

Running Head: EFFECTS OF REMINDERS, DELAYS, AND TASK DIFFICULTY ON
YOUNG CHILDREN'S INHIBITORY CONTROL

Effects of Reminders, Delays, and Task Difficulty on Young Children's Inhibitory Control

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Abstract

Children often show significant limitations in their inhibitory control (IC), or ability to stop habitual, automatic actions. Although interventions to improve early IC are of great interest, the mechanisms supporting control in young children are poorly understood. Two manipulations to improve IC have shown some promise: experimenter-imposed delays, and task-relevant reminders. In the box-search task, where 3-year-olds learn to open boxes to find stickers on the basis of go and no-go cues, task-relevant reminders, rather than delays, have been shown to improve performance. In the more difficult day-night Stroop task, where children are taught to respond 'day' to a picture of a moon and stars, and 'night' to a picture of a sun, delays do seem to improve performance, but have previously been combined with task-relevant information. In Study 1, we tested whether box-search reminders are most effective when they are provided immediately before children respond, as emphasized by accounts suggesting that young children can successfully engage control *reactively* before they can engage it *proactively*. We found that when provided in isolation, neither in-the-moment reminders nor pre-task reminders aided 3-year-old's IC relative to a control, no-reminder condition. This suggests that simply drawing young children's attention to the cue before they respond may be insufficient to support reactive retrieval of task-relevant information. In Study 2, we found that experimenter-imposed delays benefitted 4-year-olds IC in the day-night Stroop task even when deconfounded from reminders and encouragement. These findings suggest delays may be more effective in tasks with greater control demands, consistent with accounts emphasizing roles for passive dissipation of the prepotent stimulus and active computation of correct responses.

Keywords: cognitive development, response inhibition, reactive control

Effects of Reminders, Delays, and Task Difficulty on Young Children's Inhibitory Control

Children often struggle to avoid automatic actions. For example, when a child sees the ball they are playing with roll into the street, their impulsive reaction is to run after it. To avoid this automatic action, a child must keep in mind that cars are in the road, and inhibit an automatic habit (running after the ball) that is not appropriate given a change in environment (from a safe yard to a more dangerous street). The ability to override automatic responses in favor of controlled actions is supported by 'cognitive control', a set of mental processes that aid in planning and coordinating actions and behaviors (Barber & Carter, 2005). In the example regarding the run-away ball, cognitive control is necessary for remembering that there are cars in the street, creating the goal of not running after the ball until the road is clear, and helping to inhibit the impulse to run after it. Inhibitory control is one form of cognitive control that allows us to regulate and overcome these prepotent responses.

Understanding inhibitory control and its development are of great interest because identifying interventions to improve cognitive control in early childhood may benefit children long-term. Inhibitory control in childhood has been shown to predict important life outcomes such as health, academic success, and income (Moffitt et al., 2011). Improved understanding of the mechanisms supporting control in children could also inform interventions for other populations, including individuals with ADHD, autism, and schizophrenia (Alderson, Rapport, & Kofler, 2007).

Although young children show poor inhibitory control under many circumstances, some experiments have demonstrated that they can engage control when an experimenter imposes a delay before they can respond. For example, in the day-night Stroop task (Fig. 1b), children are instructed to say 'day' when they are shown a stimulus card depicting a moon and star, and

'night' when they are shown a card depicting a sun. Children make fewer errors when an experimenter presents the stimulus card, then sings a short ditty before they are allowed to respond (Diamond, Kirkham, & Amso, 2002). In the box search task (Fig. 1a), where children are taught to find stickers by opening boxes with a 'go' cue and to leave boxes with a 'no-go' cue shut, children have been shown to make fewer inhibitory errors (i.e., opening boxes that should be left shut) when an experimenter reveals a box, then pauses briefly before placing the cue on its lid (Simpson et al. 2012).

