

Perceptual Features and the Development of Conceptual Knowledge

Adam Sheya and Linda B. Smith
*Department of Psychological and Brain Sciences
Indiana University*

When children learn categories, they do not learn isolated facts but rather systems of knowledge. These systems of knowledge are composed of property–property (e.g., things with wings tend to have feathers), property–role (e.g., things with eyes tend to eat), and role–role (e.g., things that eat tend to sleep) correlations. Research has shown that even young children have knowledge of property–property and property–role correlations, but there has been little direct evidence of their knowledge of role–role correlations or for how children might acquire this knowledge. We found that 5-year-olds have knowledge of role–role correlations and 2- and 3-year-olds have different degrees of knowledge of property–role correlations. Two-year-olds needed multiple properties to infer an appropriate role, whereas 3-year-olds needed only a single property (e.g., eyes or wheels). These results suggest that role knowledge may first be linked to object (or literal) similarity, then to clusters of properties, to a single property, and finally to other roles.

Categories are systems of knowledge that include different but interrelated components. Two such components are the properties of instances and the roles those instances play in events. For example, dogs possess a number of properties such as a characteristic shape, having four legs, eyes, and mouths. Dogs also participate in events in roles such as fetching, playing, sleeping, and eating. Considerable evidence suggests that both perceptual properties and relational roles matter in children's early category learning, although there is debate about the relative importance of these two components (Booth & Waxman, 2002b; Gelman & Bloom, 2000; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Madole & Oakes, 1999; Mandler & McDonough, 1996; Nelson & Ware, 2002; Rakison &

Butterworth, 1998b; Smith, Jones, & Landau, 1996). There is less evidence on how children build a system of knowledge that integrates all these components. This is the larger question that motivates the studies reported in this article. Figure 1 illustrates three kinds of relations that might comprise a developing system of knowledge about properties and roles relevant to categories: property–property, property–role, and role–role (see Deaux & Lewis, 1984, for a similar conceptualization in a different context).

The first relation is among perceptual properties. Children's knowledge about categories might not be limited to perceptual properties but also might include knowledge about the co-occurrence of properties, for example, knowledge that things with eyes typically have mouths and things with mouths typically have feet. Many theories of categorization assume an important role for correlated clusters of properties (McRae, Cree, Westmacott, & De Sa, 1999; Rogers & McClelland, 2005; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Further, considerable evidence shows that infants and children readily learn about the properties typical of category members and property–property correlations (Mareschal, Quinn, & French, 2002; Quinn & Eimas, 1996; Rakison & Butterworth, 1998a, 1998b; Younger, 2003). In one study, Younger (1990) presented 10- to 14-month-old infants with an array of objects in which the features were perfectly correlated. For example, animals with feathered tails had ears and animals with furry tails had antlers. After familiarization, the infants detected changes in feature combinations, treating an instance with a feathered tail and antlers as novel even though both features were highly familiar (see also Younger & Cohen, 1983, 1986). Other studies show that preschool children also make inferences from one perceptual property to another. For example, Gelman (1990) reports that 3-year-olds assume that objects with eyes also have feet (see also Jones & Smith, 1993; Macario, 1991). In sum, young children learn about property–property co-occurrences and use this knowledge to make category decisions.

The second relation shown in Figure 1 is among perceptual properties and roles. That is, children's knowledge about categories could also include knowledge about the co-occurrence of physical properties and roles, for example, that mouths are used for eating and eyes for seeing, or that things with eyes typically also have some manner of eating. Knowledge about these relations seems crucial to making inferences about the behavior and functions of things and to building causal theories about why entities have the properties they do (Ahn, Gelman, Amsterlaw, Hohenstein, & Kalish, 2000). Again, considerable evidence indicates that children attend to and learn property–role relations relevant to different kinds (Mandler & McDonough, 1998). For example, children appear to know that eyes enable seeing (McCarrell & Callanan, 1995), that wings enable flying (Goodman, McDonough, & Brown, 1998), that things with feet can move (Massey & Gelman, 1988), that round things can roll, that non-rigid materials can be folded (e.g., Samuelson & Smith, 2000a), and that things with brushes on them can be used for painting

