When Do Imposed Delays Help Children’s Inhibitory Control? Effects of Stimulus Visibility in Day-Night Stroop

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When Do Imposed Delays Help Children's Inhibitory Control? Effects of Stimulus Visibility in Day-Night Stroop

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Abstract

Young children show limitations in inhibitory control, specifically having significant difficulty resisting automatic or impulsive actions. Imposing a delay before children can act has been shown to improve children’s performance on some inhibitory control tasks but not others. In a Stroop task, where children are instructed to say ‘day’ when shown a picture of a moon and stars, and to say ‘night’ when shown a picture of a sun, experimenter-imposed delays have been shown to improve children’s performance. In contrast, in a box-search task, where children search for stickers in boxes on the basis of go-and no-go cues, experimenter-imposed delays have not been shown to improve performance in three-year-olds when de-confounded from other task-relevant reminders. This study investigated whether delays help when children can see the relevant stimulus during the delay (as in prior day-night Stroop studies, but not in box-search studies), which may allow them to formulate a correct, non-prepotent response. 3.5 to 4.99 year-old children (N=80 out of a planned 105) completed one of three day-night Stroop conditions in a museum environment: a Control No Delay condition, a Visible-Delay condition, in which the stimulus card was visible across the delay period, and an Obscured-Delay condition, where the card was briefly shown to the child, then obscured across the delay. Performance was similar across all three conditions, suggesting that benefits from delays on children’s inhibitory control may be specific to quiet, non-distracting environments like a controlled laboratory. Future work should test these same three conditions to investigate if delays help when children can see the stimulus during the delay in a controlled lab environment.

Keywords: cognitive development, inhibitory control, environmental cues
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Young children often exhibit significant difficulty resisting automatic actions. For example, when a small dog approaches a child, the child’s automatic reaction might be to bend down and pet the dog. To avoid this automatic impulse, a child must use inhibitory control and remember that some dogs are unfriendly and may even bite. Three-year-olds have a challenging time avoiding impulsive actions even when they have the cognitive ability to learn the rules required to control their responses (Dowsett & Livesey, 2000). This is true for both motor and attention responses, specifically in suppressing an automatic response when it is no longer appropriate according to the rules of the task (Carlson & Wang, 2007).

The ability to overcome a dominant and automatic response in favor of a controlled action requires children to engage the mental processes that aid in planning and coordinating actions and behaviors (Barber & Carter, 2005). The higher order cognitive processes that allow individuals to overcome habits to achieve goals are known as executive functions. Executive functions allow individuals to maintain and update task goals and actions in response to changes in the environment, and to flexibly shift between tasks or mental states (Miyake et al., 2000; Miyake & Friedman, 2012). Executive functions critically underlie inhibitory control, the ability to resist automatic, or prepotent impulses in favor of a controlled, goal-relevant response (Barber & Carter, 2005; Botvinick et al., 2001). In the previous example, children must use inhibitory
control to keep in mind that dogs can bite or growl, and inhibit their automatic response to pet
the dog unless the child has asked the dog owner for permission.

Understanding how inhibitory control affects children’s long-term outcomes has been of great
importance in recent years. Childhood inhibitory control predicts the academic success of
individuals later in life (Best, Miller, & Naglieri, 2011). In addition to academic success, a past
study found that early inhibitory control led to lower internalizing behaviors, such as symptoms
of depression and anxiety, as well as higher social skills (Rhoades et al., 2009). Inhibitory
control has also been shown to contribute to the maintenance and development of healthy eating
habits, physical activity, cognitive and psychosocial well-being, and weight-related outcomes
(Anzman-Frasca, Francis & Birch, 2015).

Given the relationship between early inhibitory control and later life outcomes, developing a
better understanding of interventions aimed at supporting childhood inhibition is of great
importance. Additionally, interventions could benefit clinical populations who struggle to engage
in inhibitory control throughout their lifespan. Cognitive training programs in school-aged
children with ADHD have shown to significantly improve response inhibition, sustained
attention, executive function, and academic performance (Halperin, Bédard, & Curchack-Lichtin,
2012). Additionally, interventions targeting improvements in attention and executive function in
typically developing pre-school children have shown to improve inhibitory control, academic
performance and IQ (Halperin, Bédard, & Curchack-Lichtin, 2012). Despite this, not all
interventions designed to improve inhibitory control and executive function in young children
have shown benefits. In one study, for example, inhibitory training did not transfer to a non-
trained inhibitory task; that is, participants receiving inhibitory control training did not differ
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from the control group on a non-training inhibitory task (Thorell et al., 2009). It is unclear why some interventions have worked and others have not. Understanding why this is remains of great importance to the field.