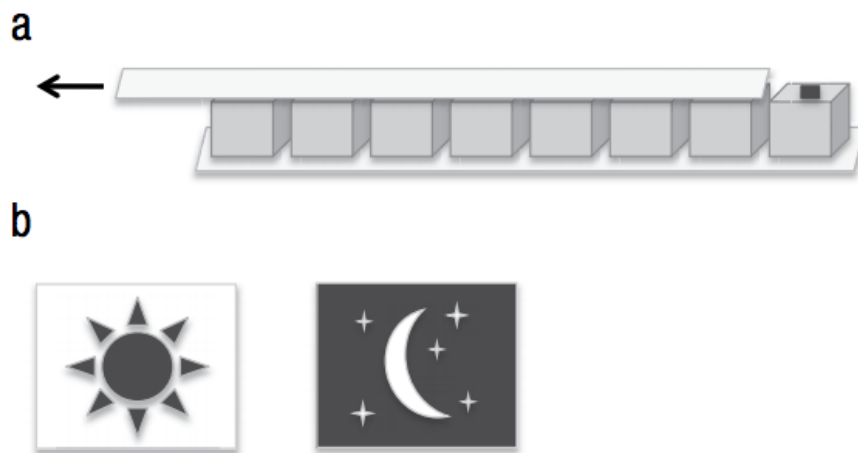


Figure 1. (a) Physical apparatus used in the box-search task. Participants are instructed to open boxes with a blue square on top because they contain stickers (go trial), and to leave boxes with a red triangle closed because they do not contain stickers (no-go trial) (Simpson et al., 2012). (b) Cards used in the day-night Stroop task. Children are asked to say “day” when shown a picture of a moon and to say “night” when shown a picture of a sun (Gerstadt, Hong, & Diamond, 1994).

Inhibitory Control Accounts

Two dominant accounts have been put forth to explain why delays might benefit children's inhibitory control, the *active computation* account and the *passive dissipation* account. In the active computation account, it is believed that children use a delay period to actively

compute appropriate responses. In tasks such as box-search, children are more likely to inhibit prepotent responses when provided time to think about task rules after viewing the stimulus. Because children often fail to pause actions on their own, they are less likely to make incorrect, prepotent responses when experimenters impose short delays (Diamond et al., 2002). The passive dissipation account posits that incorrect, prepotent responses compete with controlled responses within a race model (Simpson et al., 2012). In tasks such as box-search, the incorrect automatic response (opening boxes that should be left closed) reaches the response threshold first, then passively dissipates, enabling the correct response (leaving the box closed) to outcompete it. Delays improve inhibitory control in the box-search task even when children are occupied during the delay (via a game in which they had to guess which hand the experimenter held the cue in) (Simpson et al., 2012). This finding is consistent with the passive dissipation account and challenges the active computation account, since children were otherwise engaged during the delay period and could not use this time to 'compute' the correct answer.

A third, *goal orientation* account suggests that benefits previously attributed to delays may have instead been driven by accompanying reminders that aided children's activation of goal-relevant information (Barker & Munakata, 2015). For example, in some versions of the day-night Stroop task testing effects of delays, the delaying ditty instructed children: "Think about the answer. Don't tell me!". These lyrics include an obvious reminder about the task rules that may have improved children's performance on the task (Beck, Carroll, Brunson, & Gryg, 2011; Diamond et al., 2002). Similarly, box-search delay conditions may have also been confounded by task-reminders. In delay conditions, the experimenter prompted attention to the cue by placing it on the box in front of the child. Additionally, in delay-with-distractor conditions, the distractor task was to find the cue hidden in one of the experimenter's hands, which also drew

attention to the cue. The child also received additional instructions from the experimenter (e.g., “You mustn’t open the box until I put the shape on top because only when the shape is on can you tell if there is a sticker inside”) (Simpson et al., 2012).

Recent findings from the box-search task support the goal orientation account, suggesting that when delays and reminders are deconfounded in the box-search task, children’s improvements in inhibitory control are driven by reminders, rather than delays (Barker & Munakata, 2015). Children’s performance on the task was compared across four conditions using a between-subjects design: two conditions that replicated standard (no-distractor) conditions from Simpson et al., (2012), no-delay + cue reminder, and delay + cue reminder, and two new conditions: no delay + no cue reminder, and delay + no cue reminder. In the delay conditions, the experimenter revealed the box, paused for ~2.5 s, then placed the cue on top of the box. In the no-delay conditions, the box and the cue were revealed simultaneously by the experimenter. In the reminder conditions, children heard an additional verbal reminder of the instructions during the practice phase of the task and watched the experimenter point to or place the cue on top of the box at the beginning of each test trial. In no-reminder conditions, children received standard instructions and the experimenter did not point to or place the cue in view of the child during test trials. Results showed that reminders improved participants’ accuracy on no-go trials regardless of whether or not delays were imposed by the experimenter. The results also showed that children’s inhibitory control was predicted by their spontaneous delays, which may reflect time used for goal-oriented processes (Barker & Munakata, 2015). These findings suggest that task reminders, rather than delays, improve children’s inhibitory control.

