Self-control Responding in Children with Developmental Delays: Analog Assessment of Subjective Value of High and Low Preferred Stimuli

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Abstract

Previous research suggests that both non-human animals and humans are likely to engage in impulsive responding when provided with opportunities to choose between responses that are correlated with smaller, sooner consequences and larger, later consequences. Much of the research that demonstrates this phenomenon has been conducted in analog settings and/or with hypothetical choices, and the generality of those findings remains unknown. In the current study, we assessed impulsive responding in four children with developmental disabilities by evaluating the conditions under which preferences might shift in the context of actual choice scenarios for established reinforcers. First, we demonstrated that (a) highly preferred (HP) and relatively less preferred (LP) stimuli both maintained task selection and (b) responding was allocated toward the task associated with the more highly preferred stimulus when both stimuli were concurrently available in the context of a concurrent-chain schedule. In Experiments 1 and 2, the delay to accessing the HP stimulus was systematically increased from 0 to 60 s (Experiment 1) and 60 to 240 s (Experiment 2) while the LP stimulus remained available immediately. All participants consistently chose to wait for the HP stimulus (i.e. engaged in self-control responding) in Experiment 1 and three out of four continued to wait for the HP stimulus when exposed to extended delay values in Experiment 2. In Experiment 3, we assessed the relationship between choice responding and the presentation for the concurrent choice arrangement by manipulating whether the choice opportunity was presented in the initial or terminal link of the chain (i.e., prior to or following task completion). Results demonstrated that the presentation of a delay prior to receipt of the task was associated with greater shifts in preference (i.e. less self-control responding) for three out of four participants. These findings are discussed in relation to prevailing models of self-control responding. Additional issues for consideration include the
stability of preference over time, the substitutability of reinforcers, and interventions to increase self-control responding.
Self-control Responding in Children with Developmental Delays: Analog Assessment of Subjective Value of High and Low Preferred Stimuli

Deficits in self-control are defining features of many common behavior problems (e.g., gambling, disruptive behavior disorders, parent adherence to behavioral interventions; Nevin, 1991). Mischel & Gilligan (1964) conceptualized self-control broadly as an individual’s ability to delay gratification. In the behavioral literature, self-control is commonly conceptualized as an individual’s propensity toward choosing a larger (and presumably more preferred) delayed reinforcer over a smaller, more immediate reinforcer in a concurrent-choice arrangement (Hoerger & Mace, 2006; Rachlin 1989; Rachlin & Green, 1972).

Studies with human and non-human animals consistently demonstrate that subjects generally prefer smaller amounts of reinforcement available immediately over larger amounts of reinforcement available after a longer delay (Jackson and Hackenberg, 1996; Logue, 1995; Navarick, 1996; Rachlin, 1995). In other words, both humans and non-humans exhibit a tendency toward impulsive responding. Specifically, Rachlin, Raineri, and Cross (1991) demonstrated that the subjective value of a reinforcer tends to decrease in a systematic fashion with increasing temporal delays to its receipt. These researchers provided participants with a series of hypothetical-choice scenarios between two concurrently available response options: one in which they earned a smaller amount of reinforcement (i.e., money) immediately and one in which they earned a larger amount of reinforcement after varied periods of delay. Participants tended to choose the larger amount of reinforcement when the delay intervals were relatively short. As these intervals increased, preference shifted to the more immediate option. By presenting participants with numerous choice arrangements, the current subjective value of the larger, delayed reinforcer could be calculated based on the point at which an individual shifted
his or her responding toward the more immediate reinforcement option. This *indifference point* suggests that the current subjective value of a larger reinforcer was degraded to a point equal to that of the smaller, more immediate reinforcer, a phenomenon commonly referred to as delay discounting (Critchfield & Kollins, 2001). The precise shape of the delay discounting function, or the degree to which reinforcer value is affected by delays, can be identified by comparing the points at which participants demonstrate indifference between two alternatives associated with varying delays. Collectively, these indifference points can be used within a quantitative model of delay discounting proposed by Mazur (1987) to estimate an individual’s sensitivity to delayed reinforcement:

\[ V = \frac{A}{1 + kd} \]

In this equation, \( V \) represents the current subjective value of the reinforcer, \( A \) represents the amount of the reinforcer, \( k \) represents a fitted parameter representing sensitivity to delay (the degree to which subjective value weakens with increasing delays for a specific individual), and \( D \) represents temporal delay to reinforcement. Using this equation, increasing delays to reinforcer delivery produce a negatively decelerating curve in current subjective value of the reinforcer. This finding is consistent with prior research demonstrating a preference for more immediate reinforcement among human and non-human subjects. The slope of this curve, represented by \( k \) in the equation, indicates the degree to which subjective value deteriorates with the introduction of delay for a particular individual.

