**Young children can overcome their weak inhibitory control, if they conceptualize a task in the right way**

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**Abstract**

This article investigates the process of task conceptualization, through which participants turn the instructions on a task into a mental representation of that task. We provide the first empirical evidence that this process of conceptualization can directly influence the inhibitory demands of a task. Data from Experiments 1 and 2 (both n=24) suggested that robust difficulties on inhibitory tasks can be overcome *if* preschoolers conceptualize the tasks in a way that avoids the need for inhibitory control. Experiment 3 (n=60) demonstrated that even when all other aspects of a task are identical, simply changing how the rules are introduced can influence whether such a conceptualization is adopted – thereby influencing children's performance on the task. An appreciation of the process of conceptualization is essential for our understanding of how inhibitory control and knowledge interact in early development.

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## Introduction

Inhibitory control is the cognitive process used to prevent the execution of behavior that is incompatible with current task goals (Chevalier *et al.*, 2012). Prepotent responses can be incompatible with task goals, because they are triggered without recourse to them (e.g., Isoda & Hikosaka, 2011; Norman & Shallice, 1986; Shiffrin & Schneider, 1977). Whether a task contains a goal-inappropriate prepotent response will depend, among other things, on the way that participants *conceptualize* the task. In other words, it will depend on the contents of the mental representation that participants construct in order to perform the task. The presence of a goal-inappropriate prepotent response will have a significant effect on the performance of young children in particular, because of their weak inhibitory control.

Vygotsky (1962) was the first to propose that the way children represent a task will determine their subsequent performance on it. Indeed, conceptual understanding more broadly may be seen as central to early cognitive development (e.g., Zelazo, Frye & Rapus, 1996; Kirkham, Cruess & Diamond, 2002). Specifically in relation to inhibitory task performance, several theorists have suggested that "task conceptualization" affects inhibitory demands (e.g., Apperly & Carroll, 2009; Kloo, Perner & Giritzer, 2010; Russell, 1996; Simpson & Riggs, 2005a). However, to our knowledge, there have been no attempts to put this idea to the test. The aim of this article, therefore, is to empirically investigate how this conceptualization process affects inhibitory demands.

We start with the assertion that prepotent responses are not the product of the *world*; they are the product of the *mind*. How an individual conceptualizes a task determines whether it contains a prepotent response. Consider, for example, the Day/Night task, which is one of the Stimulus-Response Compatibility tasks used to study inhibitory control in childhood. In this task, preschoolers are instructed to say "night" to a day picture, and "day" to a night picture (Gerstadt, Hong & Diamond, 1994; Simpson & Riggs, 2005b). The prepotent responses in this task are the more obvious responses of saying "day" to the day picture, and "night" to the night picture. In a limited sense, these prepotent responses are stimulus-driven, since it is the presentation of day and night stimuli that triggers them. However, outside the Day/Night task, the mere presence of these stimuli is not sufficient to make the responses of saying "day" and "night" prepotent. This is obvious: despite their weak inhibitory control, preschoolers do not struggle to resist saying "night" every time they look at the night sky. So there must be something particular about the way that children conceptualize the Day/Night task which means the responses "day" and "night" *become* prepotent in this task.

Once we accept that prepotent responses are the product of the mind, rather than the world, it necessarily follows that the way an individual conceptualizes a task will influence whether or not it contains a goal-inappropriate prepotent response, and therefore whether the task has inhibitory demands. Crucially, it is likely that some tasks will contain a goal-inappropriate prepotent response if conceptualized one way, and will thus require inhibitory control; but they will contain no such response if conceptualized another way, thus avoiding this requirement. We refer to these contrasting types of conceptualization as "IC-requiring" and "IC-avoiding". This distinction is important when studying early cognitive development, because preschoolers have particularly weak inhibitory control (e.g., Garon, Smith & Bryson, 2014; Wiebe, Sheffield & Espy, 2012; Willoughby, Wirth & Blair, 2011). Thus, whether preschoolers use an IC-requiring or IC-avoiding conceptualization is likely to have a dramatic effect on their performance.

While it has been suggested that the way a task is conceptualized is likely to influence its inhibitory demands (e.g., Apperly & Carroll, 2009; Kloo *et al.*, 2010; Russell, 1996; Simpson & Riggs, 2005a), to the best of our knowledge, there is no direct evidence to support this suggestion. Accordingly, in this study we sought the first empirical evidence for this phenomenon. Studying task conceptualization is challenging, because mental representations cannot be observed directly, but must instead be inferred from behavior. It is therefore essential that any tasks used are reliable and well-understood. The present study therefore used Stimulus-Response Compatibility tasks, for two reasons. First, we can be confident that these tasks *have* inhibitory demands. Unlike almost any other developmental measure of inhibitory control, there is clear evidence that Stimulus-Response Compatibility tasks are difficult specifically because of their inhibitory demands (Gerstadt *et al.*, 1994; Simpson & Riggs, 2005b, 2009; Simpson, Riggs & Ferrand, 2006). The important logical consequence of this, for the experiments reported here, is that if preschoolers perform well on any variant of an Stimulus-Response Compatibility task, then the inhibitory demands of that task must necessarily be low: preschoolers' weak inhibitory control means they could not succeed if inhibitory demands were high. Success on any Stimulus-Response Compatibility task would therefore be consistent with preschoolers having conceptualized it in an IC-avoiding way.

Second, we can be confident about *why* Stimulus-Response Compatibility tasks have inhibitory demands. The precise mechanism that creates inhibitory demands in these tasks has been extensively studied (Diamond, Kirkham & Amso, 2002; Hanauer & Brooks, 2005; Montgomery, Anderson & Uhl, 2008; Montgomery & Koeltzow, 2010; Simpson & Riggs, 2005a, 2007, 2011; Simpson *et al.*, 2012). When participants are told to make two specific responses in these tasks, these two responses become primed (that is, activated to near-threshold levels, such that they can be readily produced). Stimulus-Response Compatibility tasks' "if-A-then-b/if-B-then-a" rule structure means that the incorrect primed response is triggered on each trial. This incorrect response must then be inhibited, so that the goal-appropriate response can be made instead. It is this specific aspect of these tasks that creates their inhibitory demands.

To illustrate this with an example: in the Grass/Snow task, children must point to one of two picture cards in response to verbal cues. In one version of this task (Simpson & Riggs, 2009), participants are shown a picture of a sun and a picture of a moon. They are told that when the experimenter says "moon", they should *point to the sun card*, and when the experimenter says "sun", they should *point to the moon card.* The two responses – *point to sun* and *point to moon* – become primed. The if-A-then-b/if-B-then-a rules mean that when the "sun" cue is presented, the *point to sun* response is inappropriately triggered; and that when the "moon" cue is presented, the *point to moon* response is inappropriately triggered. These inappropriate responses must be inhibited, so that the task rules can be followed correctly. Thus, the inhibitory demands of the Grass/Snow task (and other Stimulus-Response Compatibility tasks) follow on directly from the need to apply these if-A-then-b/if-B-then-a rules.

The developmental literature suggests simply that preschoolers find Stimulus-Response Compatibility tasks difficult because they have weak inhibitory control. However, because of task conceptualization this might not be the whole story. The main hypothesis of the current study is that these tasks *can* be passed by preschoolers, *if* they are able to conceptualize the tasks in an IC-avoiding way. This would be achieved with any conceptualization that allowed children to make task-appropriate responses without having to use if-A-then-b/if-B-then-a rules.