In-the-moment versus pre-task reminders

Although previous tests of the goal-orientation account suggest that delays do not help when they are de-confounded from reminders in the box-search task, these studies leave open the question of *which* reminders are most effective. Because reminders have been combined in past work, it is possible that observed performance benefits were mainly driven by in-the-moment reminders (e.g., tapping the cue in the moment before children reached), and that pre-task reminders (repeating instructions during practice phase) yielded limited or no benefits. Alternatively, additional reminders of the task rules in the pre-test phase may have strengthened children's representations of the task rules, helping them to maintain them over time and retrieve them as needed. However, the support for this reactive form of control may be less effective because it is not happening in the moment the child is responding to the cue.

There is some reason to believe that in-the-moment reminders are more beneficial to young children's response inhibition, given evidence that children show a developmental transition in the temporal dynamics of control (Chatham, Frank, & Munakata 2009). Whereas young children respond *reactively*, engaging control in the moment they are to respond, older children and adults tend to engage control more *proactively*, by anticipating and preparing future responses. Between the ages of five and eight, children also show greater consciousness of errors and increase in goal-directed behaviors, which may help them to realize when it is necessary to engage control after an inhibitory error (Macdonald, Beauchamp, Crigan, & Anderson, 2014). While in-the-moment physical reminders are considered to be a reactive reminder, instructional reminders at the outset of a task are considered to be a proactive reminder, or a less-effective reactive reminder. Given that 3-year-olds are more likely to engage reactive forms of control, in-the-moment reminders should be beneficial to young children's

inhibitory control, while children may benefit less from additional instructions at the outset of the task given that such reminders may be less effective at supporting reactive control and rely more upon proactive control.

Experimenter-imposed Delays

A second question is whether experimenter-imposed delays might aid child performance in more complex inhibitory control tasks such as day-night Stroop, which is typically difficult even for 4-year-olds who make no errors on the box-search task (Simpson, Upson, & Carroll, 2017). Children have been shown to make fewer errors in DN Stroop when an experimenter imposes a delay before children are allowed to respond. However, previous delaying ditties included either a reminder of the task rules (Diamond, Kirkham, & Amso, 2002), or positive information that may have encouraged children to continue engaging control (e.g., "I hope you have a nice time. I like you!") (Ling, Wong, & Diamond, 2016), which was not present in control conditions. Therefore, it is unclear whether benefits to inhibitory control in day-night Stroop that were previously attributed to experimenter-imposed delays can instead be explained by other factors, consistent with the goal activation account, or whether delays are more beneficial in the task because it includes additional sources of conflict.

The present studies investigate interventions supporting inhibitory control in 3- and 4-year old children, testing predictions of the goal activation account. Study 1 tests whether reminders given immediately before 3-year-olds can respond in the box-search task (i.e., tapping the cue) yield more benefits to inhibitory control than additional instructions given at the outset of the task. We predict that in-the-moment reminders should drive more improvement in 3-year-olds' inhibitory control, consistent with theories suggesting that reminders that are present

immediately before children respond should be more likely to aid young children's engagement of reactive control, relative to additional instructions provided at the outset of the task. Study 2 provides a further test of the goal activation account, by investigating whether effects previously attributed to experimenter-imposed delays can instead be explained by other factors in day-night Stroop, a more complex inhibitory control task.

