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Detecting Blickets: How Young Children Use Information about Novel Causal Powers in Categorization and Induction

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Three studies explored whether and when children could categorize objects on the basis of a novel underlying causal power. To test this we constructed a "blicket detector," a machine that lit up and played music when certain objects were placed on it. First, 2-, 3- and 4-year-old children saw that an object labeled as a "blicket" would set off the machine. In a categorization task, other objects were demonstrated on the machine. Some set it off and some did not. Children were asked to say which objects were "blickets." In an induction task, other objects were or were not labeled as "blickets." Children had to predict which objects would have the causal power to set off the machine. The causal power could conflict with perceptual properties of the object, such as color and shape. In an association task the object was associated with the machine's lighting up but did not cause it to light up. Even the youngest children sometimes used the causal power to determine the object's name rather than using its perceptual properties and sometimes used the object's name rather than its perceptual properties to predict the object's causal powers. Children rarely categorized the object on the basis of the associated event. Young children also sometimes made interesting memory errors—they incorrectly reported that objects with the same perceptual features had had the same causal power. These studies demonstrate that even very young children will easily and swiftly learn about a new causal power of an object and spontaneously use that information in classifying and naming the object.

INTRODUCTION

The world has a particular causal structure: Some events make other events happen. More specifically, objects have causal powers—they systematically influence and affect other objects in particular ways. Television remotes make the set turn on, magnets make filings move toward them, water makes a plant grow, the sun makes you get sunburned, a snake makes you scared.

Often, in fact usually, the causal structure of the world and the causal powers of objects are not immediately apparent. We can't simply predict how an object will affect other objects by seeing what it looks like. In fact, similar-looking objects may have different causal effects on other objects: The stereo remote doesn't turn on the TV, ordinary metal doesn't attract filings, vodka kills plants, indoor lights don't burn you, garden hoses aren't scary. Somehow we must learn about these causal powers of objects and determine which objects do or do not have those powers.

Understanding and learning about causal powers is extremely useful. It allows us to make important predictions about what will happen in the future and also allows us to intervene in the world effectively to make things happen ourselves. We can make TVs turn on or plants grow or we can scare our relatives. When and how do children develop these capacities? When can children learn about new causal relations between objects and about new causal powers of objects?

The classical Piagetian view, of course, was that preschool children understood objects in terms of their superficial appearances, not in terms of their causal capacities or powers. This was part of Piaget's general claim that preschoolers were "precausal" and reasoned associatively or based on perceptual similarity rather than in genuinely causal ways (Piaget, 1929). However, other recent work suggests that children may engage in some kinds of causal reasoning in the preschool period and even in infancy. In particular, children seem to understand some of the principles of "billiard ball" mechanical causality, an important part of "folk physics" (Bullock, Gelman, & Baillargeon, 1982; Cohen & Oakes, 1993; Leslie & Keeble, 1987). A further challenge to the view that early cognition is based on perception comes from studies of very young children's folk psychology and folk biology (Gelman & Wellman, 1991; Gopnik & Wellman, 1994). Children seem to talk about and explain psychological and biological events in terms of underlying, nonobvious, causally efficacious entities and laws. These include mental entities like beliefs and desires and biological forces like growth and inheritance.

Many of these studies have been done in the context of the "theory theory" of cognitive development: that is, the idea that children's everyday conceptions of the world are analogous to scientific theories (Carey, 1986, 1988; Gelman & Wellman, 1991; Gopnik, 1988; Keil,

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1989; Perner, 1991; Wellman, 1990). Understanding causal powers is a necessary, although not sufficient, condition for this sort of "theoretical" understanding (see Gopnik & Meltzoff, 1997; Gopnik & Wellman, 1994). Theories also typically have other features; in particular, they involve complex and coherent networks of causal claims. At the least, theories require that the theorizer can conceive of nonobvious causal powers.

These studies may help show that young children have theories. We must consider, however, that the "theory theory" has two components. First, the theory claims that children's knowledge has some of the structural features of scientific theories, including their causal character. Second, the theory claims that children construct theories by using some of the same processes that are involved in scientific theory formation (see Gopnik & Meltzoff, 1997; Gopnik & Wellman, 1994). Childhood theories, according to this theory, are the result of observation, experiment, and inference. The ability to learn about novel causal powers of objects would, at least, be a prerequisite for this sort of theory-formation ability. Being able to learn about causal powers is a necessary though not sufficient condition for theory formation.

We can't infer, however, that children can learn about causal powers just because they have apparently causal knowledge of everyday domains, whether physical, biological or psychological. We do not know where that causal knowledge comes from. In scientific theories, claims about causal powers are the result of learning. They stem from observation, experiment, and inference. However, it is possible that the causal entities and laws of everyday physics, biology, and psychology are innately specified (see, e.g., Atran, 1990; Leslie & Roth, 1993), rather than learned. Alternatively, children may not spontaneously understand the world in terms of causal powers but may have this structure imposed upon them by the structure of adult knowledge, particularly adult scientific knowledge. For example, Carey (1996) suggests that some of the children in Gelman's "folk biology" studies (Gelman & Wellman, 1991) who explain events in terms of growth and inheritance may be reproducing particular pieces of adult information, rather than reflecting their own understanding of biology. To test whether children learn about causal powers we would have to look at their ability to grasp novel causal powers—powers that they could not understand as a result of an innate endowment or explicit adult teaching.

One way to test whether and when children understand new causal powers is to look at their categorization behavior. As adults, we can sometimes categorize objects together, and give them the same name, when their causal effects on other objects are similar; that is, when they have the same causal powers. We may do so even when this conflicts with a purely perceptual categorization of the objects. For example, a kitchen may contain many similar jars of indistinguishable fine white powder. Each has a different name depending on its effects on other ingredients. Cream of tartar is perceptually similar to baking soda but has a different name because of its strikingly different effects on eggs. Similarly, we use names as a guide to the causal powers of objects. If the substance labeled cream of tartar makes my soufflés rise well, I can assume that a new sample with the same name will have a similar effect. These causal categorizations allow us to make important predictions about what will happen in the future.

In scientific theories, in fact, the causal powers and roles of objects are the single most important factor in determining an object's category and name, and they almost invariably override perceptual features of the objects. In fact, theoretical entities and categories in science are usually defined by their causal role (see e.g., Cartwright, 1989; Salmon, 1984). At least from a scientific point of view, gold is not gold because it glitters but because of the role it plays in causal interactions in chemistry.

Moreover, both in science and in ordinary adult life, we not only can categorize objects on the basis of our existing causal knowledge, but also can categorize them on the basis of what we learn about their new causal powers. To take other real-life cooking examples, we may discover (happily) that some perceptually similar samples of sugar make better caramel than others (it turns out that cane sugar oxidizes more readily than beet sugar) or (unhappily) that yogurt makes sauces curdle when we try to substitute it for the perceptually similar sour cream. In fact, discovering new causal powers is a major goal of scientific inquiry. Learning about new causal powers of objects may influence the way we categorize those objects. We may keep the two types of sugar in separate bins instead of combining them or make a distinction between "fool's gold" and "gold." If very young children produce these same kinds of categorization behaviors, that might indicate that they do, in fact, learn about new causal powers of objects.

Recently, a number of authors have suggested that children categorize and, in particular, name objects on the basis of perceptual features such as shape (Imai, Gentner, & Uchida, 1994; Landau, Smith, & Jones, 1988; Smith, Jones, & Landau, 1996). This might suggest that children will not, in fact, categorize and name objects on the basis of causal powers. In knowledge of everyday domains, however, causal features of objects and perceptual features are likely to be conflated. Other things being equal, objects that look alike are, in fact, likely to have similar causal powers, even though causal powers are distinct from perceptual features. This makes it difficult to tease apart whether children are paying attention to perceptual features or to causal powers in their everyday categorization and naming (see Gelman & Medin, 1993, and the discussion of this issue in *Cognitive Development*).

Two sets of studies in the literature suggest that children may indeed have the ability to categorize objects in terms of novel, nonobvious properties, even when those properties conflict with the perceptual features of the object. The first is a series of studies by Gelman (Gelman & Coley, 1990; Gelman & Markman, 1986, 1987) investigating children's inductive inferences. In these studies children saw a target object and then two other objects, one with a different name but similar perceptual properties and one with the same name and different perceptual properties. Children were then told that the target object had a novel property "x" and were asked which of the other objects was most likely to have that property. Children as young as 2½ chose the object with the same name rather than the perceptually similar object.

Objections to these studies have been raised, however, because they use pictured objects rather than real objects and involve purely verbal responses rather than real predictions (see Jones & Smith, 1993). A more crucial objection might be that both the novel property and the common name are strictly linguistic descriptions of the object. Children might feel that one linguistic label will predict another linguistic label, even if they would not use the name to predict a new observable property of the object. Moreover, the novel property is still an intrinsic property of the object rather than involving a causal effect of the object on other objects.

