of domain-specific vs
domain-neutral properties. This is an interesting question in its own right.
Have 14-month-old infants learned the difference between “essential” and
“accidental” properties? Have they learned that some properties are exclu-
sively associated with a single domain and others with more than one do-
main? In this experiment we tested two domain-neutral properties, going
into a building and being washed, and compared infants’ imitations of these
properties with two of the domain-specific properties, drinking and keying,
we had previously studied.

We measured both first and second choices of objects that the infants
made. The first choice provides information about how infants understood
what had been modeled. For example, if they watched a dog being washed,
they presumably would understand this either as a dog being washed or more
generally as an animal being washed and so choose an animal for generaliza-
tion rather than a vehicle. If, on the other hand, infants often washed the car
as their first choice, this would suggest that when infants imitate they are
less constrained by what they have observed than by their world knowledge.
Although the answer to this question is important to the interpretation of the
experiments to be reported later, for present purposes we were also interested
in whether infants made a second choice. For example, if an infant went on
to wash the vehicle after washing the dog, this would indicate that the infant
believed that washing is appropriate for vehicles as well as animals. Thus
the second choices tell us whether the domain boundaries constrain imitation
of domain-neutral properties as we found they do for domain-specific proper-
ties (Mandler & McDonough, 1996).

Method

Participants. Thirty-two infants participated. Their mean age was 14 months, 13 days
(range: 14 months, 0 days to 14 months, 27 days). Sixteen infants were tested on domain-
neutral properties and 16 were tested on domain-specific properties. An equal number of fe-
males and males were included in one group and the other group contained 9 females and 7
males. Participants were recruited from an existing pool of volunteer parents who had re-
sponded to advertisements in local newspapers. A small toy was given to the infants for their
participation. An additional 2 participants were tested but not included in the final analyses
due to experimenter error.

Objects and properties tested. Participants were tested on either domain-neutral or domain-
specific properties. The domain-neutral properties were being washed and going inside. They
were demonstrated by wiping off a small replica of a vehicle or an animal with a flat, yellow
spoon and by putting the exemplar inside a nondescript building through a large open door
on one side. Half the participants in the domain-neutral group observed the experimenter wash
either a sedan or a pick-up truck with the sponge and place either a German shepherd dog or
a pig in the building. The remaining half saw the experimenter wash the dog or the pig with
the sponge and place the sedan or truck in the building. The actions were accompanied by
appropriate vocalizations: “Wash, wash, all clean” for the washing property and “Go inside” for the going-inside-a-building property. The domain-specific properties were drinking and being keyed. These properties were modeled by putting a little cup to the face of the dog or the pig while saying, “sip, sip, umm, good” and by touching a key to the side of the sedan or the truck while saying “vroom, vroom.” The test exemplars were the same for both groups. Each test pair was composed of one animal and one vehicle. The test animals were a lamb and a horse. The test vehicles were a train engine and a three-wheeled all-terrain vehicle. Each exemplar served equally often as a test for each property (domain-neutral and domain-specific) and was paired equally often with each exemplar from the contrasting domain. The order in which the properties were modeled and assignment of modeling and test exemplars were counterbalanced.

Procedure. Participants were invited into a laboratory set up as a playroom. After a brief warm-up period they were seated either in a child’s seat or in the parent’s lap across the table from the experimenter. Parents were asked not to assist their infants in any way throughout the sessions. Two warm-up tasks, designed to accustom the participants to the imitation procedure, were administered prior to the generalization task. Both were exercises in hammering an object. In the first task, one pipe was fitted into another and a plastic hammer was used to pound them tightly together with the accompanying vocalization “bam, bam, bam, all fixed.” In the second warm-up, the experimenter put two large Lego pieces together and hammered them with the same vocalization. Participants were encouraged to imitate both actions and were praised for doing so.

Participants’ demonstrations of the properties were evaluated twice, once before the properties were modeled (baseline) and again after they were modeled (generalization).

Baseline. Before each property was modeled, participants were given both test exemplars (e.g., lamb and train) and the prop used to demonstrate the target action (e.g., sponge). The experimenter determined the amount of time for baseline exploration on the basis of whether the infant was still actively engaged with the objects. If an infant ignored any of the three objects, the experimenter would point it out saying “Look, did you see this one?” When the infant stopped responding to the objects, the experimenter took them away. The prop was left on the table and the test exemplars were placed out of sight. The experimenter then brought out the modeling exemplar (e.g., the dog) and demonstrated the target action with the prop (e.g., the sponge) three times with the appropriate vocalization (“Wash, wash, all clean”). The experimenter then removed the dog from the table so that it could no longer be seen.

Generalization test. The test exemplars (in this case, the lamb and train) were brought back and simultaneously placed on either side of the infant (with side counterbalanced). The experimenter then handed the prop (in this case, the sponge) to the infant while repeating the vocalization. The experimenter then waited until the infant no longer responded to the objects before removing them. This procedure continued until each infant had been tested on both domain-neutral or on both domain-specific properties.

Scoring. Each session was videotaped in this and the following experiments. Participants were coded for performance (or nonperformance) of the modeled actions and the exemplar they used. For the domain-neutral properties, washing was scored when an infant touched the sponge to an item. Going into the building was scored when the infants put an item through the doorway. For the domain-specific properties, drinking was scored when the infants touched the lip of the cup to an item. (Putting the item in the cup was not counted.) Keying was scored when the infants touched an item with the key. If a participant used both test exemplars to demonstrate the properties, the coder noted which was chosen first. The agreement between two coders in each of the experiments was based on every infant tested and was very high throughout, ranging from 95 to 100%. The few disagreements were resolved by a third coder. Coders were blind to the hypotheses of the experiment, but not to the acts that were modeled (they were obvious given the props that were being used and the infants’ own actions during the test).
Results

Two primary measures were analyzed. The first measure consisted of the participants’ first choice of object to use for imitating the target properties. To examine the breadth of their generalizations we used the sum of the first and second choices. (We did not enter first and second choices separately into a single analysis because not all participants made second choices.) We also calculated the conditional probability of making a second choice of the object from the nonmodeled domain, given that the first choice was to the same domain as modeled.

We first examined the two groups separately because not only did the properties differ for the two groups but there were two appropriate choices for the domain-neutral group and only one appropriate choice for the domain-specific group. We then compared the two groups directly. The first analysis was conducted on the first choices of the domain-specific group, using an analysis of variance (ANOVA) for repeated measures with Domain (appropriate or inappropriate) as the within-subject factor. The dependent measure was the number of properties demonstrated (range = 0 to 2). For purposes of comparing data across measures and conditions we report this and other measures in the form of percentages. The ANOVA showed that participants generalized the domain-specific properties more often to the appropriate (41%) than to the inappropriate (9%) domain, \( F(1, 15) = 9.62, p < .01 \). A second ANOVA was carried out on the summed first and second choice measure. Significantly more appropriate (44%) than inappropriate (18%) items were used in the imitations the infants carried out, \( F(1, 15) = 10.00, p < .01 \). Thus, as found in our previous research (Mandler & McDonough, 1996), infants tended to restrict their generalizations of the domain-specific properties to the appropriate domain. Drinking was generalized to other animals and keying was generalized to other vehicles.