Method

Three and 4-year-old children ($N = 208$) were recruited to complete both box-search (Study 1) and day-night Stroop (Study 2). Study 1 analyses were restricted to 3-year-olds to avoid ceiling effects in older children, consistent with prior work with the box-search task (Simpson et al., 2012; Barker & Munakata, 2015). Similarly, Study 2 day-night Stroop analyses were restricted to children ages 3.5-4.9 years to replicate prior work (Gerstadt et al., 1994; Ling et al., 2016). Within each of these age ranges, task order was counterbalanced among participants. This procedure was included to facilitate exploratory analyses testing whether prior experience in box-search supported DN Stroop performance in younger children. Since these analyses are not central to the current thesis, they are not reported here.

All subjects were native English speakers. Subjects were recruited from a database of families who had volunteered to participate in research at the University of Colorado Boulder's Cognitive Development Center. All participants received a small prize upon completion of the task (e.g. bubbles, stickers). The parents of children who completed the study in the Cognitive Development Center received \$5 in travel compensation. All sessions were videotaped, except in cases of parental refusal. For non-videotaped sessions, accuracy was hand-recorded after each trial (as in Simpson et al., 2012).

Study 1

In Study 1, 3-year-old children were randomized into one of three box-search task conditions: a no-reminder control condition, a pre-test instructional reminder condition, or an in-the-moment condition where a brief reminder (tapping the cue) preceded each test trial.

Method

Participants

One hundred forty 3-year-olds (mean age = 3.39; range = [3.00, 3.99]) completed a version of the box-search task. Nine additional children were dropped for non-participation (i.e., refusal to participate) ($n = 4$), experimenter error ($n = 2$), and parent interference ($n = 3$). A sample size of 45 children per condition was chosen on the basis of sample size and effect-size estimates reported by Barker and Munakata (2015), who obtained a change in odds ratio (Δ OR) of 0.011 for the contrast between older and younger children's errors across trials.

Materials

The box-search apparatus replicated the design used in previous studies in this age range (Simpson et al., 2012; Barker & Munakata, 2015). In each of two sets of test boxes, eight white boxes (each 60 mm, lids 65 mm wide \times 65 mm long) were evenly spaced on a white cardboard mounting strip (75 mm wide \times 700 mm long). The go cue was always a blue square, and the no-go cue was always a red triangle (each 40 mm per side). For practice trials, four boxes (of the same dimensions as the test boxes) were mounted to a shorter piece of cardboard (75 mm wide \times 250 mm long). A strip of cardboard was used to uncover each box one at a time.

Design and Procedure

As in past work (Simpson et al., 2012; Barker & Munakata, 2015), participants were instructed to open boxes with blue squares because they contained stickers, and to leave boxes

with red triangles closed because they did not contain stickers. Each condition included a training phase and a testing phase. During the training phase, the experimenter showed the child an example of a go box (blue square) and an example of a no-go box (red triangle), provided instructions for the appropriate condition, and presented the child with four sequential practice trials. Standardized feedback was provided following each practice trial. Children were given ~3s to reach towards the trial box before the experimenter provided feedback.

After the practice trials, the experimenter repeated the task instructions. In the instructional-reminders condition, children were additionally told, "Make sure you wait to open the box until you see the right shape". Next, each child was presented with sixteen boxes (two sets of eight), one box at a time. Eight go and eight no-go cues were presented in the same pseudorandom order in all conditions. In each trial, the participant was given ~2.5s to initiate a reach toward the newly revealed box. If the child did not reach during this period, the experimenter revealed the next box. No feedback was given during the testing phase.

No-reminders (control) condition. ($n = 48$) In this condition, the experimenter revealed a given box and its cue simultaneously (as in Simpson et al., 2012, Barker & Munakata, 2015). Children received standard verbal instructions and were allowed to respond immediately after the cue was revealed.

Pre-test instructional reminders condition. ($n = 46$) In this condition, the experimenter revealed a given box and its cue simultaneously as in the no-reminders (control) condition. However, children received an additional verbal rule-reminder at the outset of the task. The rule reminder, "Make sure you wait to open the box until you see the right shape!" was stated before the practice phase as well as before the test trials.

In-the-moment physical reminders condition. ($n = 46$) In this condition, the experimenter did not provide any additional instructional reminders to the child in the practice phase, as in the control condition. However, as the experimenter pulled the cardboard cover over the box, revealing it to the child, they tapped the cue briefly with their right index finger.