The other set of experiments involves what have been called "functional" properties of objects. Kemler-Nelson (1995) found that children would apply names to objects with the same novel functional properties even when the objects were perceptually dissimilar, as suggested earlier by Katherine Nelson (Nelson, 1973). The notion of "functional" property is not entirely clear; however, it still seems rather different from the notion of causal power. Functional properties typically involve the way that a person can use an object, rather than the effects an object itself will have on other objects and people.

Both intrinsic properties and functional properties seem to have an important causal component. Often causal powers may indicate the intrinsic properties of an object, and the causal powers of an object may play a role in the ways we can use that object. These experiments, then, suggest that causal information might sometimes play a role in categorization. However, neither novel "functional properties" nor novel "intrinsic properties" are exactly the same as novel causal powers.

When can children categorize and name objects on the basis of their underlying causal powers? When can they use names to make predictions about novel causal powers? Can children categorize objects causally when they are confronted by a novel causal power? Can children categorize objects causally when causal powers and perceptual features are directly in conflict?

In the current experiments, we "invented" a new causal power of objects: whether or not they made a particular machine light up. Children had never encountered this causal power before, but they were given direct experience of it with real objects. Because we had complete control over this causal power, we could also directly pit it against perceptual features of objects. We could arrange to have perceptually identical objects that did or did not display the causal power. We then explored whether children used information about the causal powers of the objects to categorize them. In particular, we explored whether children would give objects with similar causal powers the same name. In a control condition, we also tested whether children would perform similar categorizations when there was an association between the object and the machine but no causal relation. We investigated whether children would use names to guide their inductions about this causal power. Finally, we explored how these categorization and inductive judgments were related to perceptual similarities and differences among the objects.

EXPERIMENT 1

Method

Participants

Sixteen 3-year-olds, *range* = 3,0–4,1 (M = 3,6) and sixteen 4-year-olds, *range* = 4,3–5,3 (M = 4,9) were recruited from three different preschools near the University of California, Berkeley. Approximately equal numbers of boys and girls participated in the study. Most children were from white, middle-class backgrounds, but a range of ethnicities resembling the diversity of the Bay Area population was represented.

Materials

Two specially designed "blicket detector" boxes were constructed. They were made of wood with a lucite top and their dimensions were 5 inches × 7 inches × 3 inches. Two wires emerged from the detector's side. One was plugged into an electrical outlet and the other ran to a switchbox. If the switchbox was in the "on" position, the detector would light up and play music when an object was placed upon it. If the switchbox was in the "off" position, the detector would do nothing when an object was placed upon it. During the experiment, this wire ran to a confederate who surreptitiously flipped the switch on to allow an object to set the machine off or flipped the switch off to ensure that an object would not set the machine off. The apparatus was designed so that when the switch was on, the box "turned on" as soon as the object made contact with it and continued to light up and play music as long as the object continued to make contact with it. It "turned off" as soon as the object ceased to make contact with it. This design provided a strong impression that something about the object itself caused the effect. One of the detectors was gray with a red top and played "Für Elise;" the other was blue with a yellow top and played "You Are My Sunshine."

The wire and switchbox were hidden from the children's view and they had no suspicion of the role of the confederate. Thus, certain objects simply appeared to set off the detector and others did not. Moreover, in other studies using this machine with more verbal older children and adults, we directly asked participants to guess why the machine went off (Esterly, 1997). None of these participants detected the role of the confederate nor even mentioned intentional trickery as a hypothesis about the machine. Participants always assumed that something about the object itself had caused the effect.

During the testing session, the child was presented with seven sets of four wooden blocks each (28 blocks in total). Two collections of 28 blocks were assembled. Figure 1 depicts the nature of these seven sets of blocks. Sets 1 though 4 were the "neutral" sets. For these sets, there was no relation between the causal properties of the blocks and their perceptual properties. Set 1 contained four identical blocks. In Sets 2, 3, and 4, all four blocks were different. In Set 2, the blocks were the

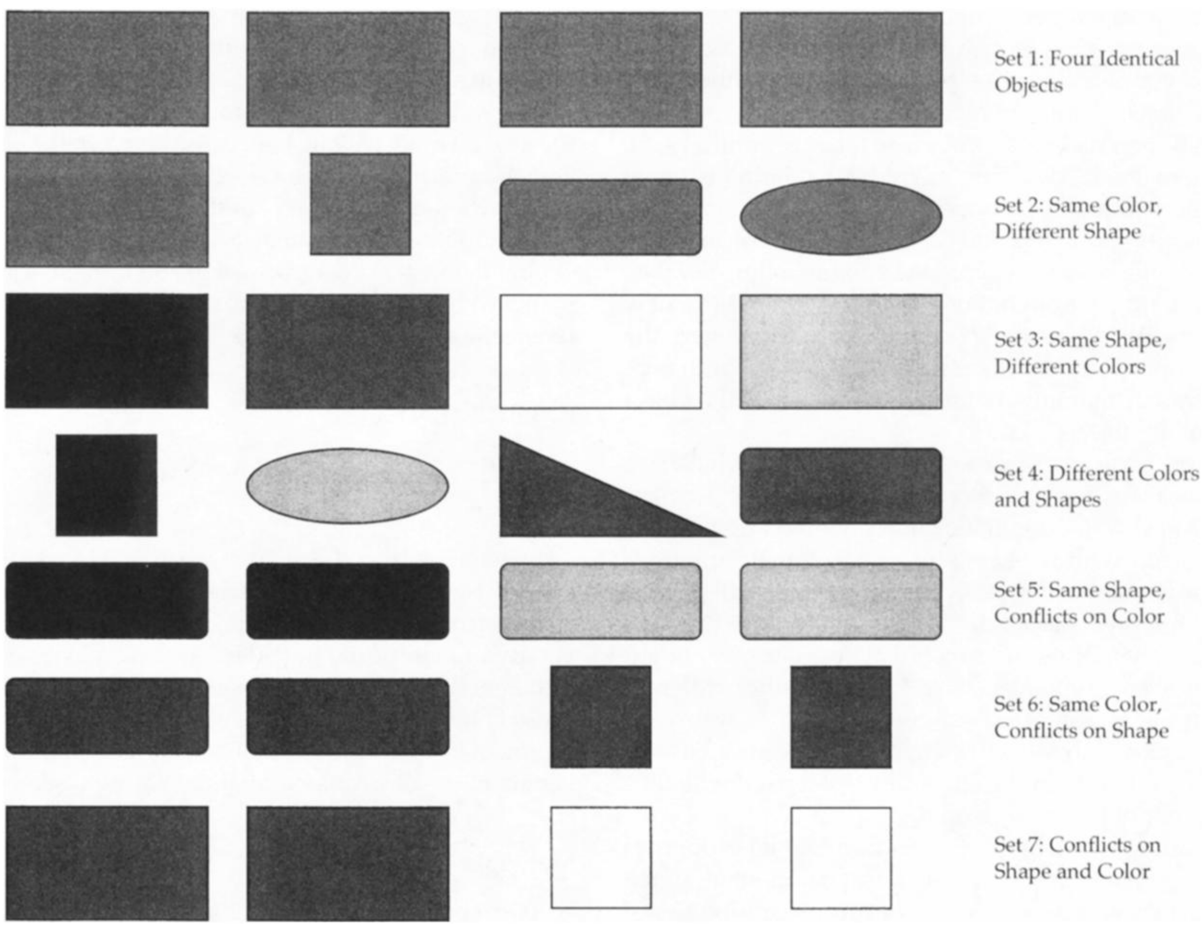

Figure 1 Pictorial representation of the seven sets of blocks used across Experiments 1–3.

same color, but four different shapes. In Set 3, they were the same shape but four different colors. In Set 4, they were four different colors and four different shapes.

Sets 5–7 were the "conflict" sets. In these cases, the causal properties of the objects conflicted with their perceptual properties. Two pairs of identical blocks were presented. In Set 5, all the blocks were the same shape, but two were one color and two were a different color. In Set 6, all were the same color, but two were one shape and two were another shape. In Set 7, two blocks had the same shape and color and the other two had a different shape and color. Other materials were a small toy helicopter, two small (approximately 1 inch in diameter) white porcelain knobs, and two small metallic tee-joints (approximately 1½ inches in height).

Procedure

Children were tested individually in two 15-min sessions. Children were randomly assigned to be in either the categorization or the induction condition in the first session and to the other condition in the second session (see below). Four children in the categorization and induction conditions were unable to make the second session and were replaced by children who were tested for only one session. There was approximately a 2-week waiting period between the two testing sessions, although this varied among children.