While interventions have been shown to improve inhibitory control and academic success in pre-school children, these children appeared to have significant difficulty on other tasks that required inhibitory control but improved when an experimenter-imposed delay was introduced (Carlson & Wang, 2007). For example, in the day-night Stroop task (Figure 1(a)), children are told to say ‘day’ when shown a card with a moon and stars on it, and ‘night’ when shown a card with a sun on it (Gerstadt, Hong, & Diamond, 1994). Four-year-olds frequently made inhibitory errors on the task (e.g., by saying ‘day’ in response to a sun card) but improved when an experimenter sang a short ditty (i.e., “Think about the answer, don’t tell me) after showing each card, delaying the child’s response (Diamond, Kirkham & Amso, 2002; Ling, Wong & Diamond, 2016). These improvements persisted even when the ditty did not include information about the task or the cue (i.e., “La-la-la-la-la-la-la-la”) (Barker, Roche & Munakata, in prep).

However, experimenter-imposed delays do not always benefit inhibitory control performance. In the box-search task (Figure 2(b)), three-year-olds are instructed to open boxes with affixed ‘go’ cues to find stickers and leave boxes with ‘no-go’ cues shut. In this task, delays have not been shown to improve performance when de-confounded from other task-relevant reminders (Barker & Munakata, 2015).
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Figure 1: a) Day-night Stroop task: Participants are instructed to say “day” when shown a picture of a moon and stars, and “night” when shown a picture of a sun. b) Box-search task: Participants are instructed to open boxes with ‘go’ cues on the lids of the boxes to find stickers and to leave boxes with ‘no-go’ cues and no stickers inside shut (Simpson & Riggs, 2007).

One key question is why experimenter-imposed delays appear to support child inhibitory control in some inhibitory control tasks (e.g., the day-night Stroop task), but not in others (e.g., box-search tasks when delays are de-confounded from other task reminders). One explanation could relate to the visibility of the stimulus object across the delay period, which varies across the two tasks. In classic box-search delay manipulations, the box was visible across the entire delay period, and children did well under this condition. In newer manipulations (Barker & Munakata, 2015), the box was obscured across the delay period and children performed poorly. This difference in obscurity of the box raises the possible explanation that delays are only
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effective when children can view the stimulus box across the delay period. This explanation could also explain positive benefits of delays that have been observed in day-night Stroop, where the stimulus card is typically visible across the ditty-delay period (Simpson, Upson, & Caroll, 2017).

Building on these findings and ideas, the current study tests effects of stimulus-visibility in day-night Stroop. Two theoretical accounts suggest that making the day-night stimulus card visible across the delay period could help children ignore their automatic response and formulate a correct response. One reason why interventions focused on experimenter-imposed delays show promise may be due to the active computation or goal orientation account. That is, delays provide children opportunities to think about the correct response or engage in goal-oriented processes in order to override prepotent responses (Barker & Munakata, 2015; Gerstadt et al., 1994). Based on an active computation or goal orientation account, children who can look at the stimulus card across the delay period may be more likely to reflect on the task rules, which activates goal relevant representations or support goal-oriented processing during the delay. The passive dissipation theories have also attempted to account for why some interventions have shown promise while others have not. This account states that incorrect automatic responses compete with controlled correct responses (Simpson et al, 2012). This occurs when the incorrect automatic response reaches the response threshold first, then passively dissipates, allowing for the correct response to emerge. Having the stimulus visible across the delay may allow time for the incorrect automatic or prepotent response to fade, representing the passive dissipation account. In contrast, revealing the stimulus, obscuring it, and then revealing it again may reactivate the prepotent response following the delay, not allowing the correct response to emerge.
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To test how the visibility of stimulus information across the delay period affects child performance in day-night Stroop, I tested three experimental conditions: a control condition, where no delay was imposed; a standard visible-stimulus delay condition, where the experimenter showed the child the stimulus card while singing the delay-ditty; and a novel delay condition, where the experimenter briefly obscured the stimulus card while singing the ditty. I hypothesized that children would perform better in the standard Visible-Delay condition relative to the Obscured-Delay condition and Control No Delay condition. Such a pattern would suggest that delays are only beneficial to children when the stimulus card is visible across the delay, either because the stimulus itself serves to remind children of what they should do when they are given time to think (consistent with active computation accounts) or because the re-introduction of the stimulus card after it is obscured initiates a renewed prepotent response (consistent with passive dissipation accounts).