Coding

A trained coder blind to all experimental hypotheses coded videos for 79% ($n = 110$) participants. A second trained coder coded videos for 46% ($n = 65$) of participants, and a third trained coder coded videos for 15% ($n = 21$) participants. Videos for 6 participants were not coded (i.e., video equipment error) ($n = 3$) and lack of parent consent to record ($n = 3$). For each participant, coders assessed accuracy for each individual trial. Inter-rater reliabilities were high (primary coding pair: $r = .94$; secondary coding pairs: $r_s = .99$ and $.97$). Scores were averaged across raters to form composite go-trial and no-go trial scores.

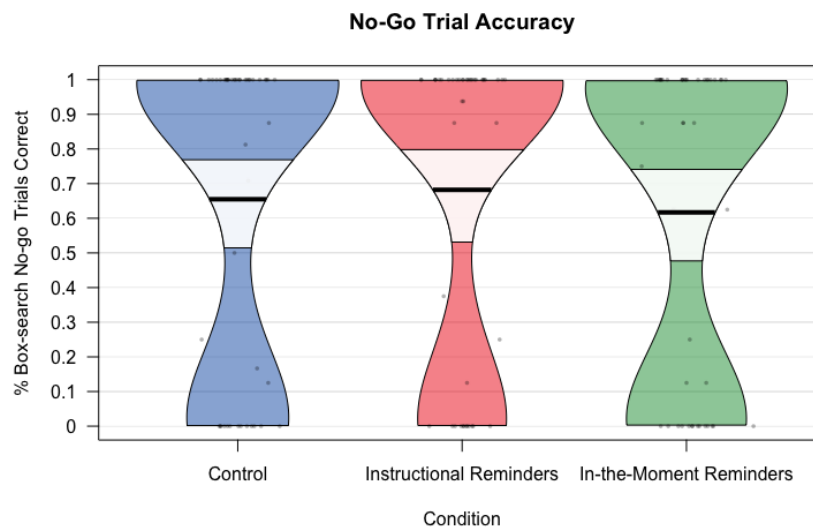


Figure 2. Box-search task average accuracy no-go trials by condition. Children did not differ in their performance on No-Go trials across conditions ($F(3,136) = 0.175, p > 0.83$; $M_{Control} = 65.49\%$; $M_{Instructional} = 68.21\%$; $M_{In-the-Moment} = 63.04\%$). Ninety-five percent confidence intervals

(CIs) are shown in white, with black bars as central tendency. Raw data are represented by points, while curved lines indicate smoothed density of data at each performance level.

Results

As expected, children performed well on Go trials across conditions ($M_{Go} = 98.99\%$; no condition-level differences), and reliably worse on No-Go trials ($M_{No-go} = 65.58\%$; $p < .0001$), indicating that children were engaged in the task.

In contrast to our prediction that in-the-moment reminders would drive more improvement in 3-year-olds' inhibitory control relative to additional instructions provided at the outset of the task, children's performance on No-Go trials did not differ significantly across conditions ($F(3,136) = 0.175$, $p > 0.83$; $M_{Control} = 65.49\%$; $M_{Instructional} = 68.21\%$; $M_{In-the-Moment} = 63.04\%$). (Fig. 2).

Discussion

Previous findings have shown that instructional and physical reminders aid children's inhibitory control in box-search when they are combined (Barker & Munakata, 2015). While additional instructional reminders at the outset of a task are considered to be a proactive reminder, in-the-moment physical reminders are considered to be a reactive reminder. Since investigations of the temporal dynamics of control across development suggest that children do not develop proactive control until approximately age 5 (Gerstadt, Hong, & Diamond, 1994), we hypothesized that 3-year-olds would be more likely to engage reactive forms of control. We therefore predicted that in-the-moment reminders would be more beneficial to young children's inhibitory control than additional instructions at the outset of the task. However, we did not find evidence that either in-the-moment reminders or pre-test instructional reminders supported children's inhibitory control when provided in isolation.

These findings could suggest that reminders are most effective in combination. For example, in-the-moment reminders may draw children's attention to the cue immediately before they respond, aiding reactive retrieval of the task rules. Additional reminders of the task rules in the pre-test phase may strengthen children's representations of the task rules, helping them to maintain them over time (proactively) and retrieve them as needed (reactively). Thus, joint benefits may indicate the importance of multiple sources of support for reactive control, or for support of both reactive control and early attempts to engage proactive control.