Warm-up and pretest. The child was led into the testing area and sat at a table across from the experimenter on which the blicket detector was placed. After 5 min of free play with the toy helicopter, the experimenter took out the two small white porcelain knobs and the two small metallic tee-joints. These were placed in front of the child. The experimenter held up one of the knobs and told the child that it was a dax and asked the child to show him the other dax. After the child responded, the experimenter picked up one of the metallic tee-joints and told the child that it was a wug and asked the child to show him the other wug. The pretest established the naming game and showed that children would extend a new name to a perceptually identical novel object.

Categorization condition. In the categorization condition, one set of blocks was placed in front of the child. Children were never told that the machine was a "blicket detector" or that some of the objects would set the machine off and some would not. Instead they were merely told, "Look!" Each block was placed on the detector one at a time. Two blocks set it off and two did not. Blocks were carefully replaced in their original positions to ensure that the child remembered which individual blocks set the detector off. After the effects of all four blocks were demonstrated, the experimenter told the child that they were going to "look at them again" and again demonstrated the effects of each block on the machine. The experimenter then held up one of the objects that had set the machine off and told the child "See, this one is a 'blicket' (in the first session) or a 'tib'" (in the second session). The experimenter then asked the child if he or she could show him another blicket/tib.

If the participant picked the other object that set the detector off, then the experimenter put the objects away and moved on to the next task. If the child did not, then the experimenter would return the object the child did pick to its original position. As a control for memory, the experimenter would then ask the child to show him "the one that set the machine off."

Induction condition. In the induction condition, a set of blocks was placed in front of the child. Two objects were held up and the child was told they were "blickets" (or "tibs" if this was the second session). The other two objects were then held up and the child was told they were "not blickets/tibs." The objects were then returned to their original positions and one of the blickets/tibs was then placed on the detector, which went off. Again, children were not told that the machine was a blicket detector or that some objects would set the machine off and others would not. Instead they were just told, "Look!" The experimenter then said "See, this one set the machine off." The experimenter then asked the child to show him another one that would set the machine off.

Neutral versus conflict tasks. In both the categorization and induction conditions, the child was presented with seven sets of blocks. In the neutral tasks (Sets 1–4; see Figure 1 above), two objects were selected at random to set the machine off. Thus, in these tasks, there was no consistent relationship between the perceptual features of the object and the underlying causal power of that object. In the three conflict tasks (Sets 5–7, see Figure 1 above), the perceptual features of the objects actually conflicted with the underlying causal power. One member of each identical pair set the machine off, whereas the other one did not.

Participants always received Set 1 first. Therefore, the first trial on both procedures was the trial in which the four objects were perceptually identical. The remaining six trials were presented to participants in a random order. The position of the objects that set the machine off differed on each trial and was also randomly determined. The gray and red "blicket" detector was always used in the first session, whereas the blue and yellow "tib" detector was used in the second session. Different sets of blocks were used in the first and second sessions so that the children never saw the same block in any two trials during a session.

Results

Pretest

In the pretest, 92.5% of the children correctly picked the second white knob as the "other dax" and the second metallic tee as the "other wug," which indicates that they could follow the basic structure of the task and would give perceptually identical objects the same name. (In this and in all the subsequent experiments we reanalyzed the data excluding the few children who failed this pretest and results were identical in every respect.)

Children's responses were coded in the following manner. For each set of blocks, children received a score of 1 if they chose the other object that had set the machine off as the other "blicket/tib" in the categorization condition and a score of 0 otherwise. In the induction condition, children received a score of 1 if they picked the other "blicket/tib" as the object that would also set off the machine. Children's scores on the seven sets were averaged.

Order Effects

Children's performance on each of the tasks was analyzed in three ways to consider possible order effects. First, children's performance on the first neutral task was compared with performance on the last neutral task and, similarly, children's performance on the first conflict task was compared with performance on the last conflict task. In neither the categorization condition nor the induction condition were there significant differences between performance on the first neutral task versus the last neutral task or between the first conflict task and the last conflict task.

Second, regressions for Tasks 2 through 7 were set up with performance on a given task as the dependent variable and position of that task in the sequence of the seven tasks as the independent variable. Task 1 was excluded from this analysis because it always appeared first. For no task did the position explain a significant amount of the variance in performance (all $Fs < 1$).

Finally, we tested to see if performance on either condition differed as a function of whether children received that condition in the first or second session. There were no such differences.

Overall Analysis

Omnibus F tests revealed no differences among the four neutral tasks nor among the three conflict tasks; therefore, children's performances on those tasks were averaged together. The percentage of causally relevant choices was compared with a 2 (age: 3-year-olds × 4-year-olds) × 2 (condition: categorization condition versus induction condition) × 2 (task type: neutral tasks versus conflict tasks) mixed ANOVA with age and condition as between-subjects factors and task type as a within-subjects factor. (Condition was treated as a between-subjects factor to deal with the replacement children who only received one condition and also to deal with the variable time intervals between the two testing sessions). A main effect of condition was found. Overall, children chose the object with the same name more often in the induction condition than they chose the causally similar object in the categorization condition (78% versus 59% respectively, $F(1, 60) = 11.73$, $p < .001$). A main effect of task type was also found. Overall, children chose the causally similar object or the linguistically similar object more often in the neutral tasks than in the conflict tasks (78% versus 56% respectively, $F(1, 60) = 23.63$, $p < .001$). In addition to these main effects, there was a significant interaction between condition and task type, $F(1, 60) = 8.04$, $p < .006$. There were no age effects. No other significant interactions were found.

Categorization Condition

Given the significant interaction involving condition, we then analyzed the results for the categorization condition and the induction condition separately. In the categorization condition, the children categorized the objects, by giving them the same name, after they witnessed each object's causal powers. Figure 2 shows the percentage of causal responses in the neutral tasks and the percentage of causal and perceptual responses in the conflict tasks. We performed a 2 (age: 3-year-olds × 4-year-olds) × 2 (task type: neutral versus conflict) mixed ANOVA with age as the between-subjects variable and task type as the within-subjects variable. There were no significant differences between the 3- and 4-year-olds, $F(1, 31) = 0.80$, $p > .10$. There was, however, a significant difference between children's causal responses on the neutral and conflict tasks (74% versus 40%, $F(1, 31) = 25.57$, $p < .001$).

On the neutral tasks, children said that the object with the same causal powers was the "blicket" on 74% of the trials, significantly above chance (33%, $t(1, 31) = 9.571$, $p < .001$). This result suggests that even 3-year-old children will use novel causal powers as a basis for categorization and naming. On the conflict trials, children categorized the object with the same causal power as the blicket on 40% of the trials. Children categorized the perceptually identical object

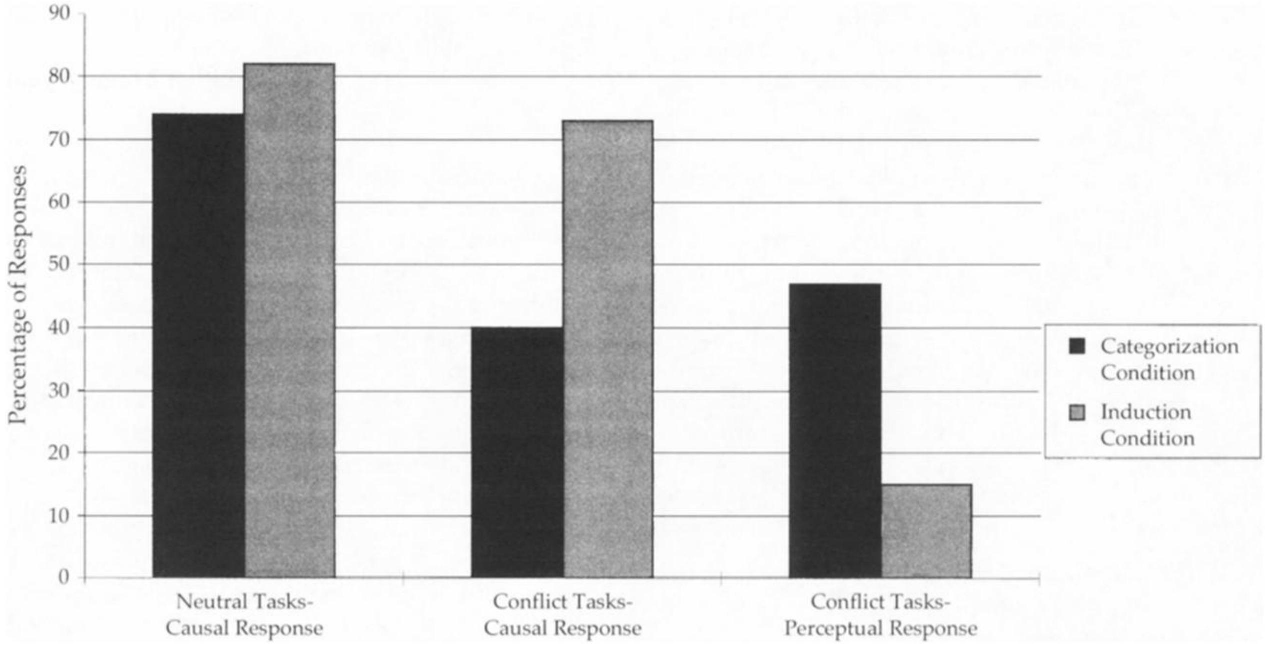

Figure 2 **Children's performance on the Categorization and Induction Conditions in Experiment 1.**

as the blicket on 47% of the trials and the distracter (the object that was neither perceptually nor causally similar) as the blicket on 13% of the trials. Children did not pick the object with the same causal power significantly more frequently than the perceptually identical object. They also did not pick either type of object more frequently than chance. They did, however, pick both the causally relevant and perceptually identical objects significantly more frequently than the distracter object (40% and 47%, respectively, versus 13%, binomial tests, both $ps < .001$). This result suggests that children were not simply picking objects at random.

