Running head: CONFOUNDING AND PLAY

Serious fun: Preschoolers engage in more exploratory play when evidence is confounded

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Abstract

Researchers, educators, and parents have long believed that children learn cause and effect relationships through exploratory play. However, previous research suggests that children are poor at designing informative experiments; children fail to control relevant variables and tend to alter multiple variables simultaneously. Thus, little is known about how children's spontaneous exploration might support accurate causal inferences. Here we suggest that children's exploratory play is affected by the quality of the evidence they observe. Using a novel free-play paradigm, we show that preschoolers (mean age: 57 months) distinguish confounded and unconfounded evidence, preferentially explore causally confounded (but not matched unconfounded) toys rather than novel toys, and spontaneously disambiguate confounded variables in the course of free play.

KEWORDS: causal learning, exploratory play, preschoolers' scientific reasoning, ambiguous evidence, confounded variables

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Causal knowledge is fundamental to our understanding of the world. It informs our moral judgments, our explanations of the past, and our plans for the future. Little wonder that Hume called causal knowledge the "cement of the universe" (1740/2000). However, relatively little is known about how children learn the causal structure of events.

Piaget believed that young children came to understand causal relationships through active exploration of their environment (1930). Recent research suggests that very young children know much more about the causal structure of the world than Piaget believed (Baillargeon, Kotovsky, & Needham, 1995; Flavell, Green, & Flavell, 1995; Gelman & Wellman, 1991; Kalish, 1996; Leslie & Keeble, 1987; Saxe, Tenenbaum, & Carey, 2005; Spelke, Breinlinger, Macomber, & Jacobson, 1992). However, the idea at the heart of the Piagetian account -- that children "construct" knowledge (and particularly causal knowledge) by active exploration -- remains widely accepted.

Yet despite substantial agreement that children learn through play (e.g., Bruner, Jolly, & Sylva, 1976; Singer, Golinkoff, & Hirsh-Pasek, 2006), little is known about how exploratory play might support accurate causal inferences. Descriptive studies of play are more common than experimental research or theoretical accounts, and much of the seminal work on exploratory play predates recent research on children's causal reasoning (Berlyne, 1954; Piaget, 1951). Except for the well-established finding that children (and many non-human animals) selectively explore novel stimuli (Berlyne, 1960; Dember & Earl, 1957; Henderson & Moore, 1980; Hutt & Bhaynani, 1972; Pavlov, 1927), there is little evidence for systematic patterns in children's exploratory behavior. Moreover, considerable research suggests that even older children and naïve adults are poor at designing causally informative experiments and have difficulty anticipating the type of evidence that would support or undermine causal hypotheses (Chen & Klahr, 1999; Inhelder & Piaget, 1958; Kuhn, 1989; Kuhn, Amsel, & O'Laughlin, 1988; Koslowski, 1996; Masnick & Klahr, 2003). Such findings pose a challenge for the constructivist account. The number of events children might explore in principle is vastly greater than the number of events they can explore in practice. If children's exploratory play is largely unsystematic, how might they generate the type of evidence that could support efficient causal learning?

We hypothesized that children's exploratory play might be affected, not just by the novelty or perceptual complexity of stimuli, but also by the quality of the evidence they observe. Although young children do not design controlled experiments, in simple contexts they seem to recognize the difference between informative and uninformative evidence (Masnick & Klahr, 2003; Sodian, Zaitchik, & Carey, 1991) and they can use patterns of evidence to make predictions, interventions, and even counterfactual claims (Gopnik & Schulz, 2004, in press; Gopnik, Sobel, Schulz, & Glymour, 2001; Kushnir & Gopnik, 2006; in press; Schulz & Gopnik, 2004; in press; Shultz & Mendelson, 1975; Siegler & Liebert, 1975; Sobel, 2004; Sobel & Kirkham, in press). We predicted that preschoolers would distinguish confounded and unconfounded evidence and would engage in more exploratory play when evidence failed to disambiguate the causal structure of events. If children systematically engage in more exploratory play when causal evidence is confounded, then even if even if children do not generate controlled experiments, they might isolate the relevant variables in the course of free play and generate the type of evidence that could support accurate causal learning.