The degree to which reinforcer value is discounted due to delay for a given individual is likely a function of learning history (Dixon et al., 1998; Ferster, 1953; Mazur and Logue, 1978), developmental level (Sonuga-Barke et al., 1992), and physiological factors (e.g., drug use; Giordano et al., 2002; ADHD status; Neef, 2005). Also, several studies have suggested that the
degree to which subjective value is discounted due to delay is directly associated with the severity of maladaptive behaviors commonly characterized as impulsive (Odum, Madden, Badger, & Bickel, 2000; Petry & Casarella, 1999). In other words, there may be a direct relationship between delay discounting and severity of clinical impairment.

Understanding individual differences in sensitivity to delayed reinforcement may have great significance for assessing and treating clinical problems associated with poor self-control. Unfortunately, most traditional clinical assessments rely on subjective, indirect measures of self-control that often focus on topographical features of the “impulsive” behavior and involve substantial inference regarding mediating cognitive processes. Operant laboratory-based assessments represent a viable approach to addressing these limitations, given their emphasis on functional and measurable aspects of self-control responding. Like traditional functional analyses, such assessments could illuminate relations between impulsive responding and environmental variables, and thus facilitate development of interventions matched to individual sensitivities (Critchfield & Kollins, 2001). For example, Dixon et al. (1998) demonstrated that individuals could be taught to exercise greater self-control using basic schedule manipulations. Three developmentally delayed adults were presented with choices between smaller, immediate reinforcers and larger, delayed reinforcers. Although these participants with developmental disabilities initially preferred smaller, immediate, reinforcers to concurrently available delayed reinforcers, all three participants demonstrated a shift in preference following the introduction of gradually increasing delays and distracting intervening activities during delay intervals.

It is important to note that the studies described above evaluated choices in the context of simple concurrent schedules of reinforcement. However, much of human behavior occurs in the context of complex reinforcement schedules. One such schedule that is particularly relevant to
research on self-control is the concurrent-chain schedule. A concurrent-chain schedule is a compound schedule in which a choice response in the initial link determines the schedule of reinforcement that will be available on the second link. Basic research on delay discounting using concurrent-chain schedules suggests that delays in the initial and terminal links of the schedule tend to be differentially associated with impulsive responding (Rachlin and Green, 1972; Davison, 1988). Traditionally, the schedule in place during the initial link is fixed and equal for both alternatives. Contingent on responding at the initial choice point (Choice X), a delay interval elapses prior to the presentation of the next choice arrangement (Choice Y). The stimuli available in Choice Y depend on the participant’s response at Choice X. An “impulsive” response at Choice X results in the concurrent arrangement of a smaller (or less preferred) stimulus at a relatively short delay and a larger (or more preferred) stimulus after a relatively longer delay. The alternative, “self-controlled” response at Choice X leads to a forced choice of the larger (or more highly valued) stimulus after the specified delay interval at Choice Y. Figure 1 shows a diagram of this standard self-control paradigm.

As delays in the initial length of a concurrent-chain schedule increase (equally for both alternatives), responding tends to be allocated toward the larger or more highly preferred stimulus despite relatively greater delays in the terminal link of the schedule. Thus, as the time between the initial choice response and the initiation of the differential delay increases, self-control responding is more likely. However, when overall delays (i.e., the sum of the delays in the initial and terminal links) are held constant, increasing the length of the initial link of the schedule tends to result in larger $k$ values (i.e., more impulsive responding) relative to increasing the length of the terminal link of the schedule. See Figure 2 for a diagram of this set of contingencies. Furthermore, in landmark studies on self-control responding conducted by
Mischel and colleagues (e.g., Mischel & Baker, 1976), participants maintained the option to alternate between schedules during delay intervals. In nonhuman animals, such arrangements have been demonstrated to result in decreased responding toward the larger, delayed stimulus (Logue & Pena-Correal, 1984). In essence, such choice formats present many repeated choices over time which increases the likelihood of impulsive responding as delays to the larger or more preferred stimulus increase.

