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Young children infer causal strength from probabilities and interventions.

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Young children infer causal strength from probabilities and interventions

We examine the interaction of two cues that children use to make judgments about cause-effect relations: probabilities and interventions. Children were shown a "detector" that lit up and played music when blocks were placed on its surface. We varied the probabilistic effectiveness of the block as well as whether the experimenter or the child was performing the interventions. In Experiment 1, we found that children can use probabilistic evidence to make inferences about causal strength. However, when the results of their own interventions are in conflict with the overall frequencies, preschooler's favor the results of their own interventions. In Experiment 2, children used probabilistic evidence to infer a hidden causal mechanism. Though they again gave preference to their own interventions, they did not do so when their interventions were explicitly confounded by an alternative cause.

Young children infer causal strength from probabilities and interventions

By five, children have learned a great deal about the causal structure of the world (Bullock, Gelman, & Baillargeon, 1982; Gopnik & Wellman, 1994; Shultz 1982). How is this learning possible? We explore the interaction of two cues that children might use to infer causal strength: the probabilistic relationships among events and the consequences of interventions.

Adults can use probability information to assess the strength of causal relations – they conclude that if X follows Y more often than X follows Z then, other things equal, Y is a stronger cause of X than Z. (Cheng, 1997; Shanks & Dickinson, 1987; Spellman, 1996; Waldmann & Hagmayer, 2001). However, adults have extensive experience and often explicit tuition in causal inference. If young children have similar causal learning abilities naturally they might play a role in children's acquisition of causal knowledge.

However, studies of children's causal reasoning have focused on deterministic rather than probabilistic causal relations (for example, Bullock, et al, 1982; Gopnik & Sobel, 2000; Gopnik, Sobel, Schulz & Glymour, 2001; Shultz & Mendelson, 1975, Shultz 1982). In a few studies (Gopnik et al, 2004; Siegler, 1976) children also inferred causal relations even when effects did not always follow causes. However, all these studies asked about causal structure (Did X cause Y?) rather than causal strength (How strongly did X cause Y?).

Interventions also play an important role in causal reasoning. They help solve one of the main problems of causal inference – the problem of confounding. When someone intervenes themselves on a cause to bring about an effect they can usually assume that the subsequent events were the result of their action, and not of other causes.

When they observe the interventions of others this assumption is less justified. It is even less justified when they simply observe that events co-vary. This commonly known fact of scientific reasoning has been formalized as part of causal Bayes-net theory (Gopnik et al, 2004; Pearl, 2000; Spirtes et al, 2001, Woodward, 2004). Adults do better on causal inference tasks when they are allowed to intervene on causes (Lagnado & Sloman, 2004; Sobel & Kushnir, 2003; Steyvers, Tenenbaum, Wagenmakers, & Blum, 2003)

Preschool children can also use intervention information to make complex inferences about causal structure (Schulz & Gopnik, 2001, Gopnik et al. 2004). However, these studies involved deterministic relations and did not ask about causal strength, and children observed the interventions of others rather than performing their own interventions.

This study addresses the following questions: Do children equate frequency of co-occurrence with causal strength? What is the role of children's own interventions in making judgments of causal strength? How do frequency information and intervention information interact? Might children implicitly recognize that their own interventions help resolve problems of confounding?

Experiment 1

We presented children with a novel causal relation between objects and a "detector" –a toy that lights up and plays music when objects are placed on it. Objects could be set to activate the toy 1, 2 or 3 out of 3 times. We also varied intervention information – sometimes the children observed the experimenter's action and sometimes the children intervened themselves.

Method

Participants

Participants in the study were 19 four-year-olds (Mean = 4;2, range 3;10 to 4;9) recruited from University of California, Berkeley preschools. One additional participant was removed for not completing the procedure.

Materials

The “ detector” was a 5”x7”x3” box made of wood with a Lucite top. A hidden switch, controlled by the experimenter, could make the box top light up and play music. The experimenter slid the switch only when an object was placed on detector, creating the illusion that the object caused the lights and music. Objects were 22 blocks, each a different color and shape.

Procedure

The experimenter introduced the detector and told the child “sometimes things make it go and sometimes things don’t make it go” and that they were going to “figure out what makes it go.”

The sequence of events in each of the ten test trials is shown in figure 1. To familiarize children with the procedure, each child was first given a deterministic warm-up trial. After the warm-up, the 10 test trials were presented in counterbalanced order, with intervention and observation trials alternating.

