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Brief article

The role of preschoolers' social understanding in evaluating the informativeness of causal interventions

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Abstract

Preschoolers use information from interventions, namely intentional actions, to make causal inferences. We asked whether children consider some interventions to be more informative than others based on two components of an actor's knowledge state: whether an actor *possesses* causal knowledge, and whether an actor is allowed to *use* their knowledge in a given situation. Three- and four-year-olds saw a novel toy that activated in the presence of certain objects. Two actors, one knowledgeable about the toy and one ignorant, each tried to activate the toy with an object. In Experiment 1, either the actors chose objects or the child chose for them. In Experiment 2, the actors chose objects blindfolded. Objects were always placed on the toy simultaneously, and thus were equally associated with the effect. Preschoolers' causal inferences favored the knowledgeable actor's object *only* when he was allowed to choose it (Experiment 1). Thus, children consider both personal and situational constraints on knowledge when evaluating the informativeness of causal interventions.

Keywords: Causal learning; Intentional action; Source knowledge; Theory of mind

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1. Introduction

Young children are extraordinary causal learners. By age five they integrate causal evidence from perceptual cues (Schlottmann, Allen, Linderoth, & Hesketh, 2002), patterns of covariation (Gopnik, Sobel, Schulz, & Glymour, 2001; Kushnir, & Gopnik, 2005), and mechanism information (Bullock, Gelman, & Baillargeon, 1982; Shultz, 1982) to make genuine causal inferences in novel situations. Additionally, preschoolers can use information from observing (and performing) *interventions* – direct manipulations of causal variables – to learn causal relations (Gopnik et al., 2004; Schulz, Gopnik, & Glymour, 2007).

Interventions are crucial for disentangling causal directionality and distinguishing between causal relations and spurious associations. They enable causal inferences in the absence of spatio-temporal, mechanistic, and/or purely associative information, a fact which has led some scholars to argue that they are central to our very notion of cause (Schulz et al., 2007; Woodward, 2003). The predominant type of causal intervention that children observe – both in the laboratory and in everyday contexts – is intentional action. It is therefore important to consider how children's developing understanding of intentional action influences their understanding of interventions, and more specifically their interpretation of evidence from interventions.

Children are aware of the difference between intentional actions and other actions (accidental, non-agentive) from an early age (Meltzoff, 1995). By preschool, children understand that intentional acts are *knowledge-driven*: actors can be knowledgeable or ignorant (Lutz & Keil, 2002), and situations may or may not allow the deployment of knowledge (e.g., if the actor is acting blindly or otherwise constrained; Gergely, Bekkering, & Király, 2002). These distinctions may have implications for causal learning: some interveners, and some interventions, may be more informative than others. Do preschoolers understand that actors and their causal actions can be differentially informative?

Evidence from the domain of children's word learning suggests that preschoolers treat sources of new words as differentially informative. When children see two speakers – one who labels objects correctly and one who labels them incorrectly – they choose to learn new words from the correct labeler (Koenig, Clement, & Harris, 2004; Koenig, & Harris, 2005). Children also learn from speakers who profess knowledge about a word over those who profess ignorance (Sabbagh & Baldwin, 2001), they prefer adult speakers to child speakers provided both are equally correct (Jaswal & Neely, 2006), and they will not generalize word meanings based on their own (uninformed) guesses (Xu & Tenenbaum, 2007).

There may (or may not) be a privileged connection between word-learning and children's judgment of others' informativeness (for example, children seem to believe that knowing words relates to knowing other things, such as object function; Koenig & Harris, 2005). Regardless, the question of whether and how children judge the informativeness of causal actions is important in its own right. Logically, not every intervention from every actor is equally informative about the causal nature of the world. It may be beneficial to consider interveners' expertise – their causal knowledge – when evaluating the informativeness of their actions. On the other hand, in causal learning, even an uninformed source can perform an efficacious intervention by accident. Physical causes (including actions) are often independent of person's knowledge, intentions, or expertise (an unthinking bull in a China shop causes havoc just as much as an intelligent arsonist). In attempting to infer causality, it may be an effective strategy, especially for young learners, to pay attention to all causal interventions regardless of source. In contrast, learning words from ignorant speakers is almost certainly a liability. Thus, the question of whether young children consider expertise in evaluating the informativeness of causal interventions remains important and unaddressed.