## Experiment 1

Experiment 1 investigated whether preschoolers can pass otherwise challenging Stimulus-Response Compatibility tasks by conceptualizing them in an IC-avoiding way. To do this, we identified two different ways of presenting the task instructions: one which emphasized the if-A-then-b/if-B-then-a nature of the task rules, and the other which emphasized an alternative way of approaching the task. Importantly, while these ways of instructing the task differed, the task stimuli and responses were otherwise identical.

Stimulus-Response Compatibility tasks are typically introduced using two rules (e.g., “When I say ‘moon’, point to the sun card”, and “When I say ‘sun’, point to the moon card”). It may be that this two-rule presentation encourages preschoolers to conceptualize the task in a way that uses if-A-then-b/if-B-then-a rules (i.e., to conceptualize the task in an IC-requiring way). In contrast, if the same task were presented with a single rule, such as “Point to the other card”, this might encourage children to adopt a different conceptualization. If this conceptualization did not entail using if-A-then-b/if-B-then-a rules, then it would not require inhibitory control. Children would still need to make the same responses (pointing to “sun” when they hear “moon”, and pointing to “moon” when they hear “sun”), but they would be doing so in a way that did not rely on their weak inhibitory control, and so they should perform better.

Two points need to be clarified. First, as previously noted, evidence suggests that it is *specifically* the application of if-A-then-b/if-B-then-a rules that makes Stimulus-Response Compatibility tasks inhibitory (Diamond, et al., 2002; Hanauer & Brooks, 2005; Montgomery, et al., 2008; Montgomery & Koeltzow, 2010; Simpson & Riggs, 2005a, 2007, 2011; Simpson *et al.*, 2012). Conceptualizing them in *any* other way will therefore remove their inhibitory demands. Thus, we don't need to know the precise nature of an alternative conceptualization to know that it will be IC-avoiding: simply knowing that it does not use if-A-then-b/if-B-then-a rules is sufficient. Second, conceptualizing a Stimulus-Response Compatibility task with a single rule rather than with two rules will probably reduce its working memory demands, although not sufficiently to make the task significantly easier. Diamond and colleagues (2002) tested this possibility using the Day/night task, and found this Stimulus-Response Compatibility task to be no easier when introduced with a single rule.

Experiment 1 used two Stimulus-Response Compatibility tasks, each of which was presented in two ways (a one-rule presentation and a two-rule presentation). We used a version of the Grass/Snow task, referred to here as the "Verbal-cue task", and a new Stimulus-Response Compatibility task which we called the "Box task". These tasks were chosen to provide baselines for both poor performance and good performance: performance on the Verbal-cue task is known to be poor when presented with two rules (Simpson & Riggs, 2009), and performance on the Box task is known to be good when presented with a single rule (Carroll, Apperly & Riggs, 2007a&b; Simpson, Riggs & Simon, 2004).

Experiment 1 compared preschoolers' performance on two versions of the Box task and two versions of the Verbal-cue task (see Table 1). In the 2-Rule versions of these tasks, the instructions encouraged children to use an IC-requiring if-A-then-b/ if-B-then-a conceptualization. In contrast, the 1-Rule versions encouraged an IC-avoiding conceptualization, which did not use if-A-then-b/if-B-then-a rules. The most parsimonious prediction was that the 1-Rule versions of the tasks would be conceptualized in an IC-avoiding way (so performance would be good), and the 2-

Rule versions would be conceptualized in an IC-requiring way (so performance would be poor).

Table 1. Instructions for the four tasks used in Experiment 1.

| | *Number of rules in the presentation of the task* | |
|---|---|---|
| *Task* | 1-Rule | 2-Rule |
| Verbal-cue | When I name one card, point at the other card. So when I say 'sun' point to the other card, and when I say 'moon' point to the other card. | When I say 'sun' point to the moon card, and when I say 'moon' point to the sun card. |
| Box | When I put the sticker in one box, point at the other box. So when I put the sticker in the small box point at the other box, and when I put the sticker in the big box point at the other box. | When I put the sticker in the small box point at the big box, and when I put the sticker in the big box point to the small box. |

In the Box task, participants were presented with two boxes – one large, one small – with windows in the side. On each trial the experimenter placed a marker (i.e., a sticker) in one box. In the 1-Rule Box task, preschoolers were told "When I put the sticker in one box, point at the other box". We predicted that preschoolers would conceptualize this task in a way that avoided the need to apply if-A-then-b/if-B-then-a rules, and performance on this task would be good. In the 2-Rule Box task, preschoolers were presented with a pair of rules: "When I put the sticker in the big box, point at the small box. When I put the sticker in the small box, point at the big box". Thus, the task was explained using if-A-then-b/if-B-then-a rules. We predicted that preschoolers would conceptualize the task in a way that used these rules, that the task would thus have high inhibitory demands, and that performance would be poor.

In the 1-Rule Verbal-cue task preschoolers were told, “When I name one card, point at the other card”. We predicted that preschoolers would conceptualize the task in an IC-avoiding way (i.e. they would avoid using if-A-then-b/if-B-then-a rules), and that performance would therefore be good. In contrast, in the 2-Rule Verbal-cue task (the standard version of this task) preschoolers were told, “When I say ‘sun’, point at the moon card; when I say ‘moon’, point at the sun card”. We predicted that preschoolers would conceptualize the task in an IC-requiring way (i.e., using if-A-then-b/if-B-then-a rules), and that therefore performance would be poor.

**Method**

**Participants.** Twenty-four children participated (12 boys, 12 girls). Children were aged from 3 years, 0 months to 4 years, 2 months (mean = 3 years, 7 months). The children attended a preschool in the town of Colchester, England. All spoke English as their first language, and none had any behavioral or educational problems. The group was predominantly white, and was of mixed social class.

**Design.** A repeated-measures design was used, with Number of Rules (1 Rule vs. 2 Rules) and Task (Box vs. Verbal-cue) as independent variables. The dependent variable was accuracy (number of correct responses from 16 test trials in each task).

**Materials.** For the Verbal-cue task, two laminated cards (one showing a sun, one showing a moon) were used, measuring 14cm by 10cm. For the Box task, two cardboard boxes, one small (7cm x 7cm x 7cm) and one large (15cm x 15cm x 15cm) were used. The boxes had windows cut into the side. A sticker was used as a marker to prompt the child.

**Procedure**. Each child completed all four tasks, across two sessions not more than one week apart. Order of presentation was counterbalanced both between sessions (the 1-Rule tasks were presented in one session, and the 2-Rule tasks in the other) and within sessions (Verbal-cue task and Box task). Children were tested individually in a quiet area within their nursery. For each task, children were shown the cards or boxes and told the rules. They then received four training trials with feedback, followed by 16 test trials without feedback. (Procedure was based on the Grass/Snow task used by Simpson & Riggs, 2009.)

In the 2-Rule Verbal-cue task, the experimenter and child sat opposite each other, with a sun card and a moon card placed side-by-side between them. The experimenter asked the child to point to the sun card and moon card in turn. The experimenter then explained "When I say 'sun' [*pointing to the sun card with her right hand*] point to the moon card [*pointing to the moon card with her left hand*]. And when I say 'moon' [*pointing to the moon card with her left hand*] point to the sun card [*pointing to the sun card with her right hand*]". The child was asked to do this, and was corrected if an error was made. Children then completed four training trials (in the order ABAB), and received feedback for both correct and incorrect responses. Children were then given 16 test trials in a fixed pseudorandom order (ABBABAABBABAABAB). During test trials, no feedback was given. If children made more than one response, the first response was recorded.

