Words and Shape Similarity Guide 13-month-olds' Inferences about Nonobvious Object Properties

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Abstract

We examined the influence of shape similarity and object labels on 13-month-old infants' inductive inferences. In two experiments, infants were presented with novel target objects with or without a nonobvious property, followed by test objects that varied in shape similarity to the target. When objects were not labeled, infants generalized the nonobvious property to test objects that were highly similar in shape (Expt. 1). When objects were labeled with novel nouns, infants generalized the nonobvious property to both high shape similarity and low shape similarity test objects (Expt. 2). These findings indicate that infants as young as 13 months of age expect those objects which share the same shape or the same label to possess the same nonobvious property.

Introduction

Inductive reasoning involves invoking the premise that things that are true for one member of a category (e.g., the blue ball bounces) will hold true for other members of the same category (e.g., therefore all balls bounce; Moore & Parker, 1989). The ability to reason inductively is an invaluable cognitive skill, allowing an individual to generalize knowledge to new instances and new situations. In recent years, a great deal of empirical attention has been devoted to examining preschoolers' inductive reasoning abilities, with particular focus on the nature of the categories that guide their inferences. In a typical inductive generalization task, preschoolers are taught a fact about a target object and then are asked whether that fact can be generalized to other test objects. Using this methodology, studies have demonstrated that by 2-1/2-years of age, children can reason inductively about object properties in remarkably sophisticated ways (e.g., Gelman, 1988; Gelman & Markman, 1986, 1987; Kalish & Gelman, 1992). For example, Gelman and Coley (1990) found that 2-1/2-year-olds will overlook perceptual similarity and generalize properties on the basis of shared underlying kind when the target and test objects are given the same count noun label.

In recent years, researchers have begun to examine the development of inductive capabilities during the infancy period using the generalized imitation paradigm. In a typical task, an experimenter will first model a specific action on a target object. He or she will then hand infants test objects and observe whether or not they imitate the target action on the various objects. Studies using this paradigm indicate that infants as young as 9 months of age will draw inferences about nonobvious object properties based on knowledge gained during the experimental session (Baldwin, Markman, & Melartin, 1993). Furthermore, research suggests that both perceptual similarity and conceptual knowledge may play a role in guiding infants' inferences (Baldwin et al., 1993; Mandler & McDonough, 1996, 1998). In a recent series of studies (Welder & Graham, in press), we found that 18-month-old infants will rely on shared shape similarity to guide their inductive inferences about novel objects' nonobvious sound properties when no other information about category membership is available. More importantly, however, when infants were provided with information about conceptual category membership in the form of shared object labels, shape similarity was either attenuated in significance (in the case of novel labels) or disregarded (in the case of familiar labels). These findings indicate that 18-month-old infants can make inductive inferences about object properties based on a conceptual notion of object kind. Furthermore, these findings suggest that infants as young as 18 months of age recognize the conceptual information conveyed by object labels. That is, they recognize that noun labels supply information about underlying object kind and that members of the same kind share nonobvious properties.

In the present studies, we pursued the investigation of infants' inductive abilities, with specific focus on the reasoning abilities of infants who are just beginning to acquire productive language. First, we examined whether 13-month-olds, like 18-month-olds, will rely on shared shape similarity to generalize nonobvious object properties, in the absence of other information about object kind (Experiment1). Second, we examined whether 13-month-olds will rely on shared object labels to direct their inductive inferences (Experiment 2). In particular, we examined whether infants will extend a nonobvious property on the basis of a shared object label, even if the objects differ in shape.

In both experiments, we employed a generalized imitation paradigm to examine infants' inductive abilities (see also Baldwin et al., 1993; Mandler & McDonough, 1996, 1998). We presented infants with novel target objects that possessed nonobvious properties (e.g., a cloth-covered object that squeaked when squeezed). The experimenter demonstrated the nonobvious property using a specific target action and then presented infants with test objects which varied in their degree of perceptual similarity to the target. We reasoned that if infants considered test objects to be members of the same category as the target, they would expect the test objects to share the same nonobvious property as the target. That is, infants' imitation of a target action on test objects would provide evidence of inductive reasoning.

