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Sorting and acting with objects in early childhood: an exploration of the use of causal cues

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Abstract

Three experiments investigated young children's ability to use a causal property, making a machine light up and play music, to sort objects together (sorting task), and then to predict how to make the machine work (action task). The results show that the performance of 30-month-old children is guided in both tasks by the causal properties of the objects. This suggests that causal information is used to categorize objects even in a task that does not involve naming. The causal interpretation of the results is supported by data showing that non-causal temporal association and perceptual prominence cannot account for the results. Finally, 36-month-olds, but not 30-month-olds, sorted objects together on the basis of a "negative" feature, namely, the fact that they lacked a particular causal property.

Keywords: Sorting and action tasks; Causal cues; Temporal association; Perceptual prominence

1. Introduction

One issue central to the study of early object categorization is the determination of the kind of cues that infants and children use to categorize objects at

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different points in development. Two lines of research have focused on either obvious/perceptual cues (such as shape, color, and texture) or non-obvious/conceptual cues (such as essence, names, functional attributes, and causal properties). Perceptual cues are easily observable and accessible. Conceptual cues are less easily accessible, more abstract and often relational in nature. Some conceptual cues have a perceptual component, but others involve some knowledge of a relation that cannot be directly observed. The present study, following up on Gopnik and Sobel (2000) and Nazzi and Gopnik (2000), focuses on children's early use of a causal cue for categorization: whether or not an object makes a machine light up and play music.

There is converging evidence that perceptual cues are used to categorize objects in infancy and early childhood. Children, but also infants as young as 3–4 months, were found to categorize both natural objects and human-made artifacts according to their visual properties, including color, shape, and characteristic object parts (Imai, Gentner, & Uchida, 1994; Jones & Smith, 1993; Landau, Smith, & Jones, 1988; Quinn & Eimas, 1997; Rakison & Butterworth, 1998; Smith, Jones, & Landau, 1996). Moreover, the ability to use simple perceptual cues appears to become more elaborate during the first 2 years (Cohen & Strauss, 1979; Madole & Oakes, 1999; Quinn & Eimas, 1997; Rakison & Butterworth, 1998; Sherman, 1985; Strauss, 1979; Younger & Cohen, 1986). Finally, research combining an experimental approach and connectionist modeling suggested that effects such as categorization asymmetries and global-to-basic shifts might be perceptually grounded (Mareschal, French, & Quinn, 2000; Quinn & Johnson, 2000; Younger & Fearing, 2000). These results were obtained with a variety of techniques, including preferential looking, manual sorting and name extension tasks.

On the other hand, many studies have investigated conceptually-based categorization. Some studies have provided evidence that infants and young children can use general conceptual information when categorizing objects. Indeed, in an object examination technique, infants as young as 7 months were found to build separate categories for objects from different domains (e.g., animals and vehicles) even when visual cues distinguishing the categories presented are minimized (Mandler & McDonough, 1993). Moreover, it was shown that infants' inferences of actions, as assessed by their imitation behavior, are guided by conceptual knowledge rather than by perceptual properties from at least 9–11 months (Mandler & McDonough, 1996; McDonough & Mandler, 1998; but see, e.g., Rakison & Poulain-Dubois, 2001, for an alternative interpretation). There is also evidence, both from a visual habituation technique and a name extension task, that 11- to 14-month-old infants have some knowledge of some familiar basic-level categories and also, to a lesser degree, some familiar superordinate level categories (Waxman, 1999; Waxman & Booth, 2001, 2003; Waxman & Markow, 1995). Finally, by at least 4 years of age, children seem to have a clear understanding of the importance of insides and essences relative to that of outer properties to determine the identity and properties of various objects (Gelman & Wellman, 1991).

Other studies have started to specify some of the specific abstract/conceptual dimensions (names, functions, causal properties) that young children can use to categorize objects. We consider that the name given to an object is a non-obvious/conceptual cue for several reasons. Unlike perceptual features, names are not observable parts of objects, but, at best, are heard in passing association with objects, and are spatially distinct from them. Moreover, names are used as the basis of inferences regarding important conceptual properties of objects.

First, children as young as 30 months old were found to extend a property of an object to a perceptually dissimilar object with the same *name* (Gelman & Coley, 1990; Gelman & Markman, 1986, 1987; Gopnik & Sobel, 2000). Moreover, 20-month-old infants (but not 16-month-olds) were found to manually sort together objects that were given the same name in the absence of any other similarities between the objects (Nazzi & Gopnik, 2001; Nazzi & Pilardeau, 2003; see also Booth & Waxman, 2002, for positive evidence at 18 months). Evidence further suggests that names are weighted more than perceptual cues for children aged 3 years (Gopnik & Sobel, 2000) and 4 years (Gelman & Markman, 1986). These studies suggest that categorization can be mediated by linguistic categories rather early in development, so that toddlers and young children will use names as predictors of object properties and as indexes of category membership.