Experiment

In this study, we introduced children to a toy and showed them either confounded or unconfounded evidence about the causal structure of the toy. We removed the toy and then returned it along with a novel toy. We allowed the children to play freely for sixty seconds. We predicted that children who observed confounded evidence would preferentially play with the familiar toy but that children who observed unconfounded evidence would show the standard novelty preference and play primarily with the novel toy.

Method

Participants

We recruited 64 preschoolers (mean age: 57 months; range: 48 – 70 months) from the Discovery Center of a metropolitan Science Museum and from urban area preschools. Sixteen children were tested in each of four conditions: a Confounded evidence condition and three Unconfounded conditions, described below. Approximately equal number of boys and girls participated in each condition (45% girls overall). While most of the children were white and middle class, a range of ethnicities and socioeconomic backgrounds reflecting the diversity of the local population were represented.

Materials

Two boxes were constructed from 15 cm x 15 cm balsa boards. One box had a single lever and was covered in yellow felt. The other box had two levers and was covered in red felt. On the yellow box a small (5 cm high) fuzzy, duck toy was attached to a dowel 20 cm in length and 1 cm in diameter that passed through a small hole in the side of the box. The dowel acted as a lever. When the dowel was depressed on the outside of the box, the inside end moved upwards, causing the duck to pop up through a slit in the felt on the top of the box. The construction of the double-lever box was identical, except there was a second lever on the side of the box adjacent to the first lever. On this second lever a small L-shaped bracket was attached to a (7 cm high) puppet made of drinking straws, so that when the second lever was depressed the straw puppet could 'pop-up' without affecting the movement of the first lever. The ends of the two levers were less than 40 cm apart and were easily manipulated, both separately and simultaneously, by preschool children.

Procedure

Children were tested individually in a quiet corner of their preschools or in the Discovery Center. The experimenter sat next to the child at a table. Both boxes were on a far corner of the table and were covered with a cloth so the child could not see them. The experimenter said, "We're going to play a game today." The experimenter brought the red, two-lever box out from under the cloth and introduced it to the child.

In the Confounded condition, the experimenter said, "You push down your lever and I'll push down my lever at the same time. Ready: one, two, three, down!" When both levers were depressed, a duck and a straw puppet popped out of the middle of the box. The spatial locations of the duck and the puppet were uninformative about their causal relationships with the lever; that is, the objects appeared in the middle of the box so it was not possible, just by looking, to determine which lever controlled which objects. After approximately two seconds, the experimenter said, "One, two, three, up!" The experimenter and the child simultaneously released the levers and the duck and puppet disappeared from view. Counting aloud was an effective means of coordinating the child's actions with the experimenter's so that the onset and offset of events appeared simultaneous; pilot work established that even adult observers failed to perceive temporal cues that would disambiguate the causal structure of the toy. The procedure was then repeated twice more, so that in total, both levers were pushed three times and both effects (the duck and the puppet) occurred three times. Because the two candidate causes were always manipulated simultaneously, the evidence failed to disambiguate the many possible causal structures that might underlie the event (either lever might activate the duck or the puppet, one or both levers might activate both, or the levers might interact).

The Unconfounded/Matched for Effect condition was designed to replicate the effects of the Confounded condition but with an unambiguous causal structure. The Unconfounded/Matched for Effect condition was identical to the Confounded condition except that the child and the experimenter pressed and released their levers simultaneously only twice. On the next trial, the experimenter said, "Let's take turns." (The order of turn-taking and the particular effect was counterbalanced between participants.) "You go ahead, one, two, three, your turn!" The child pushed his lever and just the duck popped up. The experimenter then said, "Now it's my turn." After the child released his lever, the experimenter counted “One, two, three”, pushed her lever, and just the puppet popped up. Thus, as in the Confounded condition, each effect (the duck and the puppet) occurred three times, however, this evidence fully disambiguated the causal structure of the toy: the child could see that one lever activated the duck and the other activated the puppet.

Conceivably however, the exposure to the additional trial (as indicated by the “one, two, three” counting ritual) might decrease children’s interest in the familiar toy. The Unconfounded/Matched for Trials was designed to control for the possibility that the additional trial bored the children. The condition was identical to the Unconfounded/Matched for Effect condition except that in this condition, the child and the experimenter pressed and released their levers simultaneously only once. On the second trial, the child pressed his lever by himself; on the third trial, the experimenter pressed her lever by herself. Thus each effect occurred twice, however, as in the Confounded condition, there were three distinct trials. Again, the evidence fully disambiguated the causal structure of the toy.