The purpose of the current series of studies was to quantify sensitivity to delayed reinforcement among children with impulse-related disorders by applying the logic of delay discounting to real-life choice scenarios. In Experiment 1, participants were presented choices between stimuli at multiple/graded delay intervals. It was expected that dynamic changes in reinforcer preference would emerge as a function of increases in relative delay. In Experiment 2, participants were presented with similar choices between stimuli at delay intervals that were increased by a factor of four. In Experiment 3, participants were exposed to delay intervals in various components of the reinforcement schedule (i.e., in the initial and terminal link). In all experiments, the independent variable manipulation was intended to detect the variables affecting response allocation across choices.

**Method**

**Participants and Setting**

Participants included four children aged 4 to 7 years who were enrolled in university-affiliated programs providing early intervention or treatment of severe behavior disorders. A University human subjects review board approved all procedures and pseudonyms are used to protect that participants’ confidentiality. Brian was a 5 year old male diagnosed with Autism. Chris was a 4 year old male diagnosed with Adjustment Disorder with Disturbance of Conduct.
and Attention Deficit-Hyperactivity Disorder. Stewart was a 4 year old male diagnosed with Disorder of Infancy, Childhood, or Adolescence Not Otherwise Specified. Meg was a 7 year old female diagnosed with Adjustment Disorder with Disturbance of Conduct. Brian was served in an early intervention clinic where he was reported by staff to engage in emotional and disruptive behaviors when denied immediate access to preferred leisure items. Chris, Stewart, and Meg were referred for treatment of severe behavior disorders including emotional outbursts and noncompliance when denied immediate access to preferred items and activities. For Chris and Stewart, emotional outbursts consisted of negative vocalizations (e.g., crying, screaming), flopping on the floor, and throwing items. For Meg, emotional outbursts consisted of negative vocalizations and vigorous rocking back and forth. For all participants, noncompliance consisted of failure to comply with adult instructions within a reasonable time period (e.g., 5-10 seconds).

Thus, all participants were reported by parents and/or staff to engage in “impulsive” behavior that interfered with their daily functioning. All sessions took place in individualized treatment session rooms at the outpatient clinic, thus providing minimal distraction.

**Response Measurement, Interobserver Agreement, and Treatment Integrity**

All sessions of pre-assessment procedures consisted of 10 trials. All experimental assessment sessions consisted of 12 trials. Observers recorded which reinforcer was chosen for each trial by checking a column associated with each of the choice options during each of the phases described below.

For each trial, the observer recorded the level of prompting required for a) task selection and b) task completion. All participants engaged in independent task selection (i.e., without gestural or physical prompts) on 100% of experimental trials. If the task was not completed accurately within 5 s of initiation, gestural prompts (or verbal prompts in Meg’s case) were
provided. If the task was not completed within 3 s of a gestural/verbal prompt, a physical prompt was provided. This level of prompting was required on 3 experimental trials for Stewart and 2 experimental trials for Chris. Brian and Meg consistently responded correctly following gestural/verbal prompts.

Treatment integrity (the extent to which the experimenter implemented the correct procedure) was assessed by including data collection on the experimenter’s behavior. Specifically, secondary data collectors recorded whether the experimenter delivered the correct stimulus (the stimulus selected by the participants) after the correct delay. A correct stimulus delivery was defined as the correct stimulus delivered within 2 s of the intended delay. For example, when there was no delay, a correct stimulus delivery was recorded if the correct stimulus was delivered within 2 s of the occurrence of the selection. During the 30 s delay, a correct stimulus delivery was recorded if the correct stimulus was delivered between 28 s and 32 s after the occurrence of a selection. Correct stimulus delivery was recorded on 99% of trials for Brian, 100% of trials for Chris and Stewart, and 98% of trials for Meg. For both Brian and Meg, violations of treatment integrity were the result of technical difficulties such that the selected reinforcers (i.e., video game and video respectively) could not be accessed within 2 s of the intended delay. In no circumstance was access to the selected reinforcer delayed by more than 8 s.