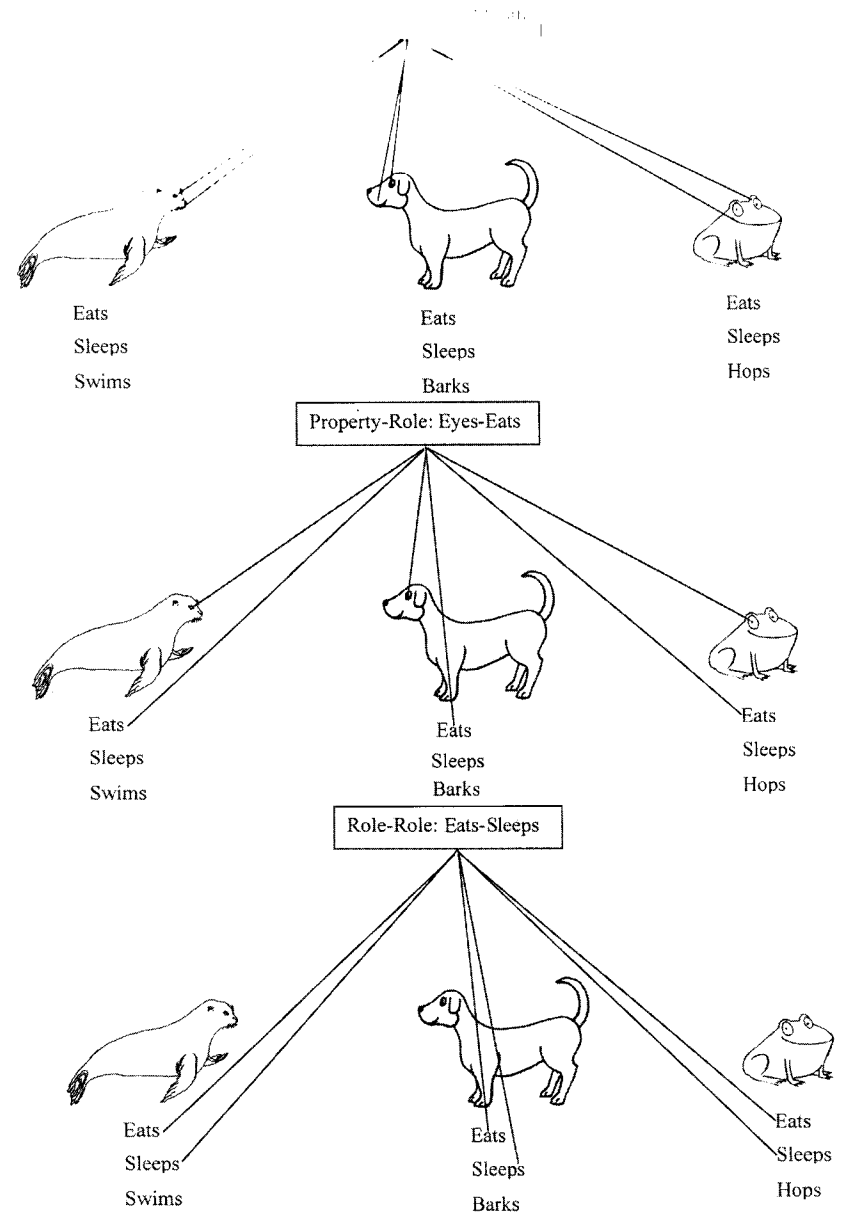


FIGURE 1 The panels illustrate the types of correlations between objects that are available in the world. The top panel gives an example of a property–property correlation, the middle an example of property–role, and the bottom role–role.

(Kemler Nelson, Russell, Duke, & Jones, 2000). Goodman et al. (1998) even showed that 2-year-olds use these property–role relations to learn new words. For example, when told “a wug eats ...,” children chose a picture of a novel animal over pictures of other novel kinds as the referent of *wug*. Further, Madole and Cohen (1995) have shown that when functions such as twisting or rolling are linked to particular parts of objects, 18-month-old children attend to those parts more than to others (see also Gershkoff-Stowe, 2005; Rakison, 2005; Rakison & Poulin-Dubois, 2002). In sum, young children learn links between roles and the characteristic properties of things that participate in those roles, and these links strongly influence their category decisions.

The third relation shown in Figure 1 is among roles—knowledge, for example, that things that eat also sleep, drink, and grow. Direct associations among roles that do not depend on links to the perceptual properties of things might be particularly crucial for reasoning about abstract and hypothetical categories. For example, such knowledge would enable one to reason—in a conceptually coherent way—about possible life forms and to make inferences about entities from their roles in events despite unusual perceptual properties. Knowledge of role–role correlations would also seem crucial to developing a higher level understanding about different kinds (Carey, 1985; Gelman & Koenig, 2003; Keil, 1979). However, in contrast to the considerable evidence on children’s developing knowledge of property–property and property–role relations, there is little evidence on children’s knowledge of role–role relations. Particularly lacking is direct evidence on what young children know about role–role correlations that is not linked through the perceptual properties of the participating entities. Accordingly, the focus of these experiments is children’s knowledge of role–role relations.

One programmatic set of studies relevant to this issue examined young children’s imitations of category-relevant roles across a diverse set of entities (Mandler & McDonough, 1996, 1998, 2000). In one study in this series, Mandler and McDonough (1996) presented 14-month-old children with a toy dog, demonstrated the action of giving it a drink from a cup, then asked children to do the same thing with similar and prototypical instances that drink (e.g., a cat), with dissimilar animals that one does not usually think of as drinking (e.g., a fish), and with entities of a different superordinate kind that do not drink (e.g., a truck). They found that these young children extended the action broadly to items in the same superordinate category (cats and fish) but not to items in a different superordinate category. In addition, children only extended actions that were appropriate to the category (e.g., when the experimenter gave a vehicle a drink, children did not imitate the action on the vehicle match). These results show that very young children’s generalizations of roles are not based solely on overall similarity.

However, Mandler and McDonough’s (1996, 1998, 2000) results do not unambiguously show direct knowledge, unmediated by perceptual properties, of role–role correlations. Indeed, Rakison and Poulin-Dubois (2001) suggested that

Mandler and McDonough’s results could reflect children’s use of a single prominent feature, such as having a mouth or having eyes, that is predictive of entities that engage in the role of drinking. Thus, children’s selective choice of objects by kind in this imitation task could reflect knowledge about how roles link to features rather than knowledge about roles that can be accessed independently of the perceptual features that co-occur with those roles.