Memory Probe

In the categorization condition, subjects received a memory probe when they failed to choose the block with the same causal powers as the "blicket." It seemed possible that the children had simply forgotten which of the objects had set off the machine. The child was therefore asked to show which object had set off the machine originally. Omnibus F tests revealed no difference in the amount of errors across the four neutral tasks or the three conflict tasks, so these were averaged. These tests also revealed no differences between 3- and 4-year-olds.

On the neutral tasks, children rarely made a mistake in reporting which other object set off the machine. They made memory errors on only 8% of the trials. They made both possible types of errors. Six percent of the time they said that an object that had not set off the machine was the blicket and also mistakenly said that that object had, in fact, set off the machine. Two percent of the time they said that an object that had not set off the machine was the blicket and mistakenly reported that a different object had set off the machine. These errors were not significantly different from each other or from chance (binomial test, $p > .10$).

On the conflict tasks, however, the pattern was somewhat different. There are six possible combinations of responses to the memory probe question. Children could pick either the perceptually similar object or the distracter object as the other blicket, and they could pick any one of the three objects (the causally similar object, the perceptually similar object, or the distracter) as the one that set the machine off. Two types of patterns of response were particularly frequent. Children chose the perceptually identical object as the other blicket 28% of the time but correctly remembered the object that had set off the machine. Interestingly, however, 17% of the time children not only chose the perceptually similar object as the other blicket but also, mistakenly, said that that object had previously set off the machine. Each of these patterns occurred significantly more frequently than any other pattern of responding (all binomial tests, $p < .05$). They did not occur significantly differently in frequency from each other (binomial test, $p > .10$).

This result suggests two possibilities. The first is that some children simply had difficulty remembering which object had set off the detector, and this fact was responsible for their choice of the perceptually identical object in the categorization task. If this were true, however, we would expect that all errors would be equally distributed and that children would also make memory errors in the neutral tasks. A more interesting possibility is that some children simply assumed that perceptually identical objects would also have similar causal powers and names. This assumption overrode even their actual experience and memory of the object's behavior. In other words, once these children decided the perceptually identical object was a "blicket," their memory of the actual events became distorted, thereby leading them to incorrectly report that the object had also set off the machine.

Induction Condition

In the induction condition, children made predictions about the causal powers of the objects, given the object's name. Figure 2 shows the percentage of responses based on the common name in the neutral tasks and the percentage of responses based on the common name and responses based on perceptual similarity in the conflict tasks. Overall, children were strikingly likely to use names as a guide to predictions about causal powers: They chose the object with the same name at a rate well above chance in both neutral and conflict tasks and on 78% of the trials overall. We looked at the percentage of times children chose the object with the same name as the one which would also set off the machine by performing a 2 (age: 3-year-olds versus four-year-olds) × 2 (task type: neutral versus conflict tasks) mixed ANOVA with age the between-subjects variable and task type the within-subjects variable. As in the categorization condition, there were no age differences. Unlike the categorization condition, there was no difference between the neutral and conflict tasks overall (82% versus 73%, $F(1, 31) = 2.26$, $p > .10$). This result explains the significant interaction between condition and task type described in the main effects.

In the conflict tasks, children predicted that the object that was called a "blicket" would set off the machine on 73% of the trials. This is significantly greater than the number of times they chose the perceptually identical object (15% of the time, binomial test, $p < .001$). This is also significantly greater than the number of times they chose the distracter object (12% of the time, Binomial test, $p < .001$). Children did not select the perceptually identical object any more often than they selected the distracter object (15% versus 13%, binomial test, $p > .10$).

Discussion

The induction condition in this experiment replicated Gelman and Markman's (1987) finding with real three-dimensional objects and causal predictions that could be observed and tested. The categorization condition also suggested that children might indeed be using causal powers to categorize and name objects and might sometimes do so even when this information conflicted with perceptual information. There were two difficulties in this study, however. First, it is possible that rather than interpreting the object's behavior causally, children simply associated the objects, the name, and the behavior of the machine. In other words, children might simply associate the word "blicket" with the machine lighting up and further associate that event with particular objects so that the causal power of the object would be irrelevant. Similarly, the event of the machine lighting up might have simply made those objects more salient and so more likely to be named.

Second, the pattern of behavior on the conflict tasks in the categorization condition could either have been the result of two conflicting strategies, one perceptual and one causal, or it could simply have been random responding, perhaps because the children were somehow confused by some feature of the task. The fact that children did well in the neutral task and that they chose the causally relevant object and the perceptually identical object significantly more often than the distracter weighs against this possibility, but still both types of responses were not significantly more frequent than chance.

EXPERIMENT 2

To test these alternative interpretations of Experiment 1, we set up a control condition that was very similar to the categorization condition, but did not encourage an interpretation in terms of the causal powers of the object. In this condition the object was simply associated with the event of the machine lighting up, but did not seem to cause that event. If children did not choose the associated object as the "blicket" in this task we could conclude that the causal relation between the object and the event was important. Moreover, if children did not choose the associated object in this task, we could infer that the causal responses in Experiment 1 were not simply the result of random responding due to some confusing feature of the general procedure. We can think of this as a kind of "base-line" condition to determine how often children would produce each type of response when there was no indication that the object had a novel causal power.

Method

Participants

Thirty-two children, sixteen 3-year-olds and sixteen 4-year-olds, participated in this experiment, M = 3,7 and M = 4,9, respectively. Children were recruited from two preschools near the University of California, Berkeley. Approximately equal numbers of boys and girls participated in the study. Although most children were from White, middle-class backgrounds, a range of ethnicities resembling the diversity of the Bay Area population was represented. No child was a participant in Experiment 1.

Materials

The same materials that were used in Experiment 1 were used here. One set of 28 blocks and the red and gray blicket detector were used in this experiment.

Procedure

All children were tested individually for approximately 15 min. Testing sessions followed exactly the same procedure and used the same materials as in the categorization condition in Experiment 1 with these differences. In Experiment 1 each block was placed on the detector and the detector lit up or did nothing. In this experiment, each block, one at a time, was held up slightly above the detector. For two of the blocks, in full view of the child, the experimenter would simultaneously press the top of the detector and the detector would go off. For two of the blocks, the experimenter would simultaneously place his hand near the detector but would not press it, and nothing would happen. The experimenter carefully coordinated these two actions so that the temporal contingencies between the objects and events were the same as in the previous experiment. Then, exactly as in Experiment 1, the experimenter held up one of the blocks that had been associated with the machine going off, told the participant that it was a "blicket," and asked the participant to show him the other blicket.

This procedure discouraged children from concluding that the objects had novel causal powers. First, the objects did not make contact with the machine. Second, there was a more plausible causal explanation for the event; namely, that it was caused by the experimenter's hand. Adults who saw these events did not think that the object had caused the machine to go off; they always assumed that the experimenter's hand was responsible. However, the associations and contingencies between the objects and the events were the same as in the previous study and the conditions were very similar perceptually.

The only other difference between the two conditions was that we did not include a memory probe. First, there was no natural way of asking the memory question that would be comprehensible to these young children, an interesting fact in itself. We would have to have said something like "Which one was I holding up at the same time I set the machine off ?"—a very complex sentence for 3-year-olds. Moreover, the lack of order effects in the previous experiment suggested that the memory check was not itself having an effect on responses. To ensure that this was indeed true, however, we reanalyzed the data in Experiment 1. We looked only at children who did not receive a memory question on Task 1 but did receive some memory question later in the experiment. We then compared the children's performance on Task 2—that is, when they had not yet had a memory question (a situation parallel to the current task)—and on Task 7, when they had had at least one such question (and usually more). There were no differences in performance.

