Title
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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 35(35)

ISSN
1069-7977

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Publication Date
2013

Peer reviewed

Causal determinism in toddlers

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Abstract

Prior research has shown that children hold a belief in causal determinism - the belief that all events are caused – by 4 years of age. In this study we investigate the developmental origins of this belief. We showed toddlers (24 months) a spontaneous or explained novel physical outcome (a toy that lit up either spontaneously or upon contact from an experimenter) and then showed them an additional candidate cause (pressing a button) while obscuring the outcome. We asked whether toddlers inferred that the two components (the button and the outcome) were causally linked. We found that toddlers represented the candidate cause as the cause of the novel outcome only when the event spontaneously occurred (Experiments 1-2), and that children spontaneously searched for plausible causes of unexplained outcomes (Experiment 3). These results suggest that toddlers, like older children, believe physical events have causes, and that this belief supports exploration and discovery.

Keywords: causal reasoning; determinism; physical causality; prediction; intervention.

Researchers have suggested that children's sophisticated causal inference abilities are at the core of theory development and the many conceptual changes that occur throughout early childhood (Carey, 1985, 2009; Gopnik & Meltzoff, 1997; Gopink & Wellman, in press, Schulz, 2012). By preschool, children engage in causal exploration, use conditional probabilities to determine the causal structure of events, and can design appropriate causal interventions (e.g., Bullock, Gelman, & Baillargeon, 1982; Gopnik & Sobel, 2000; Gopnik et al., 2004; Kushnir & Gopnik, 2007; Shultz, 1982).

What drives children's search for causal structure in the world? Although some events in the world involve visible interventions (e.g., human action) and visible outcomes (e.g., objects that move or change state), many events involve unobserved or even unobservable causal mechanisms (e.g., viruses cause disease). Thus, a challenge for theories of conceptual development is to explain how children go beyond the evidence they see.

One possibility is that children are causal determinists. In its most basic form, causal determinism is the belief that all events have causes. If an event appears to occur spontaneously (e.g., a light turns on) adults will typically infer the presence of an unobserved generative cause (e.g., a person activating a hidden switch). A belief in causal determinism could help guide children's search for unobserved variables.

Prior research suggests that by the age of five, children are determinists about physical events. In classic research on causal reasoning, Bullock, Gelman, & Baillargeon (1982) showed that 5-year-olds denied that that events could occur spontaneously. When asked to explain a novel, apparently spontaneous jack-in-the-box event, no child suggested that the event occurred on its own. Rather, all children referred to hidden variables (e.g, wires, remote controls, or "invisible batteries"). More recently, Schulz & Somerville (2005) found that four and five-year-old children also posited hidden causal variables when outcomes occurred probabilistically.

If a belief in causal determinism is integral to human causal learning and exploration, it might be in place very early in development. Note however, that it is not obvious that the assumption of determinism is necessary either for accurate prediction or effective action. In principle, it might be possible to learn statistical relationships between actions and outcomes (e.g., Blaisdell, Sawa, Leising, & Waldmann, 2006) and even to innovate causally effective tools (Emery & Clayton, 2004) without assuming that the world is saturated with causality (though see Gershman, Blei, & Niv, 2010 for evidence suggesting that inferring latent variables may be integral to causal reasoning broadly). If the assumption of determinism is a relatively late development, children might come to believe that all events have causes only after they have been instructed in unobservable causes like gravity and germs.

Here, we explore the developmental origins of causal determinism by asking whether 18- to 30-month-old children believe that physical events have causes. We show toddlers an event (a light turning on) that either appears to occur spontaneously or that appears to be caused by the experimenter's preceding intentional action. We then introduce a novel button as a plausible candidate cause for the event (but never show the toddlers any predictive relationship between the button and the light). If toddlers believe that all physical events have causes, then they should ignore the button when the experimenter's intentional action potentially explains the event but reference the button when the event is otherwise unexplained. We test the prediction that toddlers selectively infer causes for unexplained events by investigating toddlers' predictive looks (Experiment 1), their interventions (Experiment 2), and their exploratory behavior (Experiment 3).

Experiment 1

Methods

Participants Thirty two toddlers (mean: 24 months, range – 18 - 30 months) were recruited at a Children's Museum. An additional 10 toddlers were recruited but not included in the final sample due to: inability to complete the session (n = 4), parental interference (n = 4), or experimenter error (n = 2).

Toddlers were assigned to either the Spontaneous condition or the Explained condition (n = 16/condition). There were no age differences between the conditions ($p = ns$).

