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Brief article

Children's developing understanding of the relation between variable causal efficacy and mechanistic complexity

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ABSTRACT

Two experiments investigated 3–4-year-olds' ability to infer the causal mechanisms for a pair of lights. In both experiments the exterior of the two lights appeared identical. In Experiment 1, one light displayed a stable activation pattern of a single color while the other light displayed a variable pattern of activation by cycling through a series of different colors (i.e., a more varied effect). Children were asked to judge which light had a more complex internal structure. Four-year-olds were more likely to match the light with the more variable effect with a more complex internal mechanism and the light with the more stable effect with a less complex mechanism. Three-year-olds' responses were at chance. Experiment 2 replicated this finding when the activation patterns of the two lights were described verbally but never demonstrated. Taken together, these results suggest that 4-year-olds appreciate that the variability of an object's causal efficacy is related to the complexity of its internal mechanistic structure.

1. Introduction

Imagine a child at an arcade. At one machine, she puts in a token and a gumball appears from a chute. At another machine, she puts in a token and starts to play a videogame. Identifying the efficient cause of receiving the gumball and being able to play the game is straightforward. Investigations of children's causal reasoning attempt to identify the principles underlying how children make these types of causal attributions, such as how events relate to one another in time and space (e.g., Bullock, Gelman, & Baillargeon, 1982), whether events' co-occurrence indicates a causal relation or spurious association (e.g., Gopnik, Sobel, Schulz, & Glymour, 2001), and the base rate with which events co-occur (e.g., Sobel, Tenenbaum, & Gopnik, 2004). These findings suggest that even young preschoolers would have little difficulty understanding that the tokens caused the effects in both cases.

While children might make these causal inferences, they potentially know little about the specific mechanism(s) by which the causes produce their effects. This distinction was pointed out by (among others) Gopnik et al. (2001), who suggested that very young children have knowledge of *formal* principles that underlie causal inference, like those described above, but also more *substantive* principles, such as particular kinds of mechanistic knowledge. While children might register the role of certain formal principles very early in development (e.g., Sobel & Kirkham, 2006), this latter kind of knowledge clearly develops throughout childhood. Even adults do not possess a complete understanding of causal mechanisms. They often over-attribute their understanding of how a causal system works (e.g., Rozenblit & Keil, 2002), and young children show similar effects (Mills & Keil, 2004). But just because children and adults believe they possess more mechanistic knowledge than they do, does not mean that they fail to possess *any* mechanistic knowledge. Indeed, some have argued that recognizing how causes and effects are related is more important for making causal attributions than appreciating the formal principles under-

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lying causal inference, such as correlations among events (e.g., Ahn, Kalish, Medin, & Gelman, 1995; Buchanan & Sobel, 2011; Shultz, 1982).

Our goal in the present investigation is to articulate the development of one kind of mechanism knowledge young children might have available to them when they infer the efficient cause(s) of observed effects. Returning to the arcade example, nothing of the intervening mechanism is perceptually available to the child during either of the events. But children do know that the outcomes of the two events differed greatly. In one instance, the outcome was short and simple: the gumball appeared. In the other case, the outcome was variable and extended: the game lasted for some time and (if it was at all interesting) involved presumably many more visual and auditory displays. Given this information, children might form the reasonable expectation that the mechanism underlying the latter outcome is more complex than that of the former.

This hypothesis emanates from evidence that children recognize that objects' causal properties are related to their insides, which undergoes development during the preschool years. Gelman and Wellman (1991) found that 4–5-year-olds recognized that members of the same category (i.e., objects given the same label) often shared internal structure. Children believed that category membership was a better predictor of insides than external perceptual similarity. Gelman and Wellman did not test younger children, but several follow-up studies suggest that 3-year-olds do not make similar inferences about the relation between an object's causal properties or category membership and their insides (e.g., Gottfried & Gelman, 2005; Sobel, Yoachim, Gopnik, Meltzoff, & Blumenthal, 2007). For instance, Sobel et al. (2007) showed that 4-year-olds inferred that objects with shared causal efficacy had shared insides, even when a conflicting strategy based upon the objects' visual appearance was available. Three-year-olds, in contrast, relied on external appearance when making these inferences, and not causal properties.

While 4-year-olds register that an object's insides and causal efficacy are related, the present experiments examine whether they form a more sophisticated expectation: that more variable efficacy can imply the presence of a more complex internal mechanism. In Experiment 1, we showed 3- and 4-year-olds two objects that activated given the same action, but differed in the variability of their effects. We examined whether children would match the object with the more variable effect with a more complex internal structure. In Experiment 2, the objects were not activated. Instead, the experimenter described the pattern of activation for each object verbally, thereby equating the objects' visual appearance. The question underlying both experiments is whether 3- and 4-year-olds differ in their appreciation of the relation between an effect's complexity and the underlying mechanism between it and its cause.

2. Experiment 1

Three- and 4-year-olds were presented with a matching game. Children were shown two lights that activated when pressed. One light exhibited a variable pattern of activation by repeatedly flashing a series of colors. The other light displayed a stable activation pattern by maintaining a single, solid color. Children were then presented with two pictures that were purported to match the insides of the lights. One of the pictures featured a causal mechanism with only a few internal components. The other picture featured a more complex mechanism with additional components. If children expect variability in activation to imply a more complex underlying mechanism, we would expect children to match the picture featuring the complex insides to the light featuring a variable pattern of activation. If children do not form such an expectation, we would predict matching performance to be at chance.

3. Method

3.1. Participants

Thirty-three 3-year olds (13 girls, M = 41.81 months, SD = 2.73, range 35–46 months) and thirty-two 4-year-olds (14 girls, M = 52.66 months, SD = 3.72, range 48–59 months) were included in the final sample. An additional seven children were tested but excluded from the final sample due to experimenter error (n = 4) or technical difficulties (n = 3). Participants were recruited from a local preschool, a local children's museum, and a list of hospital births.

3.2. Materials

During the familiarization phase, children were shown two transparent boxes, each $5 \times 3 \times 3''$, were presented during the familiarization phase. One box contained a black triangular wooden block and the other contained a green wooden cube of similar dimensions (see Fig. 1). These objects were paired with pictures that matched the insides of the boxes; one picture featured a black triangle and the other featured a green square.

During the test phase, children were shown three round lights that switched on or off when pressed. Two were modified such that the original bulb was replaced with a LED that could be set to a variety of activation patterns. One of the lights was set to illuminate a solid color when activated. The other light cycled through a series of seven colors at a constant rate of approximately one cycle every 2 s. We will refer to these as the *solid* and *variable* lights respectively. The third light was unmodified and

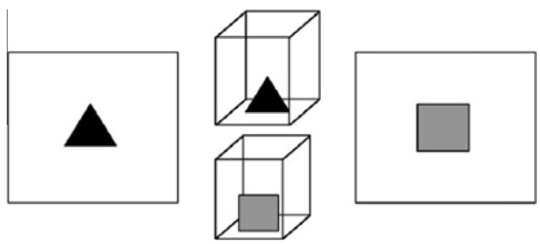

Fig. 1. A schematic representation of the materials used during the training phase as seen from the child's position.