Results

Pretests

Ninety-one percent of the children correctly picked the second white doorknob as the "other dax" and the second metallic tee as the "other wug" in the pretest. This result again suggested that they could follow the basic structure of the task. This finding was similar to the number of children who correctly picked the other dax and wug in the first experiment.

Order Effects

Children's performance on each of the tasks was again analyzed in two ways to consider the order of task presentation. Children's performance on the first neutral task was compared with performance on the last neutral task and, likewise, children's performance on the first conflict task was compared with performance on the last conflict task. There were no significant differences.

Furthermore, regressions for Tasks 2 through 7 were set up with performance on a given task as the dependent variable and position of that task in the sequence of the seven tasks as the independent variable. Again, Task 1 was excluded from this analysis because it was always first. For no task did the position explain a significant amount of the variance in performance (all Fs < 1).

Main Effects

Figure 3 shows how often the children chose the associated object on both the neutral and conflict tasks. It also shows how often children chose the perceptually similar object in the conflict tasks and, likewise, a comparison with the categorization condition of Experiment 1. An omnibus F test was done among the four neutral tasks and the three conflict tasks. No significant differences were found (all Fs < 1). A 2 (age: 3-year-old versus 4-year-old) $\times$ 2 (task type: neutral versus conflict) mixed ANOVA was performed with age as a between-subjects factor and task type as a within-subjects factor. There was a main effect of task type. Overall, children were more likely to pick the object that shared the associated response on the neutral tasks than on the conflict tasks (45% versus 11%, $F(1, 30) = 38.05$, $p < .001$). There was no difference between the age groups, nor were there any significant interactions.

Comparison with Experiment 1

Children did not choose the associated object in Experiment 2 as frequently as they chose the causally similar object in the categorization condition of Experiment 1 (see Figure 3). In the neutral tasks, children chose the associated object on 45% of the trials, not significantly better than chance (33%) and significantly less frequently than the 74% in the categorization condition of Experiment 1, $t(1, 62) = 4.979$, $p < .001$. On the conflict tasks, children chose the associated object on only 11% of the trials, significantly less than the 40% in Experiment 1, $t(1, 62) = 3.487$, $p < .001$. In contrast, they chose the perceptually identical object on 85% of the trials, significantly more frequently than the 48% in Experiment 1, $t(1, 62) = -4.184$, $p < .001$. In sum, children rarely used the information about the associated object; instead they responded randomly in the neutral trials and by picking the perceptually identical object in the conflict trials.

Discussion

Children did not use the association between the objects and the machine going off to determine which object was the other blicket. Instead, in the neutral tasks they picked objects at random. In the conflict

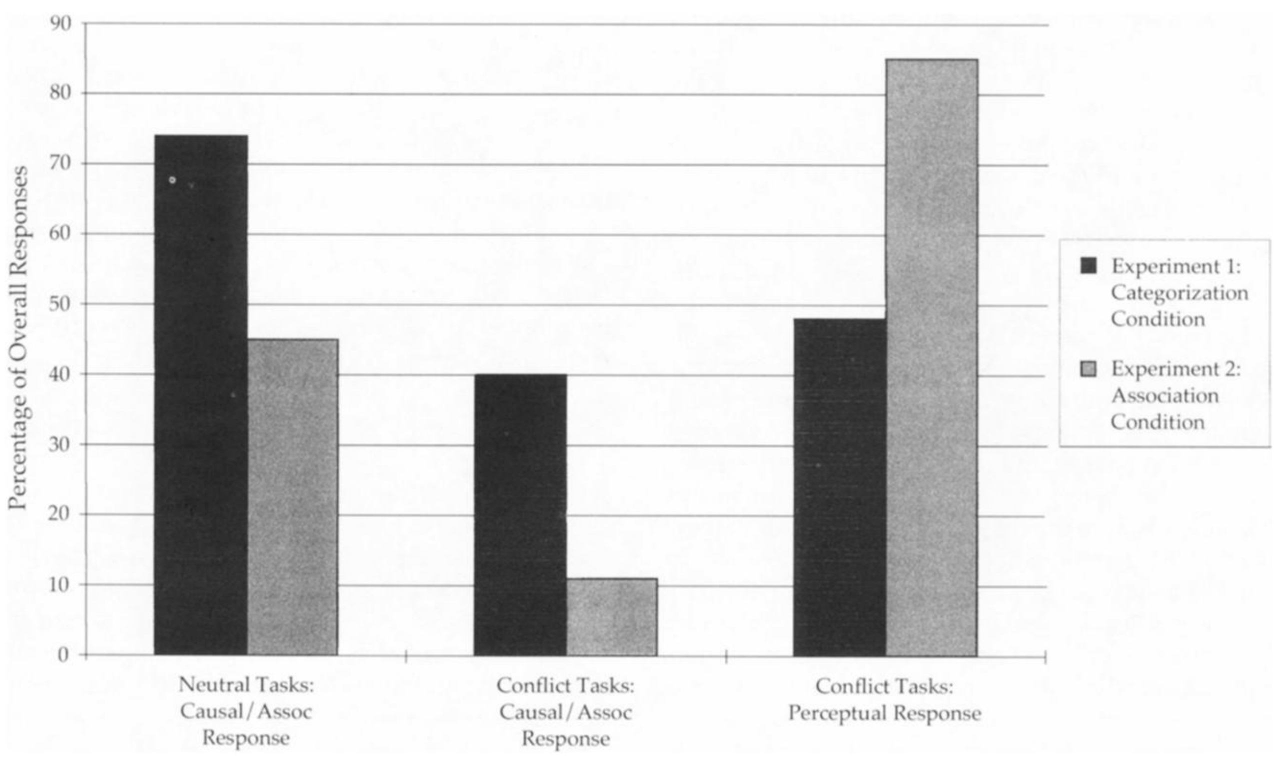

Figure 3 Comparison of Causal and Associative responses for children in Experiments 1 and 2.

tasks, where there was a perceptual basis for determining which object was the other blicket, they consistently used that perceptual basis instead of the association. To an adult, the relevant difference between these two conditions involved their causal character—in the categorization condition the object appeared to cause the machine to light up and in the association condition it did not. If this is also true for children, then this result suggests that children in Experiment 1 did categorize the objects as "blickets" because they concluded that they had novel causal powers. It also suggests that the pattern of responses in the conflict tasks in Experiment 1 were not simply the result of chance responding or confusion about the general procedure. In this very similar task, children did not behave at random but consistently chose the perceptually similar object.

EXPERIMENT 3

Experiments 1 and 2 suggested that children as young as 3 years old could categorize and name objects on the basis of their causal powers and could use names to predict causal powers. They did this even though the causal powers were novel and even when they conflicted with perceptual properties of the object. Given the lack of any age effects, we wanted to test whether even younger children would also demonstrate these abilities. Moreover, we wanted to further explore the memory effects we had discovered fortuitously in Experiment 1. In Experiment 3, we replicated the findings of Experiments 1 and 2 with 2-year-old children and included further memory checks.

Method

Participants

Forty-six children between the ages of 30 months and 33 months ($M = 30$) were recruited from the Babyfile of the Institute of Human Development at the University of California, Berkeley, and from Girton Hall Toddler Center at the University of California, Berkeley. The Babyfile contains a list of children born in several hospitals in the Bay Area. Parents of children were contacted by members of our research team and brought into the lab for participation. Children recruited from Girton Hall were tested in the center. Approximately equal numbers of boys and girls participated. Although most children were from White, middle-class backgrounds, a range of ethnicities resembling the diversity of the Bay area population was represented. Nine additional children were not included because they failed to complete the control procedures (described later).

Materials

The blicket detectors, blocks, and other stimuli from Experiment 1 were also used in this experiment.

Procedure

Each child was tested either in the categorization condition ($n = 15$) described in Experiment 1, the induction condition ($n = 15$) described in Experiment 1, or the association condition ($n = 16$) described in Experiment 2. The categorization and induction conditions were identical to those in Experiment 1 except that two further memory tasks were added. After 5 min of free play and the daxes and wugs pretest, children were presented with four identical blocks. The blocks were either placed on the machine one at a time (in the categorization condition) or were given names (in the induction condition). Two objects set the machine off and two did not, or two objects received the same name and two did not. The child was simply asked a memory question. In the categorization condition, after the demonstration, the experimenter picked up a block, placed it on the machine and told the child that it "made the machine go." The experimenter asked the child to give him the other one that made the machine go. In the induction condition, after all the objects had been named, the experimenter picked up a block and told the child it was a blicket and asked the child to show him the other blicket. This control task ensured that children understood the nature of the task and what was being asked of them and, more significantly, ensured that they could, in fact, remember which object had set the machine off or had been given the same name, even when the objects were perceptually identical. Children who did not answer this control question correctly were not included in the analysis. Note that this control task again also helped ensure that the children were not confused by the questions or the general procedure. Nine children (five in the categorization condition and four in the induction condition) were replaced for this reason.