A second observer simultaneously but independently collected data on participants’ task selection as well as treatment integrity for 100% of all sessions in Experiments 1 and 2. In Experiment 3, a second observer collected data for 100% of sessions for Chris, Stewart and Meg and 75% of sessions for Brian. For task selection, interobserver agreement was defined as both observers recording the same stimulus chosen on a given trial (i.e., checking the same column).
For treatment integrity, interobserver agreement was defined as both observers noting that the selected reinforcer was delivered within 2 s of the intended delay. Interobserver agreement was calculated for each session by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100%. Resulting percentages for both task selection and treatment integrity were 100% for all participants.

**Pre-assessment Procedures**

Prior to participating in delay exposure assessments, participants participated in the following pre-assessment procedures.

**Preference Assessment.** All participants were exposed to paired choice preference assessments (Fisher et al., 1992) to identify their relative preference for various edible items and activities. Both edible and non-edible items were included in these assessments to establish a hierarchy of preference for all potential reinforcers. Stimuli included in these assessments were identified via caregiver report of preferred items (RAISD; Fisher et al., 1996). Stimuli were randomly presented to participants in pairs until each stimulus had been paired with every other stimulus twice. At the beginning of each presentation, the therapist held both stimuli in front of the participant and provided a prompt to choose one. If the participant approached an item, he or she was permitted to consume the item (edible) or received 30 s of access to that item (non-edible) and the other item was removed. Once the participant had consumed the item or 30 s had elapsed, the stimulus was withdrawn and two different stimuli were presented in the same manner. Participants’ attempts to access both items simultaneously were blocked. If the participant did not approach either item within 5 s of presentation, the experimenter provided access to each item prior to repeating the trial. If the participant still did not approach either item, both stimuli were removed and a new trial initiated. To ensure familiarity with the stimuli,
participants were allowed to consume and/or access all of the items prior to the session. A hierarchy of preference was determined based on the percentage of trials in which each item was approached. A high-preference (HP) stimulus was defined as the stimulus approached during 80% or more of trials during the paired-choice assessment. Consistent with Roscoe et al. (1999), a low preference (LP) stimulus was defined as a stimulus approached in less than 25% of paired choice trials. For Meg, this criterion was adjusted after her least preferred reinforcers failed to maintain responding in a multiple schedule arrangement. Based on her own verbal report, she was no longer motivated to access these items. Hierarchies of preference are displayed in Figure 3 for Brian, Stewart, Chris, and Meg, respectively. Based on preference assessment data, the following items were selected as HP and LP stimuli for each of the participants: Playstation (HP) and Music (LP) for Brian; Gummy bears (HP) and ball (LP) for Stewart; Fruit Snacks (HP) and cars (LP) for Chris; Video (HP) and jelly beans (LP) for Meg.

**Multiple-schedule Baseline.** The purpose of this phase was to expose clients to the response-reinforcer contingency and to establish stable responding as a baseline for upcoming phases. The target response to be trained was selecting among identical tasks with the exception of different colors associated with the tasks. The purpose of the different colors was to arrange for schedule-correlated stimuli to facilitate discrimination between choices and their associated contingencies. To ensure that participants could accurately discriminate colors, they were asked to verbally identify the colors (e.g. “what color is this?) prior to each session. All subjects passed the color discrimination trials.

Tasks were selected individually for each participant based on their educational goals. Tasks included: completing greater/less than equations (Brian), tracing letters (Stewart and Chris), and reading sentences (Meg). For all participants, two identical tasks were presented on
distinct colors of paper in the choice arrangement. Each color was correlated with a different contingency: contingent access to the HP stimulus on a fixed-ratio FR-1 schedule (orange), contingent access to the LP stimulus on an FR-1 schedule (blue), and extinction (white). In each session, two of three different colors were present in front of the participant; the participant was presented with a choice between a task that produced a HP stimulus and a task that produced nothing (i.e., EXT) or a task that produced a LP stimulus and a task that produced nothing. The task options were placed on a table approximately 0.7 m in front of the participant and approximately 0.7 m apart, and a therapist provided the following instructions:

“Today you can earn some treats by choosing which task to do (experimenter pointed to the tasks). You will have 10 chances to earn treats. You can choose which treat you want by picking the task in front of that treat. Can you tell me how you get the treat you want? (The experimenter then waited for the child to respond correctly and repeat the instructions if necessary).”