Next we examined the domain-neutral group to see if they too would restrict their imitations to exemplars from the domain used for the modeling. An ANOVA was carried out on the first choice data with Domain (same domain, contrasting domain) as the within-subject factor. This analysis showed that participants used the same domain item (40%) more often than the contrasting domain item (16%) in their imitations, although this difference did not quite reach significance, \( F(1, 15) = 3.00, p = .10 \). In addition, the analysis of the summed first and second choices showed that participants made almost as many choices to the contrasting domain (44%) as they made to the modeled domain (53%), \( p = .27 \). Thus, in contrast to the domain-specific properties, the domain-neutral properties were frequently generalized across both domains. For example, if participants saw ‘‘going inside’’ modeled on a dog, they often generalized the action first to another animal and then to the vehicle. The preference for the modeled domain in the first choice data indicates that they attended to the modeling item and attempted
to reproduce the modeling event as closely as possible given the choices available to them. The second choice data showed that they understood that the contrasting domain was also appropriate for these properties.

The different patterns of generalization found for domain-specific and domain-neutral properties are illustrated in Fig. 1 (using the summed first- and second-choice data). As can be seen in this figure, generalization to an exemplar from the same domain was similar for both groups. However, generalization to an exemplar from the contrasting domain (which would be inappropriate for the domain-specific group and merely contrasting for the domain-neutral group) was much different. An ANOVA comparing the two groups showed that significantly more generalizations of the domain-neutral properties were made to the contrasting domain (44%) than generalizations of the domain-specific properties to the inappropriate domain (18%), $F(1, 30) = 6.32, p < .05$.

Finally, we examined second choices for those participants who initially chose the test item from the same domain as modeled. The conditional proba-
bility of making a second choice, given that they had initially chosen the same domain, was calculated. The probability for the domain-specific group was .18, whereas for the domain-neutral group it was .78. This difference is significant, \( t(18) = 3.79, p < .01 \). Thus, participants in the domain-neutral group who matched the domain used for modeling in their first choice were highly likely to generalize to the other domain, whereas the participants in the domain-specific group who made a correct first choice were much less likely to generalize to the other domain. The two contrasting patterns occurred even though the modeling and test exemplars were the same for both groups.

**Baseline and salience measures.** In this and in each of the following experiments, baseline performance was significantly less than generalization. In the present experiment, participants did not demonstrate either domain-specific property at baseline with the inappropriate items (0%), but they also did not demonstrate them significantly more often with the appropriate items (6%). The domain-neutral properties were demonstrated at baseline approximately as often on the animals (28%) as the vehicles (22%). The data were also examined in terms of which exemplars participants used to demonstrate the domain-neutral properties both at baseline and test. No domain or exemplar preferences were found, although going inside was demonstrated more frequently than washing (going inside \( M = 59\% \); washing \( M = 14\% \)), \( t(15) = 3.74, p < .01 \).

**Discussion**

These data replicate the findings of Mandler and McDonough (1996), showing that 14-month-olds have already learned various properties associated with the domains of animals and vehicles and generalize them appropriately. In addition, the present data show that 14-month-olds have differentiated domain-specific properties such as drinking or keying from domain-neutral properties such as going inside or being washed. The data also confirm that imitation is an appropriate technique for assessing the conceptual generalizations infants have made. If infants were merely attempting to reproduce what the experimenter had modeled without respect to their conceptual knowledge about the world, they should have shown the same patterns of imitation for the domain-neutral properties as for the domain-specific ones. Instead, they treated these two kinds of properties differently and representationally appropriately in that they tended to restrict their imitations of the domain-specific properties to the correct domains, but imitated the domain-neutral properties on exemplars from both domains.

At the same time the results show that infants do not solely rely on their world knowledge when imitating; they do try to reproduce what they have seen. Thus, if they watch washing an animal, their first choice is not washing a vehicle but washing another animal, even though their second choices show they consider both actions appropriate. This finding suggests that it is impor-
tant to measure second choices as well as first ones when using this technique to assess the breadth of infants’ categorical knowledge. Infants will tend to reproduce what they have understood from the modeled event when they first imitate it, even though the available choices do not allow them to do so exactly. So it is by their second choices that they tell us how far they think properties can be generalized. The remaining experiments make use of these two characteristics of infants’ imitative behavior.

The next four experiments examine whether there are circumstances under which infants do restrict domain-specific generalizations to smaller classes than the superordinate domain itself. In our previous work (Mandler & McDonough, 1996) we inferred a lack of influence of subclasses in the inductive process because we found all-or-none generalization across entire domains. But we did not specifically pit a member of the same subclass against a member of a different subclass. For example, when we modeled a property with a dog and tested generalization of that property with a rabbit and a bus, infants chose the rabbit. But we did not test generalization of that property to another dog vs a rabbit. Perhaps if we modeled a property with a dog and for the test gave the infants another dog and a rabbit or a cat, they would prefer to use the other dog for their imitations.

As we have just seen in Experiment 1, when the choices available to the infant cross domain boundaries, and the property being demonstrated is domain-specific, infants make relatively few second choices. However, if the infant is provided with more than one exemplar from within the same domain, it would be reasonable for them to use both objects to demonstrate domain-specific properties. If so, we can obtain more detailed information about how infants are construing the modeling events. For example, when infants have seen a dog drink, and they are presented with a choice of a dog or a cat, if they choose the dog or the cat equally often for their imitation this suggests that they have construed the modeling event as an animal (or perhaps a land animal) being given a drink. On the other hand, if they consistently choose another dog for their imitations that tells us that they have conceptualized the modeling event as a dog being given a drink. However, even though they have understood that it was a dog being given a drink, they might go on to give the cat a drink as well. Such behavior would suggest that they know that drinking is appropriate for other animals as well as for dogs.

EXPERIMENT 2

In this experiment we modeled animal properties on a dog and tested these properties on another dog vs a cat. We also modeled the same properties on a cat and tested them on another cat vs a dog. In addition to these animal contrasts, we modeled vehicle properties on a car and tested them on another
car vs a motorcycle. We also modeled the same properties on a motorcycle and tested them on another motorcycle vs a car.

Method

Participants. Thirty-two infants took part in this experiment. Their mean age was 14 months, 12 days (range = 14 months, 1 day to 14 months, 29 days). Participants were obtained from the same source as in Experiment 1 and were given a small gift for their participation. They were randomly assigned to two groups in order to counterbalance the stimuli used for modeling and for imitation. Each group had 16 participants with equal numbers of males and females.

Properties tested. Each subject was tested on four properties: two appropriate to animals and two appropriate to vehicles. The animal properties were drinking from a cup and sleeping. Drinking from a cup was modeled in the same way as in Experiment 1. Sleeping was modeled by putting the dog (or cat) in a little bed while saying, "Night, night." The vehicle properties were using a key, as modeled in Experiment 1, and giving a child a ride. This was modeled by placing a little doll, who was in a seated position, on top of a replica of a car (or motorcycle) and scooting it with the accompanying vocalization, "Whee, go for a ride." Animal and vehicle properties were tested in alternating order with half the participants in each group receiving one of the animal properties first and half receiving one of the vehicle properties first. The particular animal or vehicle property used first was also counterbalanced.