We also included two memory probes after the children had made the categorization or induction judgments. In this experiment, as in the categorization condition of Experiment 1, when the child chose an object that did not set the machine off as the other blicket, the experimenter asked the child to show him which other object had made the machine go. We added a similar memory probe in the induction condition. When the child failed to predict that the object that had been called a blicket would set off the machine, the experimenter asked the child to give him the other blicket.

Children in the association condition received exactly the same procedure as the children in Experiment 2.

Results

Pretest

On the pretest, 100% of the children in the induction condition, 87% of the children in the categorization condition and 100% of the children in the association condition correctly identified the other dax and the other wug. This result suggests that the 2½-year-olds could follow the nature of the task and would assign the same name to perceptually identical objects.

Order Effects

Analyses similar to those in Experiments 1 and 2 were performed and again, there were no significant differences between the first and last neutral trials or the first and last conflict trials in any of the three conditions (all *p*s > .05). Further, for each condition, regressions between performance on a particular task and the order of that particular task did not reveal any significant findings (all *p*s > .05).

Main Effects

Omnibus *F* tests revealed no significant differences among children's performance on the four neutral tasks or the three conflict tasks for the categorization or induction condition, so the scores for these were averaged. Figure 4 displays the results of children's performance on the categorization condition, as well as the results for 3- and 4-year-olds from Experiment 1. Figures 5 and 6 show similar data for the induction and association conditions, respectively.

Analyses were performed in a similar manner to that of Experiments 1 and 2. First the percentage of children's causally relevant choices was considered by conducting a 2 (task type: neutral versus conflict) × 2 (condition: categorization condition versus induction condition) mixed ANOVA with task type as the within-subjects factor and condition as the between-subjects factor. Overall, 2½-year-olds were more likely to pick the causally similar object or the object with the common name in the neutral tasks than in the conflict tasks (55% versus 29%, $F(1, 28) = 11.465$, $p < .002$). There was no significant difference between children's performance on the induction and categorization conditions. There were no significant interactions.

Categorization condition. . On the neutral tasks, children chose the causally similar object as the other blicket 55% of the time, significantly more often than

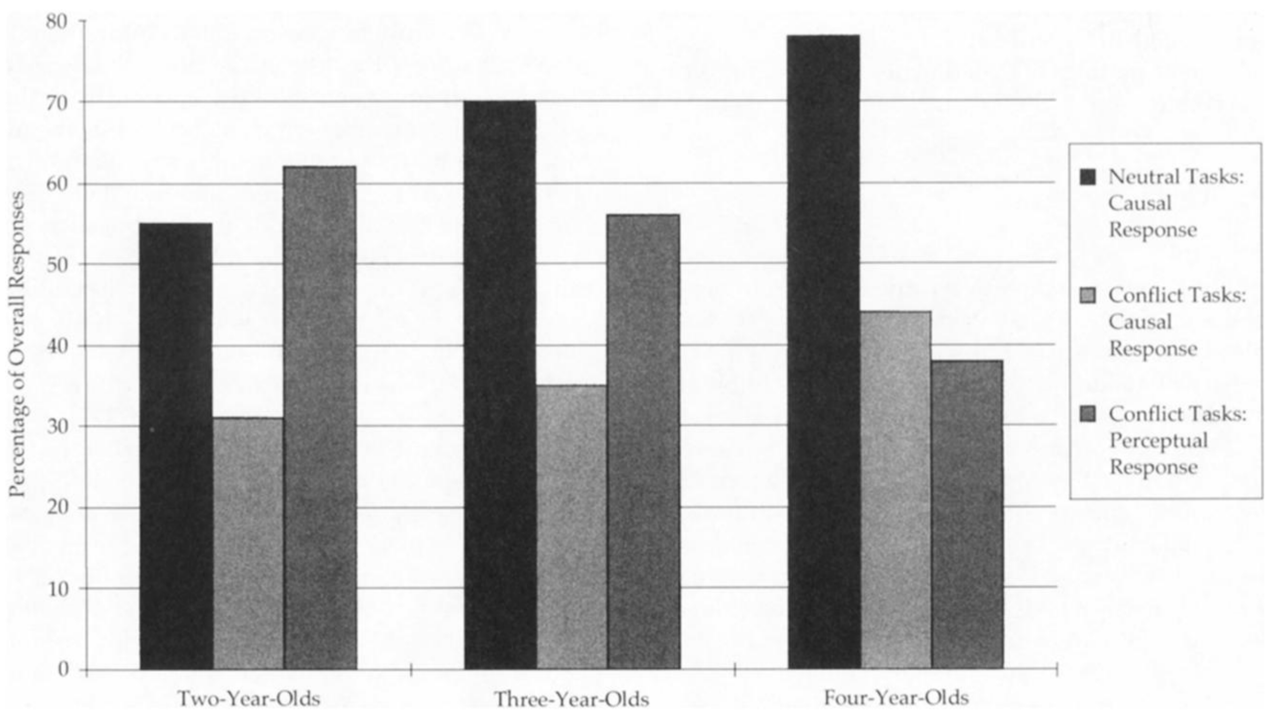

Figure 4 Children's performance on the Categorization Condition across Experiments 1 and 3.

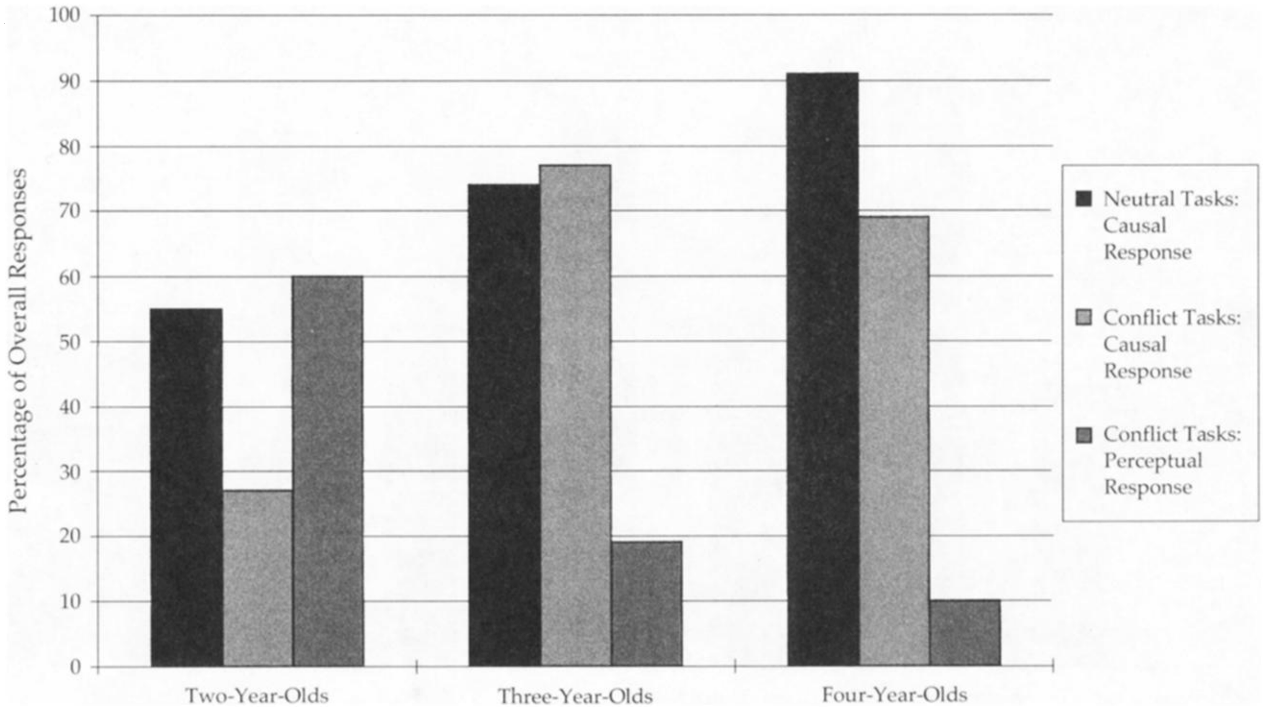

Figure 5 Children's performance on the Induction Condition across Experiments 1 and 3.

chance (33%, $t(1, 14) = 3.102$, $p < .008$). On the conflict tasks, 2½-year-olds chose the causally similar object 31% of the time, whereas they chose the perceptually identical object 62% of the time. Unlike the children in the earlier experiment, these children were significantly more likely to make perceptual responses than causal responses (binomial test, $p < .05$). As in Experiment 1, children chose both the causally relevant object and the perceptually similar object significantly more often than they chose the distracter object (binomial tests, both p's $< .05$), which suggests that they were not responding randomly.