The other three tasks were presented in a similar way, with specific instructions as follows: In the 1-Rule Verbal-cue task, the experimenter said, "When I name one card, point at the other card. So when I say 'sun' [*putting her right hand on the sun card*] point to the other card [*pointing to the moon card with her left hand*]. And when I say 'moon' [*putting her right hand on the moon card*] point to the other card [*pointing to the sun card with her left hand*]". In the 2-Rule Box task, the experimenter said, "When I put the sticker in the small box [*putting the sticker in the small box with her right hand*] point at the big box [*pointing to the big box with her left hand*]. And when I put the sticker in the big box [*putting the sticker in the box with her right hand*] point to the small box [*pointing to the small box with her left hand*]". In the 1-Rule Box task, the experimenter said "When I put the sticker in one box, point at the other box. So when I put the sticker in the small box [*putting the sticker in the small box with her right hand*] point at the other box [*pointing to the big box with her left hand*], and when I put the sticker in the big box [*putting the sticker in the big box with her right hand*] point at the other box [*pointing to the small box with her left hand*]".

**Results**

Accuracy on the four tasks is shown in Figure 1. Performance was poor on the two Verbal-cue tasks (below 50%), but good on the two Box tasks (above 90%). There were no significant effects involving order of presentation or gender. Data were analysed in a repeated-measures ANOVA with Number of Rules (1 Rule vs. 2 Rules) and Task (Verbal-cue vs. Box) as factors. There was a significant effect of Task, $F(1,23)=38.4$, $p<.001$, partial eta squared=.626, but no effect of Number of Rules, and no interaction. The pattern of results was surprising, but clear: whether the task was explained with one rule or with two rules did not affect children's performance. However, both of the Box tasks were easier than both of the Verbal-cue tasks.

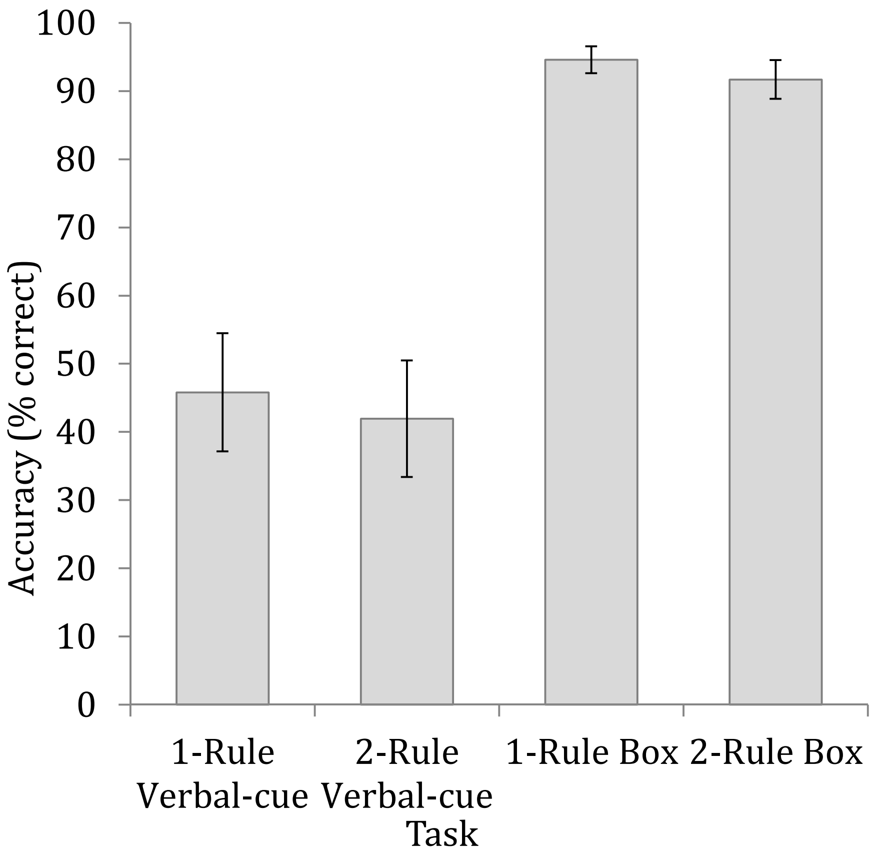


Figure 1. Accuracy on the two Verbal-cue tasks and two Box tasks in Experiment 1. Error bars show the standard error of the mean.

**Discussion**

The prediction that Stimulus-Response Compatibility performance would be good when tasks were introduced with one rule, and poor when tasks were introduced with two rules, was not supported by the data. Instead, both versions of the Box task were easy, and both versions of the Verbal-cue task were difficult, regardless of how the tasks were presented. These results showed that our hypothesis for Experiment 1 was wrong: the "one-rule" manipulation did not induce an IC-avoiding task conceptualization in either task. Furthermore, the results showed an unexpected difference in performance between the Box task and the Verbal-cue task. This difference required explanation, since it was apparent that these preschoolers had weak inhibitory control (as shown by their poor performance on the Verbal-cue task), and yet they performed very well on the two Box tasks.

We suggest that the way preschoolers conceptualize Stimulus-Response Compatibility tasks may yet be crucial – albeit not in the way we predicted. The observation that the Box task was easy strongly suggests that preschoolers *did* somehow conceptualize it in an IC-avoiding way. This must be so, because Stimulus-Response Compatibility tasks are difficult when their inhibitory demands are high (Gerstadt *et al.*, 1994; Simpson & Riggs, 2005b, 2009; Simpson *et al.*, 2006). The question is how do preschoolers conceptualize the Box task in an IC-avoiding way, whilst they conceptualized the Verbal-cue task in an IC-requiring way?

We speculate that the difference might arise from the way the experimenter cued responding: the spatial cue of placing a marker in one of the two boxes in the Box task, versus the verbal cue of naming one of the two cards in the Verbal-cue task. Our suggested explanation is as follows: in the Box task, when the experimenter places the marker in a box, preschoolers can see that one box is "marked" (i.e., it contains the sticker) and the other is "unmarked" (it is empty). This means that preschoolers could, in theory, produce the correct response simply by finding the unmarked box on each trial and pointing at it. That is, they could conceptualize the task as "select-the-unmarked-location" (or similar). Doing this would allow them to completely ignore the marked box – and so there would be no need to apply the IC-requiring if-A-then-b/if-B-then-a rules. We cannot be sure, of course, that this is what children were doing on the task in Experiment 1. We simply note that the use of a marker made it *possible* for the Box task to be conceptualized in this IC-avoiding way.

In the Verbal-cue task, in contrast, this select-the-unmarked-location conceptualization *could not* be applied, because the experimenter did not physically mark either of the cards. Instead, children's responding was cued verbally. The only way to succeed on the Verbal-cue task was to attend to this verbal cue: first, to determine whether the experimenter had said "sun" or "moon"; and then to use the IC-requiring if-A-then-b/if-B-then-a rules to point at the card *not* named by the experimenter. Children must do this irrespective of whether the experimenter introduced the Verbal-cue task using one rule or two rules. Unlike the Box task, therefore, we note that the absence of a "marker" on the Verbal-cue task means that it is not possible for children to adopt the same kind of IC-avoiding conceptualization. This hypothesis could explain why the Box task was easier than the Verbal-cue task in Experiment 1: because preschoolers *can* conceptualize the Box task in a way that lets them avoid its inhibitory demands, but they *cannot* do this on the Verbal-cue task. Experiment 2 sought to test this hypothesis directly.