Second, 2- to 5-year-old children extend the name given to an object to objects with a similar *function*, suggesting the use of functional properties to categorize and name artifacts (Kemler Nelson, 1995; Kemler Nelson, Frankenfield, Morris, & Blair, 2000a; Kemler Nelson, Russell, Duke, & Jones, 2000b). An extension of these results to a non-linguistically mediated categorization task led to similar results at the same ages (Kemler Nelson et al., 2000a). Moreover, infants as young 14 months were found to use shared functions to sort objects together (Booth & Waxman, 2002). Finally, children as young as 2 years extend artifact names based on function, even when perceptual information is absent or when it conflicts with functional information (Kemler Nelson et al., 2000b).

Third, two studies have used a name extension task to investigate children's use of *causal cues* to categorize objects (Gopnik & Sobel, 2000; Nazzi & Gopnik, 2000). The results first established that children as young as 30 months use a new causal property, that of making a machine light up and play music, to categorize objects. Moreover, in a control experiment, a similar but non-causal temporal association between the objects and the machine did not lead to similar patterns of categorization, suggesting that the children were responding to the causal nature of the object/machine interaction in the main experiment (Gopnik & Sobel, 2000). Furthermore, when perceptual and causal cues were pitted against each other, 3.5-year-olds were found to favor perceptual similarity to group objects together, contrary to 4.5-year-olds who favored causal similarity (Gopnik & Sobel, 2000; Nazzi & Gopnik, 2000). It further appeared that for 3.5-year-olds, perceptual, causal and naming cues are correlated, while for 4.5-year-olds, they have become separable and, for name attribution, more weight was given to causal attributes (Nazzi & Gopnik, 2000).

Hence, overall and contrary to the claim that early object categorization and naming relies exclusively on perceptual features such as shape (Imai et al., 1994;

Jones & Smith, 1993; Landau et al., 1988; Smith et al., 1996), there is converging evidence that children also use conceptual cues when categorizing and naming objects from about 2–2.5 years of age, and sometimes prefer such cues over perceptual cues from about 3–4 years of age (but see, e.g., Landau, Smith, & Jones, 1998). However, in order to further strengthen this interpretation, we need to establish that the use of language in the studies investigating the use of conceptual cues for categorization cannot in itself account for the pattern of results obtained. Indeed, it has been suggested that the use of language (an abstract, arbitrary property) could introduce a bias, could shift children's attention away from visual cues towards conceptual ones (e.g., Smith et al., 1996). Such efforts have already been conducted, for example, for the use of functional cues (Kemler Nelson et al., 2000a), but not for the use of causal cues.[1]

Consequently, the current set of experiments focuses on causally-based categorization, with three main goals. The first is to gather evidence that children categorize causally in contexts that do not involve word learning. The second is to provide further evidence that the children in these experiments really respond to the causal dimension of the experimental situation by exploring the relation between causality, temporal association and perceptual prominence. The third is to explore when children can construct an even more abstract type of causal category, namely the category of objects that lack a particular causal property.

In Gopnik and Sobel (2000), children saw various objects that did or did not activate a machine. Then they received a word extension task: the experimenter held up one of the objects that had activated the machine and said "This is a blicket, can you show me the other blicket?" In Experiment 1 of the current study, children similarly saw that objects did or did not activate the machine. However, instead of receiving a word extension task, they received a sorting task that did not involve naming. The experimenter took one of the objects that had made the machine work, placed it in his open hand, and asked the child to give him the "one that goes with this one." This question was used because there is evidence that infants as young as 20 months can answer it correctly when the grouping abstract property is the name given to objects (Nazzi & Gopnik, 2001; Nazzi & Pilardeau, 2003). Such a task allows us to determine whether previous reports of causal-based categorization crucially depend on the use of a word extension task.

The second task in each trial was an action task. After the child had chosen an object in the sorting task, that object was returned to the table (next to the

[1] Note however that Nazzi and Gopnik (2000) investigated the possible effects of causal language on categorization, by comparing how children use causal information to categorize objects when the causal event is described to them using a neutral ("Look, the machine works"), causal ("Look, it makes the machine work"), or perceptual ("Look, it's red") description. No differences between conditions were found at 3.5 years, while at 4.5 years, the causal description gave rise to more causal choices than the neutral and perceptual conditions (the latter two showing no differences). These results suggest that the influence of language on children's causal categorization is not mediated by the use of *causal* language alone. This however does not imply that the word extension task used by Nazzi and Gopnik (2000) could not have biased the children towards conceptual categorization.

second object they had to choose from) and the child was asked to make the machine work. This task should allow to evaluate the extent to which children genuinely understand the causal factors at play in the study, and can use this causal understanding to predict the behavior of the objects. Observing causally appropriate actions would strengthen the interpretation that what is guiding the children's categorizations in the sorting task is really causal. Note that a mature understanding of causality should not only guide the way children categorize the world, but also the way they act upon it (Gopnik & Meltzoff, 1997; Gopnik, Sobel, Schultz, & Glymour, 2001).