Attempts to pick both tasks simultaneously were blocked. If the participant did not select either task within 5 s, the therapist initiated a least-to-most graduated prompting procedure. Thus, if the participant did not respond to a verbal prompt to choose a task after 5 s, the experimenter provided a model prompt. If another 5 s elapsed and the participant had not made a choice, the experimenter physically guided a response. The schedule for exposure to either reinforcement (HP or LP) or EXT alternated for each trial that an independent response did not occur. Contingent on task selection, the therapist stated, “You chose to work for (name of item)” or “you chose to work for nothing” and least-to-most graduated guidance was provided for task completion. Upon completion of the task (at any prompt level), (a) the participant received 30 s access to the HP or LP stimulus or (b) the experimenter waited 30 s and then a new trial began
(EXT), depending on which task was chosen. Sessions alternated in counterbalanced fashion during training: HP v. EXT and LP v. EXT.

Criterion for moving to the next phase included independent responding toward the HP and LP stimuli on at least 80% of trials for 2 consecutive sessions. All participants met criteria to move to the next phase within the minimum number of sessions possible (i.e., 2 consecutive sessions with independent responding toward the task associated with reinforcement). In other words, responding occurred almost exclusively toward the response option correlated with reinforcement in both the HP v. EXT condition and the LP v. EXT condition for all participants. (see Figure 4). Thus, prompts to select a task were removed while graduated prompts continued to be provided for task completion. Reinforcement was provided for task completion at any prompt level.

**Concurrent-schedule Baseline.** This baseline condition was designed to demonstrate that participants would choose the response that produced the HP stimulus when both response options (i.e., HP and LP stimuli) were concurrently available. Procedures were identical to the *Multiple-schedule Baseline* except the discriminative stimuli (colors) correlated with the HP and LP stimuli were presented concurrently in each session, and the color correlated with EXT was not present. That is, the responses correlated with the HP stimulus and the LP stimuli were in direct competition. Criteria for moving to the next phase included selection of the task associated with the HP stimulus on at least 80% of trials for two consecutive sessions. All participants chose to access the HP stimulus 90-100% of trials for all sessions in this condition (see Figure 4), demonstrating consistent preference for the selected HP reinforcer relative to the selected LP reinforcer.
Delay Sensitivity Assessment. This condition was designed to demonstrate that participants would choose the response that produced more immediate access to reinforcement when responses to each alternative resulted in access to the same reinforcer at varying delay intervals. Procedures were identical to the Multiple-schedule Baseline except the discriminative stimulus (color) correlated with the HP stimulus was present for both response options and a kitchen timer was present for the delayed response option. If the participant chose the immediate response option, he or she received immediate access to the HP reinforcer. If he or she chose the delayed response option, he or she received access to the HP reinforcer after a delay of 60 s (signaled by the kitchen timer). During all delays, minimal social attention was provided and access to preferred items and materials was restricted. All participants chose to complete the task associated with immediate access to reinforcement on 100% of trials. These data are available upon request.

Experiment 1

Delay Exposure Assessment

In this assessment, the participants’ responding was exposed to systematic increases in the delay to reinforcement for the HP stimulus while the LP stimulus continued to be provided immediately. At the beginning of the first experimental session, the researcher provided the following instructions:

Today you can earn some treats by choosing which task to do (experimenter points to the tasks). You will have 12 chances to earn treats. You can choose which treat you want by picking the task in front of that treat. Can you tell me how you get the treat you want? (The experimenter waits for the child to respond correctly and repeats the instructions if necessary). Sometimes you will be able to have the treat right now, but sometimes you
will have to wait. Before each choice, I will tell you which treat you can have right now and how long you will have to wait for the other one. If you choose to wait, I will set this timer to go off when you can have the treat.

Two task choices were presented to the participants in the same manner as in the Concurrent-schedule Baseline condition in that each task was correlated with either the HP stimulus or the LP stimulus. Responding toward the LP stimulus continued to result in immediate access to that stimulus whereas delivery of the HP was delayed by a specified interval (of which the child was informed prior to initiation of the trial). The delay interval was signaled by a kitchen timer which began immediately following task completion. Minimal social attention was provided and access to preferred items and materials was restricted during all delay intervals. Participants were exposed to the delays for the HP stimulus in the following sequence (repeated twice per session): 10 s, 30 s, 60 s, 60 s, 30 s, and 10 s.