To address this question, we varied whether a source was knowledgeable or ignorant about a novel causal scenario in which a device activated only in the presence of certain objects. We also varied whether the source was permitted to *use* that knowledge when asked to intervene. This critical manipulation was included to test whether children understand that both *knowledge possession* and *knowledge use* are components of informative interventions. Alternatively, children could use a low-level strategy in which they use knowledge to tag sources as "good" or "bad" and disregard the circumstances surrounding knowledge use. Additionally, in all conditions, the intentions of the actors, and the outcomes of their actions, were held constant. This is critical given that past research has identified that young children's causal inferences tend to be dominated by matches/mismatches between intentions and outcomes (Meltzoff, 1995; Shultz & Wells, 1985).

In Experiment 1, the child watched while two actors (one knowledgeable, one ignorant) chose objects to activate the device. We also included two control conditions, in which the actors' knowledge/ignorance could not influence their choice of actions. In one control (Experiment 1), we asked the *child participant* to choose the objects for the two actors. In another (Experiment 2), the actors chose objects *while blindfolded*. In each control, the actors' knowledge was independent of the outcome of the interventions, and therefore expertise could not influence informativeness. Crucially, in all three conditions, both actors performed the identical action with their respective objects simultaneously. Thus, both actions were associated with the activation of the device. If children base their inferences solely on associations between interventions and outcomes, they should treat both actors as equally informative in all three conditions. If they believe that knowledge always predicts informativeness, then they should reason that the knowledgeable intervener is more informative in all three conditions. However, if they understand that *having knowledge* and *being able to use knowledge* are both important, then they should reason that the knowledgeable source is more informative only when he has the ability to choose his intervention.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Twenty-nine three-year-olds (Mean = 3.6, *SD* = 3.8 months) and 29 four-year-olds (Mean = 4.5, *SD* = 3.0 months) from a mid-sized Midwestern town participated. Fifteen children of each age were randomly assigned to the *Puppets Pick* condition and 14 of each age to the *Child Picks* condition.

2.1.2. Materials

The device was a $5'' \times 7'' \times 3''$ wooden box with a Lucite top. A hidden switch could make the box's top light up and play music. Thus, the experimenter controlled which objects appeared to cause the device's activation. The warm-up objects were four blocks that differed in color and shape (not including cubes). The test objects were five cubes of different colors. The two focal actors were puppets, a squirrel and a monkey, of approximately equal size.

2.1.3. Procedure

Each child was seated at a table opposite the experimenter, with the device between them. The experimenter introduced the device by saying, "This is my special toy. Some blocks make it go. Some blocks don't make it go." To demonstrate, she placed each warm-up block one at a time on the device. Two blocks caused it to activate and two did not.

The experimenter then introduced the child to the two puppets. Children were told that the first puppet (for example, squirrel) "has seen the toy before," "knows all about it," and "knows which blocks make it go." In contrast, the second puppet (for example, monkey) "has never seen the toy before," "doesn't know anything about it," and "doesn't know which blocks make it go."

The experimenter then brought out the cube blocks. In the *Puppets Pick* condition, the blocks were placed on the table in a pile. In the *Child Picks* condition, the blocks were in an opaque cloth bag. The experimenter said, "I have some more blocks here [in this bag]. Some of them make the toy go and some of them don't make it go." Before continuing, children were asked two memory-checking questions: "Which puppet knows which blocks make the toy go? Which puppet doesn't know which blocks make the toy go?" Three children who answered incorrectly were replaced.

The important difference between the two conditions was the way the puppets were each assigned a block. In the *Puppets Pick* condition, the experimenter said, "I'm going to let squirrel and monkey each pick a block." She then asked each puppet, "Which block do you want to try?" and they each picked one out of the pile. In the *Child Picks* condition, the experimenter said, "I need you to help squirrel and monkey." She then held out the cloth bag, asked the child to "pick one," then told her to hand it to the first puppet. This was repeated for the second puppet. Which puppet was knowledgeable (squirrel or monkey), whether the knowledgeable puppet picked (or was handed a block) first or second, and which side of the device the knowledgeable puppet was on were counterbalanced.

Then the puppets placed their blocks on the device *at the same time* and the device activated. This was repeated a second time. With the blocks on the table, the experimenter asked the child, "Which block makes the toy go?"

2.1.4. Coding and reliability

Children were coded as choosing the knowledgeable puppet's block, the ignorant puppet's block, or both blocks based on their first response (whether it was by grabbing, pointing, or verbalizing). Twenty-eight percent of responses were coded by a researcher blind to the hypotheses, condition, and puppets' knowledge, with an equal number of responses sampled from each condition. Agreement was 100%.