In Experiment 2, we explored the role of temporal association and perceptual prominence in early causal categorization, by assessing whether children will categorize or act on objects when the objects are associated with particular effects, but do not cause them.

Finally, in Experiment 3, we explored whether children will use causal information to construct a category of objects that do NOT have a causal property, as well as constructing categories that do have that property. To construct this sort of "negative" category, children would have to place together objects that were not salient or attention-getting. Earlier experiments have not explored whether children can construct this sort of negatively defined category. If children can construct such a category, that would be particularly strong evidence that they are using abstract conceptual cues rather than solely perceptual ones.

2. Experiment 1

2.1. Method

2.1.1. Participants

Sixteen 30-month-old children ($M = 30$ months, 8 days, range $= 29$ months, 28 days to 30 months, 16 days) participated in this experiment (one extra boy was tested, but refused to participate). For all the experiments reported in this paper, an equal number of boys and girls were recruited, that mostly came from white, middle-class backgrounds (although infants from other ethnic backgrounds were also represented).

2.1.2. Materials

Two small white porcelain knobs and two small metallic tee-joints were used for the pretests, and six sets of three different wood blocks were used during the test phase (blue cylinder, black square, white triangle; black cylinder, white square, yellow triangle; yellow cylinder, red square, green triangle; red cylinder, blue square, black triangle; green cylinder, yellow square, blue triangle; white cylinder, green square, red triangle).

A specially designed machine was used during the test phase. This machine was connected to (a) an electrical outlet, and (b) a switchbox that was controlled out of sight of the children by the experimenter. The machine "worked," that is, lit up and played music, only when the switchbox was in the "on" position and an object was placed upon the machine; it did nothing otherwise (i.e., when the switchbox was on the "off" position, or when no object was upon the machine). In this way, it appeared that certain objects made the machine work and others did not.

2.1.3. Procedure

Each child was tested individually for 20 min, in a quiet room of the Institute, in the presence of a caregiver. The child and the experimenter sat at a table, across from each other. The session started with a 5-min warm-up period during which the child was encouraged to play with two toy helicopters and a toy car and to interact with the experimenter. The warm-up period was followed by the pretests and the test phase.

For the first pretest, the experimenter placed either the two porcelain knobs and one metallic tee-joints, or one knob and the two tee-joints, in an alternating order in front of the child. One of the objects of the pair (either the left or the right object) was picked up by the experimenter, who then asked the child to give him the "one that goes with the one I have." After the child responded, the experimenter repeated the same protocol using the other combination of objects, and picking up the paired object from the other side.

The procedure for the six test trials went as follows. For each trial, three wood blocks were placed in front of the child. One at a time, each block was placed on the machine for a few seconds, then carefully replaced in its original position. This demonstration of the effect of the three blocks was done twice. Two of the blocks made the machine work (the block at the center, and either the right or the left, counterbalanced across trials), one didn't. While putting the objects on the machine, the experimenter said, "Look, the machine works/doesn't work." This description, which corresponds to the neutral condition used in previous studies on causal categorization, was chosen because it was found not to give more causal responses than a perceptually-biased description ("Look, it's red") at both 3.5 and 4.5 years (Nazzi & Gopnik, 2000). After the demonstration of the objects, the experimenter took the machine away, held up the center object that had made the machine work, and asked the child to give him the "one that goes with the one I have" (sorting response). After the child had answered, the experimenter replaced the left and right objects on the table, returned the machine to the table, and asked the child to "make the machine work" (action response). After the child had acted, all the objects were taken away (often with the help of the child), and the next trial started. Note that the machine worked only when the child placed the correct object onto it.

2.2. Results

All 16 children correctly performed the pretests by choosing the paired objects, indicating that the children understood the basic structure of the task.