On each trial, two novel blocks (A and B) were placed on either side of the detector. Each trial began with the experimenter placing Block A on the detector twice and Block B on the detector twice. The detector activated sometimes but not always. In the ***intervention trials*** the child was then instructed to try each object once, the detector activated on the first or second attempt or on both attempts. The matched ***observation trials*** were identical to the intervention trials but the experimenter, rather than the child, placed each object on the detector once more.[1] Starting side and order of successful activation were randomized. However, each intervention trial was matched by an identical observation trial.

Insert Figure 1 here

There were two types of trials: 3/3 trials and 2/3 trials. The 3/3 trials included one object (Block A) that set off the detector 3 out of 3 times and one (Block B) that set off the detector 1 out of 3 times. There were four 3/3 trials two intervention trials and two matched observation trials.

The 2/3 trials included one object (Block A) that set off the detector 2 out of 3 times and one (Block B) that set off the detector 1 out of 3 times. The 2/3 intervention trials could be set up to include a potential conflict between the child's intervention and the overall probabilities. When it was the child's turn to intervene, Block A only (*non-conflicting intervention*), both blocks (*ambiguous intervention*), or Block B only (*conflicting intervention*) activated the detector. In the matched observation trials the child saw the same sequences of events but was not allowed to intervene. There were six 2/3 trials overall, one observation trial and one matched intervention trial of each type.

Test question: After each trial, the child was asked to "pick the best one and make it go." In response to this the child was allowed to make one final intervention (which activated the detector). The child's choice was recorded as either 1 (high-frequency: Block A) or 0 (low-frequency: Block B).

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[1] Children had difficulty paying attention to the experimenter's turn when they were allowed to intervene first. For this reason the intervention part of the trial always occurred last.

Results & Discussion

There were no differences in responding among the four types of 3/3 trials (Cochran's Q(3)= 4.8, $p>.05$). Across the four 3/3 trials, children chose Block A, the high-frequency block, significantly more often than chance by a one-sample t-test with 50% (2 out of 4) as the comparison value (Mean = 68%; SE = 6.9%; $t(18)=2.69$, $p<.05$).

There were, however, differences among the six types of 2/3 trials (Cochran's Q(5)= 32.6, $p<.001$), therefore we analyzed the data for each type of trial separately. Children chose Block A significantly more often than chance in the first two 2/3 observation trials (observation 3, 84%; observation 4, 95%; binomial tests, $p<.01$). They responded above chance in observation 5 (63%) but not significantly so. The results of the 3/3 trials and the 2/3 observation trials suggest that children can use frequency as a measure of probabilistic causal strength.

Differences emerge when children are allowed to make their own interventions, in particular when the intervention information conflicts with frequency information. In the non-conflict intervention trial, children chose Block A significantly more often than chance (95%; binomial test, $p<.01$). There were also no differences between this trial and the matched observation trial (McNemar's test, ns). However, in the ambiguous intervention trial, children chose Block A at slightly above chance but not significantly so (63%; binomial test, ns). This was significantly different than their choice in the matched observation trial (McNemar's test, $p<.05$). In the conflicting intervention trial, children picked Block A significantly less often than chance (21% of the time, binomial test, $p<.05$). This was also significantly different from their response to the matched observation trial (McNemar's test, $p<.001$). Children seemed to weigh effects of their own intervention more heavily than the effects of others' interventions.

Experiment 2

Experiment 1 suggests that children are able to use probabilistic data to judge causal strength, but override these judgments when they conflict with the outcome of the children's interventions. There are three possible explanations for this finding. Children may weigh their own interventions more heavily because they think they are less likely to be confounded than the interventions of others. In fact, when the experimenter failed to make the detector activate, the children often spontaneously suggested explanations such as "you're not pushing hard enough" or "you put it on the wrong side of the toy." When the children were allowed to intervene, they could push as hard as they wanted or put the object wherever they wanted. Thus they could convince themselves that the intervention was free of confounding causes.

However, there are two less interesting explanations for this result. First, it could be an artifact of our test question, which required children to perform another intervention. They could simply respond by repeating their previous successful intervention, ignoring the other trials. Second, children's own actions may be more salient than the actions of others.

In Experiment 2 we controlled for these possibilities in two ways. To rule out the first explanation, we changed the dependent measure so that children did not activate the detector itself. Instead, they had to make an explicit judgment about the underlying causal mechanism of the detector. To rule out the second, we included a trial in which the action and outcome were just the same as in the conflict trial but the child was given evidence that their own intervention on Block B was confounded. If the responses in Experiment 1 were the effect of the salience of their own actions, then children should again respond by picking Block B. On the other hand, if they prefer their own interventions because they believe they are not confounded, they should pick Block A. We also included a group of six-year-old children to explore developmental differences.