Two other lines of research, although not directly asking whether young children form and use role–role connections, suggest that they might. These studies show that preschool children can treat the very same perceptual object as a different kind—as an artifact versus a material or as an animate versus an inanimate—if given information about its relational roles. For example, Gelman and Bloom (2000) found that 3-year-old children, when told that an object was intentionally created (e.g., folded, cut, sawed), labeled it as an artifact (e.g., hat, knife, belt) but when told the very same object was accidentally created (e.g., dropped, ripped, knocked), labeled it with a material term (e.g., newspaper, plastic, metal). Similarly, Booth and Waxman (2002b) showed that 3-year-old children could interpret the very same object as animate if told it had a mommy and daddy, was happy, slept, and was hungry, but as inanimate if told it was made, was fixed, got worn, and was bought. Both of these results suggest that 3-year-olds have knowledge about co-occurring and kind-defining relations that may not depend on direct links to the perceptual properties of the objects that take part in those relations.

In sum, developing category knowledge appears to include knowledge about co-occurring properties and knowledge about how these perceptual properties relate to roles, but there is less information on what children might know about role–role correlations. Further, the evidence to date provides little information on children’s developmental progress in building this system of knowledge. The purpose of the four experiments that follow is to provide evidence on how children might build this knowledge, especially knowledge of role–role correlations.

There are (at least) two possibilities as to how this knowledge might be acquired: First, knowledge about property–property, property–role, and role–role correlations might be acquired in parallel, with children building knowledge simultaneously in all domains. Second, the perceptual surface properties of things may be developmentally privileged such that children acquire knowledge about roles by linking them to the surface properties of the objects that participate in those roles. This last possibility is consistent with the idea that object (or literal) similarity is the starting basis for building conceptual knowledge (e.g., Gentner & Rattermann, 1991). Both hypotheses are related to the debate concerning whether categories are initially perceptual or conceptual for children. We consider these issues—in light of results—in the general discussion.

The experiments build on Mandler and McDonough’s (1996, 1998, 2000) generalized imitation task in that we ask children to act on an object in category-relevant ways. However, unlike Mandler and McDonough, children are not

asked to imitate an action. Instead, in our task children watch the experimenter perform one category-relevant action (one role) with the instance and then are asked to perform a second different action (another role) with that same instance. For example, in the demonstration phase the experimenter might take an object and give it a drink from a cup, a role characteristic of an animate entity. Then, in the test phase, the child is given the same object and props to support two role enactments: going to sleep in a bed or getting gas at a service station. If children see the object taking a drink, will they, in the test, pretend to put the object to sleep in the bed rather than to give it gas at the gas pump? What we manipulate across four experiments is the properties of the object—from an amorphous shape with no features predictive of the two test roles to richly detailed objects (e.g., dolls and toy vehicles). If children directly link roles to one another, they should be able to do this task—generalize the action of sleeping from the action of drinking—even when the object presents none of the properties characteristic of things that drink and sleep. Across the experiments we examine the performances of very young children, 2- and 3-year-olds, whom we expect to still be in the process of building their conceptual systems, and also older children, 5-year-olds, who might be expected to have a conceptual system with all three kinds of relations depicted in Figure 1.

EXPERIMENT 1

This experiment presented children with the strongest test of their knowledge of role–role correspondences. The experimenter demonstrated actions specific to things that are animals or vehicles with the entities shown in Figure 2, entities that did not have perceptual properties typical of animals or vehicles.

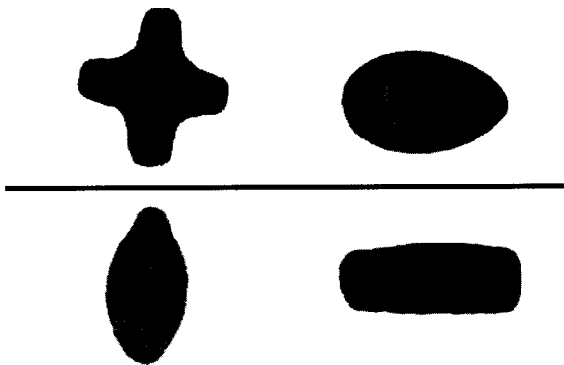


FIGURE 2 The objects used in Experiment 1.

Method

Participants

Thirty-six children (19 boys, 16 girls) participated. There were twelve 2-year-olds ($M = 25$ months; range = 24–28 months), twelve 3-year-olds ($M = 34$ months; range = 30–38 months), and twelve 5-year-olds ($M = 61$ months; range = 58–62 months). Children's names were obtained from birth announcements, and parents were first sent a letter followed by a phone call. Participants were rewarded with a small prize—a t-shirt, stuffed animal, book, or small toy—for their participation.

Stimuli

Four novel objects were created that had no perceptual features characteristic of animals and vehicles (Figure 2). These objects were paired with roles typical of animates or inanimates. In addition, two sets of choice props were used: a doll bed versus a toy gas station (a building with a gas pump and car wash) and a high chair versus train tracks. The experiment also included a warm-up phase to familiarize children with the task. The warm-up stimuli consisted of a small plastic pig, plastic grapes, a toy dish, and a toy barn.

Procedure

Task warm-up. Each session began with the same warm-up. A toy barn and a dish were placed in front of the participant, whose attention was drawn to each item as it was labeled. The experimenter then presented the grapes: "Look what I have! I have some grapes! Where do the grapes go?" This was repeated until the child responded correctly twice in a row by placing the grapes on the dish. The experimenter held up the grapes one last time and asked "Where does this go?" If the correct choice was not made the cycle of questions was repeated. Once the participant chose the dish three times in a row, the experimenter repeated the warm-up procedure with the pig, with the correct response being the placement of the pig in the barn. Feedback was given during the warm-up phase, and no participant continued into the test phase without completing the warm-up phase. All children successfully completed the warm-up phase. The purpose of the warm-up task was to teach the child the structure of the task—that they were to take the object from the experimenter and use it with one of the two choice props on the table.