Alternatively, children might play more with the familiar toy in the Confounded condition than the Unconfounded conditions because they were allowed to play independently with the toy in the Unconfounded conditions but not in the Confounded condition. To control for this possibility, children were tested in an Unconfounded/No Independent Play condition[1]. In this condition, the experimenter and the child pressed and released their levers simultaneously once. Then the experimenter pushed one lever and just the duck popped up. She released that lever and pushed the other lever and just the puppet popped up. The experimenter and the child then pressed and released their levers simultaneously a second time. As in the Confounded condition, the child never had a chance to manipulate the toy without the experimenter, however, this evidence fully disambiguated the causal structure of the toy. There was no significant difference in the length of time children were exposed to the effects of the familiar toy in the Confounded condition and any of the Unconfounded conditions (Confounded: mean = 12.1 seconds; Unconfounded/Matched for Effects: mean = 13.5 seconds; Unconfounded/Matched for Trials: mean = 11.6 seconds; Unconfounded/No Independent Play: mean = 13 seconds; for each comparison $t(30)$, $p = ns$).

After the child observed the evidence, the experimenter returned the red box to the far end of the table and uncovered the novel yellow box. The experimenter then rotated the table so that the boxes were just out of arms' reach of the child (so the child had to stretch to reach either box). The boxes were located approximately two feet apart from each other (left/right position of the boxes counterbalanced between children). The experimenter said, "I'll be back in just a minute. Go ahead and play" and walked out of the child's line of sight. After 60 seconds, the experimenter returned, thanked the child for participating and ended the experiment.

Results and Discussion

Children were counted as playing with a box as long as they were touching the box and we coded the total amount of time that each child played with each box. We analyzed children's exploratory play in three ways: we looked at whether, on average, children played longer with the familiar box or the novel box; we looked at how many individual children preferentially played with each box, and we looked at whether children's first reach was to the familiar box or the novel box. Additionally, we coded children's actions in the Confounded condition to see whether children who played with the familiar toy spontaneously disambiguated the evidence. Children were counted as fully disambiguating the evidence if, in the course of their free exploratory play, they depressed and released each lever separately at least once. If children only isolated one of the two levers, if they only ever moved both levers together, or if they engaged only in unrelated exploratory play (e.g., reaching in the box; shaking the box), they were counted as failing to fully disambiguate the evidence.

All data were coded by the second author and recoded by a blind coder.[2] Inter-coder agreement on children's play time was high across all conditions (r = .949); coders agreed perfectly on children's first reach and whether or not children fully disambiguated the evidence (% agreement = 100). If children played for less than 15 seconds overall, they were dropped from the study and replaced. One child was replaced in the Confounding condition; no children were replaced in any other condition.

By all three measures, children were more likely to explore the familiar toy in the Confounded condition than in the Unconfounded conditions; there were no differences between the three Unconfounded conditions on any analysis (see Figure 1). We compared how long children played with each toy in each condition by doing a 2 x 4 mixed ANOVA with play time on each toy as the within-subjects variable and condition as the between-subjects variable. There was an interaction between condition and toy preference, $F(3, 60) = 11.64$, $p < .0001$. There was also a main effect of toy type, F(3, 60)

= 6.53, $p < .05$ suggesting that, collapsing across the four conditions, children preferred the novel toy. There was no main effect of condition, suggesting that children in each group played for the same amount of time overall (mean playtime across conditions was 27.6 seconds per toy).

To follow-up on the omnibus ANOVA, we did pairwise analyses of the four conditions. Each analysis was a 2 x 2 mixed ANOVA with play time on each toy as the within-subjects variable and condition as the between-subjects variable. Comparisons between the Confounded condition and each Unconfounded condition revealed no main effect of play time (averaging across the two conditions, children did not prefer one toy to the other) and no main effect of condition (overall, children played for the same amount of time in each condition), but did reveal a significant interaction: children spent more time playing with the familiar toy in the Confounded condition than in the Matched for Effects condition ($F(1, 32) = 17.32$, $p < .001$), the Matched for Trials condition ($F(1, 32) = 13.86$, $p < .001$), and the No Independent Play condition ($F(1, 32) = 10.83$, $p < .01$).