Materials The light box was constructed from a black box (6 in x 6 in x 6 in) with a small blue lamp (2 in diameter) emerging from the front panel which was controlled surreptitiously by the experimenter. An orange button box was connected to the black box by a long orange rod (15 in). A black screen served as an occluder throughout the procedure. An additional black screen was placed behind the black box to obscure the experimenter's surreptitious activation of the blue lamp.

Procedure Figure 1 presents a schematic depiction of the procedure from Experiments 1-3. Upon entering the testing space, all children saw the button box connected to the light box. The experimenter directed the child's attention to all components of the novel toy (the button box, the connected rod, and the light box) without labeling the specific items (e.g., "Look at this") (see Figure 1, top panel). The button was then occluded from the child's view with the black screen. In the Spontaneous condition, toddlers saw the light box light up and flash blue (4 flashes, approximately 1 s total) apparently spontaneously. In the Explained condition, the experimenter touched the rim of the light and then light box lit up and flashed blue.

In both conditions the experimenter then moved the occluder to reveal the button box and occlude the light box. The experimenter then pushed the button for 1 s.

During the test trial, the experimenter removed the occluder from in front of the light box so that all components were visible to the child. The experimenter pressed the button but the light box did not light up and flash blue. We coded toddlers' first look in the 2-second window following the button press.

Results and Discussion

Figure 2 displays the results from Experiments 1-3. Toddlers in Experiment 1 were significantly more likely to look to the box in the Spontaneous condition (68.75 %, 11/16 toddlers) than in the Explained condition (25.00 %, 4/16 toddlers; Fisher's exact test, $p < .05$) (Figure 2, left panel). That is, toddlers inferred a predictive relationship between a novel event and a candidate cause, but only when the event had no other candidate explanation.

These results are consistent with the possibility that 2-year-olds believe that physical events have causes. When they saw a novel event that appeared to occur spontaneously and a plausible candidate cause (a button press), toddlers made a predictive look from the candidate cause to the novel event even though they had never seen a predictive relationship between the button press and the light. By contrast, when the novel event could be explained by the experimenter's action, the toddlers did not make a predictive look from the candidate cause to the light.

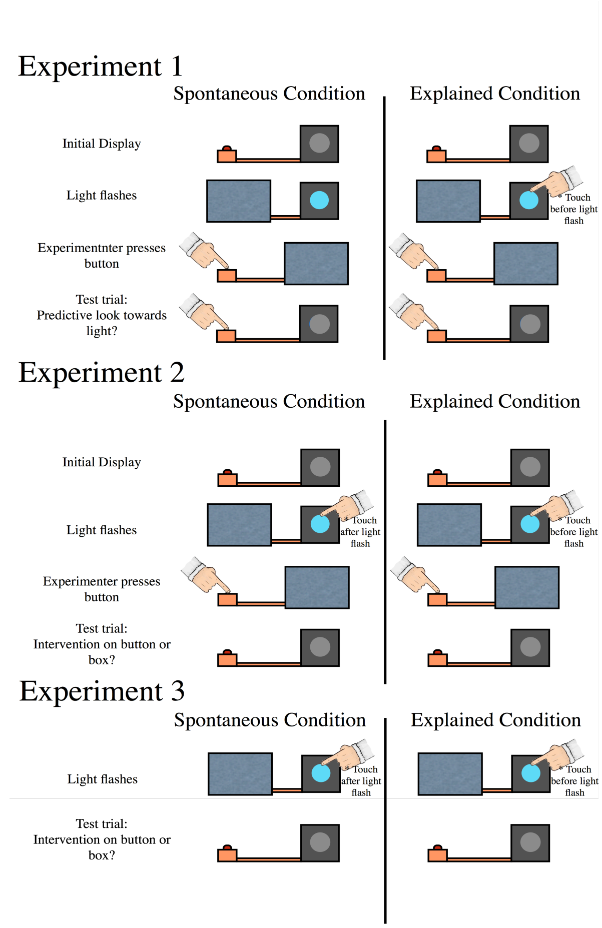

Figure 1: Procedure for Experiments 1-3.

However, not all predictive relationships are causal relationships. Predictive looking cannot establish that the toddlers in Experiment 1 inferred that the button press was the actual cause of the light activating. Also, in Experiment 1 the experimenter touched the light box in the Explained condition but not in the Spontaneous condition; arguably the experimenter's attention to the light box in the Explained condition drew the children's attention away from the button. In Experiment 2, we matched the experimenter's contact with the light box between conditions and we introduce a stronger test of children's belief in causal determinism: we looked at whether toddlers would selectively intervene on the button. If children believe in causal determinism for physical events, then when asked to turn on the light they should push the button more in the Spontaneous condition than the Explained condition.