2.2. Results

Table 1 shows the distribution of responses by condition. There were no significant differences by age in either condition, so the data were combined. In the *Puppets Pick* condition, 20 children (10 of each age) said the knowledgeable puppet's block activated the device, 3 (2 three-year-olds and 1 four-year-old) said the ignorant puppet's block activated the device, and 7 (3 three-year-olds and 4 four-year-olds) said both blocks activated the device. The distributions are significantly different from uniform for both age groups (three-year-olds: $\chi^2(2, N = 15) = 7.60$, $p < .05$; four-year-olds: $\chi^2(2, N = 15) = 8.40$, $p < .05$) and combined ($\chi^2(2, N = 30) = 15.80$, $p < .001$). Moreover, children chose the knowledgeable puppet's block significantly more often than the other responses combined (binomial test, one-tailed, $p < .05$). Thus, in the *Puppets Pick* condition children inferred that the knowledgeable puppet's intervention was most informative even though both actions were equally positively associated with the outcome.

In contrast, the distributions of children's responses in the *Child Picks* condition were not significantly different from uniform in either age group (three-year-olds: $\chi^2(2, N = 14) = 2.71$, ns; four-year-olds: $\chi^2(2, N = 14) = 1.00$, ns) or combined ($\chi^2(2, N = 28) = 3.07$, ns). Eleven children (5 three-year-olds and 6 four-year-olds) chose the knowledgeable puppet's block, twelve (7 three-year-olds and 5 four-year-olds) chose both blocks, and the remaining 5 (2 three-year olds and 3 four-year-olds) chose the ignorant puppet's block.

A direct comparison of the number of children choosing the knowledgeable puppet's block in the *Puppets Pick* condition versus the *Child Picks* condition was significant (20/30 vs. 11/28; $\chi^2(\mathrm{df} = 1, \mathrm{N} = 58) = 4.36$, $p < .05$). Thus, it seems that children did not choose the knowledgeable puppet's block merely because knowledge is overall "positive" or generally associated with correct choices. Rather, they did so only when the knowledgeable puppet used his knowledge to choose an object.

Table 1
Number (and percentage) of children choosing the knowledgeable puppet's block, ignorant puppet's block, or both puppets' blocks in each condition of Experiment 1 and Experiment 2

		Knowledgeable puppet's block	Ignorant puppet's block	Both puppets' blocks
Experiment 1	Puppets pick ($N = 30$)	20 (67%)	3 (10%)	7 (23%)
	Child picks ($N = 28$)	11 (39%)	5 (18%)	12 (43%)
Experiment 2	Blindfolded puppets pick ($N = 28$)	10 (38%)	11 (39%)	7 (23%)

However, there is still an alternative interpretation to consider: in the *Child Picks* condition, children may have based their inferences on the efficacy of their *own* choices rather than on the puppets' inability to demonstrate knowledge. Indeed, children are often overconfident in their own causal efficacy (Kushnir & Gopnik, 2005). Therefore, we conducted an additional study identical to the *Puppets Pick* condition, except that the puppets picked blocks *while blindfolded*. The blindfold prohibited the knowledgeable puppet from demonstrating knowledge while still allowing the puppets to intervene themselves. We predicted children would again choose blocks at chance in this condition.

3. Experiment 2

3.1. Methods

3.1.1. Participants

Twenty-eight children (14 3-year-olds and 14 4-year-olds) from a Midwestern town participated.

3.1.2. Materials

The device and objects were the same as in Experiment 1.

3.1.3. Procedure

After the device and the puppets were introduced (see Experiment 1), the experimenter said, "We are going to play a trick on Squirrel and Monkey. We are going to make them pick blocks without looking." She then introduced the blindfold by saying, "Do you know what a blindfold is? A blindfold is a piece of cloth that covers your eyes so you can't see." She placed one blindfold on each puppet.

The rest of the procedure was the same as the Puppets Pick condition of Experiment 1, with the addition of the blindfolds.[1] The blindfolds were removed just prior to asking the final question, to match the end state of Experiment 1.

3.1.4. Coding and reliability

Coding was identical to Experiment 1. Twenty-five percent of responses were coded by a researcher blind to the research hypotheses and to the puppets' knowledge states. Agreement was 100%.