Induction condition. On the neutral tasks, children chose the object with the common name 55% of the time, which was significantly greater than chance, $t(1, 14) = 3.310$, $p < .005$. On the conflict tasks, children chose the object with the common name 27% of the time and chose the perceptually identical object 60% of the time. Again, children were significantly more likely to make perceptual responses than causal responses (binomial test, $p < .05$). As in the categorization condition, they chose both the perceptually similar object and the object with the same name more frequently than the distracter object (binomial tests, both ps $< .05$), again suggesting nonrandom performance.

Association condition. The performance of 2½-year-olds on the association condition was similar to that of 3- and 4-year-olds. Children's choice of the causal and associated stimuli was examined by a 2 (task type: neutral versus conflict) × 2 (condition: categorization versus association condition) mixed ANOVA with task type as the within-subjects variable and condition as the between-subjects variable. A significant main effect for condition was found, with children more likely to select the causally relevant object in the categorization condition than to select the associated object in the association condition, $F(1, 29) = 6.188$, $p < .013$. There were no significant interactions.

As in Experiment 2, 2½-year-olds were overall more likely to use the associative information in the neutral tasks than in the conflict tasks (44% versus 6%, $F(1, 15) = 20.25$, $p < .001$). Performance on the neutral task did not significantly exceed chance levels. On the conflict tasks, 2½-year-olds, like the children in Experiment 2, used perceptual information rather than associative information (94% versus 6%, $F(1, 15) = 213.40$, $p < .001$).

Comparison with Experiments 1 and 2

We wanted to assess whether the 2½-year-olds behaved differently than the 3- and 4-year-olds in Experiments 1 and 2. A 2 (task type: neutral versus con-

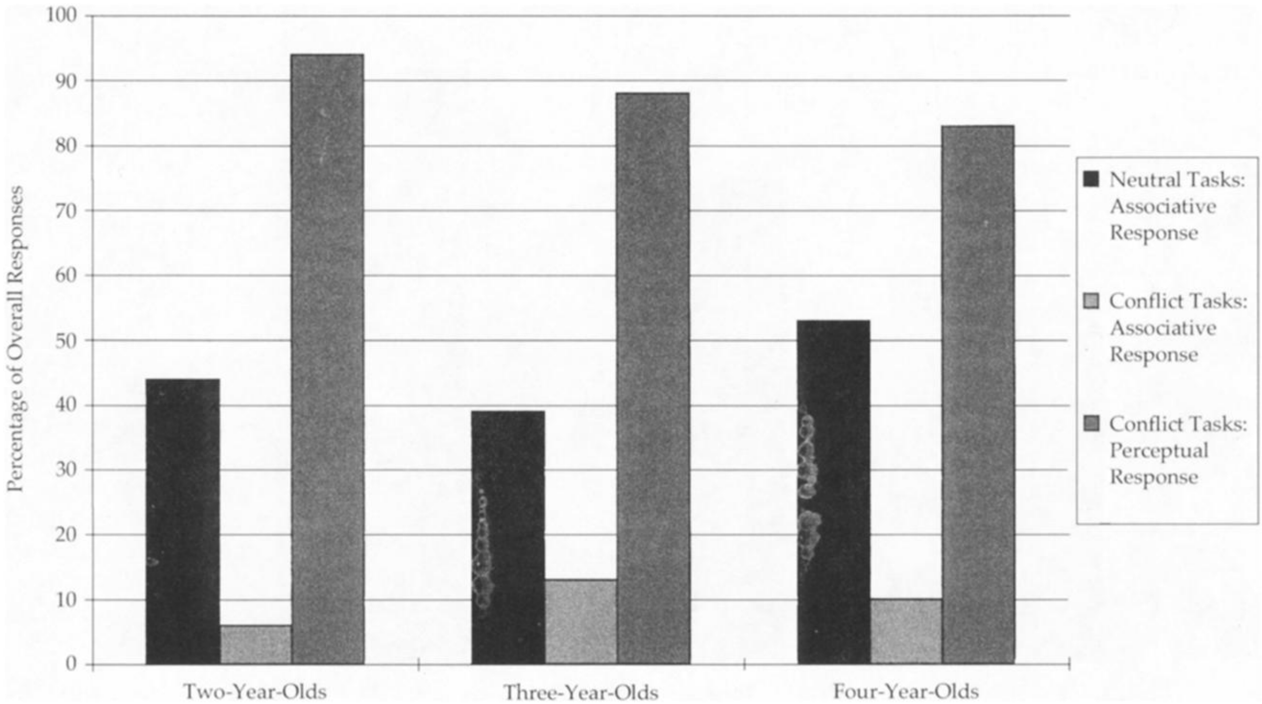

Figure 6 Children's performance on the Association Condition across Experiments 2 and 3.

flict) × 3 (condition) × 3 (age) mixed ANOVA was performed. There were significant task-type and condition effects but also a significant age effect, $F(2, 133) = 11.385$, $p < .001$. In addition, there were two significant interactions: between task-type and condition, $F(2, 133) = 3.377$, $p < .037$, and between age and condition, $F(4, 133) = 3.030$, $p < .019$. We therefore examined each condition separately.

Categorization condition. A 3 (age) × 2 (task-type) mixed ANOVA on children's performance in the categorization condition was performed. There were no significant overall age effects. However, 2½-year-olds did use the causally relevant information significantly less than the 4-year-olds in the neutral tasks (55% versus 78%, $t(1, 31) = -2.710$, $p < .011$). The 2½-year-olds produced fewer causal responses than the 3-year-olds, but this difference was not statistically significant. (55% versus 70%, $t(1, 31) = -1.945$, $p < .13$). There were no significant age differences in the conflict tasks. Overall, the 2½-year-olds performed quite similarly to the older children, although there was some evidence for fewer causal responses in the neutral tasks.

Induction condition. In the induction condition, we performed a 3 (age) × 2 (task type) mixed ANOVA which revealed a significant effect of age, $F(2, 44) = 15.24$, $p < .001$, and a significant effect of task-type, $F(1, 44) = 9.489$, $p < .003$. There was also a significant interaction between age and task-type, $F(2, 44) = 3.768$, $p < .031$. Although there was a trend for the 2½-year-olds to make fewer causal responses on the neutral tasks than the 3-year-olds, this difference did not reach significance (55% versus 73%, $t(1, 29) = -1.974$, $p < .054$). There was a significant difference between the 2½- and 3-year-olds in their performance on the conflict tasks (27% versus 77%, $t(1, 30) = -4.452$, $p < .001$). There was also a significant difference between the 2½-year-olds and the 4-year-olds for both task types (55% versus 91% in the neutral tasks, 27% versus 65% in the conflict tasks, t tests, both $ps < .05$.). Overall the younger children were less likely to make predictions about causal powers on the basis of names and more likely to use perceptual information than the older children.

Association condition. Finally, we performed a similar ANOVA comparing the 2½-year-olds in the association condition with the older children in Experiment 2. There were no significant age effects. The 2½-year-olds responded in the same way as the older children.

Memory Probes

Categorization condition. Children's errors on the memory probes were examined next. First, we examined the categorization condition. In the neutral tasks, on 20% of the trials they picked the item that they also, incorrectly, said was the other blicket. On 8% of the trials, they picked the fourth, distracter item as having set the machine off. Both of these were significantly greater than the number of errors made by the children in Experiment 1 (6% and 2% respectively: t tests, both $ps < .05$). In the conflict tasks, again, six possible combinations of responses were possible (incorrectly choosing the perceptually similar object or the distracter as the "blicket" and choosing either the causally similar, perceptually similar or distracter object in the memory probe). One response pattern was overwhelmingly most frequent. On 40% of the trials, children not only chose the perceptually similar object as the other blicket, but they also incorrectly chose it as the one that had previously set off the machine. This response occurred significantly more frequently than any of the other patterns of response on the memory tasks (binomial tests, all $ps < .05$). In contrast, children chose the perceptually identical object as the other blicket, but correctly remembered which object had set off the machine, on only 13% of the trials.

We compared these errors with the errors of the older children in Experiment 1. On the conflict tasks, the 2½-year-olds made significantly more memory errors overall than the children in Experiment 1, $t(1, 45) = -3.157$, $p < .003$. More specifically, many more 2½-year-olds than older children made the perceptual error and also incorrectly responded that the perceptually similar object had set off the machine (40% versus 17%, $t(1, 46) = -2.559$, $p < .014$). In other words, the younger children made more errors, and, in particular, were more likely to misremember that the causal powers of the object were correlated with its perceptual properties.