Study 2

Study 2 investigated whether reminders help young children engage control in the day-night Stroop task, and whether effects previously attributed to experimenter-imposed delays can instead be explained by other factors. Children completed one of two day-night Stroop conditions: delay or no-delay.

Method

Participants

One hundred two children completed the DN Stroop task (mean age = 4.14; range=[3.50 - 4.99 years]). Thirty-six children were dropped for non-participation (i.e., failure to pass practice trials) ($n = 15$), enrollment before DN was added to the protocol ($n = 13$), refusal to participate ($n = 6$), failure to complete task ($n = 1$), and experimenter error ($n = 1$). The sample size of 35 subjects per condition for the day-night Stroop task was chosen on the basis of sample size and effect-size estimates reported by Diamond, Kirkham, and Amso (2002).

Materials

Materials used in the day-night Stroop task imitate those described in Diamond, Kirkham, and Amso (2002). The same sixteen cards were used for all conditions. The cards were

cardboard rectangles (100 mm wide x 140 mm long). The front side of eight of the cards was black with a white moon and one star. The front side of the other eight cards was white with a large bright-yellow sun. The backs of all cards were brown.

Design and Procedure

In this task, children were asked to say “day” when shown a picture of a moon and to say “night” when shown a picture of a sun. Participants first completed a training phase in which instructions were given, and children were tested on what response to give to each card. To pass training, the child had to respond correctly to each card on one of three trials. If a child gave an incorrect response to either card, the experimenter repeated the instructions beginning with the fragile rule first (i.e., the rule on which the child had erred), as in Diamond, Kirkham, and Amso (2002). If children passed this initial phase, they were given three additional practice trials that corresponded to their assigned condition. For the delay condition, children were told “We are going to try some more cards, but now before you tell me the answer, I’m going to sing a little song that goes like this: La-la-la-la-la-la-la-la-la”. For the no-delay condition, children were told “We are going to try some more cards, but now before I show you the card, I’m going to sing a little song that goes like this: La-la-la-la-la-la-la-la-la”. To continue to the test phase, children had to respond correctly to each card on one of three additional trials.

After passing the training phase, condition-specific rules were reiterated. Children were presented with sixteen subsequent trials of their assigned condition (i.e., no-delay condition, delay condition). No feedback was given during the testing phase.

No-delay condition. ($n = 31$) In this condition, the experimenter sang the contentless ditty “La-la-la-la-la-la-la-la-la “, then showed the child a picture of either a sun or moon.

Delay-condition. ($n = 35$) In this condition, the experimenter showed the child a picture of either a sun or moon. While the card was being presented, the experimenter sang the contentless ditty, after which the child could respond.

Coding

A trained coder blind to all experimental hypotheses coded videos for 88% participants ($n = 90$). A second trained coder coded videos for 14% ($n = 14$). Videos for 2 participants were not coded due to equipment malfunction ($n = 1$) and lack of parent consent to record ($n = 1$). For each participant, coders assessed accuracy for each individual trial. Inter-rater reliability was high ($r = .99$). Scores were averaged across raters to form composite correct and incorrect scores for both day and night cards.

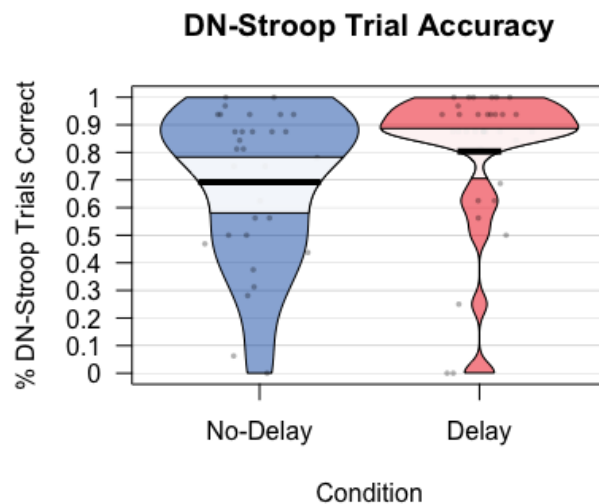


Figure 3. Day-night Stroop task average accuracy for correct trials by condition. Children's performance across trials was better in the delay condition compared to the no-delay condition ($F(1,64) = 6.671, p < .05; M_{Delay} = 80.36\%; M_{No-Delay} = 69.25\%$). Ninety-five percent confidence intervals (CIs) are shown in white, with black bars as central tendency. Raw data are represented by points, while curved lines indicate smoothed density of data at each performance level.