Both groups received the same test exemplars. The animal properties were tested on a dog (terrier or collie) and cat (tabby or Persian); the vehicle properties were tested on a car (Jeep or Ferrari convertible) and motorcycle (all-terrain vehicle or motorscooter). Once baseline was assessed, the test exemplars were put away. The experimenter then brought out the modeling object. For one group, the modeling objects were a German shepherd dog and a station wagon. For the other group, the modeling objects were a Siamese cat and a Kawasaki motorcycle. After the modeling exemplars were put away, generalization was assessed by bringing out the test exemplars (the dog and cat or the car and motorcycle), placing them to each side of the infant, and handing the infant the prop with accompanying vocalization (e.g., "night, night"). The particular animals and vehicles used as test items were counterbalanced for the two groups (e.g., whether the test dog was a terrier or a collie). Scoring for drinking and keying was carried out in the same way as for Experiment 1. Sleeping was scored if an infant put a test exemplar in the bed, and giving a ride was scored if an infant put the doll on top of a test exemplar. Again, scoring took place from videotapes. In this experiment coders were not only blind to the hypotheses under test but also to the exemplar used for modeling (dog or cat, car or motorcycle). Reliability was again calculated for every subject and exceeded 98%.

Results

As for Experiment 1, two primary measures were analyzed: the participants’ first choice of object to use for imitating the target properties and the sum of their first and second choices. Means for first choices for the animal properties are shown in the leftmost columns of Fig. 2A. These columns show the percentage of first choices of the same basic-level category as used in modeling (whether dog or cat) and of the other basic-level category (i.e., the one not used for modeling). Means for first choices for the vehicle properties are similarly displayed in the leftmost columns of Fig. 3A.

Data for these choices were entered into an ANOVA with Model (dog and car as modeling exemplars; cat and motorcycle as modeling exemplars) as the between-group factor and Domain (animal, vehicle) and Category
FIG. 2. Experiments 2 through 5: Generalization of animal properties. (A) First choices and (B) summed first and second choices.
FIG. 3. Experiments 2 through 5: Generalization of vehicle properties. (A) First choices and (B) summed first and second choices.
(same category, contrasting category) as the within-subject factors. A main effect for Domain, \( F(1, 30) = 13.71, p < .001 \), showed that participants demonstrated more of the animal properties (\( M = 42\% \)) than the vehicle properties (\( M = 30\% \)). The infants performed approximately the same number of actions with the exemplar from the same basic-level category (\( M = 39\% \)) as with the exemplar from the contrasting category (\( M = 33\% \)). This difference was not significant (\( p = .34 \)) nor did this factor significantly interact with domain (\( p = .27 \)). Thus, for neither animals nor vehicles did the participants show a strong preference for using the modeled category for their imitations. The Model factor also was not significant (\( p = .55 \)), indicating the infants responded the same regardless of which stimuli were used for modeling.

Next the summed first and second choice measure was analyzed. A pattern similar to the results of the first choice data was found, as can be seen in Figs. 2B and 3B. A main effect for Domain, \( F(1, 30) = 22.88, p < .001 \), indicated that more animal (63\%) than vehicle (37\%) properties were generalized. Infants performed approximately the same number of actions on the same category exemplar (53\%) as on the contrasting category exemplar (47\%), \( F(1, 30) = 1.47, p = .24 \). No interaction between Domain and Category was found (\( p = .22 \)). Thus, in this experiment basic-level category boundaries did not significantly influence generalization of either the animal or vehicle properties. The infants generalized widely beyond the modeled category for both first and second choices.

We also examined the conditional probability of choosing a contrasting category as a second choice, given that the first choice was to the same basic-level category as the modeling exemplar. When participants first generalized a property to the same basic-level category, 37\% of the time they went on to generalize it to the contrasting basic-level category as well. This result is markedly different from our previous work in which we studied the same four properties but contrasted whole domains (animals vs vehicles) instead of subdivisions within domains (Mandler & McDonough, 1996, Experiment 1). In that experiment, when participants generalized to a test exemplar from the same domain as the model, they made second selections from the other domain only 13\% of the time. The difference in these conditional probabilities was significant, \( t(40) = 2.47, p < .05 \), again indicating the greater tendency of infants to choose other exemplars from within the same domain than to cross domain boundaries.

Baseline and salience analyses. Baseline for the animal properties was 21\% and for the vehicle properties 13\%, which did not significantly differ. Neither were there significant differences among the exemplars within domains. In addition to these analyses, \( \chi^2 \) tests were conducted to see if there were any preferences for the properties. No significant differences between drinking and sleeping were found nor were there differences between keying and riding.
Discussion

We know that 14-month-olds can distinguish the difference between dogs and cats as well as between cars and motorcycles, but when imitating events they have observed, they act as if these differences were unimportant. When we modeled an appropriate property with a dog and gave the infants a choice between another dog or a cat they were just as likely to choose the cat as the dog. In the same way, when we modeled an appropriate property with a cat they were just as likely to imitate it with a dog as with another cat. This result supports the hypothesis based on our prior categorization work that even by the second year, infants still treat many (or all) land animals as equivalent (Mandler et al., 1991; Mandler & McDonough, 1993). The infants appeared to construe the events they observed in which dogs or cats took part as land animals (or perhaps merely as animals) drinking and sleeping. Similar results were found for the car–motorcycle contrast with infants not seeming to distinguish clearly between cars and motorcycles when they watched them being keyed or giving rides.

At the same time, Fig. 3 suggests somewhat more selectivity in the vehicle domain. We have found inconsistent data on this issue in the past. Using the object-examination test we found that 7- to 11-month-olds categorized cars and motorcycles as different (Mandler & McDonough, 1993), whereas using the more difficult sequential-touching test, toddlers did not make this distinction until 24 months of age (Mandler et al., 1991). Therefore, it seemed advisable to replicate Experiment 2 with another vehicle contrast to assess the generality of the results. We included another animal contrast as well.

EXPERIMENT 3

This experiment tested two animal properties that were modeled on a dog and tested on another dog vs a rabbit, and two vehicle properties that were modeled on a car and tested on another car vs a truck.

Method

Participants. Sixteen infants (8 females and 8 males) were seen when they were 14 months of age (mean = 14 months, 12 days; range = 14 months, 1 day to 14 months, 27 days). Participants were recruited from the same source as in Experiment 1 and were given a small gift for their participation. All participants who were tested were included in the analyses.

Properties tested. Again, each subject was tested on four properties, drinking and sleeping for animals and keying and giving a ride for vehicles. A German shepherd and a station wagon were used for the modeling. To test the animal properties, the exemplars were a terrier or a poodle and a jack rabbit or a domestic rabbit. To test the vehicle properties, the exemplars were a VW beetle or a Ferrari convertible and one of two pick-up trucks.

Procedure. The same procedure was followed as in Experiments 1 and 2. Following two warm-up tasks, baseline for the first event was assessed by giving the participants the opportunity to manipulate the text exemplars and prop (e.g., a poodle, a rabbit, and the bed). Then
the test items were put away and the modeling object (e.g., German shepherd) was brought out. The experimenter modeled the first event (putting the German shepherd in the bed). Generalization was then assessed by bringing back the poodle and rabbit, placing them to each side of the subject, and handing the subject the bed with the accompanying vocalization ("night, night"). This sequence was then repeated until all four events had been tested. The order of the modeling events was counterbalanced.