## Experiment 2

While the surprising results of Experiment 1 indicated that our specific hypothesis for that experiment was wrong, it nevertheless suggested that the overall hypothesis of this article – that preschoolers *could* succeed on an Stimulus-Response Compatibility task, *if* they were able to conceptualize it an IC-avoiding way – might yet prove correct. We speculate that children were able to use just such an IC-avoiding conceptualization on the Box task, possibly by conceptualizing the task as a search for the unmarked location, rather than as one where they must follow IC-requiring if-A-then-b/if-B-then-a rules. In order to directly test this hypothesis, we required two new and closely matched Stimulus-Response Compatibility tasks on which this marked/unmarked difference could be compared. We devised two such tasks for Experiment 2: the 2-Card task and the 4-Card task.

The 2-Card and 4-Card tasks used picture cards (like the Verbal-cue task) and marker-cued responding (like the Box task). In the 2-Card task, the experimenter and child shared a single pair of cards for prompting and responding. In the 4-Card task, the experimenter and child each used their own pair of cards. The 2-Card task made it possible for children to adopt an IC-avoiding conceptualization (such as select-the-unmarked-location), since the correct response in this task would always involve pointing to the unmarked location. In contrast, on the 4-Card task it was not possible to adopt this IC-avoiding conceptualization, since neither of the cards the child would respond to were marked.

In the 2-Card task, the experimenter cued one of the two cards by placing a star-shaped marker on it. Children were told, “When I put the star on the sun, point at the moon. When I put the star on the moon, point at the sun”. Our hypothesis was that performance on the 2-Card task would be good, as it was possible to conceptualize this task in an IC-avoiding way. If children adopted a select-the-unmarked-location conceptualization, they could succeed by simply pointing to whichever of the two cards was not marked (thus avoiding any need to apply if-A-then-b/if-B-then-a rules).

In the 4-Card task, the experimenter used one pair of cards for prompting (one sun, one moon), while children responded on a separate pair of cards (one sun, one moon). The important feature of this task was that children could not respond simply by selecting the unmarked card: they pointed at a different pair of cards to the experimenter, and so *both* their cards were always unmarked. This meant it was not possible to conceptualize this task using the IC-avoiding select-the-unmarked-location conceptualization. Our hypothesis was that in the 4-Card task, children would have to use the IC-requiring if-A-then-b/if-B-then-a conceptualization, and that performance would therefore be poor.

In Experiment 2, performance on the 2-Card task and the 4-Card task was directly compared. In addition, to provide baselines for good and poor performance, the 1-Rule Box task and 2-Rule Verbal-cue task (from Experiment 1) were included. We made two predictions: first, that performance on the 2-Card task and 1-Rule Box task would be good, as both could be conceptualized in an IC-avoiding way (such as select-the-unmarked-location). Second, we predicted that performance on the 4-Card task and 2-Rule Verbal-cue task would be poor, as neither could be conceptualized in an IC-avoiding way. This experiment also tested an alternative hypothesis for the data obtained in Experiment 1: that Stimulus-Response Compatibility tasks are harder when responding is cued verbally, as in the Verbal-cue task, than physically, as in the Box task. We predicted that performance on the 4-Card task would be poor, despite it being physically cued, which would be incompatible with this alternative hypothesis.

## Method

**Participants.** Twenty-four children participated (13 boys, 11 girls). Children were aged from 3 years, 0 months to 4 years, 2 months (mean = 3 years, 6 months), and attended a preschool in the town of Colchester, England. All spoke English as their first language, and none had any behavioral or educational problems. The group was predominantly white and of mixed social class. None of the children had participated in the previous experiment.

**Design.** A repeated-measures design was used, with Task (2-Card, 4-Card, 1-Rule Box, 2-Rule Verbal-cue) as the independent variable. The dependent variable was accuracy (number of correct responses from 16 trials in each task).

**Materials.** Four picture cards were used (two showing sun pictures, and two showing moon pictures). Each card measured 14cm by 10cm. A gold star was used as a marker.

**Procedure**. Children were tested on all four tasks, over two sessions not more than one week apart. Order of presentation was counterbalanced (the four tasks were presented in each of the 24 possible orders). For each task, children received four training trials (with feedback), followed by 16 test trials (without feedback).

In the 2-Card task, a single pair of cards (a sun card and a moon card) was placed face-up between the child and the experimenter. On each trial, the experimenter placed a star on one of the two cards (in the top right corner). Children were told that when the experimenter put the marker on the sun, they should point to the moon; and when she put the marker on the moon, they should point to the sun. In the 4-Card task, there were two pairs of cards (each comprising one sun card and one moon card). On each trial the experimenter gave cues using one pair of cards, and children made their responses using the other pair of cards. The experimenter's cards were attached to a magnetic board, and were arranged vertically. The experimenter explained that the pictures on the board were her pictures, and that the two on the table belonged to the child. The experimenter placed the marker on one of the pictures on the board, and the child responded by pointing to the pictures on the table. The 1-Rule Box task and 2-Rule Verbal-cue task matched those in Experiment 1.

**Results**

Accuracy on the four tasks is shown in Figure 2. Performance was poor on the 4-Card task and the 2-Rule Verbal-cue task (below 50%). In contrast, performance was good on the 2-Card task and the 1-Rule Box task (above 90%). There were no significant effects involving order of presentation or gender. Data were analysed in a repeated-measures ANOVA with Task (2-Card, 4-Card, 1-Rule Box, 2-Rule Verbal-cue) as the factor. There was a significant effect of Task, $F(3,69)=49.7$, $p<.001$, partial eta squared =.684. Planned comparisons revealed that performance on the 2-Card task was significantly better than on the 4-Card task, $t(23)=10.7$, $p<.001$, 95% CI 49.1 to 72.8%. Performance on the 2-Card task did not differ significantly from the 1-Rule Box task, and performance on the 4-Card task did not differ from the 2-Rule Verbal-cue task.