Experimental trials. Each experimental trial consisted of two stages: A demonstration of an action with the object and then the child's action on the object using one of the two choice props on the table. The two props were available on the table throughout the trial, and the experimenter labeled them at the beginning of the trial (e.g., "This is a bed. See the bed. This is a garage [gas station]. See the

garage [gas station].” The demonstration stage began with the experimenter presenting an object and acting on it. For example, the experimenter would move the object on the table as if it were walking and then ask “Thirsty?” The object was then given a drink with a cup, and the experimenter made a slurping sound. This action was repeated two more times. After the object was presented the participant was asked, “Where does this go?” If no choice was made the question was repeated; if still no choice was made, the action was repeated on the object. If after this second presentation still no choice was made, the experimenter moved on to the next trial.

Four trials used four objects, each object paired with a different action. Two of the actions were vehicle actions. In one case the experimenter took a key, pretended to turn it to “start” the object, and then moved the object about on the table, making motor (or vroom-vroom) sounds. In the other case, the experimenter put a small toy man on the target object and moved them together on the table saying, “Chugga, chugga, chugga.” Two of the actions were animate actions. In one case, the experimenter walked the object out on the table, asked if it was thirsty, and gave it a drink from a cup by placing the cup against the object and making a slurping sound. In the second case, the experimenter took the object, walked it out, put a hat on it, and then gave it a hug and said, “Big hug, good hug.” For the keying and drinking trials, the choice props were the bed versus the gas station; for the ride and hug trials, the choice props were a high chair and a set of train tracks. No feedback was given during this stage and, other than the language previously described, the experimenter avoided the use of words (such as pronouns) that might signal the object as animate. The order of presentation of the stimuli was counterbalanced across participants, as was the right-left orientation of response locations.

Results and Discussion

During the test phase, the experimenter coded children’s responses in terms of the prop chosen (e.g., bed or gas station). Twenty-five percent of participants were recoded from videotape. There was 100% agreement among coders. Only the 5-year-olds used the perceptually ambiguous object with the category-appropriate prop ($M = .79$, $SD = .18$). Ten out of twelve 5-year-olds performed at or above 75% correct. The 2-year-olds ($M = .40$, $SD = .31$) and 3-year-olds ($M = .56$, $SD = .11$) did not infer a second role from the experimenter-provided one. Only three 2-year-olds and three 3-year-olds performed at or above 75% correct. An analysis of variance (ANOVA) revealed an effect of age, $F(2, 33) = 10.08$, $p < .001$, and Tukey’s honestly significant difference test indicated that 5-year-olds differ from both 2-year-olds ($p < .001$) and 3-year-olds ($p = .037$), who do not differ from each other ($p = .16$). Only the 5-year-olds’ performance differed significantly from chance (.50), $t(11) = 5.63$, $p < .001$, two-tailed. An examination of performance as

a function of category (animal vs. vehicle) suggested no systematic bias to make correct inferences for one kind of action or the other.

These results indicate that by 5 years of age, children can make inferences from one role to another and do so without the support of the perceptual properties that are characteristic of the things that participate in those roles. In contrast, 2- and 3-year-old children showed little evidence of this ability. In the next experiment, we provided a single cue characteristic of the kind to see if the younger children would make property-to-role inferences.

EXPERIMENT 2

Research by Rakison and Butterworth (1998a, 1998b) suggests that children attend to a small set of diagnostic features when grouping objects, so it might be the case that young children use these features as anchors in relating roles to roles. That is, instead of learning role–role relations directly, children may link roles to objects and their properties and thus infer that a novel object participates in a role because of its properties. In this experiment, one feature typical of the animal and vehicle categories (e.g., eyes or wheels) was added to the novel objects used in Experiment 1. Eyes and wheels were chosen because research has demonstrated that very young children both attend to these properties and use them to classify animates and vehicles (Colunga, 2003; Jones & Smith, 1993; Rakison & Butterworth, 1998a, 1998b). These objects were presented both with and without the experimenter’s demonstration of the roles used in Experiment 1 (drinking, hugging, driving, and giving a ride). If children can infer the role only when both the role and perceptual information is available, then it shows that they have knowledge of role–role relations but that it is mediated by the perceptual properties. If they infer a role when only the feature is available (but no role has been demonstrated), it would suggest that role knowledge is directly linked to the feature. If performance is equivalent given the presence of a feature when the role is demonstrated and when it is not, it would suggest that the demonstrated role (and knowledge of role–role connections) does not contribute to children’s generalization of a different role to the entity.

