Improving Children's Inhibitory Control: Effects of Prior Task Instructions versus in-the-Moment Reminders

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Improving Children’s Inhibitory Control: Effects of Prior Task Instructions versus in-the-Moment Reminders

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Abstract

Young children are notorious for being inadequate at stopping their automatic actions during tasks that require inhibition (Munakata et al., 2011). The mechanism by which we are able to inhibit those automatic actions is regulated by cognitive control, which is a set of processes that allow us to maintain goal-relevant behavior over the course of a given task. Previous research has established that there is a marked transition during childhood in the form of cognitive control that is deployed to aid during a given task (Chatham, Frank, & Munakata, 2009). Younger children are more in-the-moment thinkers while older children are able to anticipate a prompt and can therefore prepare an answer. One particular study looking children’s cognitive control was constructed to assess which type of rule reminder during a task helped younger children to perform successfully throughout a task (Barker & Munakata, in prep). This study found that cue-highlighting reminders throughout the task helped younger children with their performance.

The present study seeks to investigate which category of reminder during a box-search task is most helpful to 3-4.5 year olds in inhibiting their automatic reactions, which is an extension of the Barker & Munakata task. Our findings indicate that children did worse in go-trial tasks than expected across all conditions. In the no-go trial tasks, which are designed to test inhibitory control, in contrast to our hypothesis, children performed worse in the reactive reminder condition than the proactive reminder condition. These results create interesting questions that can lead us to further research.
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Children are notoriously inadequate at stopping themselves from carrying out impulsive, automatic actions. For example, when a child sees their mom pull a fresh batch of cookies right out of the oven, their impulsive reaction is to reach right out to grab a cookie. However, the child must keep in mind that the cookie is still very hot and they should wait for it to cool before they can have their cookie (Munakata & Yerys, 2001).

To inhibit automatic actions, children rely on cognitive control, a set of mental processes that aid in planning actions and coordinating behaviors (Barber & Carter, 2005). These behaviors include inhibitory control, mental set shifting, and the maintenance and updating of goal-relevant information (also known as executive functions (Blair & Razza 2007; Diamond 2012). Therefore, cognitive control is necessary for remembering that the cookie is too hot, creating the goal of not reaching out for it until it is cool, and helping to inhibit the impulse to grab it anyway.

Cognitive control develops gradually across childhood (Chatham, Frank, & Munakata 2009). For example, in the day-night Stroop test, a standard measure of inhibitory control, participants are shown either a card with a sun or a card with a moon and stars, and are instructed to respond with the word “night” when the daytime image is presented, and “day” when the nighttime image is presented. Young children (3 to 4-year-olds) struggle to inhibit their natural tendency to say
the word that corresponds with what they see on the card (i.e., “day” for the sun card and “night” for the moon card), in order to say the opposite response, which is appropriate given the task instructions (Gerstadt, Hong, Diamond 1994).

Performance on day-night Stroop and other inhibitory control tasks improves with age (Gerstadt, Hong, Diamond 1994; Carver, Livesey, & Charles 2001).

One explanation for why young children struggle to inhibit automatic actions is that they employ cognitive control in a qualitatively different way than adults. Young children engage cognitive control *reactively*, by responding to stimuli in-the-moment, as they appear in the environment (Chatham, Frank, & Munakata 2009; Chatham, Snyder, & Munakata 2013). By contrast, older children typically exhibit a more *proactive* form of cognitive control, in which they anticipate that a prompt will occur, and prepare an appropriate response prior to the prompt. Across childhood, children transition from a predominantly *reactive* form of control to a predominantly *proactive* form of control. By age 8, children begin to recruit more adult-like, proactive response patterns in tasks where responses can be planned (Chatham, Frank, Munakata 2009; Chatham, Snyder, & Munakata 2013).