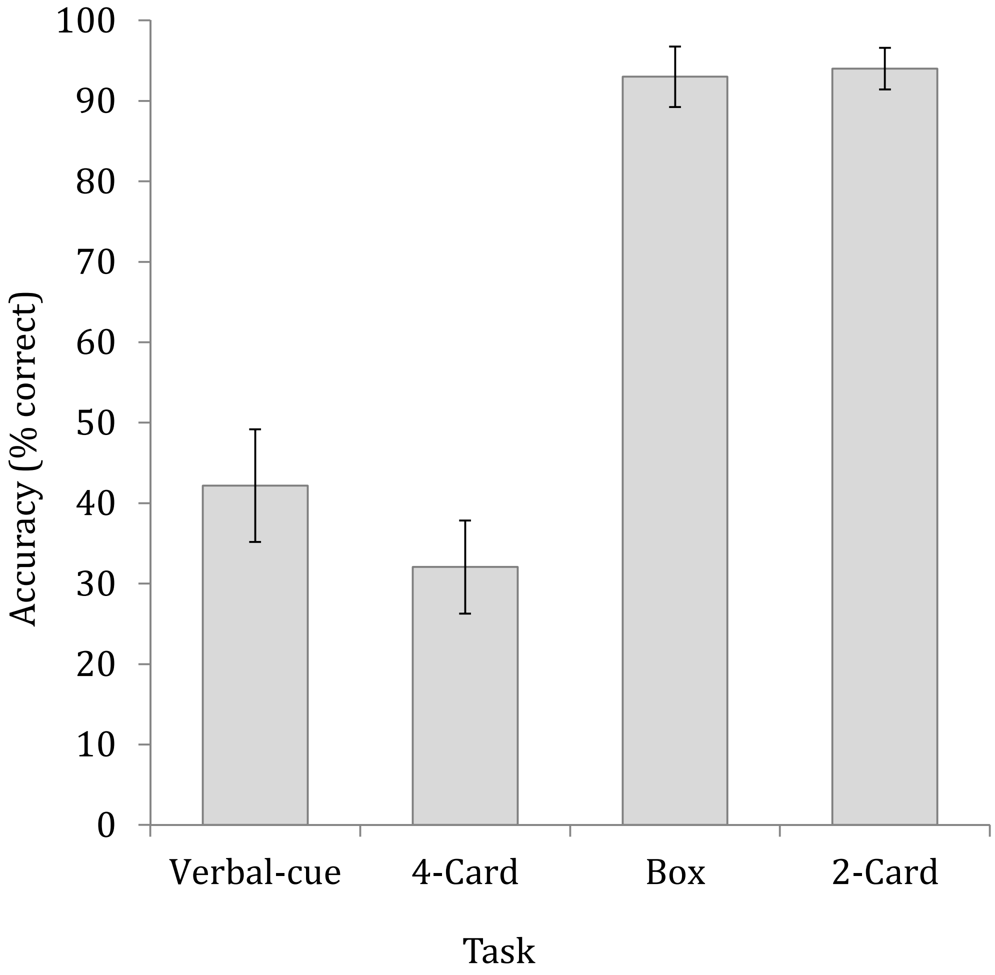


Figure 2. Accuracy on the four tasks in Experiment 2. Error bars show the standard error of the mean.

## Discussion

In line with predictions, performance on the 2-Card task was much better than on the 4-Card task. This was consistent with the hypothesis that the 2-Card task is easy because it is possible to conceptualize it in an IC-avoiding way. Results were also consistent with the hypothesis that the 4-Card task is difficult because it *cannot* be conceptualized in this way, as both response locations remain unmarked. The task must therefore instead be conceptualized in an IC-requiring way, following if-A-then-b/if-B-then-a rules. Thus, these data are consistent with our overall hypothesis that it is possible for preschoolers to perform well on an Stimulus-Response Compatibility task if they conceptualize it in an IC-avoiding way. The poor performance on the 4-Card task also speaks against the possibility that Stimulus-Response Compatibility tasks are easier when responding is cued physically rather than verbally (as in the Verbal-cue task).

These data support the proposal that conceptualization can directly affect inhibitory demands on a task. However, there were other differences between the 2- and 4-Card tasks that might have affected performance. The stimuli used in the 4-Card task were necessarily more complex than those used in the 2-Card task: there were two pairs of cards rather than one pair, and the orientation of the two pairs of cards differed. There was no specific reason to think that these differences affected performance. Nevertheless, as task conceptualization cannot be directly observed, evidence for it would be more compelling if its effects were seen in the absence of any such differences. In Experiment 3, therefore, we sought to test whether, in the absence of other differences, the way an Stimulus-Response Compatibility task is conceptualized is sufficient on its own to drive differences in task performance.

## Experiment 3

Testing whether conceptualization alone can determine children's performance on an Stimulus-Response Compatibility task requires a task that can be conceptualized in different ways. To that end, we adapted the 4-Card task used in Experiment 2. This task is difficult for preschoolers, and we can be confident that it has high inhibitory demands. It also uses two cue cards and two response cards, meaning that it offers scope for varying instructions and conceptualization. For Experiment 3, we compared the 4-Card task – henceforward referred to as the Standard Card task – with two new versions: the 1-Rule Card task and the 2-Rule Card task. These two tasks were identical apart from the way that their instructions were presented, with the 2-Rule presentation intended to induce a conceptualization using if-A-then-b/if-B-then-a rules, and the 1-Rule presentation intended to induce an IC-avoiding conceptualization (outlined below). The logic was therefore the same as Experiment 1, in that the aim was to induce two different conceptualizations of the same task.

An important feature of the 1-Rule and 2-Rule Card tasks was that the experimenter's cards and the child's cards were placed *next to* each other, as shown in Figure 3. This meant the experimenter's sun card was adjacent to the child's moon card, and her moon card was adjacent to the child's sun card. In consequence, when children responded correctly, they would also be *mirroring* the experimenter's actions. For example, when the experimenter pointed to her sun card (on her left), to make a correct response the child would point to their moon card (also on the experimenter's left), thus mirroring the experimenter's action. If children conceptualized the Card task using if-A-then-b/if-B-then-a rules, then it would be IC-requiring and difficult. However, if children conceptualized the task as "point the same way as the experimenter" (or similar), this would allow them to avoid the task's inhibitory demands, and perform well.