Method

Participants

Fifty-four children (26 boys and 28 girls) participated in the experiment. There were thirty-one 2-year olds ($M = 25$ months; range = 23–29 months) and twenty-three 3-year olds ($M = 38$ months; range = 35–44 months). Three additional 3-year-olds were dropped due to experimenter error. Participants were ran-

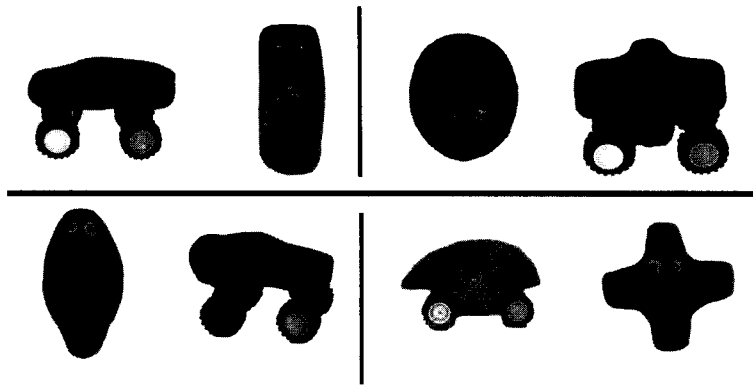


FIGURE 3 The objects used in Experiment 2.

domly assigned either to a feature-and-demonstrated-role condition or a feature-only condition.

Stimuli and Procedure

The same ambiguous objects used in Experiment 1 were used in this experiment; however, either wheels or eyes were added to each object (see Figure 3). The procedure was the same as in Experiment 1 in the feature-and-demonstrated-role condition. In the feature-only condition the objects were presented without a demonstrated action. In this condition, the experimenter simply showed the object to the child and asked, "Where does this go?"

Results and Discussion

When shown objects with a single feature typical of animals versus vehicles, 3-year-olds systematically used the object with the category-appropriate prop, performing at 73% correct ($SD = 20\%$) in the feature-only condition and 77% correct ($SD = 21\%$) in the feature-and-demonstrated-role condition. Individually, 8 of 11 and 8 of 12 performed at 75% correct or better in the feature-plus-demonstrated-role and feature-only condition, respectively. Two-year-olds performance in the feature-and-demonstrated-role condition ($M = 56\%$, $SD = 25\%$) did not differ from performance in the feature-only condition ($M = 56\%$, $SD = 20\%$). Half of the 2-year-olds in the feature-plus-demonstrated-role condition but only one third of the 2-year-olds in the feature-only condition chose the correct role at least 75% of the time. However, the number of children performing at or above 75% is not significantly different from that expected by chance in either condition (binomial test, $p > .25$ in both cases). A 2×2 ANOVA with age

and condition as between subject factors was conducted, and there was a main effect of age, $F(1, 50) = 10.37$, $p = .002$, but not of condition $F(1, 50) = .146$, $p = .704$. In sum, 3 year olds generalized new roles to the entities equally well in both conditions, and 2 year olds generalized new roles to the entities equally poorly in both conditions.

The fact that the 3 year olds performed the same in the feature-only condition as in the feature-and-demonstrated-role condition suggests that the role information is not helping them; rather, minimalist features appear to be enough even when placed on novel-ambiguous objects. Considered jointly, the results of the first two experiments indicate developmental growth in children's ability to make inferences about roles. Two-year-olds do not use minimalist features, a role, or both, whereas 3-year-olds use minimalist features and 5-year-olds succeed in generalizing a new role to an entity given a demonstration of a different role but no supporting object properties.

EXPERIMENT 3

In the first two experiments, most 2-year-olds did not demonstrate knowledge of role-role correlations or property-role correlations. It could be that they do not understand the task for reasons unrelated to knowledge of roles and properties. Alternatively, it could be that they lacked sufficient knowledge about roles. Finally, it could be that they simply need more perceptual support. To provide information relative to these possibilities, richly detailed dolls and vehicles were used in this experiment. In two between-subject conditions, these richly detailed objects were presented both with an experimenter-demonstrated role as in Experiment 1 and without a demonstrated role.

Method

Participants

Twenty-four 2-year-olds ($M = 25$ months; range = 23–27 months) participated in the experiment. There were an equal number of male and female participants. Children were randomly assigned to one of two conditions. Three children were dropped from the experiment because of parental interference during the testing stage.

Stimuli and Procedure

Richly detailed objects (e.g., dolls, toy car, toy train) were used (see Figure 4). All role-eliciting choice props were the same as in previous experiments. In the rich-object-only condition, the child was shown the object and simply asked (with

the experimenter pointing to the object), "Where does this go?" In the rich-object-and-demonstrated-role condition, the experimenter demonstrated a role using the object and then asked, "Where does this go?"

Results and Discussion

The 2-year-olds chose the category-appropriate role more often than expected by chance (.50) in both the rich-object-only condition ($M = .79$, $SD = .21$), $t(11) = 4.84$, $p < .001$, two-tailed, and in the rich-object-and-demonstrated-role condition ($M = .75$, $SD = .15$), $t(11) = 5.75$, $p < .001$, two-tailed. Nine of 12 and 10 of 12 children chose the category-appropriate object on 75% or greater of the test trial, in the rich-object-only condition, and in the rich-object-and-demonstrated-role condition, respectively. Performance did not differ between the conditions, $t(22) = .56$, $p = .58$, two-tailed.