Experiment 1

The goal of Experiment 1 was to examine the role of shape similarity in guiding infants' generalization of nonobvious object properties when they are presented with novel object categories. Infants were presented with object sets consisting of a target object followed by a high similarity match, a low similarity match, and a dissimilar object in three within-subjects conditions. The high and low similarity matches within each set varied in shape and color but shared similar textures. The dissimilar objects in each set, however, differed from the target object in texture, shape, and color. The dissimilar objects were included to ensure that infants' inductive generalizations were <u>specific</u> to objects that they perceived as belonging to the same category and to ensure that infants were not merely imitating the experimenter's actions on any object, regardless of whether an expectation was generated.

We presented infants with target and test objects in three within-subjects expectation conditions. In the <u>surprised</u> condition, the target object possessed an interesting sound property (e.g., squeaked when squeezed), but the test objects were disabled so that they could not exhibit the property (e.g., could not squeak when squeezed). This condition was of particular interest, as infants' performance would indicate whether they expected test objects to possess the same nonobvious property as the target. In the <u>baseline</u> condition, neither the target nor the test objects possessed the interesting property (e.g., neither produced a squeak sound). This condition provided a baseline measure of infants' exploratory actions. A comparison of infants' performance in the baseline condition to the surprised condition would indicate whether the target property of the target object was, in fact, nonobvious upon visual inspection. In the <u>predicted</u> condition, both the target and test object possessed the property (e.g., both could squeak). This condition was included to preclude the development of the expectation that all test objects were disabled (as all test objects in both the surprised and baseline conditions were), leading infants to become bored or frustrated with the stimuli.

We expected that infants would use shape similarity to guide their generalizations of the nonobvious property as object shape is easily perceived and is often an excellent index of object kind (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). More specifically, we predicted that the greater the degree of shape similarity between a test object and a target object, the higher the frequency of target actions performed on that test object.

Method

Participants Participants were 20 infants ranging in age from 12.07 months to 13.92 months (<u>M</u> = 12.73; <u>SD</u> = .53). Ten infants were male and 10 were female.

Stimuli Four objects were used for the warm-up trials: a garlic press, a roller ball, a clicking clock, and a clothesline pulley. Three object sets (a "squeaking" set, a "ringing" set, and a "rattling" set) were created for use in the imitation task. There were four objects in each set: a target object, and three test objects (a high similarity object, a low similarity object, and a dissimilar object). The high similarity test objects possessed the same shape and texture as the target object but differed in color. The low similarity objects shared the same texture as the target object but differed in shape and color. The dissimilar object shared no properties in common with the target object. The dissimilar objects included a plastic orange file (squeaking set), a small white strainer (ringing set), and a plastic green hose splitter (rattling set). There were two versions of each target and test object in each set: a functional version that could produce the target sound and a nonfunctional version that was disabled and thus unable to produce the target sound. In the functional squeaking object set, objects could produce a squeaking noise when squeezed. In the functional ringing set, objects could produce a ringing noise when tapped. In the functional rattling set, objects could produce a rattling noise when shaken.

To establish whether test objects could reliably be categorized as high or low in shape similarity relative to the target object, 15 adults rated the similarity of each test object to its target. The adult ratings followed the expected pattern. That is, the high and low similarity test objects in each object set were perceived as significantly different in shape from one another (all t-tests: $p < .05$), in the direction intended.

Design For each infant, one of the three object sets was presented in the <u>surprised</u> condition, one set was presented in the <u>baseline</u> condition, and one set was presented in the <u>predicted</u> condition. The specific object set assigned to the surprised, baseline, and predicted conditions was counterbalanced across infants.

The imitation task was comprised of three blocks of three trials each: one trial in the surprised condition, one trial in the predicted condition, and one trial in the baseline condition. Each object set was presented once within each block. That is, one of the test objects (e.g., a high similarity object) from a given set was presented in the first block, another (e.g., a low similarity object) was presented in the second block, and a third (e.g., a dissimilar object) was presented in the third block. The order of presentation of test objects was randomized within each block and order of presentation of expectation condition within each trial block was counterbalanced across infants.

Procedure Infants were seated in their parent's lap at a table in a testing room with the experimenter seated across from them. Before testing began, the experimenter instructed parents to interact with their infant as little as possible and not to direct their infant's attention to the objects. Parents were also instructed to silently place objects back on the table within the infant's reach if objects were dropped on the floor near the parent or if the infant handed objects to the parent. All sessions were videotaped for coding purposes.