Recent evidence suggests that young children’s reactive control can be improved when they are given reminders in the moment before they need to respond. In a recent study on inhibitory control in 3-4-year-olds (Barker & Munakata, under revision), children’s inhibitory control was tested using a go/no-go task in which participants had to respond when presented with one cue (by opening a box to find stickers) and withhold the tendency to respond when presented with a different cue (leaving the box closed) (Figure 1). During this task, children have a
strong tendency to want to reach automatically to open the boxes to find stickers. No-go trials serve as a measure of inhibitory control because children must maintain task rules to inhibit this prepotent response and stop themselves from reaching when given no-go cues. The study tested whether children’s inhibitory control was more likely to be improved by delays, consistent with a passive dissipation account (in which a prepotent response reaches a “response threshold” before a correct response does), or reminders, consistent with a reactive control account (an in-the-moment reminder of the target cues). Performance was compared across four conditions: no delay + cue reminder, delay + cue reminder, no delay + no cue reminder, and delay + no cue reminder. In the Delay conditions, the experimenter revealed the box and after waited ~2 seconds, 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 Reminder conditions, children heard an additional verbal reminder of the instructions and saw the experimenter point to or place the cue on the box at the beginning of the trial. In No Reminder conditions, children received standard instructions, and did not see the experimenter point to
or place the cue. Reminders improved participants’ accuracy on no-go trials regardless of whether or not delays were imposed by the experimenter, suggesting that task reminders, rather than delays, improve children’s inhibitory control.

Although the study revealed that task reminders can be used to improve young children’s inhibitory control, it is not clear whether children’s performance was improved in Reminders conditions because of additional instructions provided at the beginning of the task, or because of physical reminders provided during each trial. This is a crucial differentiation to make because additional instructions at the outset of a task are considered to be a proactive reminder while the physical reminders during each trial are considered to be a reactive reminder. Therefore, it is beneficial to tease these conditions apart in order to see if, in fact, a reactive reminder is more beneficial for a reactive child.

In our current study, we sought to tease apart the effects of additional reminders and cue highlighting on young children’s (ages 3 to 4.5 years) performance in a computerized version of the box search no-go task. We predicted that in-the-moment cue highlighting would be more beneficial to young children’s inhibitory control than additional instructions at the outset of the task, since children in this age range should be more likely to rely on reactive, in-the-moment forms of control.

**Methods**

**Participants**
Seventy-six children participated in the study \(M_{\text{age}} = 3.78 \text{ years}; \text{range} = (3-4.5 \text{ years}); \text{males} = 57\), out of a projected total of 90. Participants were randomly
assigned to one of three conditions (target $N = 30$ per condition): control, additional instructions, or highlighted cues. Half of the participants in each condition ($N = 15$) were recruited from a database of families who had volunteered to participate in research, and completed the task in a standard laboratory setting. The remaining half were recruited from among visitors to the Children’s Museum of Denver in Denver, CO as part of a Living Laboratory collaboration. Participants in the museum were recruited through signs and parental inquiries about their child participating in a scientific research project. Participants who did not speak English as their first language were excluded from participation. 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.

**Design and Procedure**

Children were randomly assigned to one of three conditions: a control condition, an additional reminder condition, or a cue-highlighting condition. Children in each condition completed two computerized, touchscreen-based tasks programmed in ePrime 2.0. Children completed a simple reaction time task before moving on to the inhibitory control task in order to establish baseline reaction time as well as familiarity with the touchscreen interface. Task order was fixed across conditions. Children completed the inhibitory control box search task for four minutes, in order to conform to data collection constraints imposed by museum data collection. Go and no-go trials were presented in random order. To increase the prepotency of the go response, go trials were presented more frequently, such that
two-thirds of programmed trials were go trials, and 1/3 of trials were no-go trials.

Because this task was developed to test a wide age range of subjects, it also included an adaptive component: each participant’s go-trial response window was set to the 70th percentile of ongoing correct go RTs, calculated over the last 10 trials; after each missed go trial, 250ms were added to the adaptive deadline.