Clearly, 2-year-olds can do this task and can link recognizable objects to the roles suggested by the choice props. However, there is no evidence in these data that they know anything about the correspondence among different roles. Because 2-year-olds performed equally well when richly detailed objects were presented with and without role information, it seems likely that in both conditions they were using the perceptual properties of things to decide on the appropriate choice prop. However, two kinds of processes could underlie 2-year-olds' performances in this experiment. First, because the objects were richly detailed typical versions of well-known things, it could be that children first recognize the objects as instances of well-known categories and then, through the category, link the object to the role. Second, because these objects present relatively many features predictive of roles, it could be that a single feature such as eyes or wheels is not enough but that clusters of predictive features are enough. To provide preliminary information on this

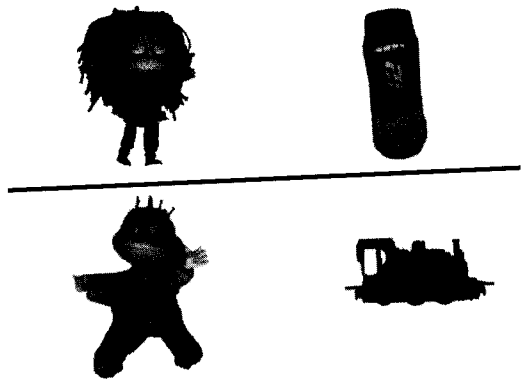


FIGURE 4 The objects used in Experiment 3.

issue, in the next experiment, we used unfamiliar objects with a cluster of predictive features characteristic of animates versus vehicles.

EXPERIMENT 4

Table 1 summarizes the first three experiments and shows developmental growth in children's dependence on perceptual properties when making inferences about roles. Whereas information about an object's participation in a particular role is sufficient for 5-year-olds to correctly infer another category-appropriate role for that object, 3-year-olds require at least one diagnostic property predictive of both roles, and 2-year-olds make category-appropriate inferences only when given richly detailed objects typical of the category. The purpose of Experiment 4 is to probe more deeply 2-year-olds' knowledge of property-role relations. To determine if 2-year-olds have linked roles to specific categories (such as *doll* or *car*) or if they have linked the roles to the clusters of object properties instances of these categories present, four stimulus conditions were used: (a) novel objects with no predictive features (as in Experiment 1), (b) novel objects with one predictive feature (as in Experiment 2), (c) less typical (unfamiliar) objects with a cluster of predictive features (a new stimulus condition), and (d) familiar objects with many predictive features (as in Experiment 3). In every stimulus condition, the objects were presented with a demonstrated role, and the task asked children to generalize a different role to the object.

Method

Participants

Fifty-three 2-year-olds ($M = 26$ months; range = 23–30 months; 30 boys and 23 girls) participated in the experiment. Participants were randomly assigned to one of four stimulus conditions. Nine additional 2-year-olds were dropped due to experimenter error or because of fussiness.

TABLE 1
Mean Percent of Category-Appropriate Trials by Age
and Stimulus Condition

Age	Experiment 1		Experiment 2		Experiment 3	
	Role Only	Feature and Role	Feature Only	Rich Object and Role	Rich Object	
2 years	.40	.56	.56	.75	.79	
3 years	.55	.77	.73			
5 years	.79					

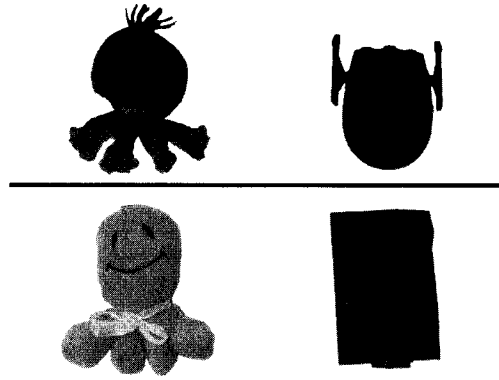


FIGURE 5 The objects used in Experiment 4.

Stimuli

The stimuli and choice props used in Experiments 1, 2, and 3 were used along with four new objects in the unfamiliar-object-with-many-features condition. The new objects are shown in Figure 5. They consist of objects with faces and roughly octopus-like limbs and fantastical vehicles. The experiment also contained a warm-up phase in which plastic flowers, a toy hammer, a vase, and a toolbox were used.

Procedure

In an effort to make the task more transparent to the 2-year-olds, we used a slightly different procedure. Instead of presenting children at test with one object and the choice between two roles (indicated by the choice props), we presented children with one role (indicated by the choice prop) and asked which of two objects went with that role.

Task warm-up. Each session began with the same warm-up. The plastic flowers were presented: "Look what I have! I have some flowers!" Then the experimenter smelled the flowers and encouraged the participant to do the same: "Your turn! Can you smell the flowers?" After the participant imitated the experimenter three times, a toy hammer was presented in the same manner. The experimenter demonstrated hammering the table and asked the child to imitate the action with object. After this was repeated three times, a vase was presented and labeled. The hammer and the flower were placed on either side of the vase and the participant was asked, "What goes with this?" while the experimenter pointed inside the vase. A toolbox was presented as the choice prop on other trials and in total the child was

tested with the vase and the toolbox each three times. Feedback was given throughout the warm-up phase.

Experimental trials. The experimental trials used the same format as the warm-up phase except no feedback was given. Each trial consisted of two stages: a demonstration stage and a test stage. First the experimenter demonstrated one of the roles (drinking, hugging, driving, giving a ride) with one target object (e.g., an animate role with the animate target object). The child was asked to imitate this role with the object. The second object was presented with a different role (e.g., a vehicle role with the vehicle target object). If the first role was characteristic of an animate object then the second role was characteristic of a vehicle, or vice versa. After the child had repeated the roles for each object, one choice prop was introduced. The target objects were placed on either side of the prop, and the experimenter asked, "What goes with this?" while pointing at the prop. If the child chose both objects or made no choice, the question was asked up to two more times. Next, a second prop was introduced, and the procedure was repeated. If the first prop was associated with an animate object, then the second was associated with a vehicle, or vice versa. Finally, two additional demonstration objects were used in the same manner as the first two, for a total of four test trials. The order of presentation of the stimuli was counterbalanced across participants.