During the warm-up phase, the experimenter demonstrated a target property of each of the warm-up objects to the infant and asked the parent to do the same. After demonstrating the target property, parents silently handed the object to their child for him/her to imitate the actions observed.

During the test phase, the experimenter began each trial by presenting infants with one of the target objects from a given object set. She introduced the object (e.g., "Look at this one!") and demonstrated the nonobvious property of the target object five times (e.g., shaking the rattle). Only the properties of target objects in the surprised and predicted conditions were demonstrated (as the target objects in the baseline condition did not possess the property). The experimenter handed the object to the infant's parent who demonstrated the property of the target object twice. The parent then passed the object to the infant. After a period of 10 seconds, the experimenter retrieved the object and placed it within the infant's view, but out of reach. The experimenter then presented the infant with a test object and infants were allowed to explore the test object for 20 seconds. This same procedure was repeated for each of the other 8 trials. The target object from each object set was reintroduced to infants on each trial; however, parents only demonstrated the property the first time a target object was introduced. The experimenter continued to demonstrate the target object's property on each trial. If an object was dropped off the table or passed/thrown out of the infants' reach during the session, the experimenter quickly placed the object back within their reach. Time lost due to these actions was not compensated for, as they were considered to be intentional actions of frustration or disinterest (see Oakes, Madole, & Cohen, 1991).

Coding Coders, blind to the hypotheses of the experiment, recorded the frequency of actions performed by the infants on the target and test objects. Only the experimenter's back was visible on the videotapes and all sessions were coded with no volume. Thus, the coders could not detect whether the experimenter had demonstrated a target action on an object and could not hear whether objects actually made sounds when actions were performed by either the experimenter or the infants. Thus, we were confident that the coders could not distinguish the surprised, baseline, and predicted conditions from one another.

A detailed coding scheme for each target action was developed for each object set. The target action for the squeaking set was defined by a squeezing motion, that is, the infant gripped and then compressed his/her fingers together on the object (not tapping the object, hitting the object on the table, shaking the object, or gripping it to look at it or passing/throwing it to the experimenter or parent). The target action for the ringing set was defined by a tapping, hitting, or patting motion (not squeezing the object, hitting it on the table, shaking it, or gripping it to look at it or pass/throw it to the experimenter or parent). Finally, the target action for the rattling set was defined by a shaking motion with the wrist and/or whole arm in a back/forth or up/down motion (not tapping the object, squeezing it, hitting the table or a body part with it, or gripping it to look at it or pass/throw it to the experimenter or parent). If the infant performed a fluid shaking movement, then only one target action was counted.

Results

The mean frequency of target actions performed on the different test objects in the surprised and baseline conditions are presented in Table 1[1]. We first examined whether the target properties of the object stimuli were indeed nonobvious to infants by comparing the number of target actions infants performed on test objects after having first seen a functional target object (in the surprised condition) versus a nonfunctional target object (in the baseline condition). We used one-tailed dependent t-tests to compare the frequency of target actions in the surprised condition to those in the baseline condition at each level of shape similarity. (Note that we used one-tailed tests as our predictions were directional). As

[1] In all analyses, we chose not to include the data from the predicted condition as it was difficult to interpret why infants continued to perform target actions on test objects in this condition. That is, it was impossible to distinguish those target actions performed as a result of an expectation about an object's nonobvious property from those performed as a result of the reinforcing nature of the sound property of the test objects themselves (see Baldwin et al., 1993 for a discussion of this issue).

Table 1:Frequency of Target Actions Performed on Test Objects at Each Level of Shape Similarity within each Expectation Condition (Expt. 1).

	Shape Similarity to Target		
Condition	High	Low	Dissimilar
Surprised	2.1 (2.9)	0.6 (1.3)	0.2 (0.9)
Baseline	0.4 (0.7)	0.6 (1.2)	0.0 (0.0)

expected, infants performed significantly more target actions on the high similarity objects in the surprised condition than in the baseline condition, t (19) = 2.39, $p < .03$. In contrast, infants did not differ significantly in their performance of target actions on the low similarity objects or on the dissimilar objects in the surprised condition versus the baseline condition, (t (19) = .00, $p > .99$; no statistic was computed for the dissimilar object comparison as no target actions were performed in the baseline condition). These analyses indicated that the appearances of the high similarity objects did not suggest that the objects possessed the nonobvious properties. Instead, infants performed target actions on test objects only after they had been exposed to the properties of particular functional target objects during the testing session.