Additionally, more children spent the majority of their time playing with the familiar toy in the Confounded condition than in the Matched for Effects condition (χ^2 (1, $N = 32$) = 8.13, $p < .01$), the Matched for Trials condition (χ^2 (1, $N = 32$) = 6.15, $p < .025$), and the No Independent Play condition (χ^2 (1, $N = 32$) = 4.5, $p < .05$). Finally, children were more likely to reach first for the familiar toy in the Confounded condition than in the Matched for Effects condition (χ^2 (1, $N = 32$) = 5.24, $p < .025$) and there was a similar trend for children in the Matched for Trials condition (χ^2 (1, $N = 32$) = 3.46, $p = .06$) and the No Independent Play condition (χ^2 (1, $N = 32$) = 3.46, $p = .06$).

Within the Confounded condition, children played significantly longer with the familiar toy than the novel toy ($t(15) = 2.79$, $p < .01$). These results reversed for children in the Matched for Effects ($t(15) = 3.1$, $p < .01$) and Matched for Trials conditions ($t(15) = 2.48$, $p = .01$). Children played equally long with both toys in the No Independent Play condition ($t(15) = 1.06$, $p = ns$). In the Confounded condition, a non-significant majority of children played most with the familiar toy ($p = ns$ by binomial test; one-tailed throughout) but more children played most with the novel toy in the Matched for Effects ($p = .01$ by binomial test) and Matched for Trials conditions ($p < .05$ by binomial test) and were marginally more likely to play with the novel toy in the No Independent Play condition ($p = .07$ by binomial test). Finally, in the Confounded condition, children's first reach was just as likely to be for the familiar toy as the novel toy ($p = ns$ by binomial test), whereas children were significantly more likely to reach first for the novel toy than the familiar toy in all Unconfounded conditions (Matched for Effects: $p < .01$ by binomial test; Matched for Trials: $p = .01$ by binomial test; No Independent Play: $p < .01$ by binomial test).

It is possible that the children were simply more interested in the simultaneous effects than the separate effects. However, if children were more interested in the three simultaneous effects of the Confounded condition than, for instance, the two simultaneous effects of the Unconfounded/Matched for Effects and No Independent Play conditions, one might also expect children to play more with the familiar toy in those conditions than in the Unconfounded/Matched for Trials condition where the effects occurred simultaneously only once. In fact, there were no significant differences among the Unconfounded conditions. This suggests that it is the absence of disambiguating evidence rather than the presence of simultaneous effects that encourages children's exploration.

We also looked at the actions children performed on the familiar box in the Confounded condition. In the course of their free play with the familiar box, children often manipulated the levers simultaneously. Critically however, 12 of the 16 children (75%) also manipulated each lever separately, fully disambiguating the evidence.[3] This suggests that children's free exploratory play could, in principle, generate the type of evidence that would support accurate causal learning.

General Discussion

Our findings suggest that preschoolers' spontaneous exploratory play is sensitive, not just to stimulus features such as novelty and perceptual salience, but also to formal properties of evidence, like confounding. Note that in all four conditions, children were familiarized with the same toy and children's exposure to the toy's effects and affordances was closely matched across conditions. A single manipulation seemed to drive the effect: if the two levers were moved separately, on just a single trial, the children spent most of their free time playing with the novel toy; if the two levers were always moved simultaneously, children spent most of their free time playing with the familiar toy. Children appear to recognize confounded evidence and are motivated to explore stimuli whose causal structure is ambiguous.

In this study we relied on an implicit measure of children's understanding of confounding – spontaneous exploratory play. Because previous research suggests that children have a poor metacognitive understanding of confounding and experimental design (Chen & Klahr, 1999; Inhelder & Piaget, 1958; Kuhn, 1989; Kuhn, et al., 1988; Koslowski, 1996; Masnick & Klahr, 2003), we expected that children might not be aware of their own motivation for exploration. However, it is possible that at least some of the children might have been able to say that they were more curious about one toy than another or articulate why they wanted to play with one toy more than another. Further research might investigate the extent to which preschoolers' explicitly recognize confounded evidence. Additionally, the majority of children in this study were visitors to a science museum, an environment particularly likely to encourage exploratory play. Future research might look at the extent to which these findings generalize to other settings and populations.