Results

Again, the two primary measures were the participants’ first choice of object to use for imitating the target properties and the sum of their first and second choices. For both measures, repeated-measure ANOVAS were used with the within-factors of Domain (animal, vehicle) and Category (same category, contrasting category).

Means for the first choice data are shown in the second set of columns in Fig. 2A for animals and Fig. 3A for vehicles. There was a significant interaction between Domain and Category, $F(1, 15) = 4.92, p < .05$. Just as for the previous experiment, infants were not significantly more likely to choose the same-category test exemplar over the different-category exemplar when demonstrating the animal properties; indeed, the mean choice of the dog (28%) was actually lower than choice of the rabbit (47%), although this difference was not significant ($p = .28$). However, in this experiment, the infants did imitate the vehicle properties with the same category exemplar ($M = 53\%$) significantly more often than with the contrasting category exemplar ($M = 16\%$), $F(1, 15) = 6.43, p < .05$. Thus, the nonsignificant tendency to prefer the same basic-level category in the vehicle domain found in the previous experiment was significant in the present experiment. This result suggests that the infants construed the event as a car being keyed or giving a ride (as opposed to a more general construal of, say, a four-wheeled road vehicle).

Means for the summed first- and second-choice data are shown in Figs. 2B and 3B. There was a main effect for Category, $F(1, 15) = 7.50, p < .01$, indicating that more imitations were made using the same category (63%) than the contrasting category (50%). Although the interaction between Domain and Category was not significant, as it had been in the first choice data, the Category main effect appeared to be primarily due to participants demonstrating more of the vehicle actions on the same category item (59% vs 38%), whereas they demonstrated the animal properties equally often to both categories (66% vs 63%). Because of this apparent disparity and also because of our previous work suggesting earlier differentiation of the vehicle domain (Mandler & McDonough, 1993), we analyzed animals and vehicles separately. As the means suggested, the tendency to do more imitation with the same category exemplar than with the contrasting category exemplar was significant for vehicles, $F(1, 15) = 4.62, p < .05$, but not for animals ($p = .77$). As can be seen in Figs. 2 and 3, in a fashion similar to the first-choice data, participants generalized animal properties to different basic-level cate-
gories in the animal domain, but preferred to stay within the same basic-level category when generalizing in the vehicle domain.

We also again examined the conditional probability of choosing a contrasting category as a second choice, given that the first choice was to the same basic-level category as the modeling exemplar. Similar to the results of Experiment 2, when participants first generalized a property to the same basic-level category, 41% of the time they went on to generalize it to the contrasting basic-level category as well. Again, this finding can be contrasted with the 13% conditional probability found when the contrasting category came from another domain (Mandler & McDonough, 1996). The difference in these conditional probabilities was significant, $t(28) = 4.34, p < .01$.

Baseline and salience analyses. Baseline for the animal properties was 21% and for the vehicle properties 11%, a nonsignificant difference. Baseline scores did not differ for the two exemplars within each domain. For example, there was no preference for either the rabbit over the dog or the truck over the car to account for the choice of the modeled basic-level category during the test trials.

Discussion

The data for the animal domain confirm the results of Experiment 2. Just as they did not discriminate between dogs and cats in their imitations in that experiment, infants did not discriminate between dogs and rabbits in the present one. This result supports the hypothesis based on our prior categorization work (Mandler et al., 1991; Mandler & McDonough, 1993; 1996) that even by the second year, infants still treat many (or all) land animals as equivalent. However, a different pattern of responses was obtained with vehicles. When we modeled an appropriate property with a car, the infants were more likely to use another car than a truck for their imitations. Thus, the infants showed that the difference between cars and trucks matters to them in a way that the difference between dogs and rabbits does not. This result too is consistent with the tendency (albeit an insignificant one) in Experiment 2 for infants to be more selective in the vehicle domain, as well as with our earlier categorization findings that infants (at least in urban southern California) are sensitive to at least some differences among different kinds of vehicles (Mandler & McDonough, 1993).

It is important to note, however, that even though the infants preferred to use the same basic-level vehicle category for their imitations, they not infrequently generalized to both. This kind of response indicates that the

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6 The same nonsignificant tendency to demonstrate more animal characteristics in baseline was also observed in Experiment 2 and happened again in Experiment 4. It is accounted for by a slightly lesser tendency to put the toy doll on top of the vehicle. This action was a little clumsy for the infants to perform and although they did so frequently following modeling, they did it somewhat less often spontaneously.
infants construed the modeling vehicle specifically as a car, rather than merely as a vehicle; nevertheless, they did generalize their responses to a truck as well. Thus, the present data suggest that 14-month-olds have progressed further in developing meaningful distinctions in the vehicle domain than in the animal domain, where conceptual distinctions among land animals still appear to be lacking in infants’ interpretations of events.

EXPERIMENT 4

The data described so far suggest that 14-month-olds are generally not yet making any conceptual distinctions among dogs, cats, and rabbits. On the other hand, there is evidence from other object-manipulation tasks that infants do make a distinction between air and land animals (Mandler et al., 1991; Mandler & McDonough, 1998). Therefore, in order to see if any animal distinctions are being made insofar as imitation is concerned, we repeated Experiment 3, contrasting dogs with birds and cars with airplanes. This contrast in the animal domain is a life-form contrast and should be quite salient, and the comparable contrast in the vehicle domain should be as well. We modeled the animal properties on a dog and tested generalization on another dog vs a bird. Similarly, we modeled the vehicle properties on a car and tested them on another car and an airplane.

Method

Participants. Sixteen participants, 8 females and 8 males, were tested when they were 14 months of age (Mean: 14 months, 12 days; range: 14 months, 1 day to 14 months, 25 days). Participants were obtained from the same source as in Experiment 1 and were given a small gift for their participation.

Procedure. The animal and vehicle properties tested in Experiments 2 and 3 were used again. Animal properties were modeled on a dog and tested on another dog and a bird. Vehicle properties were modeled on a car and tested on another car and an airplane. Participants’ demonstrations were tested at baseline (before the actions were modeled) and at generalization (after the actions were modeled). As in the previous experiments, participants were not allowed to manipulate the modeling exemplars at any time.

Results and Discussion

The results contrast with those of Experiments 2 and 3, in that stronger preferences for the same “life-form” category were found. Participants preferred to generalize both the animal and vehicle properties to the same category as the modeling exemplars, and for the vehicle properties they were less likely to cross the land-air boundary even for their second choices.

First choices were entered into an ANOVA for repeated measures with Domain (animal, vehicle) and Category (same category, contrasting category) as within-subject factors. Percentages for these data can be seen in the

7 We put “life-form” in quotes because there is no comparable term for vehicles.
third set of columns in the left half of Figs. 2 and 3. A main effect was found for Category, $F(1, 15) = 37.87, p < .001$, indicating that participants performed more actions with the same-category exemplar (66%) than with the contrasting category exemplar (6%).