We next examined the influence of shape similarity on infants' generalization of nonobvious properties within the surprised condition only. As predicted, infants performed significantly more target actions on the high similarity objects than on the low similarity objects (t (19) = 2.55, $p < .02$), or the dissimilar objects (t (19) = 2.55, $p < .02$). Furthermore, infants did not differ significantly in their performance of target actions on the low similarity objects and dissimilar objects, t (19) = 1.16, $p > .25$. The results of these analyses indicate that infants expected objects that shared a high degree of shape similarity to share nonobvious properties, consistent with our hypotheses.

Discussion

As expected, infants performed significantly more target actions on the high similarity test objects in the surprised condition than in the baseline condition. This finding indicates that the appearance of the objects did not suggest the nonobvious properties. Furthermore, in the surprised condition, infants generalized the nonobvious properties to the high similarity test objects but not to the low similarity objects (which still shared textural similarity with the target object), nor to the dissimilar test objects (which differed from the target object in texture, shape, and color). Infants' lack of performance of the target actions on the low similarity objects and on the dissimilar objects indicates that they were not simply imitating any action that the experimenter did--they only imitated the target action when they viewed the test object as a member of the same category as the target object.

The results of this experiment thus indicate that 13-month-old infants will form specific expectations about the nonobvious properties of objects from knowledge gained during the testing session. Furthermore, these findings indicate that infants were relying solely on shared shape similarity to index category membership, an issue discussed further in the General Discussion.

Experiment 2

In Experiment 2, we examined whether 13-month-old infants would treat labels for novel objects as a conceptual marker of object kind and expect those objects that shared the same label to possess the same nonobvious property. The design of Experiment 2 was similar to that of Experiment 1 with one exception: The experimenter labeled the target and test objects with novel count nouns when she introduced them. We predicted that infants would generalize the nonobvious property to objects that shared the same label, even if they shared little shape similarity with the target object.

Method

Participants Participants were 20 infants ranging in age from 12.20 months to 13.85 months (M = 13.02; SD = .54). Ten infants were male and 10 were female.

Stimuli Same as Experiment 1.

Design Same as Experiment 1.

Procedure The procedure was similar to that of Experiment 1, with one exception: The experimenter introduced the target and test objects using novel count nouns (e.g., "Look at this blint!"). Note that the same count noun was used to label the target object and the test objects in a given set (i.e., the target and the test object from the rattling set were all labeled as blints).

Coding Identical to Experiment 1.

Results

The mean frequency of target actions performed on the different test objects in the surprised and baseline conditions are presented in Table 2. As in Experiment 1, we first examined whether the target properties of the object stimuli were nonobvious to infants by comparing the number of target actions infants performed on test objects after having first seen a functional target object (the surprised condition) versus a nonfunctional target object (the baseline condition). (Note we again used one-tailed t-tests as our predictions were directional). As expected, infants performed significantly more target actions on the high similarity objects in the surprised condition than in the baseline condition, t (19) = 2.76, $p < .005$. Similarly, infants performed more target actions on the low similarity objects in the surprised condition than in the baseline condition, t (19) = 1.86, $p < .05$. In contrast, infants did not differ significantly in their

Table 2:Frequency of Target Actions Performed on Test Objects at Each Level of Shape Similarity within each Expectation Condition (Expt. 2).

	Shape Similarity to Target		
Condition	High	Low	Dissimilar
Surprised	2.7 (3.9)	2.2 (3.1)	0.5 (1.4)
Baseline	0.3 (0.7)	0.7 (2.3)	0.0 (0.0)

performance of target actions on the dissimilar object in the surprised condition versus the baseline condition (no statistic was computed as no target actions were performed on this object in the baseline condition). These analyses indicated that the appearances of the high and low similarity objects did not suggest that the objects possessed the nonobvious properties.

We next examined the influence of labels on infants' generalization of nonobvious properties within the surprised condition only. In contrast to Experiment 1, infants did not perform more target actions on the high similarity objects than on the low similarity objects (t (19) = 0.51, $p > .60$). However, infants performed significantly more target actions on both the high similarity objects and on the low similarity objects than on dissimilar objects, t (19) = 2.31, $p < .03$ and t (19) = 3.31, $p < .01$, respectively. The results of these analyses indicate that infants expected objects that shared the same label to share nonobvious properties, regardless of shape similarity.