Method

Three and four-year old children (N=128) were recruited at the Children’s Museum of Denver at Marsico Campus to complete the day-night Stroop task. Each child was randomly assigned to one of three experimental conditions upon recruitment.

All participants were native English speakers and were recruited as walk-by participants at the children’s museum, meaning they were approached by researchers while in the museum and were not recruited before that day. All participants received a small bottle of bubbles and stickers upon completion of the task. All sessions were videotaped, except in cases where parents did not consent to videotaping. Accuracy of child performance was hand-recorded for every participant.
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using a coding sheet after each trial (as in Simpson et al., 2012) and checked for accuracy using
the video recording.

Participants

I completed data collection for 128 children between the ages of 3.50 and 4.99 years (mean
age = 4.46; sample range = 3.50-4.99)\(^1\). A sample size of 35 subjects per condition was chosen
on the basis of sample size and effect-size estimates reported by Diamond, Kirkham, and Amso
(2002). Data collection is ongoing, and I present findings from a partial set of participants
(Control No Delay = 29; Visible-Delay N = 31; Obscured-Delay N = 20). An additional 48
children were excluded from the study after enrollment because they refused participation after
beginning the task (n=8); because they failed to pass practice or training trials (n = 37); because
of experimenter error (n = 1); and because of parent interference (n=2).

Materials

The task consisted of sixteen stimulus cards used in all three conditions. The cards were
rectangular shaped, measured 100 mm wide x 140 mm long, and were made of cardboard. Eight
of the cards were black and contained an image of a white moon and white stars. The other eight
cards were white and contained an image of one large, yellow sun. The back of each card was
brown. These materials replicate materials used in Diamond, Kirkham, and Amso (2002).

\(^1\) An additional thirty children completed the task who were younger than 3.50 years; these
children were excluded from the current study since they are outside the age range established in
prior work (Gerstadt et al., 1994; Ling et al., 2016).
Design and Procedure

Children were randomly assigned to one of three conditions: Control No Delay, Visible-Delay, and Obscured-Delay (Table 1). In each condition, children were instructed to say “day” when shown a card of a moon and stars and to say “night” when shown a card of a sun (Diamond, Kirkham & Amso, 2002). All participants first completed a practice phase in which instructions were given by the experimenter and children were tested on what response to give to each card. Children were told, “See this card? It has a moon on it. If you see a moon on the card, you should say “day”. Can you say “day” for me?” If the child said “day”, the experimenter would move on and say, “See this card? It has a sun on it. If there is a sun on the card, you should say “night”. Can you say “night” for me?” To pass this training phase, children had to respond correctly to one of the three practice trials. If a child gave an incorrect response to either card, the experimenter said, “oops, you should say “day/night” when you see that card”, and then repeated the instructions beginning with the rule that the child had erred on first, 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, as described below.

For the delay conditions, a wordless ditty was sung by the researcher (Barker, Roche & Munakata, in prep). To continue on to the test phase, children had to respond correctly to one of the three practice trials. Children were told one of three instruction sets, corresponding to their assigned condition, as described below:
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<table>
<thead>
<tr>
<th>Condition</th>
<th>Stimulus Visible During Delay Period?</th>
<th>Description of Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control No Delay</td>
<td>No</td>
<td>The researcher sang the ditty, then revealed the stimulus card to the child</td>
</tr>
<tr>
<td>Visible-Delay</td>
<td>Yes</td>
<td>The researcher revealed the card, then sang the ditty (with stimulus card visible) for ~3.5 s; after the ditty, the child was allowed to respond</td>
</tr>
<tr>
<td>Obscured-Delay</td>
<td>No</td>
<td>The researcher briefly showed the stimulus card to the child and then obscured the stimulus during the ditty. After the ditty, the researcher revealed the card for the child to respond.</td>
</tr>
</tbody>
</table>

Table 1: a) Three conditions in the day-night Stroop task: Control No Delay, Visible-Delay, and Obscured-Delay.

**Control No Delay condition.** (n = 29) In this condition, the experimenter sang the wordless ditty “La-la-la-la-la-la-la-la”, and then showed the child a card of either a sun or moon and stars. After the experimenter finished singing the ditty, the child could respond. Specifically, 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, and
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you’ll do the same thing you did before.” This condition acted as the control condition and had no delay, ensuring that the task was not influenced by the ditty itself.

**Visible-Delay condition.** (n = 31) In this condition, the experimenter sang the wordless ditty “La-la-la-la-la-la-la-la”, while simultaneously showing the child a card of either a sun or moon and stars. After the experimenter finished singing the ditty, the child could respond. Specifically, 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, and you’ll do the same thing you did before.” This condition was adopted from past work, and I hypothesized that children’s performance would improve in this condition due to the visibility of the stimulus during the delay.