Recall that the children received a memory probe only when they did not make a causal response on the categorization task. Because 2½-year-olds made fewer causal responses overall than the older children, we wanted to control for this difference. These data can also be analyzed in terms of the percentage of memory errors of different types. When 2½-year-olds received the memory probe, 58% of the time they specifically chose a perceptually similarly object and reported that that same object had set off the detector. In contrast, when 3- or 4-year-olds received the memory probe, they made this kind of error only 28% of the time.

It is also important to remember that these children successfully answered the memory probe at the beginning of the experiment. They did so, moreover, in a task that involved remembering which of four identical objects had set off the machine—a task that should be at least as difficult as the conflict task, which involved remembering which of two identical objects had set off the machine. This result suggests that their memory errors were not simply a result of general information processing difficulties but rather were a result of the fact that the children had actively categorized the perceptually similar object as a "blicket."

Induction condition. We also examined children's performance on the memory probes in the induction conditions. On the neutral tasks, children made relatively few errors. They incorrectly chose the object that they incorrectly picked would set the machine off as the other blicket 15% of the time. On the conflict tasks, just as in the categorization condition, six possible combinations of responses were possible. Again, one type of response was overwhelmingly most common. Children not only predicted that the perceptually similar object would set off the machine but also chose it as the one that had been called a blicket 44% of the time. Children produced this pattern of responding more than any other pattern (binomial tests, all $ps < .05$). Children predicted that the perceptually identical object would set off the machine but correctly remembered which object had been called the blicket only 11% of the time. These children behaved the same way they did in the categorization condition. When the child received a memory probe, they both chose the perceptually similar object and incorrectly reported that that same object had been previously named a "blicket" 61% of the time (similar to the 58% in the categorization condition). Again, recall that these children had all passed the memory control task, in which they had to remember which of four identical objects had been previously named a blicket.

Discussion

The 2½-year-olds were quite similar to the older children in the categorization condition. Like the older children, they both used information about causal powers to categorize objects and also sometimes used causal information in favor of perceptual information. They did not behave in this way when the object was simply associated with the machine but did not appear to have a causal effect on it. Overall, the younger children seemed somewhat more likely to rely on perceptual information and less on causal information than the older children, but these differences did not translate into significant age effects.

In contrast, whereas the 2½-year-olds did use common names as a basis for making predictions about the causal powers of objects, they were less likely to do so than the older children. In cases of conflict, they were more likely than the older children to rely on perceptual similarity to make inductive predictions. Overall, the 2½-year-olds' performance on the categorization and induction tasks was quite similar, whereas the 3- and 4-year-olds did much better on induction than categorization. This contrasts with Gelman and Coley (1990), who found no difference between 2½- and 3-year-olds on their induction task. The 2½-year-olds in our study, however, were younger than the children in Gelman and Coley's study and there was a sizable gap between the mean age of the 2½-year-olds (2,6) and of the 3-year olds (3,6).

We also found that 2½-year-olds were more likely to misremember information about the objects' names or causal powers than the older children. Importantly, however, they rarely made errors on the memory control pretest or on the neutral tasks, which suggests that the children did not simply have difficulty remembering the events per se. By far the most frequent error occurred when children claimed that the perceptually identical object was the blicket or would set off the machine. At that point, on most trials, the 2½-year-olds also said that the perceptually identical object had set off the machine earlier or had originally been called a blicket. This was also the most frequent type of memory error for the older children in Experiment 1, but it occurred much less frequently than in the present experiment with 2½-year-olds.

GENERAL DISCUSSION

The results of these studies suggest that even very young children, as young as 2½ years old, can use information about novel causal powers to categorize and name objects and can use names to make inductive inferences about novel causal powers. First, we found that children of all ages could consistently use novel causal powers to categorize and name objects in the neutral tasks. Moreover, children of all ages would sometimes use causal powers in preference to perceptual similarity in the conflict tasks. Children of all ages did not categorize on the basis of associations between objects and events. This result suggests that even these young children understand and use causal information, including novel causal information.

These findings also suggest that children do not simply name objects on the basis of their shape, as argued by Imai et al. (1994), Landau et al. (1988), Smith et al. (1996), and others. Instead, it appears that children can also name objects on the basis of their causal powers, and this information can override information about shape. This finding is related to, though not identical with, Gelman and Kemler-Nelson's earlier findings that children will name objects on the basis of their kind membership or function (see also discussion about kinds in Gelman & Coley, 1991). Interestingly, however, the results also suggest that children will not categorize and name objects on the basis of any kind of information; they did not categorize on the basis of mere associations between objects and events.

Moreover, as in the Gelman induction studies (Gelman & Coley, 1990; Gelman & Markman, 1986), we found that 3- and 4-year-old children consistently preferred to use names, rather than perceptual features of objects, as a guide to predicting new properties of objects. Significantly, we found these results even when using real objects and not pictures and even when new properties were not just linguistically specified but were actually observed and predicted. Moreover, we found this effect even when the novel properties were not intrinsic to the objects but involved their causal effects on another object. We also found, however, that although 2½-year-olds sometimes used names as a guide to induction, in preference to using perceptual information, they did so less frequently than the older children.

Third, we found that children did not categorize or name objects on the basis of noncausal associations between the objects and events. Naming is influenced by information about kinds, functions, and causal powers, but children won't extend names on the basis of mere associations between objects and events. This result also suggests that children were not simply using the causal information as a "default" in the neutral tasks and were not simply responding randomly in the conflict tasks. When there was no evidence of a causal relation between the object and the event, children of all ages responded at chance in the neutral tasks and consistently chose the perceptually similar object in the conflict tasks.

Finally, we found that when the youngest children, the 2½-year-olds, did use perceptual information, rather than causal or linguistic information, to make categorization or inductive judgments, they also tended to misremember the causal or linguistic information. One-third of the 3- and 4-year-old children who said that the perceptually identical object was the blicket also said, incorrectly, that that object had set off the detector. The vast majority of the 2½-year-old children who chose the perceptually identical object also misremembered the name and the causal powers of the object, in spite of their good performance on the memory control task and in the neutral tasks. This result suggests that even children who made a perceptual response may still have thought that there was a link between names and causal powers. These memory errors may suggest that children, particularly the youngest children, assumed that perceptual, causal, and linguistic properties would be correlated and used this assumption to guide both their categorization and induction—and even their memories. In contrast, if children are simply using a purely perceptual strategy to categorize, name, and make inductions about objects, these errors are puzzling.

The memory probe results are also interesting because they suggest that young children will reinterpret and even misremember events that took place only a moment or so before in the light of their higher level beliefs and expectations. Other studies show similar effects in children's judgments about folk psychology (Gopnik & Astington, 1988; Moses & Flavell, 1990) and folk physics (Karmiloff-Smith, 1992).

A further noteworthy feature of these results is that the children were presented with a brand-new causal property, one they had never experienced before. This suggests that children can spontaneously organize their concepts and their language in terms of causal powers, even without any innate knowledge of those powers or explicit information from adults. Moreover, it suggests that children do not simply infer a correlational pattern from their past experiences of properties and assign names on that basis, as Jones and Smith (1993) suggest, for example. These children were presented with a conflict between inferring that perceptually identical objects had the same name, an inference very strongly supported by past experience, and inferring that objects with a brand-new causal property, one they had never seen before, had the same name, an inference not supported by past experience. Nevertheless, 3- and 4-year-old children were as likely to apply a name on the basis of the causal powers as on the basis of perceptual identity.

Finally, these results also suggest something about the cues young children use to infer novel causal relations. The contingency relations and the temporal relations between the objects and events were very similar in the categorization condition and the association condition. There were two differences, however, first, and most obviously, the object did not make spatial contact with the machine. In addition, however, we also provided the children with an alternative causal explanation of the event (namely the experimenter's contact with the machine). Experiments suggest that adults perform this kind of "discounting" in drawing novel causal inferences from patterns of contingency (Cheng, 1996); they do not infer new causes if there is already a sufficient causal explanation for the event. It would be interesting to see whether either of these factors, by itself, influences causal reasoning and what other factors determine when children will or will not infer a causal relation between an object and an event and categorize the objects on that basis.

Overall, these studies suggest that very young children's understanding of the world may indeed be like scientists' understanding of the world. Like scientists, the children in our studies appeared motivated to explain the unexpected new causal events they had witnessed and to use language to do so. They could learn about a new causal power and quickly and spontaneously use that information to categorize the object. An anecdote may make this point most clearly. Several months after this study had been completed, we piloted a new procedure with the blicket detector on one of the participants in this study, who had had no exposure to the machine or the objects in the interim. In the new procedure the child simply saw a quite different set of objects set off the detector or not and was asked why they did so. The child promptly replied, "They set it off because they're blickets!"

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