Analyses using both first and second choices showed a similar pattern of results (see the right portion of Figs. 2 and 3). As found for the first choice data, there was a main effect of Category showing that more generalizations were made to the same than the contrasting category (71% vs 27%), $F(1, 15) = 38.68, p < .001$. In addition, a main effect of Domain was found showing that participants demonstrated more animal (61%) than vehicle properties (36%), $F(1, 15) = 7.50, p < .05$. Although there were more choices from the same category than from the contrasting category for both animal and vehicle properties, 44% of the participants’ choices in the animal domain were for the contrasting category, whereas only 9% were for the different category in the vehicle domain. This difference is significant, $F(1, 15) = 7.35, p < .05$. Finally, although more animal properties were demonstrated in baseline (17%) than vehicle properties (6%), this difference was not significant.

These data suggest that 14-month-olds make a life-form distinction in the animal domain in the sense that birds are not considered as acceptable a substitute for dogs as are cats and rabbits. As found in Mandler and McDonough (1996), infants are willing to generalize drinking and sleeping across the entire domain, as shown by their frequent second choice of the bird. Nevertheless, when it is available to be used, they make a distinction between land and air animals. When these data are considered in conjunction with Experiments 2 and 3, in which no distinction was made between dogs, cats, and rabbits, it suggests that the infants were interpreting the modeled event as happening to a land animal, not to any kind of animal.

The data also indicate that 14-month-olds make an even sharper distinction between cars and planes in that our participants were less likely to cross the land–air boundary than they were for animals. Again, they did cross this boundary for their generalizations in Mandler and McDonough (1996) when they watched a car being keyed, for example, and were given a choice between an airplane and an animal for their imitations. In the present experiment, however, when given the narrower choice between cars and planes they rarely generalized from one to the other. Thus, a distinction between land and air vehicles shows up consistently from about 7 months onward on the object-manipulation test (Mandler & McDonough, 1993) and the sequential-touching test (Mandler et al., 1991) as well as on the generalized imitation test.

**EXPERIMENT 5**

In our prior work on inductive generalization (Mandler & McDonough, 1996; McDonough & Mandler, 1997) we found that 9-, 11-, and 14-month-
olds generalized drinking and sleeping to models of new animals such as anteaters that they had never seen before and also generalized keying and riding to models of vehicles such as forklifts that they had never seen before. Such generalization shows that infants recognize new exemplars in both of these domains. For example, an infant does not need to have seen an anteater to understand that anteaters drink.

However, we have seen in the present experiments that infants can be more selective when they are given a choice between exemplars from within the same domain than when they are given a choice only of an exemplar from one domain and an exemplar from another domain. The question arises as to just how readily they generalize to novel instances. For example, if they observe a familiar animal drinking, will they be less likely to generalize their imitation to one they have had no experience with than to one with which they have some acquaintance? In the present experiment we used as test items an exemplar from the same basic-level category as the model and a novel exemplar from the same domain. Specifically, we modeled drinking with a dog and tested generalization with another dog vs an anteater and a muskox. We also modeled keying a car and tested generalization with another car vs a shoveler and a forklift.

Method

Participants. Eight participants, 5 females and 3 males, were tested when they were 14 months of age (Mean: 14 months, 15 days; range: 14 months, 1 day to 15 months, 21 days). Participants were obtained from the same source as in Experiment 1 and were given a small gift for taking part in the experiment.

Procedure. The procedure followed in Experiments 2, 3, and 4 was used again. The animal properties of drinking and sleeping were modeled on a dog and tested on another dog and either an anteater or a muskox. The vehicle properties of riding and keying were modeled on a car and tested on another car and either a shoveler or a forklift. Participants’ imitations were tested at baseline (before the actions were modeled) and at generalization (after the actions were modeled).

Results and Discussion

On the generalization test trials, first choices were entered into an ANOVA for repeated measures with Domain (animal, vehicle) and Category (same category, contrasting category) as the within-subject factors. Although infants tended to generalize more often to the same category (41%) than to the contrasting category (28%), this difference was not significant, \( F(1, 7) = 0.30, p = .60 \). Domain was not a significant source of variance \( (p = .35) \) nor did it interact with Category. Thus, infants performed similarly when choosing animals or vehicles. They chose the dog 44% and the novel animal 32% of the time. They chose the car 38% and the novel vehicle 25% of the time.

Analyses using both first and second choices showed that generalization was made equally often to the same and contrasting category (60% vs 56%), \( F(1, 7) = 1.0, p = .35 \). The domain factor was marginally significant (\( F(1, \))
7) = 3.94, p = .09) with more animal (65%) than vehicle properties (44%) being performed. However, again there was no interaction between Category and Domain, indicating roughly equivalent generalization in both domains. For animals infants chose the dog 75% of the time and the novel animal 56% of the time. For vehicles, they chose the car 44% of the time and the novel vehicle also 44% of the time.

Baseline ANOVAs indicated that participants were more likely to spontaneously perform the target action with the familiar dog and car (38%) than with the novel animals and vehicles (25%), $F(1, 7) = 7.00, p < .05$. Thus, the infants may have more readily recognized that dogs drink and sleep and that cars are keyed and used for riding; however, after modeling they did not limit their generalizations to dogs and cars. As found in both the first choice data and the summed first and second choice data, they generalized the properties to both familiar and novel exemplars.

We used a smaller sample in this experiment because it was a replication of two previous experiments showing that infants both the same age and younger are willing to imitate using novel exemplars they have never seen before (Mandler & McDonough, 1996; McDonough & Mandler, 1998). The main point of the present experiment was simply to show that infants do not generalize imitation just because they have observed the particular instances in the past. Infants haven’t seen anteaters sleep or forklifts being keyed. They had the clear choice of using another example of the familiar animal or vehicle that they observed in the modeling, but fairly often did not do so in either domain. We conclude that infants have indeed generalized properties such as drinking and sleeping to all animals and keying and giving rides to all vehicles, not just to the exemplars they have observed in the past. Furthermore, they display this kind of inductive inference on their first encounter with new exemplars. One interesting aspect of Experiment 5 is that for vehicles there was more generalization to the novel exemplar than was shown in Experiments 2 to 4, when the choices were all familiar. We do not know why this occurred, although it is possible that the infants enjoyed making a novel instance conform to the category norm.

EXPERIMENT 6

We have seen that infants make broad generalizations in both the animal and vehicle domains, frequently showing they are willing to attribute various properties to all members of a domain. At the same time they do make some finer distinctions, especially in the vehicle domain when the various instances are familiar ones. The properties we have tested to date were appropriate for all instances of a domain (or beyond, in the case of the domain-neutral properties tested in Experiment 1). The question arises, then, have 14-month-olds learned any properties that are less general? Specifically, have they
learned any “basic-level properties” such as that dogs chew on bones but birds do not?

It is widely assumed that basic-level concepts are the first to be formed (e.g., Mervis & Crisafi, 1982). Our categorization and generalization work calls this view into question in the sense that we have shown global concepts of animals and vehicles from as early as 7 months and also that in a number of domains few if any distinctions are made within these global concepts. In infants up to 2 years of age we see little differentiation of basic-level categories within land animals, furniture, utensils, or plants (e.g., Mandler et al., 1991; Mandler & McDonough, 1998). Furthermore, in our previous generalization work (Mandler & McDonough, 1996), we found overgeneralization of animal properties such as drinking to fish and generalization of vehicle properties such as keying to forklifts. If we are correct in our assumption that many early concepts are global in nature, then we should expect basic-level properties, such as that dogs chew bones, to be overgeneralized as well.