3.2. Results

The distribution of responses is shown in Table 1. There were no age differences, so the data were combined. The results were uniformly distributed across the three response types ($\chi^2(2, N = 28) = .93$, *ns*). Ten children (5 of each age) picked the

[1] No child failed the memory-checking questions.

knowledgeable puppet's block, eleven (4 three-year-olds and 7 four-year-olds) picked the ignorant puppet's block, and seven (5 three-year-olds and 2 four-year-olds) said both blocks activated the device. Thus, when the knowledgeable puppet could not choose his block due to being blindfolded, children did *not* treat his intervention as more informative.

A direct comparison to Experiment 1 further confirms this finding. Significantly more children chose the knowledgeable puppet's block when the puppets could see than when the puppets were blindfolded (20/30 vs. 10/28; $\chi^2(df = 1, N = 58) = 5.56$, $p < .05$). A comparison of children choosing the knowledgeable versus ignorant puppets' blocks across conditions was also significant (*Puppets Pick*, 20/23; *Blindfolded Puppets Pick*, 10/21; $\chi^2(df = 1, N = 44) = 7.83$, $p < .001$). Comparisons of each response type between the *Child Picks* condition and the *Blindfolded Puppets* control were all non-significant. The results thus extend the findings and confirm the interpretation of Experiment 1: Children reasoned that the knowledgeable puppet's interventions were informative only when his ability to demonstrate knowledge was unconstrained – in the previous experiment, by not being able to choose, and in this experiment, by being blindfolded.

4. Discussion

Preschool children pay special attention to interventions when engaged in causal learning (Gopnik et al., 2004; Schulz et al., 2007). We have now shown that young children pay attention to the *source* of interventions as well. In particular, children understand that interventions may or may not be *knowledge-driven*, and that this influences their informativeness. In the *Puppets Pick* condition, children were more likely to infer that the interventions chosen by the knowledgeable rather than the ignorant source were effective, even though both interventions were equally associated with the effect. However, when the knowledgeable source did not make a choice (*Child Picks* condition), or chose blindfolded (Experiment 2), children did not prefer his interventions. Thus children appropriately consider an intervener's knowledge as relevant to causal inference, but do not trust a knowledgeable source merely because he is knowledgeable. Rather, they consider *having* knowledge and being able to *use* that knowledge as two separate components of informativeness.

These findings clearly support the conclusion that young children can discriminate between informative and uninformative sources of information, as is becoming apparent in the domain of word learning. We have additionally demonstrated that children distinguish between knowledge possession and knowledge use. Studies relating speaker knowledge to word learning have not made this distinction, which provides a critical control for children's use of simple strategies rather than a true understanding of knowledgeable informants. More research is needed to learn what cues children use to establish informativeness, how these insights develop, and whether these cues vary depending on the domain of inference.

Our findings also add to the growing evidence that, in causal learning, preschool children do not treat all associations between interventions and outcomes in the same way. Children's interpretation of interventions can be affected by spatial contiguity cues (Kushnir & Gopnik, 2007), domain-specific mechanisms (Schulz & Gopnik, 2004), statistical information (Sobel, Tenenbaum, & Gopnik, 2004), category membership (Gopnik & Sobel, 2000), and direct experience (Kushnir & Gopnik, 2005). Uniquely, however, this study addresses children's understanding of properties of interventions themselves. Crucially, we show that preschoolers can recruit their emerging social knowledge to interpret interventions and guide their use of statistical information.

Thus, understanding specific features of intentional actions informs children about physical as well as social causality, and is important to children's conceptual development in both these core domains. In this regard, our data suggest that children at times evaluate knowledge separately from intention. Intentions dominate children's interpretation of human actions even at 12 months (Gergely, Nádasdy, Csibra, & Bíró, 1995; Legerstee, 2005; Phillips, & Wellman, 2005; Woodward, Sommerville, & Guajardo, 2001). Early on, children reliably link intentions to outcomes, inferring that intentions are satisfied only if they achieve desired outcomes (Meltzoff, 1995), and that success of outcomes determines an actor's intention (Shultz & Wells, 1985). In this study, however, intentions and outcomes are held constant. Therefore, in some contexts, preschool children seem to understand that causal knowledge mediates the relationship between intentions and outcomes. This result has implications for theories of mental state understanding, person perception, and causal attribution (Heyman & Gelman, 1998; Schult, 2002; Shultz & Wells, 1985; Yuill & Perner, 1988).