**Obscured-Delay condition.** (n = 20) In this condition, the experimenter showed the child a card of either a sun or moon and stars on it, flipped the card over to hide the card, therefore obscuring the stimulus, and then sang the wordless ditty, “La-la-la-la-la-la-la-la.” After the experimenter finished singing the ditty, the card was revealed one last time to the child, allowing the child to respond. Specifically, children were told, “We are going to try some more cards, but now, before you tell me the answer, I’m going to hide the card, and sing a little song that goes like this: La-la-la-la-la-la-la-la, and you’ll do the same thing you did before.” This condition was created to specifically answer my research question, testing if the ditty improved performance only during the delay.

In all three conditions, the experimenter sat directly across from the child at a child-sized table. The table was set up on the second floor of the children’s museum, directly between two
popular exhibits. Participants were recruited as they and their parents walked past the table, and parents were asked whether they had a child in the appropriate age range. Siblings, friends, or by standers often stood to watch the task. Video recording started before the task began. During both the practice trials and test trials, the stimulus cards were presented to the child one at a time in a smooth, fluid manner. The deck of stimulus cards was held face down in the experimenter’s hand, ensuring the child did not see the stimulus until the experimenter turned the card over. This was consistent with past research (Diamond, Kirkham & Amso, 2002; Ling, Wong & Diamond, 2016).

After passing the training phase, condition-specific rules were reiterated one last time. Children were presented with sixteen subsequent trials of their assigned condition (i.e. Control No Delay condition, Visible-Delay condition, or Obscured-Delay condition). The cards were presented in a fixed pseudorandom order: sun (s; Trial 1), moon (m; Trial 2), m, s, s, m, s, m, m, s, s, m, s, m, m, s. On all trials, the correct response was the opposite of what the image on the card represented. No feedback was given during the testing phase. 

**Coding**

A trained coder manually recorded all participant responses during the task in the museum (n= 128), and also coded videos for participants (n=121). Videos for seven participants were not coded due to equipment malfunction (n=1) and lack of parent consent to record (n=6). Each participant’s first response was recorded, even if the child rapidly corrected their original answer,
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in line with previous research (Ling, Wong & Diamond, 2016). In the future, scores will be averaged across raters to form correct and incorrect scores for both day and night cards.

Results

To confirm random assignment yielded well-matched conditions, I tested for group differences in child age and gender, and found no significant variation (p’s > .20; Control No Delay: \( M_{age} = 4.46 \) years; Visible-Delay: \( M_{age} = 4.46 \); Obscured-Delay: \( M_{age} = 4.45 \)). I therefore excluded these covariates from subsequent group comparisons. Gender composition did not vary across the three conditions (\( \chi^2 (2) = 3.20, p > .2 \)).

Next, I tested whether delays yielded improvements in children’s day-night Stroop performance even when the stimulus card was obscured across the delay period. Unexpectedly, neither delay condition improved children’s performance relative to the Control No Delay condition (p’s >.3). Performance was similar across all three conditions (Control No Delay: \( M = 11.69 \); Visible-Delay: \( M = 11.55 \); Obscured-Delay: \( M = 11.45 \). (Fig. 1). I failed to replicate previous findings which have shown that experimenter imposed delays benefit children’s inhibitory control when the stimulus is visible across the delay period (Diamond, Kirkham & Amso, 2002; Barker, Roche & Munakata, in prep).

\[ \text{In a few instances, children responded “morning” instead of “day”. Because these responses are semantically similar, I counted these responses as correct. I could not find any discussion of how such responses were counted in the literature, so they were counted as correct for the purposes of this study.} \]
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Figure 1: Children’s performance was consistent across all three conditions.

Discussion

Past research has shown that delays sometimes support child inhibitory control. In certain conditions of the box-search task where delays did not seem to help, the stimulus was not always visible across the delay; but in day-night Stroop, where delays did seem to help, the stimulus was always visible across the delay (Diamond, Kirkham & Amso, 2002; Ling, Wong, & Diamond, 2016). The current study investigated the impact of stimulus visibility on three- and four-year-old children’s inhibitory control in the day-night Stroop task. I hypothesized that children would perform better in the standard Visible-Delay condition relative to the Control No Delay condition and the Obscured-Delay condition based on past box-search findings showing that when the box was obscured across the delay period, children performed poorly (Barker & Munakata, 2015). Although data collection was not completed in this study, my pattern of results suggested that the
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Visibility of the stimulus during the delay did not impact children’s performance and children’s overall performance was similar across all three conditions that I tested. That is, performance did not differ between a Control No Delay condition, a Visible-Delay condition in which the stimulus card was visible across the delay period, and an Obscured-Delay condition where the card was briefly shown to the child, then obscured across the delay period. I also failed to replicate a previous day-night Stroop finding that showed improvement in children’s inhibitory control when the stimulus was visible across the delay period, relative to a Control No Delay condition.