**Reaction time task.** In this task, children saw a set of black boxes presented on the computer screen. Children were instructed to look at black boxes on the screen while holding down the keyboard spacebar. At intervals, a target box on the screen turned red. When the red target box appeared, children were instructed to release the spacebar and press the box as quickly as possible, using the same hand that had been previously holding down the spacebar. After the child tapped the red target box, the box color changed back to black. At this point, the child was instructed to return his or her finger to the spacebar. Each child first completed a four trial practice round. During practice trials, the target box alternated between two 7.5 centimeters by 4.5 centimeters boxes located centrally on the screen (4.7 centimeters from the screen edge). Children received feedback during the practice trials to let them know that they were performing correctly and to keep them motivated during the task. After completing practice, children completed 16 test trials. During test trials, target boxes appeared in one of eight locations spaced evenly around the perimeter of the screen, located at 2.1 centimeters distance from the screen edge. During test trials, children received auditory feedback (a neutral
clicking sound) for all correct responses. This task provided a baseline measure of processing speed reaction times.

**Inhibitory control task.** Following the reaction time task, children completed a computerized go/no-go inhibitory control task. Children were randomly assigned to one of three conditions: a control condition, a cue-highlighting condition, or an additional instructions condition. In each inhibitory condition, children saw eight doors on the perimeter of the screen. The participant was instructed to hold down the spacebar until one of the doors opened, revealing a box. Participants were instructed, “You should tap the box with the blue diamond on the front because they have puppies inside! But don’t tap the box with the red star on the front because they don’t have puppies inside.” Each child played the inhibitory control task for four minutes. During this task, the trial would not begin until the child held down the spacebar (as opposed to just tapping it briefly). This was done to ensure that all children began reaching from a common starting point at an equal distance away from the screen, which produced standardized reaction time measurements. Importantly, the task conditions differed in the instructions provided and whether or not the cues were highlighted.

**Control Condition**
In the control condition, children were read the standard task instructions. Go and no-go trials (blue diamonds and red stars, respectively) were presented in random order without cue-highlighting.

**Cue Highlighting Condition**

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1 Auditory feedback was added after the first 20 subjects were run.
In the cue highlight condition, the participant received the same, standard instructions as in the control condition. However on each test trial, the cue shape (either a red star or a blue diamond) was outlined with a .2 mm yellow stripe. Additionally, as the box was revealed, an animated finger pointed down to the shape on the box. There was no delay between the opening of the door and the presentation of the cue. This manipulation was intended to direct participants’ attention to the shape at the time the box was revealed (Figure 2).

**Figure 2.** Depiction of cue-highlighting, a yellow outline around the cue as well as animated finger that points to the cue. Representations of a single go trial (A) and a single no-go trial (B) in the cue-highlighting condition

**Additional Instructions Condition**

In this condition, the experimenter explained the task instructions twice as opposed to the control and cue highlight conditions in which participants were only exposed to the instructions once. After the initial explanation of go and no-go rules (which replicated the standard instructions in the first two conditions), the experimenter provided the additional instructions: “Remember, tap the boxes with the blue diamonds on the front, because they have puppies inside! But don’t tap the boxes with the red stars, because they don’t have puppies inside.” Test trials
IMPROVING CHILDREN'S INHIBITORY CONTROL

Results

The present findings are based on preliminary data collection (Control N = 31, Cue Highlight = 29, Additional Instructions = 16).

Go Trial Performance

On average, children completed 64% percent of go-trials correctly (MControl = 69%; MCueHL = 58%; MInstruc = 68%). Older children showed higher accuracy in go-trials than younger children (F(1,47) = 4.26; p < .05). There were no differences in go-trial accuracy across the two testing locations, and the presence of auditory feedback during reaction time trials (which was added after 31 subjects) did not affect performance in inhibitory control task go (p > .3) or no-go trials (p > .9). We therefore report combined results across participants who received auditory feedback in RT trials and those who did not. There were no differences in go-trial performance between the control, cue highlight, and additional instructions conditions, controlling for age (p’s > .18).
Figure 3: Go-trial accuracy, by condition. There were no significance differences in go trial accuracy across conditions. Errors bars on graph included to illustrate variance in means and standard deviation away from the mean.