Results

Consistent with previous findings showing that experimenter-imposed delays support young children's performance in day-night Stroop, children in the delay condition made fewer errors than children in the no-delay condition ($F(1,64) = 6.671, p < .05; M_{Delay} = 80.36\%; M_{No-Delay} = 69.25\%$) (Fig. 3).

Discussion

In contrast to the box-search task, where delays fail to support children's inhibitory control unless they are combined with reminders, the present study provides further support for the benefits of delays to children's day-night Stroop performance (Diamond & Amso, 2002; Ling, Wong, & Diamond, 2016). We find that an experimenter-imposed delaying ditty is effective in improving children's performance on the day-night Stroop task even when it is uninformative and provides no encouragement. One interpretation is that differences in the efficacy of delays across box-search and day-night Stroop is driven by differences in task demands such as response set effects (Diamond et al., 2002), semantic interference (Simpson and Riggs, 2005), response prepotency (Simpson, Upson, & Carroll, 2017), and the visibility of proponent information.

General Discussion

Study 1 investigated whether box-search reminders provided immediately before children could respond (calling attention to the cue by tapping it) yielded more benefits to children's inhibitory control than additional instructions provided during the pre-task phase. We predicted that in-the-moment reminders should drive more improvement in 3-year-olds' inhibitory control relative to additional instructions provided at the outset of the task because reminders that are present immediately before children respond should be more likely to aid young children's

engagement of reactive control. Instead, we found no differences between reminder conditions, suggesting that reminders are most beneficial in box-search when they are provided in combination (as in Barker & Munakata, 2015). Joint benefits may indicate the importance of multiple sources of support. Future work could explore whether strengthening one or both kinds of reminders (by given extended instructional sessions at practice, or making in-the-moment reminders more salient) yields further benefits to inhibitory control.

In Study 2, we tested whether delays improve children's performance on the day-night Stroop task, and whether or not previous work attributing the benefits of delays could instead be explained by other factors. We hypothesized that it was not the delays that benefited children, but the task-relevant content of the delaying ditties that may have encouraged children to engage control. Contrary to our hypothesis, we found that the delay condition yielded a benefit when compared to the no-delay condition, consistent with other findings from day-night Stroop (Diamond & Amso, 2002; Ling, Wong, & Diamond, 2016). Future work could explore whether box-search performance similarly benefits from delays when task demands more closely match day-night Stroop (e.g., by including additional sources of conflict such as semantic interference and response set effects).

Although our study did not aim to tease apart the inhibitory control accounts used to explain the benefits of delays, our results from the day-night Stroop task could be consistent with either the active computation or passive dissipation view. In support of the active computation account, it could be argued that the delaying ditty allowed time for children to resolve additional sources of conflict in day-night Stroop and actively compute the correct answer. On the other hand, one could assert that the delaying ditty allowed time for the incorrect prepotent response to fade, in favor of the passive dissipation view. When children were presented with a stimulus

card, for example a sun, the prepotent response “day” competes with the correct response “night” within a race model. The experimenter-imposed delay allows time for the incorrect prepotent response (day) to fade, before the child responds with the correct response (night). Although it is clear an experimenter-imposed delay benefited children's performance on the task, it is impossible to know what children were thinking about during the delay period.

An important direction for future work is understanding why experimenter-imposed delays may benefit child performance on the day-night Stroop task, but not on the box-search task. While children generally perform at ceiling on the box-search task by age 4, the day-night Stroop task is particularly challenging for children of the same age. Delays have been shown to help in more complex inhibitory tasks in several studies. For example, in counter-factual reasoning tasks, 3- and 4-year-olds indicated the correct counterfactual location more often when a delay was introduced before they could respond (Beck et al., 2011).