Discussion

In this experiment, infants performed as many target actions on the low similarity objects as on the high similarity objects. This finding indicates that infants relied on shared labels, rather than shape similarity, to guide their inferences about nonobvious object properties, an issue discussed further in the General Discussion. It is important to note, however, that the presence of labels, however, did not lead infants to completely disregard perceptual information. That is, labeling the dissimilar object with the same count noun as the target object did not lead infants to generalize nonobvious object properties to that object. Recall that the dissimilar object shared no perceptual properties in common with the target object. Thus, it appears that some minimal perceptual overlap is necessary for infants to generalize the nonobvious properties.

General Discussion

The present studies were designed to examine the role of object shape similarity and object labels in guiding 13-month-old infants' inferences about nonobvious object properties. The results of our studies yielded three major insights into the nature of infants' inductive reasoning. First, the results of both experiments provide evidence that infants between 12 and 13 months of age will form expectations about shared properties of novel objects after only a ten second experience with a functional target object. Furthermore, infants will extend a specific nonobvious property from a target exemplar to other objects perceived as members of the same category, consistent with the results of previous studies (e.g., Baldwin et al., 1993; Mandler & McDonough, 1996, 1998; Welder & Graham, in press). Thus, our finding that infants could rapidly and efficiently form expectations about the nonobvious properties of novel objects provides important evidence that infants possess well-developed inductive reasoning abilities by the end of the first year of life.

Second, our findings indicate that infants will rely on shape similarity to generalize nonobvious object properties, in the absence of other information about object kind. In Experiment 1, infants were more likely to generalize a nonobvious object property to objects that were highly similar in shape than to objects that were less similar in shape. These findings provide clear evidence that infants expect that objects that share a high degree of shape similarity will also share other "deeper" characteristics. Furthermore, this result suggests that infants appreciate that shared shape similarity is predictive of category membership. That is, infants attend to shape information because it serves as a perceptually-available cue to the underlying structure of a category (see Bloom, 2000; Gelman & Diesendruck, 1999 for a discussion).

Finally, our findings demonstrate that when a novel object is labeled with a novel count noun, infants will overlook shape information and rely on the label to generalize the nonobvious property. In Experiment 2, infants performed as many target actions on low similarity objects as on high similarity objects, when objects were labeled with the same count noun. As discussed earlier, labeling the objects did not lead infants to completely disregard perceptual information as they did not generalize the nonobvious object properties to the dissimilar object (which shared no perceptual features with the target object). Thus, when infants are provided with information about category membership in the form of shared object labels, perceptual information is attenuated. This finding provides clear evidence that young infants can form novel categories and make inductive inferences about nonobvious properties based on a conceptual notion of object kind (see also Mandler & McDonough, 1996, 1998; Welder & Graham, in press). Moreover, our findings indicate that infants as young as 13 months of age recognize the conceptual information conveyed by object labels. That is, infants, like preschoolers, appear to recognize that count noun labels supply information about underlying object kind and furthermore, that members of the same kind share nonobvious properties. This finding is particularly compelling given that the infants in our studies are only just beginning to acquire productive language. Finally, these findings add to a growing body of literature indicating that naming can foster infants' formation of object categories (e.g., Balaban & Waxman, 1997; Graham, Baker, & Poulin-Dubois, 1998; Waxman, 1999; Waxman & Hall, 1993; Waxman & Markow, 1995) and moreover, these findings provide evidence that labels enhance the inductive potential of categories for young infants.

In summary, the results of these experiments have advanced our understanding of infants' inductive abilities, indicating that 13-month-old infants will use shape similarity and count noun label information for making inferences about nonobvious object properties. These results also suggest a number of important directions for future research. For example, it remains to be seen whether infants who have not yet acquired productive vocabulary (i.e., infants younger than 12 months of age) can rely on object labels to guide their inferences about object properties, and whether count noun labels (versus words from other form classes or versus nonlinguistic stimuli) are privileged in guiding infants' inferences. Research into these issues is currently underway in our lab and we expect that the results of these studies, in conjunction with other recent empirical work, will lead to a coherent account of the developmental processes underlying inductive reasoning during infancy.

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