No-Go Trial Performance

Children showed high accuracy in no-go trial accuracy across conditions (MControl = 87%; MCueHL = 81%; MInstruc = 97%). There was no effect of age (p > .3) or experimental location (p > .6) on children’s no-go trial performance. In contrast to our prediction, children in the cue highlight condition showed worse accuracy on no-go trials compared to children in the control condition (F(1, 48) = 4.40; p < .05) and marginally worse performance than children in the additional instructions condition (F(1, 48) = 3.76; p < .06), controlling for age. Children in the additional instructions condition (p > .2) did not show statistically different no-go
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trial performance from children in the control condition.

Figure 4: Children in the cue highlight condition performed with worse accuracy on the no-go trials, compared to children in the original Barker & Munakata (in prep) study.

Discussion

The present study attempted to tease apart the effects of different reminders (cue highlighting versus additional instructions) on inhibitory control during a box search task. In contrast to our predictions, we found that on trials that require inhibitory control (no-go trials), younger and more reactive children (3-4.5 year olds) performed worse when given a reactive reminder (highlight the cue in the moment) as opposed to a proactive reminder (a set of additional instructions at the outset of the task).

These preliminary results are intriguing, however they arrive with some limitations. First, data collection is currently incomplete, so the present results are
under-powered. The present trends may not persist when all data has been collected. Future directions for this study would begin with additional running of subjects in all conditions.

Across conditions, children showed low go-trial accuracy, which may have impacted our ability to find fine-grained condition-level differences in no-go trials; if children did not form a prepotent tendency to go on go-trials, they may have had a weaker tendency to go on no-go trials. Go-trial performance in this study was lower than go-trial accuracies reported in studies using the physical box search apparatus (e.g., 98% accuracy in Simpson et al., 2012, and 98% accuracy in Barker & Munakata, under revision). One explanation is that children found rewards in the computerized version of the task less salient: whereas children received a physical reward (a sticker) in the physical version of the task, only auditory feedback (the sound of a puppy barking) was provided in the computerized task. A future direction regarding this limitation is to pursue to procedural change in which we can identify if there is a difference between the saliency of the rewards for the participants.

An additional future direction for this project might include looking at social factors between this current study and the one that preceded it. Identifying if there is a difference between social and physical rewards and reminders vs. rewards and reminders given via computer screen would be a beneficial direction for this study which might uncover subtleties in learning that were not uncovered in this current study. A study investigating if and why cue information is most important when it is provided in a social (rather than computerized) task context may be important for
identifying children’s motivation, effort, and attention which would be an important contribution of this future direction (Locke & Braver, 2008).

Another limitation could be the added monitoring component in the computerized version versus the physical version. If the participant missed the cue or were late in touching the screen, they may have produced a lower accuracy than in the physical version where they did not have to monitor for the randomized location of the cue presentation. Another future direction for this study would be a manipulation of the procedure to assess accuracy in monitoring between a randomized stimulus placement and a more predictable placement that existed in the physical version of this task. However, in previous research, children performed better on a switching task when given in-the-moment cue reminders that were relevant to the given task, meaning that the reminders were not distracting, instead were helpful to participants (Chevalier et al, 2011). Therefore, it would be beneficial to investigate the inconsistent findings in these studies.

Given that there were no differences in go-trial accuracy between conditions, it is difficult to explain why children in the cue highlight condition made significantly more errors in no-go trials. One explanation is that additional cue information in cue highlight trials (e.g., the moving finger and yellow outline) distracted children, resulting in more errors. An additional study would analyze this differentiation and investigate which actually helps performance.

Overall, the present study gave valuable insight into the contribution of reminders in a child’s performance during an inhibition task. However, it is very
beneficial to pursue future directions in order to further assess our results and potentially adjust procedure protocol in order to further investigate our hypothesis.
References