Table 1
Number of occurrences of the different response patterns across the 96 trials (Experiment 1)

Action	Sorting		
	Correct	Incorrect	Total
Correct	63	13	76
Incorrect	12	8	20
Total	75	21	

The proportion of causal choices was submitted to a two-way ANOVA with the main within-subject factor of task (sorting vs. action) and the main between-subject factor of sex. Both main effects and the interaction were non-significant ($F(1, 14) < 1$). Children performed significantly above chance on both tasks (78.1% on the sorting task, $t(15) = 6.26$, $P < .001$, and 79.2% on the action task, $t(15) = 7.00$, $P < .001$). An analysis of order effects provided no indication that they were learning the correct answer in the course of the session.[2] Finally, breaking down the responses according to whether, on a particular trial, children were consistent across both tasks revealed a majority of consistent responses (63 correct–correct, 8 incorrect–incorrect), over inconsistent responses (12 correct–incorrect, 13 incorrect–correct; see Table 1).

2.3. Discussion

The sorting behavior of the children in this experiment shows that 30-month-olds will use a causal property to sort together perceptually-dissimilar objects in the absence of labels. It complements Experiment 3 of Gopnik and Sobel (2000), in which similar results were obtained in a situation in which the target object was labeled. Hence we now have evidence that by 30 months, children can use a causal property to categorize objects in both naming and sorting contexts.

Second, the present data shows that 30-month-olds can use their experience with causal events to act upon objects, even when they experience a completely new causal property of unfamiliar objects, as is the case here. Indeed, when asked to make the machine work, children always picked up an object and, most of the time, chose the one they had previously seen making the machine work.

Interestingly, there was a high degree of consistency between children's categorizations and actions: in two-thirds of the trials, they selected the same object (the second one that made the machine work) as the one "going with" the tar-

[2] ANOVAs with trials as the repeated measure were conducted for the sorting and acting results of all experiments. Only one of these analyses revealed a significant effect, for the 30-month-olds' sorting performance of the present experiment ($F(5, 75) = 2.75$, $P = .024$). The children's performance was higher on the first three trials (92% correct responses) than on the last three trials (65%), suggesting that the children are not learning the correct answer (but more probably that they are getting tired). Note however that the children were performing above chance level on both blocks.

get object and as the one used to make the machine work. This might suggest that the causal property is used to categorize the objects as well as to act upon them: After having appropriately attached the causal property to the objects that made the machine work, as revealed by their sorting behavior, 30-month-olds use that new knowledge to predict the future behavior of the objects. However, although the above effects are consistent with causal-based behavior, they might also be due to alternative factors. Children might simply be associating the objects and the machine's activation rather than understanding the causal link between these two events. Moreover, the concordance between the object choices in the sorting and action tasks could reflect a repetition strategy, infants choosing the same object twice. We will come back to this issue in discussing the following experiments.

3. Experiment 2

The present experiment explores whether the children in Experiment 1 were really responding to the causal dimension of the experimental situation, by presenting them with a similar but non-causal situation. In this non-causal temporal association condition (see also Gopnik & Sobel, 2000), the objects are held above the machine, rather than put on the machine, and the experimenter puts his finger on the machine on the events in which the machine works. Thus, the activation of the machine appears to be due to the experimenter's action, rather than to be the product of an intrinsic property of the objects. Nevertheless, the associated objects will still be temporally linked to the effects; because the lights and sound should make them more attention getting than the non-associated objects, they will therefore be more perceptually prominent than the non-associated objects. Hence, if children were responding to causal properties in Experiment 1, they should respond at chance in the sorting task of this non-causal association experiment. Moreover, on the action task, they should use their finger rather than the associated objects to make the machine work. Alternatively, if non-causal temporal associations are sufficient ground for categorization, or if children simply choose the objects that are more perceptually prominent, children should predominantly choose the associated object in both the sorting and action tasks.

3.1. Method

3.1.1. Participants

Sixteen 30-month-old children ($M = 30$ months, 6 days, range $= 29$ months, 24 days to 30 months, 19 days) participated in this experiment (one extra girl was tested but refused to participate).

3.1.2. Materials

They were identical to those in Experiment 1.

3.1.3. Procedure

The procedure was identical to that used in Experiment 1, except for the following modifications. The demonstration of the working of the machine was done as follows. First, each object was held slightly above the machine rather than placed upon it. Then, for two of the objects, the experimenter pressed the top of the machine with his finger and the machine activated. Hence it appeared that the machine worked because the experimenter was pressing its top with his finger.

Finally, after the completion of the six test trials, all the objects were cleared from the table, and, with only the machine left on the table, the children were asked to make it work. If the children believe that the experimenter's action is really what made the machine go they should not be perturbed by the absence of objects.

3.2. Results

All children correctly performed the pretests by choosing the paired objects, indicating that the children understood the basic structure of the task.

Unlike for Experiment 1, the responses for the sorting and action tasks were analyzed separately. This was due to the fact that the range of possible responses to the action task was much more varied and complex than before, and could not be classified into the same categories.