The present experiment tested this hypothesis. We chose four properties that are associated with specific classes of objects, two from the natural realm, and two from the artifactual realm. In each case we studied whether infants confined their imitations of the property tested to the particular class that they had observed. We tested whether infants generalize eating bones from dogs to geese, sniffing flowers to sniffing trees, drinking from a cup to drinking from a frying pan, and sleeping in a crib to sleeping in a bathtub. If generalized imitation is based only on what infants have actually observed (and not on the inductive generalizations they have made), then one would expect such basic-level properties to be constrained by basic-level category boundaries. In this experiment we tested 20-month-olds in addition to 14-month-olds.

Method

Participants. One group of 14-month-olds (N = 12; mean age = 14 months, 10 days; range = 14 months, 2 days to 14 months, 27 days) and another group of 20-month-olds (N = 12; mean age = 19 months 13 days; range = 18 months, 0 days to 23 months 0 days) took part in the experiment. Participants in each group were balanced for gender. Participants were obtained from the same source as in Experiment 1 and were given a small gift for their participation.

Procedure. The same procedure was followed as in the previous experiments. Four basic-level properties were tested. Two of these properties are associated with natural kinds (dogs and flowers) and two are associated with artifacts (cups and beds). The dog property was chewing a bone. It was modeled by placing a dog bone on the table and moving the dog (German shepherd) to it, placing its mouth on the bone and moving the dog’s head back and forth as if it was chewing on the bone. Test objects were a different dog (beagle) and a goose. Sniffing a flower was modeled by placing a single-stemmed rose to the nose of an adult doll who acted as the prop for this action. The test objects were a daisy and a nonflowering tree with distinctive trunk, branches, and leaves. Drinking was modeled by placing a teacup to the mouth of a doll (the prop) and tested with a coffee mug and frying pan. Sleeping was modeled
by placing a baby doll (the prop) in a crib and patting it. Test objects were a bed with a headboard, footboard, and blanket and a bathtub with a faucet. Each property was modeled with appropriate vocalizations (‘Give him a bone’ plus a gnawing sound, a sniffing sound, ‘sip, sip,’ and ‘night, night’). As in the previous experiments, baseline was assessed by giving the participants the opportunity to manipulate the test exemplars and props. Once baseline was assessed, the test exemplars were put away. The experimenter then brought out the modeling object. The property was modeled three times with the accompanying vocalizations. After the modeling exemplar was put away, the test exemplars were returned to the table and simultaneously handed to the subject (one to the participants’ right side, the other to the left). The prop was then handed to the subject with the vocalization (e.g., ‘night, night’).

Results

In this experiment we again analyzed first choices and also the summed first and second choices. However, because there are clearly appropriate and inappropriate choices in this experiment, we emphasize first choice data somewhat more than we did in the prior experiments in which (with the exception of the domain-specific group in Experiment 1) both choices were correct. The number of participants’ first choices was entered into a mixed-design ANOVA with Age (14 and 20 months) as a between-group factor and Property (natural, artifact) and Category (appropriate, inappropriate) as within-subject factors. A main effect was found for Property, $F(1, 22) = 15.47, p < .001$, showing that significantly fewer natural properties than artifact properties were demonstrated (23% vs 40%). This finding was qualified by an interaction with Age, $F(1, 22) = 6.04, p < .05$. Follow-up analyses showed that this difference was significant for the 14-month-olds (13% vs 40%), $F(1, 11) = 22.40, p < .01$, but not for the 20-month-olds (34% vs 40%).

There was also a marginally significant interaction between Age and Category, $F(1, 22) = 2.84, p = .10$. This interaction suggested that 14-month-olds did not discriminate between appropriate and inappropriate categories, whereas the 20-month-olds did, and so follow-up analyses were carried out. These analyses indicated no effect for Category for the 14-month-olds; at this age, participants imitated the basic-level properties using the inappropriate exemplars (26%) as often as they did using the appropriate exemplars (28%). For example, they gave the bone to the goose as often as to the dog and demonstrated drinking with a frying pan as often as with a coffee mug. In contrast, there was a significant effect for Category for the 20-month-olds; the appropriate category was chosen 53% of the time, whereas the inappropriate category was chosen only 21% of the time, $F(1, 11) = 4.84, p = .05$. This difference suggests that the correct associations between the properties and their associated basic-level categories had been learned. However, as can be seen in Fig. 4, these associations were learned primarily for the artifact properties, not the natural properties. This conclusion is confirmed by the analysis of the summed first and second choice data.
FIG. 4. Experiment 6: Generalization of basic-level properties using the first choice data.

The data on the summed first and second choices were entered into an ANOVA with Age (14 months, 20 months) as the between-subjects factor and Property (natural, artifact) and Category (appropriate, inappropriate) as within-subject factors. Main effects for Category ($F(1, 22) = 11.36, p < .01$) and Property ($F(1, 22) = 10.30, p < .01$) were found as well as a significant interaction between them, $F(1, 22) = 5.42, p < .05$. Subsequent analyses showed that the interaction was due to significantly more imitations being made with the appropriate (73%) than inappropriate exemplars (38%) for the artifact categories, $F(1, 22) = 12.25, p < .01$, but not the natural properties (38% vs 30%), $F(1, 22) = 0.19$. An interaction was also found between Property and Age, $F(1, 22) = 5.25, p < .05$. The 20-month-olds imitated more natural properties than the 14-month-olds (48% vs 19%; $p < .01$), whereas no differences due to age were found for the artifact properties (57% vs 54%; $p = .76$).
Baseline and salience analyses. Baseline for the natural properties (10%) was significantly lower than for the artifact properties (23%), \( F(1, 22) = 6.66, p < .05 \). However, baseline scores for demonstrating the properties on appropriate and inappropriate exemplars did not differ significantly (appropriate = 20%, inappropriate = 14%). There was only a marginal effect of age, with 14-month-olds spontaneously demonstrating 11% of the properties and the 20-month-olds demonstrating 22%, \( F(1, 22) = 3.96, p = .06 \). We also examined the data for differences between the two properties within the natural and artifact categories. The \( \chi^2 \) analyses revealed no significant differences. Participants were as likely to demonstrate chewing a bone as sniffing and sleeping as drinking.

Discussion

The results of this experiment show that 14-month-olds overgeneralize some common properties that are associated with the basic-level concepts of dogs, flowers, cups, and beds. They may or may not have observed dogs chew on bones, but they have certainly observed people drinking from cups and mugs. Nevertheless they have generalized drinking to frying pans. The data strongly suggest that infants at this age have learned more general associations than those specific to basic-level classes. That is, they know about eating food and drinking from containers rather than eating specific kinds of food or drinking from culturally approved containers. These data are consistent with our previous observation that infants have seen people keying cars, but they generalize this property to many other vehicles, such as fork-lifts (Experiment 5; also Mandler & McDonough, 1996). What is particularly interesting about these data is their implications for the principles governing associations. If infants observe drinking from cups but associate it with other containers they have not seen being used for drinking such as a frying pan, this again suggests that it is rather global meanings that are controlling the associations that are formed.