Due to my finding that delays did not seem to benefit children in the museum regardless of the delay condition, I determined that revealing the stimulus across the delay period may help in some situations, but not all situations. I collected my data in a naturalistic children’s museum environment, which was frequently loud and distracting for participants as the task was set up in a public area with a lot of foot traffic. I did not see delay-related improvements in child performance in this environment. However, in a controlled lab environment, free of noise and distraction, child performance may be improved due to their ability to think about the answer without external distraction (consistent with ‘active computation’ accounts). Based on an active computation account, due to the loud and distracting environment of the museum, children may be unable to use the delay period to actively compute the correct answer. From a passive dissipation account, the prepotent response may be reaching the threshold and dissipating, however, due to the distracting environment of the museum, the correct response may be unable to out compete the prepotent response and emerge. In a distracting environment, goal representation may be weaker and may not be competing as effectively with the prepotent
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response compared to in a non-distracting laboratory environment. Examining children’s inhibitory control in a real-world setting, different from past day-night Stroop work taking place in controlled lab environments, showed me that context may matter.

The question of whether stimulus visibility across a delay period matters is still valid and open for future investigation. Future work may aim to further explore inhibitory control accounts, specifically the active computation and passive dissipation accounts in a controlled laboratory environment, to examine potential benefits of experimenter-imposed delays. Researchers could investigate if children are able to use the delay period to actively compute the correct answer, supporting the active computation account and if children’s incorrect prepotent responses fade, allowing for a correct response to emerge, supporting the passive dissipation account. Using a distraction-free environment, researchers could explore these two accounts to examine if they contribute to improvements in day-night Stroop performance.

The difficulty of the task and presentation of the stimulus cards may have also contributed to my inability to confirm my hypothesis. My results showed a right skew, which displayed that more kids performed well on the task than I had expected. Attrition and the overall difficulty of the task itself may have impacted generalizability and may help explain why my results showed a right skew. This is a possible explanation for my not seeing effects across the three conditions. Additionally, the presentation of the card in the Obscured-Delay condition may have been distracting to the children who performed poorly on the task. In this condition, the researcher rotated her hand, flipping the stimulus card over to obscure the stimulus across the delay period. Children that were doing exceptionally well on the task may not have been distracted by the stimulus, however, those who failed the pre-test trials may have been very distracted by the
stimulus, resulting in their poor performance. Due to the uncertainty of this potentially distracting presentation, future studies may aim to address this going forward.

Although it is difficult to draw firm conclusions about why manipulations to obscure the stimulus did not affect child performance in this study, future investigations might benefit from testing similar condition manipulations in a controlled laboratory environment. If I were to continue to see no differences between stimulus-visible and stimulus-obscured conditions in laboratory conditions, I may investigate whether the stimulus manipulation used in the present study could be improved to make it less distracting. Future work using this condition may involve the researcher presenting the card to the child in a different manner. One example of how this may be done in future work is to place a paper flap over the card, and simply lift and lower the flap to reveal the stimulus to the child. Lifting and lowering this flap may be a less distracting presentation, as it would not involve physically rotating the card, allowing for the child to stay focused on what image is being presented to them.

Although I was able to observe children’s inhibitory control in a more naturalistic environment, the effects of delays on inhibitory control in a lab may not be transferrable to the real world. Certain aspects that work in a lab may not always work in a museum environment and vice versa. Ultimately, interventions may be context-specific and work in one context, but not work in another context.

**Conclusion**

These findings allow me to gain insight into the significance of inhibitory control interventions by showing that the efficacy of interventions may vary across contexts and tasks.
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Past findings suggest that experimenter-imposed delays may yield improvements in inhibitory control for four-year-olds in the more difficult day-night Stroop task; however, my results indicated that experimenter-imposed delays may not improve performance in naturalistic environments filled with noise and distraction. An important direction for future work is to test stimulus visibility across a delay period in a controlled laboratory environment and further specify the mechanisms that support inhibitory control. Considering long-term outcomes associated with young children’s inhibitory control remains of great interest.
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