Results and Discussion

As expected, 2-year-olds consistently chose the category-appropriate role in the rich-object condition ($M=.75$, $SD=.32$). In the unfamiliar-object-with-many-features condition, they also consistently chose the category-appropriate object ($M=.85$, $SD=.20$). Individually, 9 of 12 and 10 of 12 performed at 75% correct or better in the rich-object condition and unfamiliar-object-with-many-features condition, respectively. In the single-feature condition ($M=.58$, $SD=.20$) and the role-only condition ($M=.54$, $SD=.09$), children did not consistently choose the category-appropriate object. Individually, 7 of 15 and 2 of 13 performed at 75% correct or better in the single-feature condition and the role-only condition, respectively. The number of children performing at or better than 75% did not differ from that expected by chance (binomial test, $p > .25$ in both cases).

An ANOVA revealed an effect of condition, $F(3, 49) = 5.69$, $p = .002$, and planned comparisons confirmed that performance in the stimulus conditions with clusters of perceptual properties differed from performance in the stimulus conditions with one or no typical feature ($p < .001$). However, performance did not differ between the multiple-property conditions ($p = .24$) and between the single- or no-property conditions ($p = .59$). Only performance in the rich-object condition, $t(12) = 2.79$, $p = .002$, two-tailed, and the unfamiliar-objects-with-many-features condition, $t(11) = 6.188$, $p < .001$, two-tailed, was significantly different from chance (.50).

The results from this experiment indicate that 2-year-olds link roles to clusters of perceptual properties. The key fact is that these children were able to infer the appropriate role given an unfamiliar object that presented relatively many properties predictive of the roles. This is potentially quite telling about the nature of development and the function of properties in the human conceptual system. First, it is consistent with the idea that children's knowledge of roles is mediated through, or linked to, perceptual properties *per se* rather than linked to specific recognizable things. Second, and because of this, it means that children's emerging knowledge of roles and functions is generalizable across tasks and categories. Children can extend their knowledge about the roles and functions to new things as long as these things present a sufficient number of known diagnostic properties. From this beginning, one can also imagine how knowledge about roles and their relations to properties can become increasingly abstract. As the links between roles and a cluster of properties become stronger, children may need fewer properties (indeed, only one) to activate the whole system of relevant knowledge, including roles. We consider these issues further in the General Discussion.

GENERAL DISCUSSION

The results show a clear developmental progression. Five-year-olds infer a category-appropriate role given a novel object with no perceptual properties typical of the category, whereas 3-year-olds require at least one diagnostic feature to link an object to a role and 2-year-olds require multiple features to do so. These results contribute to our understanding of two sets of issues. First, they provide new insight into the emerging power of category knowledge with development to go beyond the information given. Second, they provide new insights into how a system of category knowledge is built and interrelated.

Development of role knowledge consists of a loosening of dependence on the perceptual properties of things. Five-year-olds' knowledge about the roles characteristic of different kinds appears to be accessible independently of knowledge about co-occurring perceptual properties. Because of this, their inferences about roles can transcend the immediate perceptual input. This is potentially important in that role–role relations that are not tied to specific perceptual properties can provide a powerful engine within the human conceptual system connecting kinds that are very different from one another. Role–role connections unencumbered by specific perceptual properties may be the basis of metaphor and analogy, enabling children, for example, to generalize what they know about drinking in people to inferences about “drinking” in plants or from traffic jams to clogged arteries (see Gentner et al., 1997; Goswami & Brown, 1990).

Relative to 5-year-olds, 3-year-olds' access to the roles relevant to different kinds is more limited because it is dependent on the perceptual properties of the

specific object in question. However, at this age, a single diagnostic property appears to license a category-relevant role for the object. The fact that only a minimal perceptual feature is necessary means that role knowledge is also transportable for these children, perhaps not across radically different kinds, but certainly quite broadly within a kind. In this context, we note that property–role knowledge, with activation of roles requiring only minimal perceptual support, can also be a quite powerful underpinning for conceptualization. Consistent with Rakison's (2003) suggestions, highly diagnostic features may be important landmarks—anchors—in the conceptual system, serving as cues to attention and memory in real time and in specific tasks, taking the cognizer to the right set of ideas in a conceptual system that is, after all, quite large and complex. This proposal is also consistent with Booth and Waxman's (2002a) notion that highly diagnostic features such as eyes serve as “gateways” to conceptual knowledge.

At first glance, it might seem that 2-year-olds' dependence on perceptual features is quite limiting, as they seem to require the presence of many diagnostic features to apply a category-relevant role to the object. This finding fits the evidence that very young children's category inductions and comprehension of metaphors and analogies are highly dependent on overall similarity (Gentner & Rattermann, 1991). However, even these children's knowledge about roles is generalizable to novel and unfamiliar things. The results of the last experiment show that 2-year-olds will generalize roles to unfamiliar things if they present enough diagnostic features. Presented with something new that has eyes and mouth and limbs, they do make appropriate inferences about possible roles. Given that the diagnostic perceptual properties of things are typically causally related to roles, an early dependence on clusters of properties may also be an important first step to a causal understanding of why things have the properties they do and why they play the roles they do.