3.2.1. Sorting

The proportion of causal choices on the categorization measure ($M = 53.1\%$; S.D. $= 9.08$) was not significantly different from chance ($t(15) < 1$). Moreover, there was no difference between the boys ($M = 54.2\%$, S.D. $= 7.7$) and the girls ($M = 52.1\%$, S.D. $= 10.7$; $t(7) < 1$).

3.2.2. Action

In Experiment 1, all responses observed involved putting one of the two available objects onto the machine. Those responses were also available to the children in the present experiment, but they did not cover the range of possible actions. Given the specific structure of the present task, possible actions could vary regarding whether children would use an object or not to make the machine work, which object they would choose (associated or not) and how they would use it (e.g., held above the machine, put on it, or just touched), whether they would use a finger or not, and in which order they would perform the different actions (i.e., object or finger first). The types of the responses observed should inform us of the nature of the children's understanding of the situation. Two children refused to act at all on any of the trials and their data are excluded. Table 2 summarizes the actions performed by the remaining children.

The 52 times that the children used both an object and their finger (i.e., touched the machine with the finger of one hand, and brought the object(s) to the machine using the other hand) could be subdivided as follow. Eight times out of 52, they used the object before their finger. The associated object was chosen 3 times

Table 2
Number of occurrences of the different types of action performed by the 14 “acting” children (Experiment 2)

Refusal to act	2
Finger alone	23
Associated object alone	3
Non-associated object alone	4
Associated object and finger	30
Non-associated object and finger	21
Both objects and finger	1
Total	84

(put on machine: 2; touched: 1), the non-associated 4 times (put on machine: 2; touched: 2), and both objects were touched once. The other 44 times, the children put their finger on the machine before using the object. The associated object was selected 27 times (put above machine: 16; on machine: 8; touched: 3), while the non-associated object was selected 17 times (above: 11; on: 2; touched: 4).

One might think that children were simply imitating the experimenter’s action, given that they often used both their finger and an object. However, several aspects of the data undermine this possibility. First, on the last question in which the children were asked to make the machine work in the presence of the machine alone, all of the 14 “acting” children put their finger on the machine, an action the experimenter had never performed alone. Second, the children are not consistent in their object choices, selecting the associated object 33 times (39.3%) and the non-associated one 25 times (29.8%), ratios comparable to those obtained on the sorting task. Third, they do not consistently hold the object above the detector. Even when they chose the associated object, they only held it above the machine 16 times (19.0% of the time). Fourth, they do not reproduce the sequence of actions in the same order as the experimenter. While the experimenter consistently put the object above the machine before touching the top of the machine with his finger, the children most often brought their finger in contact to the machine before the object (44 times), rather than the other way round (8 cases). In fact, no child ever produced a complete imitation of the experimenter, placing the associated object over the machine and then using a finger to activate the machine.

3.3. Discussion

The present results first show that 30-month-old children will not categorize objects together when they are related by non-causal temporal associations, while they did so when they were causally related (Experiment 1). This finding has now been found in both a word-learning situation (Gopnik & Sobel, 2000) and a sorting situation (present experiment). Taken together, these results suggest that the children do not use every kind of association between objects and events (here a non-causal association) to sort them together. Moreover, the experiment also suggests that children do not simply sort objects together because they are more perceptually prominent. Hence it appears that objects associated to the same event will be grouped together only if there appears to be a shared intrinsic causal property responsible for this object–event link.

If this is correct, then a corollary is that children in this experiment did not attribute the cause of the working of the machine to the objects. Several elements of the results in the action task suggest that indeed children attributed the working of the machine to the experimenter's actions. First, the children almost always used their finger to make the machine work (89.3%), either alone (23 times, 27.4%) or with an object (52 times, 61.9%). Second, they used their finger alone (23 times, 27.4%) more often than an object alone (7 times, 8.3%). Third, they appeared to have no problems making the machine work when they were not offered any object. Finally, the children did not seem to simply be imitating the experimenter. Instead, it appears that the children tried out a variety of hypotheses about the right action to activate the machine, including various combinations of spatial contact, objects, and finger-pressing. Importantly, however, this pattern of responses suggests that children were giving less importance to the object than had been given by the experimenter (by sometimes not using it, or other times using it after the finger). This pattern is very different from the one in Experiment 1 where the most common response was to place the correct object on the machine.

Hence, the present experiment suggests that children did not interpret the temporal association between objects and events as a causal relationship, which led them not to group together the associated objects. It also suggests that the 30-month-old children here have uncovered that the machine is made to work through the mediation of the experimenter's behavior, rather than through distinctive properties of particular categories of objects. Both results strengthen our interpretation of Experiment 1 in terms of a use of causal properties to build object categories by 30 months.