Semantic Interference and Response Set Effects

One explanation for why day-night Stroop is more difficult for children than box-search is that the task includes additional sources of conflict that are not present in simple go/no-go inhibitory tasks such as box-search. The first source of additional conflict is semantic competition across stimuli. Children show better inhibitory control in versions of day-night Stroop where the instructed target responses (‘dog’ and ‘pig’) is unrelated to the pictures of night and day, relative to the standard day-night Stroop condition (Diamond et al., 2002). In the standard version of day-night Stroop, stimuli activate pre-existing links to their associates (e.g., day → night; night → day) and the activated associates can interfere with the retrieval of the target word. Dual activation of the distractor term caused by its depiction and its close semantic

association with the target response enhances its salience to a level exceeding young children's ability to resist its interference. These response set effects likely make the day-night Stroop task more difficult for young children than simple go/no-go tasks that do not involve semantic interference.

Additionally, the day-night Stroop task results in heightened allocation of attentional resources to both words in the response set. Response set effects can be distinguished from semantic interference: for example, if children are told to respond to the set pig:hat/hat:pig, they experience response set conflict, but not semantic conflict, as hats are not semantically related to pigs. When response set effects are present, both responses are primed, making them more likely to interfere with each other since they are relatively equal in activation levels. Simpson and Riggs (2005a, Experiment 1) attempted to discriminate between semantic competition and response set effects. In one condition of their experiment, preschoolers were instructed to say 'book' in response to a picture of a car and 'car' in response to a picture of a book. These stimuli are semantically unrelated, but members of the same response set. In a second condition, the cards maintained a semantic relationship ('yellow' in response to a black card and 'green' in response to a white card) but eliminated the response set effect. In the control condition, the responses and stimuli were distinct and were semantically unrelated (sun: 'pig', moon: 'dog'). Performance in the response set and semantic competition conditions did not significantly differ from each other; however, performance in both conditions was significantly worse than in the control condition. This suggests that semantic competition and response set effects may only alter performance when combined. Experimenter-imposed delays may be more effective at reducing the demands on children's inhibitory control in tasks that include additional sources of conflict.

Response Prepotency

Another distinction between the day-night Stroop and box-search task that may cause differences in difficulty relates to how children respond in each task (physically, as in box-search, versus orally, as in day-night Stroop). One study has found young children make more errors in tasks with response set conflict when they are asked to respond verbally (e.g., say 'cup' when shown an image of a phone, say 'phone' when shown a cup) than when they are told to respond with a non-prepotent action (e.g., lift a cup to their ear when shown a phone, put a phone to their mouth when shown a cup) (Simpson, Upson, & Carroll, 2017). This finding suggests that the prepotent association between stimulus object and its name (e.g., between an image of a box and 'box') is greater than the strength of association between a stimulus object and its action (e.g., between an image of a box and the desire to open it). These findings suggest day-night Stroop may be more difficult for children because unlike box-search, (1) task stimuli and their responses are associated in day-night Stroop, and (2) children must make verbal responses. In combination, these conditions result in high levels of prepotency. It is possible that imposing delays in the day-night Stroop task improve children's performance by reducing this prepotency.

Visibility of Prepotent Information

An additional source of difficulty that is present in day-night Stroop task, but not in the box-search task is the visibility of prepotent information. In versions of box-search which included a delay but no reminders, the prepotent stimulus (the box) was revealed, then covered during the delay. (This served to hide cue placement after the delay so that children did not observe a reminder of the cue's presence.) In day-night Stroop, the stimulus card was present across the delay period; the experimenter continued to display the card to the child while singing

a ditty. It is possible that delays may be effective only when they are coincident with presentation of the stimulus. Making the card visible across the delay period may help children to discard an initial prepotent incorrect response, and prepare a controlled correct response.

Conclusion

These findings refine our understanding of interventions used improve children's inhibitory control by showing that the efficacy of interventions may vary across tasks, ages, and contexts. An important direction for future work is to further specify the mechanisms that support inhibitory control, and to evaluate how engagement of control changes as children get older. Considering the long-term outcomes associated with young children's inhibitory control, gaining a deeper understanding of this topic remains of great interest.

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