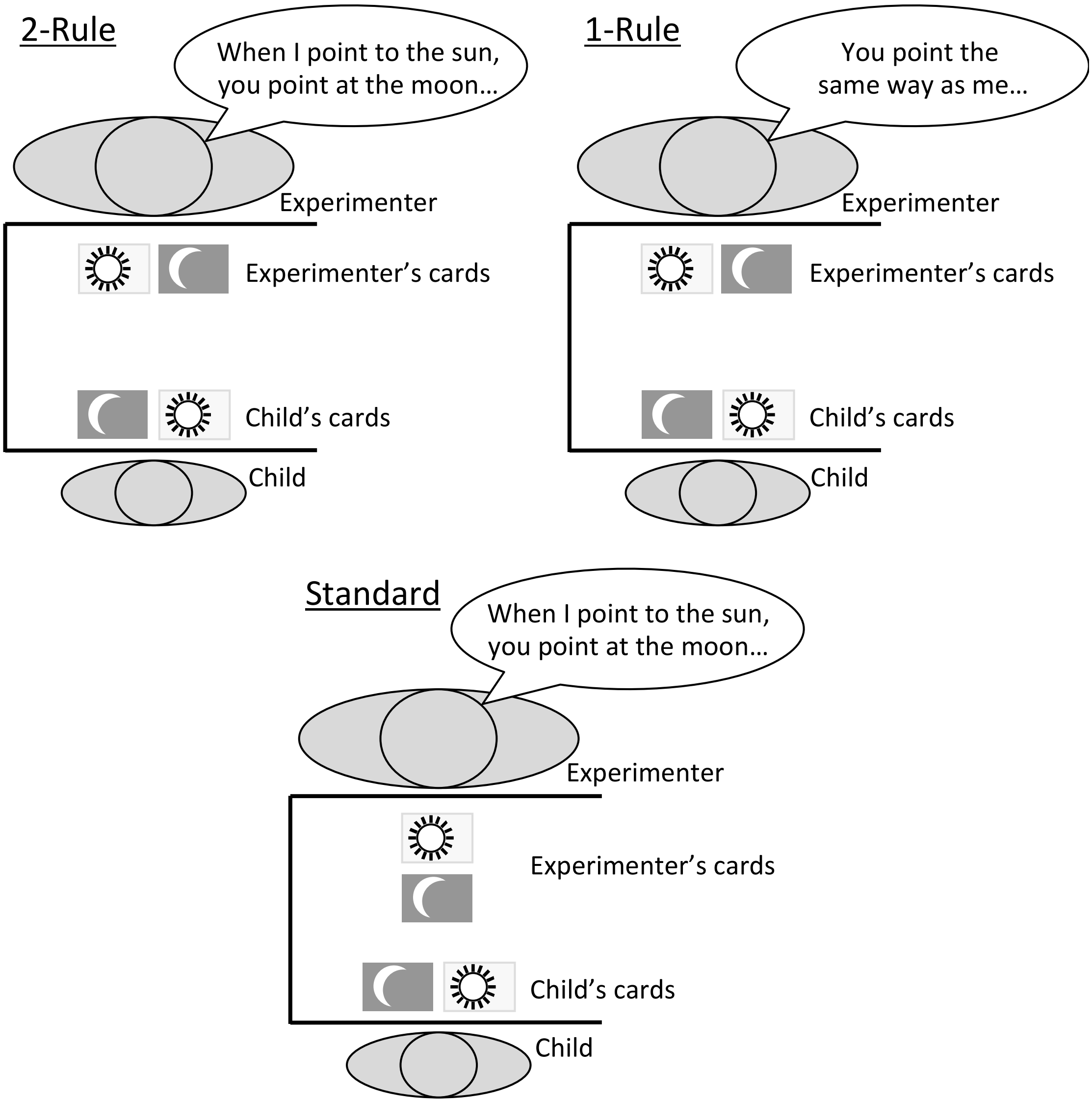


Figure 3. Schematic representation of the card arrangements and instructions given in the 4-Card tasks used in Experiment 3.

This card arrangement meant that it was possible for children to adopt *either* an IC-requiring conceptualization *or* an IC-avoiding conceptualization, and allowed us to test whether differences in conceptualization alone can lead to differences in task performance. To do this we compared performance using two different kinds of instructions. In the 2-Rule Card task, the standard Stimulus-Response Compatibility instructions were used ("When I point to the 'sun', you point to the 'moon'; and when I point to the 'moon', you point to the 'sun'"). These rules direct children to respond on the basis of IC-requiring if-A-then-b/if-B-then-a rules, and so performance would be expected to be poor. In the 1-Rule Card task, children were told to respond by following a single rule ("Point the same way as me"). This directs children to conceptualize the task as one where they simply point the same way as the experimenter. The cards were not named when introducing the task, making it unlikely that children would be aware that if-A-then-b/if-B-then-a rules could be applied. Thus, children would use an IC-avoiding conceptualization, and so performance was predicted to be good. In both tasks, the cards were arranged in the same way and children needed to make the same responses to the same cues. The only difference was how the instructions led them to conceptualize the task.

As well as directly testing the effects of conceptualization on a single task, Experiment 3 allowed a further comparison. By comparing performance in the Standard Card task (known from Experiment 2 to be difficult) with performance on the 2-Rule Card task, we could test whether children adopted an IC-avoiding conceptualization, even when the task instructions did not specifically direct them to do so. The Standard and 2-Rule tasks used the same instructions; what distinguished them was that it was *possible* to adopt an IC-avoiding mirror-the-experimenter conceptualization in the 2-Rule Card task, but *not* possible to use this conceptualization in the Standard Card task (because of the centrally arranged cue cards). If some children in the 2-Rule Card task spontaneously adopted an IC-avoiding conceptualization, then performance on this task should be somewhat better than the Standard Card task. A between-participants design was used to rule out the possibility that children might transfer their knowledge of an IC-avoiding mirror-the-experimenter conceptualization from the 1-Rule Card task to the 2-Rule Card task.

## Method

**Participants.** Sixty children participated (31 boys, 29 girls). Children were aged from 3 years, 0 months to 4 years, 2 months (mean = 3 years, 7 months), and all attended a preschool in the town of Colchester, England. All spoke English as their first language, and none had any behavioral or educational problems. The group was predominantly white, and of mixed social class. No children had participated in either previous experiment.

**Design.** A between-participant design was used (to avoid any transfer of task conceptualizations between tasks), with Task (Standard Card task, 2-Rule Card task and 1-Rule Card task) as the independent variable. The dependent variable was accuracy (number of correct responses from 16 trials in each task).

**Materials.** Four picture cards were used (two “sun” pictures, and two “moon” pictures). Each card measured 14cm by 10cm.

**Procedure**. Children were randomly assigned to one of the three tasks. For each task, children were introduced to the rules and then received four training trials (with feedback), followed by 16 test trials (without feedback). The experimenter gave cues using one pair of cards, and children responded using the other pair of cards. The experimenter’s cards were placed on a red sheet of paper to distinguish them from the child’s cards. The experimenter explained that the pictures on the red paper were hers, and that the two in front of the child belonged to the child.

The Standard Card task was identical to the 4-Card Stimulus-Response Compatibility task reported in Experiment 2. The 2-Rule Card task and 1-Rule Card task differed from the Standard Card task in that the experimenter’s cards were arranged left-to-right, rather than centrally (see Figure 3). These two tasks differed from each other only in how they were explained. In the 2-rule Card task, the experimenter said, “When I point to the sun [*pointing to the sun card with her right hand*], you point at the moon [*pointing to the moon card her left hand*]. And when I point to the moon [*pointing to the moon card with her right hand*], you point at the sun [*pointing to the sun card her left hand*]”. In the 1-rule Card task, the experimenter said, “You point the same way as me. When I point to this card [*pointing to the sun card with her right hand*], you point the same way [*pointing to the moon card her left hand*]. And when I point to this card [*pointing to the moon card with her right hand*], you point the same way [*pointing to the sun card her left hand*]”.

**Results**

Accuracy on the three tasks is shown in Figure 4. Accuracy was highest on the 1-Rule Card task (87%). Accuracy was lower on the 2-rule Card task (69%), and lowest on the Standard Card task (51%). Data were analysed in a between-participants ANOVA with Task (Standard Card task, 2-Rule Card task and 1-Rule Card task) as the factor. There was a significant effect of Task, $F(2,53)=13.02$, $p<.001$, partial eta squared =.314. Planned comparisons revealed that performance on the 1-Rule Card task was better than the 2-Rule Card task, $t(38)=2.75$, $p=.009$, 95% CI 4.7% to 30.9%. In turn, performance on the 2-Rule Card task was better than the Standard Card task, $t(38)=2.30$, $p=.027$, 95% CI 2.14% to 33.5%.