4. Experiment 3

Experiments 1 and 2 explored whether 30-month-olds would group together the two causal objects or the two associated objects. In both cases, this choice could be facilitated by the fact that these objects were more perceptually prominent than the remaining object due to the attention-getting nature of the working of the machine. The fact that 30-month-old children did not respond in the same way in these experiments suggests that perceptual prominence alone cannot entirely explain their sorting behavior in Experiment 1. However, one could argue that even if children really understand the causal nature of the object properties, that very fact may make those objects more salient: objects that make other things happen may be intrinsically more salient than those that do not, even if this salience is not just the result of perceptual features. In the present experiment, we investigate whether children would sort together objects in the absence of any salience support, that is we asked children to sort together the objects that did NOT have the causal power to make the machine work.

One possibility is that the causal status of objects is used in and of itself to categorize objects. Thus, presented with a group of objects and a causal situation, children will separate the objects into two groups, those that have the causal property and those that do not. In this view, both the causal and non-causal objects are categorized, and they are memorized equally well independently of their salience. Alternatively, in the same situation, children could notice that some of the objects have interesting effects on the machine, and remember those objects as having the same causal property. Here then, only the causally salient objects are categorized, which gives them a memorization advantage.

Both hypotheses predict similar outcomes in a situation like that in Experiment 1, but different outcomes in a situation when children are shown causal and non-causal objects and asked to group together the non-causal ones. Moreover, grouping objects based on a property that they do not have is, in itself, an interesting abstract and conceptual type of categorization. However, there are no empirical studies exploring when children might be able to categorize in this way.

To evaluate these hypotheses, we presented 30- and 36-month-old children with triads of objects, using the same procedure as in Experiment 1 except for the crucial difference that only one of the three objects made the machine work. After the demonstration phase, the experimenter took one of the non-causal object, asked the children to give him “the one that goes with this one,” and then to make the machine work. To answer correctly in the sorting task, children have to group together the two objects that *did not* make the machine work (those that lack the causal property). That is, they have to choose the object that is not salient. In contrast, to answer correctly in the action task, children have to choose the causally salient object. Note that if children can switch objects, this will also tell us that the consistency of children’s responses in Experiment 1 was due to some cognitive processes guiding both categorization and action rather than reflecting a repetition strategy.

The view that children use causality in and of itself predicts that children should have built two separate groups of objects during the demonstration phase (one of the causal object, one of the two non-causal objects). When asked to sort, they should give the other non-causal object, and then choose the causal object to make the machine work. The view that children only build categories based on positive causal properties, that is categories that include the more salient objects, predicts that children should remember that they saw one interesting object after the demonstration phase, but should not have built a category of non-causal objects. Hence, they should not really know what to do in the sorting task: faced with one object that did not grab their attention, they should not know whether to give the experimenter the other boring object or the interesting one. However, they should succeed in the action task.

4.1. Method

4.1.1. Participants

Sixteen 30-month-old children (M = 30 months, 7 days, range = 29 months, 24 days to 30 months, 20 days) and sixteen 36-month-old children (M = 36 months, 2 days, range = 35 months, 17 days to 36 months, 19 days) participated in this experiment (one extra 36-month-old girl refused to participate).

4.1.2. Materials

They were identical to those in Experiment 1.

4.1.3. Procedure

The procedure was almost identical to that used in Experiment 1, with one crucial difference. Instead of the object triads consisting of two objects that made the machine work and one that did not make it work, they consisted of just one object that made it work, and two that did not. The experimenter placed one of the ineffective objects in his hand when he asked the sorting question. Hence, a correct answer to the sorting question involved the choice of the second object that didn't make the machine work, while a correct answer to the action question involved the choice of the object that did make it work.

4.2. Results

All children at both ages correctly performed the pretests by choosing the paired objects, indicating that the children understood the basic structure of the task.

The proportion of causal choices was submitted to a three-way ANOVA with the main within-subject factor of task (sorting vs. action) and the main between-subject factors of age and sex. There was a significant effect of task ($F(1, 28) = 23.21$, $P < .001$), and no effect of either age ($F(1, 28) = 1.67$, $P = .21$) or sex ($F(1, 28) < 1$). The only significant interaction involved task and age ($F(1, 28) = 4.79$, $P = .037$). As can be seen in Table 3, children's correct categorizations improved with age, while both age groups performed equally well on the action

Table 3
Number of occurrences of the different response patterns across the 96 trials at both ages (Experiment 3)

Action	30-month-olds			36-month-olds		
	Sorting			Sorting		
	Correct	Incorrect	Total	Correct	Incorrect	Total
Correct	41	42	83	56	22	78
Incorrect	10	3	13	10	8	18
Total	51	45		66	30	

task. Given this interaction, the results were further analyzed by separating the data according to age.