Do children actually learn causal relationships from the evidence of their own interventions? Our experiment does not address this directly, although in simple cases (i.e., when each lever either does or does not cause an effect) it seems probable that children would. However, we do not want to suggest that in all cases children's free exploratory play reliably leads to accurate causal learning. There is every reason to believe that in many contexts children's spontaneous exploratory play might not suffice for correct causal inferences. Children might be inaccurate for many reasons: because they are unable to disambiguate the relevant variables, because they fail to disambiguate the relevant variables, or because they fail to attend sufficiently to the evidence they generate in exploratory play. Nonetheless, children's tendency to selectively explore confounded events could be advantageous for causal learning; whether or not children learn from their explorations in any particular instance, overall, they would be more likely to explore where there is something to be learned.

Importantly however, recent research suggests that children do indeed learn from exploratory play in some contexts. Preschoolers for instance, were able to use disambiguating evidence generated by their spontaneous play with a gear toy to distinguish causal chain and common cause structures (Schulz and Gopnik, in press). Such findings are consistent with the possibility that children's selective exploration of confounded evidence might support causal learning. Future research might investigate the generality of this hypothesis by A) looking at the range of contexts and ages in which children are sensitive to and selectively explore confounded evidence (e.g., whether such findings hold for toddlers and infants); B) looking at the extent to which children's free exploratory play generates informative evidence, and C) looking at the extent to which children learn from the evidence of their own interventions.

Children's exploratory play is a complex, dynamic phenomenon, indubitably affected by many factors (e.g., the child's temperament, the child's comfort and energy level, and the perceived cost or benefit of various actions in terms of effort expended, knowledge gained, and external reinforcement). However, these results suggest that children's normative understanding of evidence and their curiosity about the causal structure underlying observed evidence play a significant role in their decision to explore. At least in simple cases, preschool children distinguish confounded and unconfounded evidence and selectively engage in more exploration when the causal structure of events is ambiguous. The exploratory play of even very young children appears to reflect some of the logic of scientific inquiry.

References

Baillargeon, R., Kotovsky, L., & Needham, A. (1995). The acquisition of physical knowledge in infancy. In D. P. D. Sperber (Ed.), *Causal cognition: A multidisciplinary debate. Symposia of the Fyssen Foundation; Fyssen Symposium, 6th Jan 1993, Pavillon Henri IV, St-Germain-en-Laye, France*. New York, NY: Clarendon Press/Oxford University Press.

Berlyne, D. E. (1954). An experimental study of human curiosity. *British Journal of Psychology, 45*(4), 256-265.

Berlyne, D. E. (1960). *Conflict, Arousal and Curiosity*. New York: McGraw Hill.

Bruner, J., Jolly, A., & Sylva, K. (1976). *Play-Its Role in Development and Evolution.* New York: Basic Books, Inc.

Chen, Z. & Klahr, D. (1999). All other things being equal: Acquisition and transfer of the control of variables strategy. *Child Development, 70*(5), 1098-1120.

Dember, W. N. & Earl, R.W. (1957). Analysis of exploratory, manipulatory, and curiosity behaviors. *Psychological Review, 64*(2), 91-96.

Flavell, J. H., Green, F. L., & Flavell, E. R. (1995). Young children's knowledge about thinking. *Monographs of the Society for Research in Child Development,* Serial 24, *60*(1).

Gelman, S. A. & Wellman, H. M. (1991). Insides and essence: Early understandings of the non-obvious. *Cognition 38*(3), 213-244.

Gopnik, A. & Schulz, L. E. (in press). *Causal learning: Psychology, Philosophy, and Computation.* New York: Oxford University Press.

Gopnik, A. & Schulz, L. E. (2004). Mechanisms of theory-formation in young children. *Trends in Cognitive Science, 8*(8), 371-377.

Gopnik, A., Sobel, D. M., Schulz, L. E., & Glymour, C. (2001). Causal learning mechanisms in very young children: Two-, three-, and four-year-olds infer causal relations from patters of variation and covariation. *Developmental Psychology, 37*(5), 620-629.

Henderson, B. & Moore, S.G. (1980). *Children's Responses to Objects Differing in Novelty in Relation to Level of Curiosity and Adult Behavior.* New York: Dover.