Experiment 2

Participants Thirty two toddlers (mean: 24 months, range – 18 - 30 months) were recruited at a Children's Museum. Seven additional toddlers were recruited but not included in the final sample due parental interference (n = 3) and failure to intervene (n = 4). Children were assigned to either the

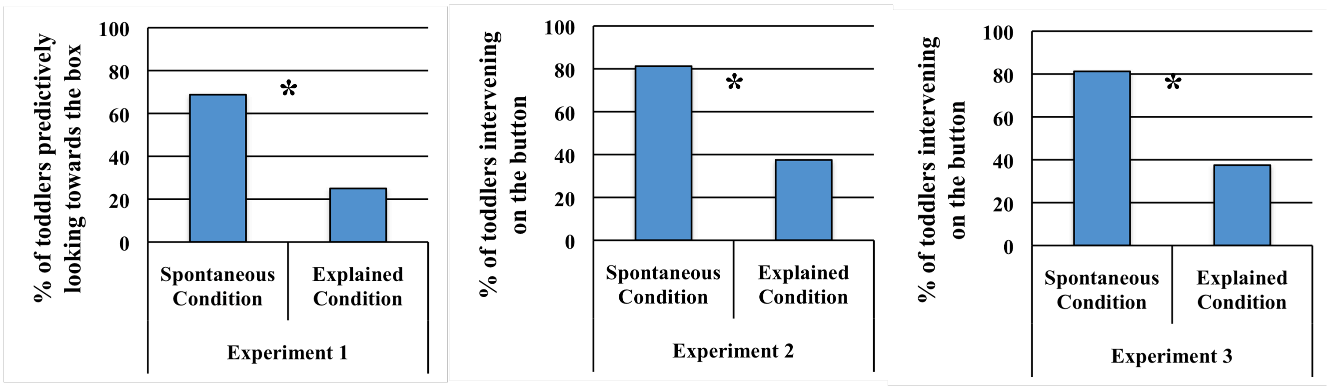

Figure 2: Results of Experiments 1-3.

Spontaneous or Explained condition (n = 16/condition). There were no age differences between conditions ($p > .05$).

Materials The same materials used in Experiment 1 were used in Experiment 2.

Procedure The procedure was identical to Experiment 1 with the following exception (see Figure 1, middle panel). The experimenter touched the light box in both conditions: in the Spontaneous condition he touched the light box immediately after the light turned on (so that it looked like a response to, rather than potential cause of, the light activating); in the Explained condition, he touched the light box immediately before (as in Experiment 1).

During the test event, the experimenter did not push the button. Instead, he asked the child to "make the light turn on." We coded whether the child first touched the button or the light box within a 30-second window following the prompt.

Results and Discussion

Toddlers were more likely to intervene on the button in the Spontaneous condition (81.25 %, 13/16 toddlers) than in the Explained condition (37.50 %, 6/16 toddlers; Fisher's Exact test, $p < .05$)) (see Figure 2, middle panel). In contrast, toddlers were more likely to initially intervene on the light in the Explained condition (62.5 %, 10/16 toddlers) than in the Spontaneous condition (18.75 %, 3/16 toddlers; Fisher's Exact test, $p < .05$)). Toddlers seemed to infer a causal relationship between the button and the light only when the light did not already have an apparent cause.

The data from Experiment 2 provide stronger evidence that toddlers believe in causal determinism for physical events. Using interventions as a measure of causal knowledge, toddlers selectively accept candidate causal mechanisms for outcomes only when the event appears to occur spontaneously.

Note that the experimenter contacted both the button and the light in both the Spontaneous condition and the Explained condition. The only difference between the conditions was whether the experimenter's action on the light could be represented as a cause of the lights flashing; in the Explained condition it could, but in the Spontaneous condition it could not. Thus, the children's tendency to imitate the experimenter's action was influenced by the children's causal attributions.

Experiments 1 and 2 suggest that children's belief in causal determinism affects their search for unobserved causes of physical events. However, neither of these experiments provides a direct test of children's causal exploration. In the prior experiments, toddlers were given a potential causal mechanism (a button) and a relevant action on that mechanism (pressing the button). We do not know whether toddlers in the Spontaneous condition (1) inferred the presence of an external cause and actively searched for it or (2) whether they linked the two subevents of the spontaneous light flash and the button press only *after* the experimenter directed the child's attention towards the button by acting on it. If a belief in causal determinism guides children's causal exploration, then children might search for a candidate cause even if the experimenter does not direct the children's attention towards it.