Method

Participants

Participants in the study were 18 four-year-olds (Mean age = 4;6, range 3;11 to 5;3) and 18 six-year-olds (Mean age =6;2 months, range = 5;7 to 6;10). Four-year-olds were recruited from a preschool in Portland, Oregon, and six-year-olds were recruited from a kindergarten in Lafayette, California. Three additional subjects were tested and excluded from the analysis due to procedural errors.

Materials

The detector and blocks were the same as in Experiment 1. There was also an additional switch that could be plugged in to the detector.

Procedure

The experimenter introduced the detector in a similar manner to Experiment 1, adding: "Things that make it go have special stuff inside. The special stuff makes it go." Before brining out blocks, the experimenter brought out the additional switch and plugged it in to the detector. She told the child, "The switch makes the toy go when you flip it" and allowed the child to intervene on the switch and watch it activate the detector. She then unplugged the switch and set it aside.

Children were first given a warm-up with one deterministic trial and one 3/3 trial. They then saw a sequence of four 2/3 trials (counterbalanced): Non-conflicting intervention, matched observation, conflicting intervention and matched observation, precisely as in Experiment 1. The procedure is summarized in figure 2.

Insert Figure 2 about here

Test question: After each trial the child was asked which object had "more special stuff inside." The child's choice was coded 1 (Block A) or 0 (Block B).

Confounded intervention: After the four 2/3 trials, the experimenter brought out the switch and plugged it in. She then placed two blocks on the table and proceeded with exactly the same sequence of events as in the conflicting intervention condition. The only difference was that, during the child's intervention, the experimenter flipped the switch at the exact time the child placed Block B on the detector. The experimenter then asked the child the same test question and recorded his/her choice.

Results & Discussion

Experiment 2 replicated the strength judgments of Experiment 1 with a different and more explicit measure of causal strength. There were also no significant differences between the four- and six-year-olds on any measures, so the rest of the analysis was conducted on the combined dataset. (A separate analysis of the four year olds also showed the same pattern of results as in the first study, though performance on all the observation trials was significantly above chance). A Cochran's Q test revealed significant differences among the trials (Cochran's $Q(4)= 58.93$, $p<.001$). Children said that Block A had "more stuff inside" in the observation trials significantly more often than chance (97% and 81%; binominal tests, $p<.001$). They also said this in the non-conflicting intervention trial (100%; binomial test, $p<.001$) .

However, in the conflicting intervention trial children chose Block A only 33% of the time, which was marginally below chance (binomial test, $p=.067$). It was also significantly different from their choice in the matched observation trial (McNemar's test, $p<.001$). This replicated the intervention effect in Experiment 1.

Crucially, the children did not show the intervention effect in the confounded intervention control. They chose the high-frequency object 69% of the time, significantly above chance (binomial test, $p<.05$) and significantly more often than in the conflicting intervention trial (McNemar tests, $p<.01$) .

The results of Experiment 2 parallel those of Experiment 1; in general children said that the object that was effective more often had more stuff inside, but they favored the results of their own intervention. However, when children had explicit knowledge that their interventions were confounded they did not show this preference.

General Discussion

The results of this study suggest that even young children make judgments of causal strength based on covariation. They use frequency of co-occurrence to decide on the best intervention and to infer the strength of a hidden causal mechanism.

Children's own interventions also affect their judgments. When frequency information conflicted with evidence from their own interventions, children gave more weight to the intervention information. This does not seem to be just an effect of action, since children used evidence from their own interventions to infer hidden mechanisms and they did not give preference to their own interventions when they were explicitly confounded.

These results suggest that children favor the results of their own interventions because they implicitly believe that they are less likely to be confounded than the interventions of others. In Experiment 2 when their own intervention was confounded by the experimenter's parallel intervention, they no longer favored their own action. More extensive studies would be needed to confirm this hypothesis, however.

The current results do, however, clearly demonstrate that young children can use probabilistic information to infer causal strength in much the way that adults do. Moreover, children seem to differentiate their own interventions from the interventions of others and to give special weight to their own interventions. They are also able to recognize when their own interventions are confounded and do not use information from confounded interventions to infer causal strength. These causal learning abilities may be responsible, at least in part, for young children's impressive causal knowledge.