The proportion of causal choices at 30 months was submitted to a two-way ANOVA with the main within-subject factor of task (sorting vs. action) and the main between-subject factor of sex. There was a significant effect of task ($F(1, 14) = 17.25$, $P = .001$), and no effect of sex ($F(1, 14) = 1.61$, $P = .23$) or interaction between the two factors ($F(1, 14) < 1$). Children, both boys and girls, were responding above the 50% chance level on the action task (86.5%, $t(15) = 8.36$, $P < .001$), but not on the sorting task (53.1%, $t(15) < 1$). Finally, it appeared that 44 responses were consistent across both tasks (41 correct–correct, 3 incorrect–incorrect), while 52 were inconsistent (10 correct–incorrect, 42 incorrect–correct; see Table 3).

Thirty-six-month-olds performed differently. The proportion of causal choices was submitted to a two-way ANOVA with the main within-subject factor of task (sorting vs. action) and the main between-subject factor of sex. There was a main effect of task ($F(1, 14) = 6.00$, $P = .028$), no effect of sex ($F(1, 14) < 1$), and no interaction between the two factors ($F(1, 14) = 2.66$, $P = .13$). Even though children's performance was higher in the action task compared to the sorting task, they were responding above the 50% chance level in both conditions (68.8% for sorting, $t(15) = 5.09$, $P < .001$; 81.3% for action, $t(15) = 6.90$, $P < .001$). It further appeared that across both tasks consistent responses (56 correct–correct, 8 incorrect–incorrect) outnumbered inconsistent responses (10 correct–incorrect, 22 incorrect–correct; see Table 3).

4.3. Discussion

The results of the present experiment show differences in the way the two age groups performed on the two tasks. In the sorting task, we observe a developmental pattern: the 36-month-olds were able to appropriately choose the second object that did not make the machine work; the 30-month-olds' choices were equally distributed between the causal and the non-causal objects. These results contrast with those of Experiment 1 in which the 30-month-olds had no difficulty in the sorting task.

In contrast, both age groups did well in the action task. Even the 30-month-olds had little difficulty using the appropriate causal object to make the machine work (if anything, they did slightly better than in Experiment 1 or than the 36-month-olds). This result shows that children at both ages remember which is the causal object when asked to make the machine work. What is noteworthy, given that the action task was always given after the sorting task, is that at both ages, correct responses on the action task outnumbered incorrect responses, whether the children had responded correctly or incorrectly in the sorting task. Thus, it appears that failure in the sorting task cannot simply be due to memory problems, both for the 36-month-olds who overall performed well, and for the 30-month-olds who were selecting the other non-causal object only about half of the time.

With respect to the two hypotheses of how children use causality to categorize objects, the above results suggest a developmental shift between 30 and 36 months. At 30 months, our results show that salience has an influence on sorting behavior. These results are consistent with the idea that children build categories of causal objects, but do not put the non-causal objects into a complementary category. In contrast, the results at 36 months suggest that these older children might now be able to separate objects into two categories according to whether they have a causal property or not. Accordingly, the role of salience is reduced at that age: although the proportion of correct sorting (68.8%) is lower than for the 30-month-olds in Experiment 1 (78.1%), it is nevertheless above chance level, in contrast to the 30-month-olds in this experiment (53.1%).

Finally, the results show that children do not necessarily give the same answer to both the sorting and action tasks (in this experiment, contrary to Experiment 1, 30-month-olds gave more inconsistent than consistent answers). This undermines the idea that in Experiment 1, the consistency of children's responses across the two tasks was just the reflection of a repetition strategy, in which the children were choosing the same object on both tasks, whether or not it was relevant. On the contrary, it supports the idea that children's causal understanding is guiding both the way children organize the world (object categorization) and the way they act on it (action with objects).

5. General discussion

The present study investigated the role of causal properties in determining children's object categorizations and actions with objects at 30 months. This study had several goals. First, it aimed at extending the results of previous studies establishing that children as young as 30 months old use causal properties to extend newly-acquired object names (Gopnik & Sobel, 2000; Nazzi & Gopnik, 2000) to an experimental situation independent of word acquisition. The present study did not involve naming the objects and so was less likely to bias children towards using abstract categorization cues. Second, our study further tested whether children were responding to the causal nature of the display, rather than being guided by simple temporal associations or perceptual prominence. Moreover, the action task was intended to provide information regarding whether the children had genuinely understood the causal character of the relation between the blocks and the machine. Finally, it investigated when children could construct an even more abstract category, namely the category of objects that do not have a causal property.