Hume, D. (2000). *A Treatise on Human Nature*. New York: Oxford University Press.

Hutt, C. & Bhavnani, R. (1972). Predictions from play. *Nature, 237*(5351), 171-172.

Inhelder, B. & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence.* New York: Basic Books.

Kalish, C. (1996). Causes and symptoms in preschoolers' conceptions of illness. *Child Development, 67*(4), 1647-1670.

Koslowski, B. (1996). *Theory and Evidence: The Development of Scientific Reasoning*. Cambridge, MA: MIT Press.

Kuhn, D. (1989). Children and adults as intuitive scientists. *Psychological Review, 96*(4), 674-689.

Kuhn, D., Amsel, E., & O'Laughlin, M. (1988). *The development of scientific thinking skills.* Orlando, FL: Academic Press.

Kushnir & Gopnik (in press). Conditional probability versus spatial contiguity in causal learning: Preschoolers use new contingency evidence to overcome prior spatial assumptions. *Developmental Psychology.*

Kushnir & Gopnik (2005). Children infer causal strength from probabilities and interventions. *Psychological Science, 16*(9), 678-683.

Leslie, A. M., & Keeble, S. (1987). Do six-month-old infants perceive causality? . *Cognition, 25*(3), 265-288.

Masnick, A. M. & Klahr, D. (2003). Error Matters: An initial exploration of elementary school children's understanding of experimental error. *Journal of Cognition and Development, 4*(1), 67-98.

Pavlov, I. P. (1927). *Conditioned Reflexes: An Investigation of the Physiological Activy of the Cerebral Cortex*. New York: Dover.

Piaget, J. (1930). *The child's conception of physical causality*. New York: Harcourt, Brace & Company.

Piaget, J. (1951). *Plays, Dreams, and Imitation in Childhood*. London: Routledge and Kegan Paul Ltd.

Saxe, R., Tenenbaum, J.B., & Carey, S. (2005). 10 and 12-month-old infants' capacity for causal attribution. *Psychological Science, 16*, 995-1001.

Schulz, L. E. & Gopnik, A. (in press). Preschoolers learn causal structure from conditional interventions. *Developmental Science*.

Schulz, L. E. & Gopnik, A. (2004). Causal learning across domains. *Developmental Psychology, 40*(2), 162-176.

Shultz, T. R. & Mendelson, R. (1975). The use of covariation as a principle of causal analysis. *Child Development, 46*, 394-399.

Singer, D. G. , Golinkoff, M. R., & Hirsh-Pasek, K. (2006). *Play = Learning: How play motivates and enhances children's cognitive and social-emotional growth.* New York: Oxford University Press.

Siegler, R. S. & Liebert, R.M. (1975). Acquisition of formal scientific reasoning by 10 and 13-year-olds: Designing a factorial experiment. *Developmental Psychology, 11*, 401-412.

Sobel, D. M. (2004). Exploring the coherence of young children's explanatory abilities: Evidence from generating counterfactuals. *British Journal of Developmental Psychology, 22*, 37-58.