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Figure Captions

Figure 1. Procedure of Experiment 1.

Figure 2. Procedure of Experiment 2.

Figure 1

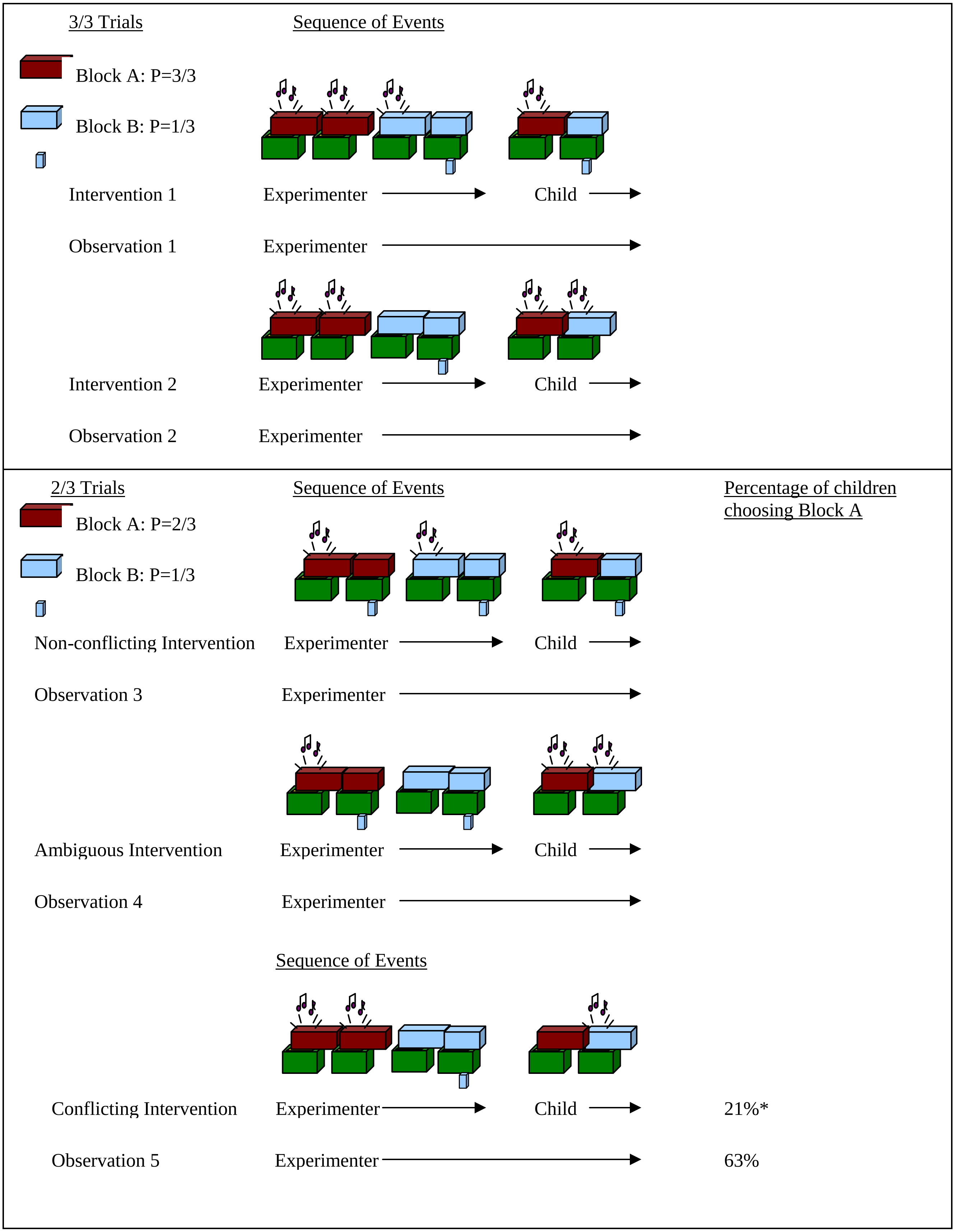
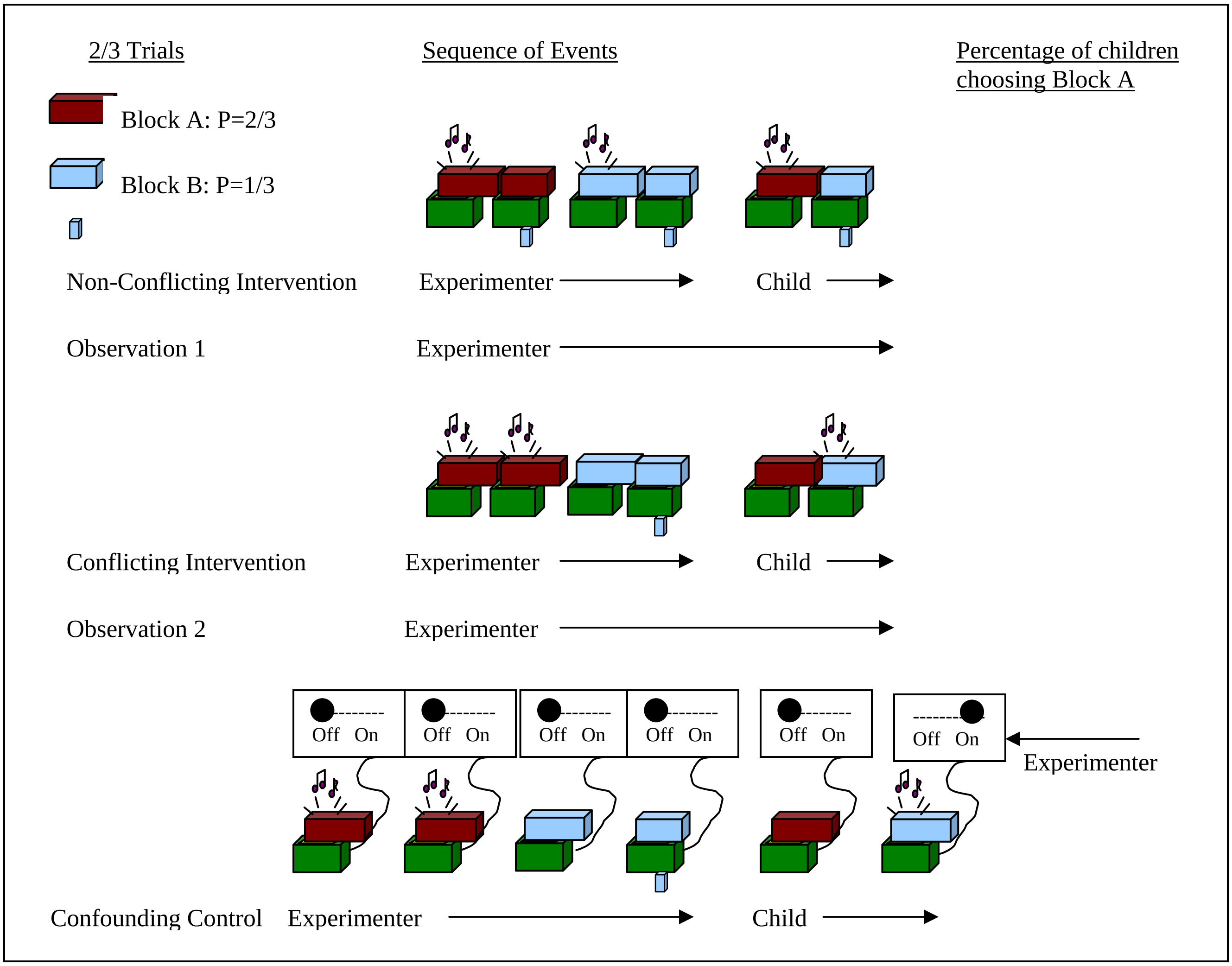

3/3 Trials
Sequence of Events
Block A: P=3/3
Block B: P=1/3
Intervention 1
Experimenter
Child
Observation 1
Experimenter
Intervention 2
Experimenter
Child
Observation 2
Experimenter
2/3 Trials
Sequence of Events
Percentage of children choosing Block A
Block A: P=2/3
Block B: P=1/3
Non-conflicting Intervention
Experimenter
Child
Observation 3
Experimenter
Ambiguous Intervention
Experimenter
Child
Observation 4
Experimenter
Sequence of Events
Conflicting Intervention
Experimenter
Child
21%*
Observation 5
Experimenter
63%

Figure 3


2/3 Trials
Sequence of Events
Percentage of children choosing Block A
Block A: P=2/3
Block B: P=1/3
Non-Conflicting Intervention
Experimenter
Child
Observation 1
Experimenter
Conflicting Intervention
Experimenter
Child
Observation 2
Experimenter
Off On
Off On
Off On
Off On
Off On
Off On
Experimenter
Confounding Control
Experimenter
Child