The results of Experiment 1 first show that, by 30 months, children consistently group together two objects that both make a machine work. These results then extend the results found by Gopnik and Sobel (2000) for name extension to a task that does not involve names, and again shows that 30-month-olds are capable of causal categorization. This suggests that the previous name-based extension results showing effects of causal properties cannot be accounted for by saying that the use of names (introducing the abstract linguistic system) had crucially biased children towards conceptual cues.[3]

The action task, in which children were asked to make the machine work, shows that 30-month-olds' attempts to make the machine work are consistently guided by causal information. Although Experiment 1 itself could not rule out that children's success on the action task was due to repetition or imitation effects, converging evidence from Experiments 2 and 3 ruled out this possibility by showing various dissociations between the two tasks. It then appears from the action task results, that not only are children sensitive to causal information, but that newly learned causal properties can spontaneously be used to guide 30-month-olds' predictions and interventions.

Experiment 1 then provides new evidence compatible with the idea that children as young as 30 months are able to build causally-motivated categories of objects. However, this interpretation crucially depends on showing that children are responding specifically to the *causal* dimension of our stimuli and situations.

In Experiment 2, the temporal association between the objects and the machine was non-causal due to the existence of another causal interpretation: the experimenter pressing the top of the machine with his finger. The sorting results show that 30-month-old children do not sort together the two associated objects, demonstrating that children do not use all associations to sort objects together. They further show that perceptual prominence is not always used to group objects together. These sorting results thus suggest that the children in Experiment 1 were responding to the causal dimension of the experimental situation. Finally, the action results bring the first direct piece of evidence that children actually understood that in this situation the finger, and not the object, was crucially involved in making the machine work.[4]

Another original contribution of the present study is the evaluation of the relation between salience and causal categorization. Can children sort together objects that do not have a particular causal property, and so have reduced rather than enhanced salience? Experiment 3 begins to address this issue. Its results first show that there are important changes between 30 and 36 months. Even though children at both ages remembered well which were the causal objects (as attested by their good performance on the action task), only the older children succeeded in consistently grouping together the two non-causal/non-salient objects. Thus, in a way, salience

[3] Whether naming had an impact at all in previous studies is beyond the goal of the present study, and would require direct comparison of the name-extension and sorting conditions.

[4] Indeed, children had no difficulty making the machine work by pressing on it with their finger when no object was provided. Moreover, when objects were provided, they almost always used their finger when trying to make the machine work, they used their finger alone more often than an object alone, and they did not consistently choose the associated object more often than the other object.

seems to be necessary to group objects together at 30 months, but not at 36 months: the younger children can group together the causally salient objects, but not the non-causal/non-salient ones.

One possible interpretation of these results is that the way children use causality to categorize objects changes between 30 and 36 months. The results at the younger age are compatible with the idea that children memorize and group together the causal objects, helped by the fact that they are salient. In contrast, the results for the older children suggest a more mature understanding of causality. In a given situation, they use causality in and of itself (at least if it is pragmatically justified), resulting in the building of complementary categories of objects: one for the objects having the causal property, one for the objects lacking that property.

At this point, our research does not constitute definitive evidence for the above interpretation, and many questions are left open. For example, although we know that young children can build two different categories in parallel, we do not know whether they can do so when a new causal cue is involved. One way to test this would be to present children with series of objects; some of them would make, say, a machine play music, while others would make a second machine light up. Moreover, our experiment is to our knowledge the first demonstration that children can categorize objects together based on a "negative" property, namely the fact that they do NOT have a causal power. Therefore, we do not know whether 30-month-olds can construct categories of objects lacking a conceptual property at all. Given that previous research has found that names are used to categorize objects before causal cues (Gopnik & Sobel, 2000; Nazzi & Gopnik, 2001; Nazzi & Pilardeau, 2003), we could start exploring this issue by testing whether 30- and 36-month-olds can group together objects that are not named. Similarly, we could explore when children will group together objects that lack a particular perceptual property, such as color or shape.

In conclusion, the present study brings new pieces of information regarding young children's use of a causal cue to categorize objects, and supports previous findings regarding the use of conceptual cues for object categorization by preschool children (Gelman & Coley, 1990; Gelman & Markman, 1986, 1987; Gopnik & Sobel, 2000; Kemler Nelson, 1995; Kemler Nelson et al., 2000a, 2000b; Nazzi & Gopnik, 2000, 2001; Nazzi & Pilardeau, 2003). More specifically, our results provide evidence that causal information is used by 30-month-olds both to categorize objects in a situation that does not involve word learning (hence generalizing results by Gopnik & Sobel, 2000; Nazzi & Gopnik, 2000), and also to appropriately predict the actions of objects. The causal interpretation is further strengthened by showing that a non-causal temporal association, with similar perceptual prominence characteristics, leads to different sorting/acting results. Finally, it appears that children's use of causality to categorize objects changes between 30 and 36 months. By 36 months, though not before, children will sort together objects on the basis of the fact that they do not have a particular causal effect.

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