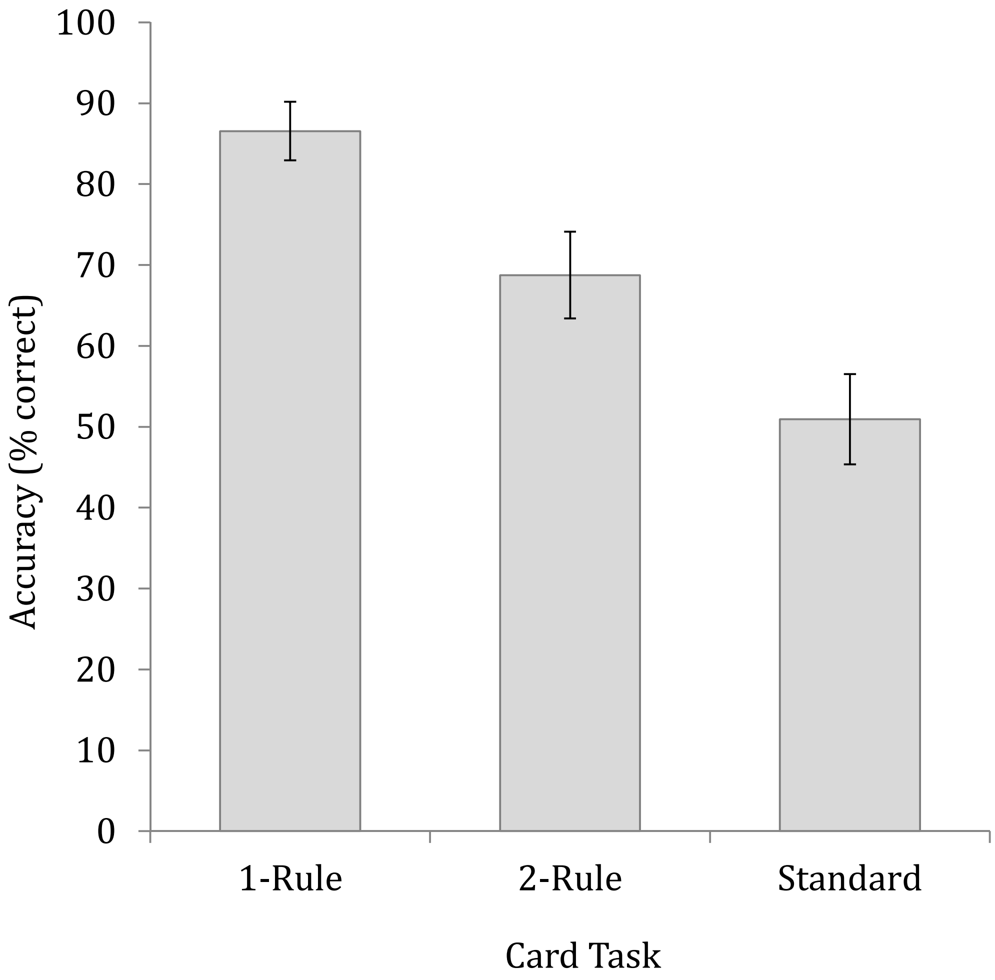


Figure 4. Accuracy on the three versions of the Card task used in Experiment 3. Error bars show the standard error of the mean.

**Discussion**

Experiment 3 sought to test whether children's performance on an Stimulus-Response Compatibility task could be affected simply by changing the way the task was introduced to them. Two closely matched versions of the 4-Card task were compared, differing only in the way the tasks were introduced. Performance was good on the 1-Rule Card task, in which the task was explained with instructions that encouraged children to adopt an IC-avoiding conceptualization; and poor on the 2-Rule Card task, whose instructions encouraged an IC-requiring conceptualization. Importantly, these two tasks required children to make the exact same responses to the exact same cues. On one task, doing so was challenging, while on the other, it was easy. These data offer strong support for the proposal that children with weak inhibitory control can overcome difficulties on an Stimulus-Response Compatibility task by conceptualizing that task in an IC-avoiding way.

Performance on the 2-Rule Card task was better than the Standard Card task, in which the orientation of the experimenter's cards meant that it was not possible for children to adopt an IC-avoiding conceptualization. This suggests that in the 2-Rule Card task, at least *some* children adopted the IC-avoiding mirror-the-experimenter conceptualization, even when the task instructions did direct them to. However, significantly fewer children used this IC-avoiding conceptualization in the 2-Rule Card task than in the 1-Rule Card task.

Overall, there were three levels of performance in Experiment 3. Preschoolers' accuracy on the 1-Rule Card task was better than the 2-Rule Card task, which in turn was better than on the Standard Card task. We suggest that these different levels of performance are best explained by different proportions of children adopting an IC-avoiding conceptualization in each task. Performance was best when *most* children conceptualized the task using the IC-avoiding conceptualization, when it was suggested by the task instructions in the 1-Rule Card task. Performance was intermediate when *some* children spontaneously adopted the IC-avoiding conceptualization, even though it was not suggested to them in the 2-Rule Card task. Finally, performance was poorest when *no* children used the IC-avoiding conceptualization in the Standard Card task, because the orientation of the cards prevented its use.

## General Discussion

Task conceptualization is the process by which the instructions provided by an experimenter are turned into a mental representation of that task in the participant's mind. Together, the three experiments in the present article show this conceptualization process at work. They provide the first direct evidence that the way children conceptualize a task influences whether that task has inhibitory demands. In doing so, they highlight an important and neglected aspect of cognitive development, by which problems are overcome not through an increase in a particular cognitive capacity, but by changing the way that a problem is conceived. These findings also inform our understanding of the relationship between conceptual knowledge and inhibitory demands.

*Using IC-avoiding conceptualizations of Stimulus-Response Compatibility and other inhibitory tasks*

The present study tested the hypothesis that preschoolers *could* succeed on an Stimulus-Response Compatibility task *if* they conceptualize it an IC-avoiding way. These data provide direct evidence that preschoolers can use task conceptualization to eliminate a task's inhibitory demands. They also provide the first insight into the question of when an IC-avoiding conceptualization is adopted. Our data suggest that *all* children were able to spontaneously adopt the IC-avoiding select-the-unmarked-location conceptualization on the Box task, even when it was not suggested to them by the instructions (the 2-Rule Box task in Experiment 1). In contrast, with the Card task, only *some* children adopted the IC-avoiding mirror-the-experimenter conceptualization, when it was not explained to them (the 2-Rule Card task in Experiment 3). These findings raise two questions: why did more children spontaneously adopt the IC-avoiding conceptualization of the Box task than did with the Card task? And what distinguishes children who adopted an IC-avoiding conceptualization from those who did not?

On the first question, one possibility is that preschoolers just found the IC-avoiding select-the-unmarked-location conceptualization of the Box task easier than the IC-avoiding mirror-the-experimenter conceptualization of the Card task. This is possible, though unlikely. We suggest that preschoolers are comfortably able to use *both* these IC-avoiding conceptualizations. Selecting the unmarked location requires understanding the concept of absence (i.e., the absence of a marker from a location), which is associated with understanding negation. Language research (Bloom, 1970, 1993; Nordmeyer & Frank, 2014; Pea, 1980) shows that children can demonstrate an understanding of negation from infancy. This strongly suggests that children have the cognitive abilities needed to select an unmarked location, and should therefore be well able to adopt the IC-avoiding conceptualization of the Box task. Children seem just as equipped to generate the IC-avoiding conceptualization of the Card task. This requires them to mirror the experimenter's actions. Children engage in imitation from a very young age (e.g., Meltzoff, 1995; Paulus, Hunnius, Vissers & Bekkering, 2011), and so clearly have the cognitive ability needed to adopt the IC-avoiding conceptualization of the Card task.