By 20 months, infants have begun to restrict some of their associations to basic-level concepts. However, this restriction appears to be operative primarily in the domain of artifacts rather than for natural kinds. They now realize that people drink from cups rather than pans and sleep in beds rather than bathtubs. However, they still seem quite uncertain about which animals chew on bones or whether one sniffs flowers or maple trees. We do not know the reason for the discrepancy between learning about the realms of artifacts and natural kinds, but we are currently testing more properties to see if the difference is a pervasive one.

It may be noted that it was not easy to find behaviors uniquely associated with specific basic-level classes, let alone ones that 14-month-olds are apt to know. There are not a great many behaviors uniquely associated with individual animal kinds (e.g., rabbits eat carrots but so do people and horses).
The functional properties associated with various artifacts can often be carried out with other artifacts (e.g., hammering a nail into a wall with the heel of a shoe). Nevertheless, the behaviors studied in Experiment 6 are closely, even though not uniquely, associated with particular basic-level kinds. Even if infants were to observe someone drink from a frying pan, the data suggest that by 20 months infants have begun to learn the cultural and other restrictions that make people typically drink from cup-containers rather than pan-containers. In any case, 14-month-olds would be even less likely to have experienced the “inappropriate” behaviors used in this experiment than the 20-month-olds; therefore, any lack of uniqueness of the appropriate basic-level properties is probably irrelevant to the overgeneralization the younger infants showed in demonstrating them.

GENERAL DISCUSSION

This series of experiments used the technique of generalized imitation to explore the knowledge base that year-old infants have built up about animals and vehicles. This technique takes advantage of the fact that when infants imitate they try to reproduce what they have observed. Because we do not give the infants the exact objects used for modeling but instead provide a range of other objects from which they can choose for their imitations, we can use their choices to assess how they have interpreted the modeled events. Serendipitously, when more than one appropriate object is available infants often imitate more than once. Their first choice indicates the closest available approximation to what they have understood by the modeled event. If they make a second choice that indicates that they consider the other object a possible substitute as well. Thus, the technique both assesses how infants have interpreted the event and provides information about how far they are willing to generalize the appropriateness of the modeled behavior.

In our previous work (Mandler & McDonough, 1996; McDonough & Mandler, 1998) we modeled events such as drinking that are associated with animals and events such as keying that are associated with vehicles. We tested whether 9-, 11-, and 14-month-olds were willing to generalize from animals to vehicles or vice versa. We found that they were not; they would use any animal we provided for an animal event and any vehicle we provided for a vehicle event, but would rarely use an exemplar from the inappropriate domain for their imitations. In the first experiment in the present study we replicated this finding and contrasted it with domain-neutral behavior such as being washed, which was appropriate to both domains. When domain-neutral properties were tested, the infants behaved quite differently. They still tended to choose an exemplar from the same domain as that used for modeling for their first choice, but they frequently went on to demonstrate the behavior with the exemplar from the other domain as well, much more
so than they had done in the previous experiments studying domain-specific properties. This finding indicates that by 14 months infants are already differentiating appropriate and inappropriate behavior for animals and vehicles. They understand that it was, say, an animal being washed, but demonstrate their knowledge that vehicles are washed as well. Thus, they first try to match what they have seen and then imitate more broadly. The results from these studies are also important because they show that infants do indeed rely on their real-world knowledge when they imitate and do not simply imitate whatever the experimenter does. This selectivity is shown not only in their differential response to domain-specific and domain neutral properties but also in their unwillingness to imitate something they consider to be incorrect (Mandler & McDonough, 1996; Experiment 3).

In the next four experiments, we studied appropriate behavior within each domain separately in order to determine more exactly how infants interpreted the modeled events. We modeled events such as a dog drinking and provided infants with another dog and a cat, rabbit, bird, or unfamiliar animal such as an anteater. Similarly we modeled events such as keying a car and provided infants with another car and a motorcycle, truck, airplane, or unfamiliar vehicle such as a forklift. Here we found different behavior for the animal and vehicle domains. In the animal domain the infants did not prefer one land animal over another, even for their first choices. They were as likely to choose the rabbit or cat as the dog to reproduce the modeled event of a dog drinking. On the other hand, they did prefer the other dog to a bird; in this case their first choice was more often the dog. Nevertheless, they still frequently went on to demonstrate the bird drinking as a second choice. In the vehicle domain, the infants were for the most part more selective. When imitating a car giving a ride or being keyed, they preferred to imitate first using another car rather than a truck, although this preference was weak when the contrasting category was a motorcycle or an unfamiliar exemplar. They were even more selective when the contrast was between a car and a plane. Here they nearly always chose the other car and rarely used the plane even as a second choice.

This discrepancy in treatment of animals and vehicles is consistent with other data we have collected from categorization tasks in the first year (Mandler & McDonough, 1993). Infants, at least in our urban southern California sample, make finer categorical distinctions in the vehicle domain earlier than they do for animals. We have speculated that the more rapid accumulation of information about vehicles is due to infants’ experience with a greater variety of kinds of vehicles than kinds of animals, but we do not have any direct evidence that this is what accounts for the difference. Indeed, this hypothesis would be more plausible if infants also differentiated kinds of furniture, with which they have had even more experience and a good deal of variety, but on our categorization tasks do not do so (Mandler & McDonough, 1998). It may be that a combination of familiarity and attentive
interest in moving objects accounts for the earlier differentiation of the vehicle domain.

One might also speculate that the present data could be explained by infants imitating only what they have seen in the past. They have seen both dogs and cats drinking and so are as likely to imitate using a cat as a dog when we modeled a dog drinking. They are less likely to have seen birds drinking and so are less likely to choose the bird over the dog. They are most likely to choose a car because they have seen cars keyed, for example, more than they have seen motorcycles keyed, and they have never seen an airplane keyed. Although this kind of explanation is superficially attractive, there is other evidence that makes it unlikely to be the case. When infants imitate they initially try to reproduce what they have seen (provided it makes sense to them) rather than what they know in general. Experiment 1 showed that when both choices were appropriate, infants nevertheless chose to match what was modeled before going on to the other object. Thus, when they saw a car being washed they washed another vehicle before washing an animal. In addition, Experiment 5 showed that infants often chose an unfamiliar animal such as an anteater even for their first animal imitations and similarly often chose an unfamiliar vehicle such as a forklift for vehicle imitations. So it cannot be that they choose a cat as often as a dog simply because they may have seen both drink. They have not seen anteaters drink but still are willing to use an anteater to imitate drinking even as their first choice. Furthermore, we have a similar finding from two other experiments; in both Mandler & McDonough (1996) using 14-month-olds and McDonough & Mandler (1998), using 9- and 11-month-olds, there was no difference in amount of generalized imitation using familiar and novel test exemplars.

In short, it does not seem to be the case that infants choose objects for their imitations on the basis of whether they have seen these objects engage in the behavior in the past. Rather they attempt to reproduce what the experimenter has shown them. The fact that they are fairly unselective as far as land mammals are concerned strongly suggests that they are not clear that there are any important differences among them. Thus, these results support the view that infants are indifferent to whether they use a dog, cat, or rabbit to imitate an event modeled with a dog because they consider them all to be the same kind of thing. They can see the perceptual differences among these items, but their imitations are based on their conceptual interpretations of what they have observed, not the physical appearance of the items per se. This point is sometimes difficult for adults to appreciate because we are so used to thinking of dogs, cats, and rabbits as different kinds of animals. But there is little difference in principle between our considering both a kitchen and a dining chair to be the same kind of thing and an inexperienced infant considering a dog and a cat to be the same kind.