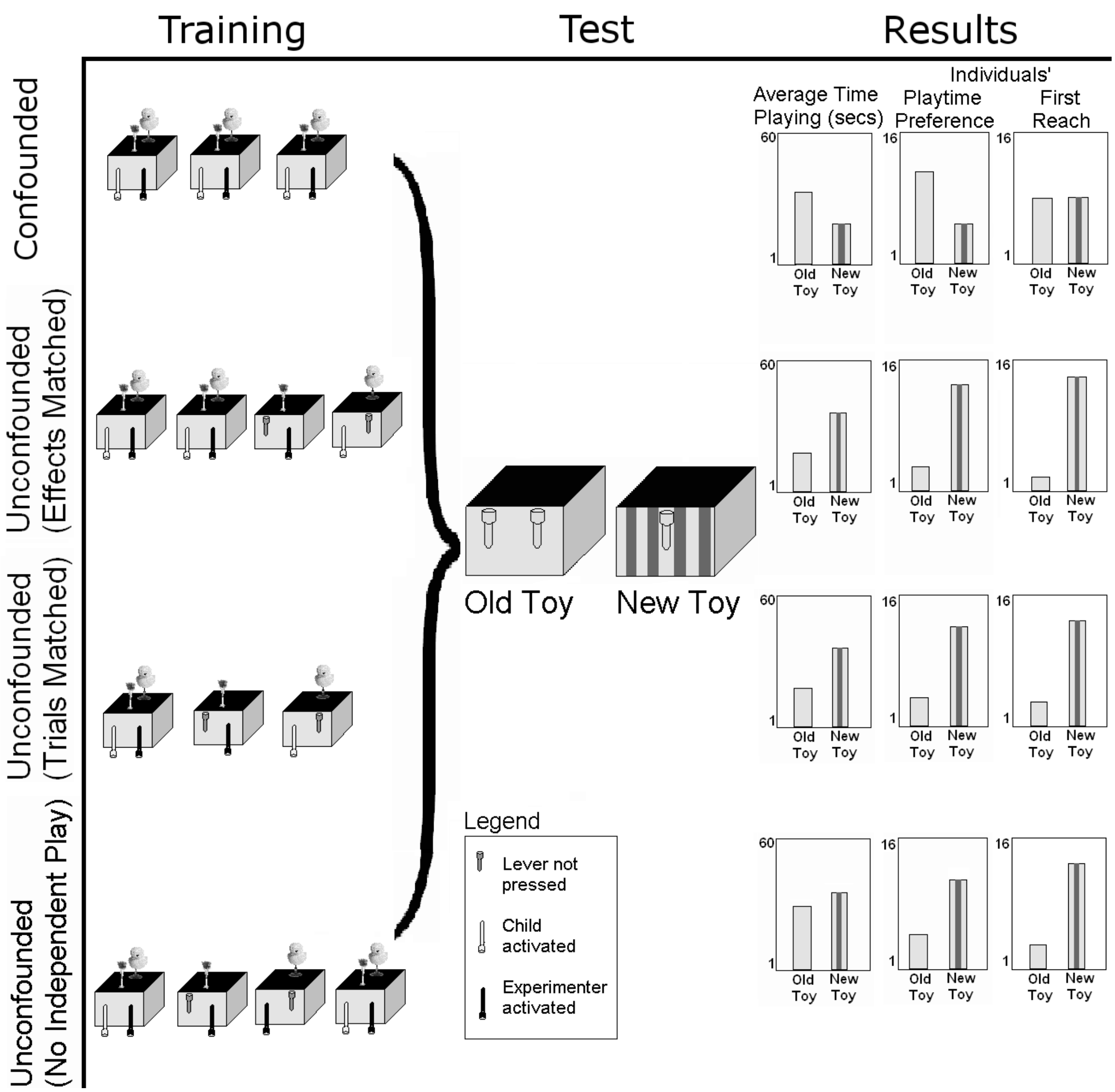
Sobel, D. M. & Kirkham, N. Z. (in press). Blickets and babies: The development of causal reasoning in toddlers and infants. *Developmental Psychology.*

Sodian, B., Zaitchik, D., & Carey, S. (1991). Young children's differentiation of hypothetical beliefs from evidence. *Child Development, 62*, 753-766.

Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of Knowledge. *Psychological Review, 99*(4), 605-632.

Figure Captions

Figure 1. Experimental design and results


Training
Test
Results
Confounded
Unconfounded (Effects Matched)
Unconfounded (Trials Matched)
Unconfounded (No Independent Play)
Average Time Playing (secs)
Individuals' Playtime Preference
Individuals' First Reach
60
16
1
Old Toy
New Toy
Legend
Lever not pressed
Child activated
Experimenter activated

Footnote

[1] We are indebted to an anonymous reviewer for suggesting this control condition.

[2] The clips for two children in the Unconfounded/No Independent Play condition were lost due to technical error after the original coding. These two children were not recoded.

[3] We subsequently coded children's actions on the familiar box in the Unconfounded conditions. In the Matched for Effects condition, 31% of the children manipulated each lever separately; in both the Matched for Trials and No Independent Play conditions, 50% of the children manipulated each lever separately (this percentage does not include the two children in the No Independent Play condition whose clips were lost, see footnote 2). Of course, the children played longer with the familiar box in the Confounded condition. However, it is interesting that the children were, if anything, more likely to manipulate the levers separately in the Confounded condition than in the Unconfounded conditions, where they had actually observed the separate manipulations.