In the literature on cognitive development, a dependence on the immediately available perceptual input—as is the case for 2- and 3-year-olds in this study—is often seen as a “nonconceptual” solution to cognitive problems (see Madole & Oakes, 1999). The data in this study suggest an alternative view: Conceptual knowledge—even at its most abstract and transcendent—does the child no good unless it can be brought to bear in real time in specific tasks (cf. Harnad, 1990). Further, researchers cannot measure this knowledge unless it is used in some way (Samuelson & Smith, 2000b). These facts make the immediate in-task cues—the perceptual properties that ground knowledge to the specific objects at hand—essential parts of the conceptual system; it is that information that must direct the child to the relevant regions of the conceptual system. The static perceptual features of things thus serve as in-task, in-the-moment pointers within the conceptual system. Viewed in this way, it is perhaps not surprising that 2-year-olds with more fragile links to more tenuous role knowledge may need many real-time cues to activate the relevant knowledge, that 3-year-olds with more robust links between perceptual cues and more robust conceptual knowledge need fewer such cues, and that

5-year-olds with a more entrenched system need only in-the-task transient cues about one role to activate their knowledge about other roles.

The results presented here also provide new insight into the mechanisms relevant to building a conceptual system. In particular, the developmental trend suggests that the surface perceptual properties of things may not function simply to activate relevant role knowledge in a task but may also serve, at least initially, as the glue that links components in an emerging knowledge system. This idea is strongly suggested by studies of infants' use of features in categorization and the real-time attentional binding of roles and perceptual properties (Madole, Oakes, & Cohen, 1993; Rakison & Cohen, 1999). The results in our study, particularly those of the 3-year-olds, are also strongly suggestive of this idea. To generalize a role to a novel thing, these children do not require that it be similar overall to known things that function in that role, but apparently they do need at least one surface feature to bridge from one instance to a role, and in this way, from one role to another role.

This proposal that perceptual features serve an important function in the acquisition and binding together of a conceptual system is strongly underdetermined by this data and by the extant data in the literature. The strongest test would be a training experiment in which one attempted to teach role–role relations with and without correlated perceptual features. We have begun such investigations in a series of experiments with adults, and those results indicate that learning a system of role–role relations requires a concrete static perceptual cue as a kind of binding agent, but that once role–role relations are well learned they are transportable to kinds that do not present that static perceptual cue (Sheya, Hanania, & Demir, 2004). Thus, the function of surface properties in a developing conceptual system that eventually transcends those very properties may be a general characteristic of the human conceptual system and not limited to young children.

Why might static surface features be crucial to building a conceptual system that ultimately transcends those very features? We offer four (not mutually exclusive) hypotheses that may help guide future research: *statistical regularities*, *causal links* between features and roles, *stability of features*, and *roles are about objects*. By the statistical regularities hypothesis, static perceptual features are not intrinsically better than transient roles (or action events) as glue to hold together an emerging conceptual system, but rather simply happen to be better predictors of roles than roles are of other roles. This seems plausible in that the static surface properties of an object are regularly available to the learner whenever an instance is. In contrast, different roles (say drinking and hugging) are evident only in specific contexts, and two roles relevant to the same kind may rarely occur together. By the causal links hypothesis, the physical features of things are not only predictors of their roles and functions but also often causal determiners of those roles. Wheels, for example, afford rolling and movement. The extant evidence (Gibson & Pick, 2000; Rakison, 2003) suggests that the very presence of such features invites relevant actions on the part of the child. These actions may direct attention se-

lectively to causal features. By the stability of features hypothesis, features are more potent than roles in early development because they are more stable, more self-similar across different objects and contexts, than are the events that signal a role. The idea here is that wheels (or eyes) are recognizably similar to a perceptual system that can parse objects into parts, whereas individual events of transporting (or sleeping) are not so self-similar (see, e.g., Baldwin, Baird, Saylor, & Clark, 2001; Woodward, 1999).

The final hypothesis is, perhaps, the global outcome of the various processes outlined in the first three hypotheses: Roles (and functions and relations) are about objects. Gentner (1982) has argued persuasively in her discussions of children's acquisitions of nouns and verbs that arguments are logically, computationally, and developmentally prior to the predicates they take. This priority may be evident in, made manifest in, a variety of cognitive processes—including the perceptual system, the organization of human memory, sentence comprehension, and in processes involved in reasoning and making analogies (Gentner & France, 1988; Gentner & Rattermann, 1991).

The results discussed here fit this general framework in that the first three aforementioned hypotheses are similar in several respects to aspects of Falkenhainer, Forbus and Gentner's (1989) "structure mapping engine," specifically in the idea that conceptual structure develops from and is tied to surface similarities. This study, particularly the results from 3-year-olds, extends this idea by showing that overall similarity may not be required. Rather, there is a developmental point at which children can make inferences across overall dissimilar objects as long as they share at least one category diagnostic feature.

In sum, these results suggest a developmental trend in the acquisition of role–role knowledge that goes through perceptual features. However, this study only examined a specific cluster of features and kinds of categories in a particular task. The abilities displayed by the children might well be expected to be different given other category-relevant features, other categories (about which children perhaps know more), or in a task providing more or less support of their developing knowledge about roles. Still, given our results from training experiments with adults, we suggest that the general developmental trend may be the same—from clusters of surface features connected to roles, to single perceptual features predictive of roles, to roles directly linked to other roles—with faster or slower progress given different degrees of expertise or different support provided by the task.

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