The point that infants imitate what they have understood from a modeled event, rather than what they have observed more generally in the past, is
brought home by Experiment 6. Here so-called “basic-level” properties were tested, such as that one drinks from cups, not frying pans, and that dogs eat bones but birds do not. We have claimed that even at 14 months infants still have hazy ideas about the differences among subclasses of animals, plants, and furniture (along with somewhat more knowledge about different kinds of vehicles). If this is the case they should be just as likely to generalize these highly specific properties as properties more widely distributed across a domain. Experiment 6 shows they do exactly that at 14 months for both natural and artifact properties, and even at 20 months they are still quite likely to inappropriately generalize natural properties. We find this particularly convincing evidence that infants are using large domains as their initial conceptual structure and make their generalizations on the basis of domain limits rather than on the particular subclass that they observe. Thus, they generalize that all animals drink. This result could be due to seeing more than one kind of animal drink. However, because they also generalize that birds chew bones and people sleep in tubs, they may not need to observe more than one kind to make such broad generalizations. This hypothesis needs specific testing, but is certainly suggested by the data from Experiment 6, showing the breadth of generalizations that infants make even about properties they have observed on only one basic-level category. In addition to these data, we found a similar result in our earlier work (Mandler & McDonough, 1996; McDonough & Mandler, 1998), in which infants generalized keying cars, which they have observed, to keying all other vehicles, which they have not.

We believe these data convey an important message about the way infants form associations. The data indicate that property association and generalization are controlled not by the features of objects that infants have actually observed or by perceptual similarity per se, but instead are controlled by the concepts that infants have formed. In the initial stages the boundaries of these concepts are very broad. The world has been divided into a few global domains of different kinds of things. The meaning of these broad classes, such as animals or vehicles, does not arise from commonality of physical features; rather it arises from how such objects behave in events. We have suggested that the first concept of animal, for example, is something that moves in a “biological” way, starts itself, and engages in contingent interaction with other objects (Mandler, 1992; see also Bertenthal, 1993; Legerstee, 1992; Molina, Spelke, & King, 1996; Poulin-Dubois, Lepage, & Ferland, 1996). Similarly, a first concept of vehicle might be something that moves in a “mechanical” way and starts only when people get in or on it and that carries people around. A great deal of research will be needed to determine the details of these early concepts, but the point we are making here is that it is these or similar meanings that are controlling the associative learning, not the features of the objects themselves. That is, physical features and
characteristic behaviors become associated with each other (e.g., mouths with eating) via the meaning of the class as a whole.

Babies do learn the common features of objects, of course. Indeed, features are necessary for recognizing exemplars, both old and new. Infants can do this even in categorization tasks in which the models are not taking part in events. We assume that from a fairly early age infants pick out the individual features of mouths and legs, wheels and windows. These features become associated with the roles that animate things play in events and wheels and windows become associated with the roles that inanimate things play (Nelson, 1985), and so these features can be used to identify objects even when they are not engaging in their customary activities. But recognizing new exemplars of a category is not the same thing as understanding what a category means nor does using learned features for identification purposes imply that it is those features that are the basis for making inferences about new category members.

Thus, even though infants use various physical features to tell animals such as dogs and cats apart (Mandler & McDonough, 1998; Quinn et al., 1993), they do not rely on them to construe the meaning of an event or generalize from it. As we have seen, infants do not restrict the associations they make to basic-level classes. The fact that infants are as apt to choose a cat as a dog to demonstrate an association modeled on a dog is one illustration of this principle. Here are some others. Two of the airplanes we have used in our studies have a Flying Tiger face, but our infants do not feed them. The association is not between mouths and feeding but between animals and feeding. We have already mentioned the example of our infants using a key on forklifts and airplanes, associations which they have never observed. Their personal experience of keys with vehicles has usually been confined exclusively to cars. So it cannot be a feature such as a door or an ignition that constitutes the meaning of ‘‘vehicle’’ for the young infant. Whatever that meaning is, it is what is fixing the limits on generalization, not the various physical properties themselves. And infants presumably have not seen people sleeping in bathtubs or drinking from frying pans, yet they generalize broadly to these pieces of furniture and containers.

It is not infrequently suggested to us that because animals look different from vehicles that our various categorization and inferencing results can be explained solely on perceptual grounds without recourse to meaning or conceptual knowledge. Although animals typically do look more like each other than they look like vehicles, by itself this does not constitute a comprehensive theory of how perceptual similarity predicts and explains our various

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If similarity is judged completely without regard to meaning, this statement is clearly not without exception. A model of a bird with outstretched wings looks more like a model airplane than like a dog, and a turtle looks more like a VW car than like a bird.
results. Domain-wide generalizations about animals that shift abruptly as the domain boundary is crossed (Mandler & McDonough, 1996) would suggest something like categorical perception, which to our knowledge occurs only for a few physical dimensions such as hue, not to objects as wholes. Nor can perceptual similarity explain the results of Experiment 1, in which the very same objects were treated differently depending upon whether the property being modeled was conceptually appropriate to one or both. This is not to deny that perceptual similarity influences the likelihood of making a generalization; it often does, particularly within conceptual domains when there may be little else to rely on; rather we emphasize that attempting to explain our data by perceptual similarity alone becomes theoretically unparsimonious. Medin expressed a similar view when he noted that trying to describe category structure in terms of similarity is useful only to the extent that we specify “which principles determine what is to count as a relevant property and which principles determine the importance of particular properties. It is important to realize that the explanatory work is being done by the principles which specify these constraints rather than the general notion of similarity” (Medin, 1989, p. 1474).

In summary, our results indicate that the traditional view that the earliest inductive generalizations occur solely on the basis of common parts or physical similarity and therefore take place at the basic level will have to be modified. It does not appear to be the case that infants first generalize at the basic level on the basis of physical appearance and then go on to generalize more abstractly to the domain level. On the contrary, as far as the domains of animals and vehicles are concerned, infants generalize very broadly at first. The data also suggest that they learn to narrow down their inferences to the basic level as they gain more experience and that this differentiation takes place in the vehicle and other artifactual domains earlier than in the animal domain for the population we have studied.

Finally, we would like to suggest that the tendency to first conceptualize a domain very broadly on the basis of a few highly general properties and then use the boundaries set by those properties to generalize how exemplars of that domain behave is both a plausible and efficient way to build up a conceptual knowledge base. Infants observe events from birth. We have suggested that they first make some very general categorizations of the large number of objects they see, such as dividing them into things that move in a biological way and interact contingently with other objects versus those things that either don’t move at all or if they do, move in a very different way and do not interact with other objects. If infants begin conceptualizing animate and inanimate things in some such general way, this would allow them to learn rapidly the other characteristics of these broad domains. Such conceptualizations would emphasize the roles that objects take in events rather than what objects look like. Although it would lead to some mistakes, on the whole this procedure would be productive and would allow infants
to flesh out their knowledge of the characteristic behaviors of animals and artifacts rapidly and economically.

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