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Preschoolers perform more informative experiments after observing theory-violating evidence



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ABSTRACT

This study investigated the effect of evidence conflicting with preschoolers' naive theory on the patterns of their free exploratory play. The domain of shadow size was used—a relatively complex, ecologically valid domain that allows for reliable assessment of children's knowledge. Results showed that all children who observed conflicting evidence performed an unconfounded informative experiment in the beginning of their play, compared with half of the children who observed confirming evidence. Mainly, these experiments were directed at investigating a dimension that was at the core of children's initial theory. Thus, preschoolers were flexible in the type of experiments they performed, but they were less flexible in the content of their investigations.

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Introduction

The Piagetian claim that young children construct knowledge by active exploration has been accepted widely (e.g., Singer, Golinkoff, & Hirsh-Pasek, 2006). The claim implies that young children are capable of integrating observed evidence with prior knowledge to formulate hypotheses, designing experiments, and drawing conclusions that enable learning. This process requires the use of substantive domain-specific knowledge as well as formal knowledge—general abilities that allow

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for translating hypotheses into effective experiments and drawing conclusions from these experiments (Gopnik, Sobel, Schulz, & Glymour, 2001; Gopnik et al., 2004).

Recently, several studies have provided empirical evidence for preschoolers' possession of such formal knowledge (see Schulz, 2012, for a review). These studies demonstrate rationality and systematicity in preschoolers' exploration. Researchers have looked at how characteristics of evidence affect children's exploratory play, showing that uncertainty about the causal structure of an event promotes preschoolers' exploration (Bonawitz, Van Schijndel, Friel, & Schulz, 2012; Cook, Goodman, & Schulz, 2011; Gweon & Schulz, 2008; Legare, 2012; Legare, Gelman, & Wellman, 2010; Schulz & Bonawitz, 2007). Researchers have proposed that such findings are consistent with a Bayesian inference framework (Bonawitz et al., 2012; Cook et al., 2011; Schulz, 2012).¹ A specific case of uncertainty arises when children's theories conflict with the evidence children observe (e.g., Berlyne, 1960; Chinn & Brewer, 1993). Legare et al. (2010) and Legare (2012) showed that this type of evidence affects preschoolers' explanatory reasoning, which in turn was shown to be related to their exploratory play. Bonawitz et al. (2012) demonstrated that this type of evidence affects the duration of young children's exploratory play. They assessed 6- and 7-year-olds' prior knowledge in the domain of balance and classified children as having a center theory (objects balance on their geometrical center) or a mass theory (objects balance on their center of mass). Children were then confronted with evidence that either confirmed or conflicted with their balancing theory, and those who observed conflicting evidence played longer with a balancing toy than children who observed confirming evidence.

Several studies have shown that it is the patterns of children's exploration, rather than the time spent exploring, that determine opportunities for learning (e.g., Bonawitz et al., 2012; Gweon & Schulz, 2008; Schulz, Gopnik, & Glymour, 2007). Testing children's ability to use exploratory play for learning, therefore, implies not only a demonstration of children selectively exploring after observing conflicting evidence (Bonawitz et al., 2012) but also a demonstration of children selectively performing specific patterns of exploration after observing this type of evidence. Cook and colleagues (2011) investigated these patterns in the situation where children observe ambiguous evidence, that is, evidence that is ambiguous with respect to which variable controls the effect. However, to our knowledge, these patterns have not been investigated in the situation where children observe conflicting evidence. The goal of the current study, therefore, was to investigate the effect of evidence conflicting with preschoolers' naive theory on the patterns of their free exploratory play.

Preschoolers' patterns of exploration have been quantified in different ways such as by looking at the variability or objectives of children's actions (e.g., Legare, 2012; Sobel & Sommerville, 2010). For example, Legare (2012) used the blicket detector paradigm—a machine that activates (lights up and plays music) when some objects (blickets), but not others, are placed on it (Gopnik & Sobel, 2000; Nazzi & Gopnik, 2000). Legare then coded the objectives of actions by looking at hypothesis-testing strategies that children used to investigate conflicting evidence. Two such strategies are switching locations of object pairs on the machine and trying to open an object. Variability in actions was then coded by looking at how many of these different strategies children employed. In the current study, we focused on children's use of unconfounded informative experiments, that is, experiments from which valid causal conclusions can be drawn. Performing unconfounded experiments is a domain-general skill that is at the core of scientific practice; therefore, the learning of the skill is considered to be of importance in the development of scientific reasoning (e.g., Chen & Klahr, 1999; Klahr & Nigam, 2004). In science education research, the skill of designing unconfounded experiments is called the *control of variables strategy*, and several studies have demonstrated that primary school-aged children have difficulty with the use and transfer of the strategy (e.g., Chen & Klahr, 1999; Klahr & Nigam, 2004; Kuhn, Garcia-Mila, Zohar, & Andersen, 1995). These findings stand in contrast to studies in the field of developmental psychology showing young children's ability to perform unconfounded experiments (e.g., Cook et al., 2011; Schulz et al., 2007; Sobel & Sommerville, 2010). The current study investigated whether theory-violating evidence leads preschoolers to selectively perform

¹ The Bayesian inference framework provides a formal account of how children's prior theories interact with observed evidence to affect exploratory play. Specifically, Bayesian inference specifies how children update their beliefs on a hypothesis given the observed data. An explanation of the account is beyond the scope of this article. See Bonawitz and colleagues (2012), Cook and colleagues (2011), and Schulz (2012) for more information.

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