This prediction requires a caveat however. Whether a learner actually engages in search depends on many factors, including the learner's prior knowledge, the size of the search space, and exploration/exploitation trade-offs relating the cost and benefit of exploration to the cost and benefit of other actions the learner might take (see e.g., Gittens, 1979). Thus a belief in determinism does not mean that learners will always search for unobserved causes whenever they see unexplained events. Even as adults, we see events every day that we cannot explain; we accept that these events have causes but we rarely bother to seek out the causes ourselves. Nonetheless, if toddlers actively search for plausible candidate causes when events appear to occur spontaneously, then they should be more likely to explore a well-constrained, plausible search space (e.g., the button itself) in the Spontaneous condition than the Explained condition, even if they never observe an intervention on the button. We test this prediction in Experiment 3.

Experiment 3

Participants Thirty two toddlers (mean: 23 months, range – 18 - 30 months) were recruited at a Children's Museum. Thirteen additional toddlers were recruited but not included in the final sample due to an inability to complete the session (n = 1), parental interference (n = 4), and failure to intervene (n = 8). Children were assigned to either the Spontaneous or Explained condition (n = 16/condition). There were no age differences between conditions ($p > .05$).

Materials The same materials used in Experiment 1 were used in Experiment 3.

Procedure The procedure was similar to Experiment 1 except that the toddler did not see the button until the test event (see Figure 1, bottom panel). After the toddler viewed the novel event occur either spontaneously (Spontaneous condition) or as a result of the Experimenter's contact (Explained condition), the Experimenter removed the screen from in front of the button, and then told the child it was his/her turn to play. She did not make any reference to the button and did not explicitly request that the child turn on the light.

We coded whether children intervened on the button within the following 30-second window.

Results and Discussion

Toddlers were more likely to intervene on the button in the Spontaneous condition (81.25 %, 13/16 toddlers) than in the Explained condition (37.50 %, 6/16 toddlers; Fisher's Exact test, $p < .05$) (see Figure 2, right panel). Even though children had not seen the experimenter act on a plausible candidate mechanism, children selectively explored the candidate mechanism when the novel event seemed to occur spontaneously.

General Discussion

The current study suggests that toddlers believe that physical effects have causes. When they saw a novel physical event, they predicted relationships between, intervened on, and explored plausible candidate causes only when the event appears to occur spontaneously. While prior research had shown that four and five-year-olds believe in causal determinism, the current study suggests that the assumption of determinism is present much earlier in development, at least by two years of age.

One possibility is that toddlers' performance in the Spontaneous condition was not driven by a belief in causal determinism, but instead by a prior belief that buttons cause events to happen in the world. That is, toddlers may have made a predictive look towards the light in Experiment 1 because they expected the button press to make something happen rather than because they were looking for a cause of the light. Some evidence that this is not the case comes from the fact that children do not look to the light following the button press when the light's activation can be explained by another cause. Additionally however, we are currently running a control condition in which toddlers see the button press but never see the light activate. If toddlers look expectantly to the other object on the stage simply because they believe buttons make things happen, they should look in this condition as well. However, preliminary data suggest that toddlers do not make predictive looks following an intervention on the button if they do not have an event to explain.

In the current study, we restricted our investigation of causal determinism to the domain of physical artifacts. Toddlers may assume that events involving artifacts (like a box lighting up) have causes without extending this assumption more broadly. We do not know to what extent children are determinists about naturally occurring physical events. Nor do we know to what extent either adults or children believe in causal determinism for psychological events (e.g., assuming that behaviors like crying, laughing, and thinking always have causes that fully account for their outcomes). The range of contexts under which children believe in causal determinism is an area for future inquiry.

The current research also leaves open the kind of constraints on children's hypothesis space for candidate causes. In this study we provided children with a very plausible, familiar candidate cause: a button. Arguably, as discussed above, children's search for causal structure may rely heavily on the presence of known plausible candidate causes. Alternatively, a belief in causal determinism could guide children's exploration and discovery of genuinely novel causal mechanisms over development. Further work is necessary to know whether toddlers might accept and explore a wider array of candidate causes to account for otherwise unexplained events.

Here, we investigated the simplest form of a belief in causal determinism – that all events have causes. However, a belief in causal determinism can also entail the assumption that causes produce their outcomes deterministically. If events occur probabilistically, a determinist can assume either that a generative cause is sometimes missing or that an inhibitory cause is sometimes present. In related research in our laboratory, we find that toddlers also posit unobserved causes to explain stochastically occurring events. When the event occurs deterministically, they do not make this inference (Wu, Muentener, & Schulz, 2013; this conference).

Thus a belief in causal determinism may help drive causal learning and exploration starting in early childhood and throughout development. If we assume that all events have causes, then all events are candidates for discovery and exploration, and we can engage in the boundless inquiry that characterizes human cognition.

Acknowledgments

This research was funded by an NSF Faculty Early Career Development Award, a John Templeton Foundation Award, and James S. McDonnell Collaborative Interdisciplinary Grant on Causal Reasoning to L.S.

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