Interventions, in the form of intentional actions, are vital to everyday causal inference. The current study shows that children take into account both personal and situational constraints on knowledge – both *knowledge possession* and *knowledge use* – when evaluating the informativeness of causal interventions. Children's ability to evaluate causal evidence within a social context may be an important contributor to their impressive causal knowledge.

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References

Bullock, M., Gelman, R., & Baillargeon, R. (1982). The development of causal reasoning. In W. J. Friedman (Ed.), *The developmental psychology of time* (pp. 209–254). New York: Academic Press.

Legerstee, M. (2005). Infants' sense of people: Precursors to a theory of mind. Cambridge University Press.

Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature, 415*, 755.

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*, 165–193.

Gopnik, A., Glymour, C., Sobel, D. M., Schulz, L. E., Kushnir, T., & Danks, D. (2004). A theory of causal learning in children: Causal maps and Bayes nets. *Psychological Review, 111*, 1–30.

Gopnik, A., & Sobel, D. M. (2000). Detecting blickets: How young children use information about causal properties in categorization and induction. *Child Development, 71*, 1205–1222.

Gopnik, A., Sobel, D. M., Schulz, L., & Glymour, C. (2001). Causal learning mechanisms in very young children: Two, three, and four-year-olds infer causal relations from patterns of variation and covariation. *Developmental Psychology, 37*, 620–629.

Heyman, G., & Gelman, S. (1998). Young children use motive information to make trait inferences. *Developmental Psychology, 34*, 310–321.

Jaswal, V., & Neely, L. (2006). Adults don't always know best: Preschoolers use past reliability over age when learning new words. *Psychological Science, 17*, 757–758.

Koenig, M., Clément, F., & Harris, P. (2004). Trust in testimony: Children's use of true and false statements. *Psychological Science, 15*, 694–698.

Koenig, M., & Harris, P. (2005). Preschoolers mistrust ignorant and inaccurate speakers. *Child Development, 76*, 1261–1277.

Kushnir, T., & Gopnik, A. (2005). Children infer causal strength from probabilities and interventions. *Psychological Science, 16*, 678–683.

Kushnir, T., & Gopnik, A. (2007). Conditional probability versus spatial contiguity in causal learning: Preschoolers use new contingency evidence to overcome prior spatial assumptions. *Developmental Psychology, 44*, 186–196.

Lutz, D., & Keil, F. (2002). Early understanding of the division of cognitive labor. *Child Development, 73*, 1073–1084.

Meltzoff, A. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*, 838–850.

Phillips, A., & Wellman, H. (2005). Infants' understanding of object-directed action. *Cognition, 98*, 137–155.

Sabbagh, M., & Baldwin, D. (2001). Learning words from knowledgeable versus ignorant speakers: Links between preschoolers' theory of mind and semantic development. *Child Development, 72*, 1054–1070.

Schlottmann, A., Allen, D., Linderoth, C., & Hesketh, S. (2002). Perceptual causality in children. *Child Development, 73*, 1656–1677.

Schult, C. (2002). Children's understanding of the distinction between intentions and desires. *Child Development, 73*, 1727–1747.

Schulz, L. E., & Gopnik, A. (2004). Causal learning across domains. *Developmental Psychology, 40*, 162–176.

Schulz, L. E., Gopnik, A., & Glymour, C. (2007). Preschoolers learn causal structure from conditional interventions. *Developmental Science, 10*, 322–332.

Shultz, T. R. (1982). Rules of causal attribution. *Monographs of the Society for Research in Child Development, 47*, Serial No. 194.

Shultz, T., & Wells, D. (1985). Judging the intentionality of action-outcomes. *Developmental Psychology, 21*, 83–89.

Sobel, D., Tenenbaum, J., & Gopnik, A. (2004). Children's causal inferences from indirect evidence: Backwards blocking and Bayesian reasoning in preschoolers. *Cognitive Science, 28*, 303–333.

Woodward, A., Sommerville, J., & Guajardo, J. (2001). *How infants make sense of intentional action. Intentions and intentionality foundations of social cognition*. Berlin: The MIT Press (pp. 149-169).

Woodward, J. (2003). *Making things happen: A theory of causal explanation*. New York: Oxford.

Xu, F., & Tenenbaum, J. B. (2007). Sensitivity to sampling in Bayesian word learning. *Developmental Science, 10*, 288–297.

Yuill, N., & Perner, J. (1988). Intentionality and knowledge in children's judgments of actor's responsibility and recipient's emotional reaction. *Developmental Psychology, 24*, 358–365.