It seems more likely that what distinguishes the Box task from the Card task is how likely children are to encode the information needed to use the IC-avoiding conceptualization – specifically when the task is introduced using the standard two-rule instructions. Describing the task with these instructions encourages children to attend to the boxes or cards used in the task, since using the if-A-then-b/if-B-then-a rules requires children to identify which is being cued in order to work out how to respond (e.g., "The experimenter selected 'sun', so I need to point to 'moon'"). In the

Box task, attending to the boxes makes the IC-avoiding conceptualization easy to spot. During the training trials, children observe that just one of these boxes is unmarked, and that this is the one they should select. In the Card task, which uses four separate cards, there are twice as many locations available to encode. In addition, attending to these locations is likely to distract from adopting the IC-avoiding mirror-the-experimenter conceptualization. Mirroring the experimenter requires children to attend to the *direction* in which the experimenter is pointing, rather than the *identity of the location* selected. Thus, attending to which card has been selected in the Card task may make it harder to spot that an easy IC-avoiding conceptualization is available. Concentrating on following the if-A-then-b/if-B-then-a rules, children may fail to notice that they are mirroring the experimenter.

Second, what distinguishes preschoolers who spontaneously adopt an IC-avoiding conceptualization from those who use the IC-requiring conceptualization? One possibility is that children are distinguished by their metacognitive awareness: that is, their awareness of what makes the Card task difficult, and what strategies they can use to make it easier. It could be that children who spontaneously adopt the IC-avoiding conceptualization of the 2-Rule Card task had better metacognitive awareness, and so realized that this conceptualization makes the task easier. At present we have no data about the role of metacognitive awareness in children's spontaneous adoption of IC-avoiding conceptualizations when performing Stimulus-Response Compatibility or other tasks. Future research should investigate this possibility.

This article investigated the role of task conceptualization in creating the inhibitory demands of Stimulus-Response Compatibility tasks. What about other tasks used to study inhibitory control? Our hypothesis is that in order for a task's inhibitory demands to be high, participants must not be adopting an IC-avoiding conceptualization when performing it (either because one is not available, or because participants are not 'spotting it'). With adults, we suspect that IC-avoiding conceptualizations are often not available on inhibitory tasks, because of the way the tasks are structured. Specifically, in order to determine the correct response on many adult inhibitory tasks, participants must attend to a stimulus which then triggers an inappropriate response. For example, in the colour conflict Stroop task, in order to determine the appropriate response (the ink color of that word), participants have to attend to the stimulus that triggers the inappropriate response (the word presented on each trial). With young children, in contrast, it seems more likely that IC-avoiding conceptualizations are possible, but they fail to spot them. Again, this is a topic for future research.

*How do inhibitory control and task conceptualization interact?*

The present study also informs our understanding of the relationship between inhibitory control and conceptual knowledge. We believe that task conceptualization is likely to be directly influenced by conceptual knowledge. What children know, and when they know it, will determine which conceptualizations of a task will be available to them during development. This idea leads on, in turn, to consideration of how conceptual knowledge may determine executive demands across a range of domains. The present article investigated the application of an IC-avoiding conceptualization to a single task, as a means of illustrating a more general principle: that the ability to use IC-avoiding conceptualizations depends on children's understanding of the *specific domain* being tested. If children's understanding of the domain is good, then that understanding may make IC-avoiding conceptualizations more likely.

The process of task conceptualization emphasizes the extent to which inhibitory control and conceptual knowledge *interact* during early cognitive development. Traditionally, weak inhibitory control has been viewed as a block to the expression of good conceptual understanding. For example, it has been suggested that young children have good conceptual understanding in domains as diverse as theory of mind (Scott & Baillargeon, 2009), the physical world (Baker *et al.*, 2011), counterfactual thinking (Beck *et al.*, 2011), and strategic reasoning (Apperly & Carroll, 2009) – but that sometimes their knowledge cannot be expressed because of their weak IC. In other words, preschoolers "know" the right answer, but fail to inhibit the wrong answer. The proposal of the present article – that task conceptualization influences inhibitory demands – suggests that inhibitory control and conceptual knowledge can interact in another way. Poor conceptual knowledge can expose preschoolers' weak inhibitory control, because they only need to apply inhibitory control *if* poor understanding leads to an IC-requiring conceptualization. A better understanding could have produced an IC-avoiding conceptualization – one that rendered their weak inhibitory control irrelevant.

To illustrate this point with an example, consider tasks that test two kinds of reasoning: counterfactual reasoning and future hypothetical reasoning (Perner, Sprung & Steinkogler, 2004; Riggs, Peterson, Robinson & Mitchell, 1998; Robinson & Beck, 2000). In a counterfactual reasoning task, preschoolers are asked how the current location of an object would be different if the past had been different (e.g., "What if the car had gone the other way – which garage would it be in?"). Preschoolers find this task difficult, and evidence suggests it requires inhibitory control (Beck, Riggs & Gorniak, 2009; Drayton, Turley-Ames & Guajardo, 2011). Preschoolers seem to have difficulty resisting pointing to the current location of the object in the counterfactual task. In comparison, in a future hypothetical reasoning task, preschoolers are asked how the future location of an object could be different from its current location (e.g., "What if next time the car goes the other way – which garage would it be in?"). This task is easy for preschoolers, despite their poor inhibitory control. From this, we can conclude that inhibitory demands on the future hypothetical task are low or absent.

Why can preschoolers resist pointing to the current location of the object in the future hypothetical task, but not in the counterfactual reasoning task? The questions in the two tasks are similar, yet children's performance is strikingly different. Informed by the findings from the present study, we suggest that the answer may lie partly in the way that preschoolers conceptualize the tasks. In the counterfactual reasoning task, preschoolers think that the current location of the object *is relevant* to a question about its current location (albeit a hypothetical question). This means that counterfactual reasoning tasks require inhibitory control to prevent a response to that location, and so preschoolers perform poorly. In contrast, in the future hypothetical task, preschoolers think that the current location of the object *is not relevant* to a question about its future location. This allows them to adopt an IC-avoiding conceptualization of the task, meaning that they perform well on future hypothetical tasks.

Our suggestion is that the future hypothetical task does not require inhibitory control because preschoolers have a sound conceptual understanding of the relationship between the present and the future. They know that the future is different from the present. In contrast, their understanding of counterfactuality is poor: they are not fully conversant with the notion that counterfactual facts supersede current reality. Preschoolers therefore regard the current location of the object as potentially relevant in a counterfactual reasoning task, and so must rely on their weak inhibitory control to suppress any reference to it. We argue that it is the *combination* of an inadequate task conceptualization and weak inhibitory control that causes poor performance on counterfactual reasoning tasks. There must therefore be multiple routes to developmental success on counterfactual tasks: children could perform better either through increases in inhibitory control, or through improved conceptual understanding. Such a view would also suggest that when adults succeed on measures of counterfactual thinking, it may not be because they are better at inhibiting the wrong response. Rather, their increased conceptual understanding may mean that the wrong response is unlikely to arise in the first place.

*Conclusion*

The present article is the first to directly study how task conceptualization influences inhibitory demands. This process was investigated in preschoolers, whose weak inhibitory control means that whether they conceptualize a task in an IC-requiring way or an IC-avoiding way has a dramatic effect on performance. Having demonstrated that this process exists, it remains for future research to establish in what other situations conceptualization is used by young children to reduce inhibitory demands (with future hypothetical reasoning being a likely candidate domain); as well as to identify and understand the factors that determine its use across development more generally.

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