Results and Discussion

Figure 5 shows results of Experiment 1 for Brian, Stewart, Chris, and Meg in panels 1, 2, 3, and 4 respectively. Proportion of responding for the HP stimulus is plotted on the y-axis and delay values are plotted on the x-axis for all graphs. At delay values ranging from 10 s to 60 s, three of the four participants (Brian, Stewart, and Meg) displayed exclusive responding towards their respective HP stimuli. Chris demonstrated nearly exclusive responding toward his HP stimulus with a shift in preference at a delay of 30 s on one trial. In sum, none of the subjects demonstrated a reliable shift in preference from their HP to their LP reinforcers at delays equal to or less than 60 s. Rather, they each emitted patterns of responding indicative of low $k$ values. That is, the HP stimulus maintained its subjective value even as delays to its receipt increased.
Obtained results were not consistent with participants’ referral concerns (deficits in self-control) or with previous research on delay fading during functional communication training (Hanley, Iwata, & Thompson, 2001; Fisher, Thompson, Hagopian, Bowman, & Krug, 2000) demonstrating decrements in functional communicative responses at delays larger than 30 s. Although the procedures are not directly analogous, there are no applied studies to date that provide guidance for selecting delay values during delay-discounting procedures. One exception is a study by Vollmer Borrero, Lalli, and Daniel (1999) that demonstrated high levels of self-control behavior (i.e., manding) at delay intervals between 10 s and 10 min in duration. However, this pattern of responding was demonstrated with only one individual and delay values were progressively increased based on prior self-control responding. Thus, given the dearth of research on delay intervals, it seemed reasonable to select these values based on the most closely related research available. When the selected delay values did not produce consistent shifts in response allocation, we hypothesized that the obtained results could have been due to 1) insufficient delay values (i.e. larger delay values might be associated with differential response allocation), 2) the timing of the delay interval (i.e., during the initial link or the terminal link of the concurrent chain), or 3) the manner in which the participants were exposed to the delays (e.g., ascending and descending delays during sessions vs. massed trials at each delay value). In Experiments 2 and 3, we evaluated these hypotheses by exposing participants to extended delay values and by alternating the timing of delay intervals respectively.

**Experiment 2**

**Extended Delay Exposure**

Procedures were identical to those in Experiment 1 with the exception that delay values were extended. Thus, participants were exposed to delays for the HP stimulus in the following
sequence (repeated twice): 60 s, 120 s, 240 s, 240 s, 120 s, and 60 s. In order to equate overall session time, regardless of the tasks selected, a procedure for controlling for overall reinforcement rate was instituted for Brian and Meg. Contingent on a response toward the LP stimulus, a post-reinforcement delay period (i.e., an inter-trial interval) equal to the delay value for the HP stimulus was initiated prior to presenting the next trial. Minimal social attention was provided and access to preferred items was restricted during all post-reinforcement delay intervals.

**Results and Discussion**

Figure 6 shows results of Experiment 2 for Brian, Chris, Stewart, and Meg, respectively. At delay values ranging from 60 s to 240 s, three of the four participants (Brian, Chris, and Meg) continued to display high levels of responding toward their respective HP stimuli. Brian continued to demonstrate exclusive responding toward his HP stimulus at all delay values. Chris and Meg demonstrated nearly exclusive responding toward their HP stimuli. Meg demonstrated a shift in preference toward her LP stimulus at a delay of 120 s on one trial, and Chris demonstrated a similar shift in preference at delays of 60 s and 120 s. However, he continued to allocate 100% of his responding toward the HP stimulus at delays of 240 s. Indeed, both of these participants continued to allocate responding toward their HP stimulus on the majority of trials at all delay values. Stewart was the only participant in this experiment who demonstrated a reliable disruption in preference. At a delay of 60 s, Stewart allocated his responding toward his HP stimulus on 75% of trials. At higher delay values (120 s and 240 s), he chose to allocate his responding toward his LP stimulus on 50% of trials.

Despite exposure to longer delay values that were expected to be more similar to those participants experience in their natural environments, participants did not display “impulsive”
responding as expected given their referral concerns. Even when overall reinforcement rate was greater for responding toward the LP stimulus (for Chris and Stewart), only one participant demonstrated a disruption in preference. One possible explanation for these discrepant findings involves the manner in which choices were presented. Specifically, many of the choice scenarios children encounter in their natural environments involve choices that do not bind them to a single course of action. A child may initially choose to engage in a ‘self-controlled’ or socially appropriate behavior to access highly valued outcomes, however the opportunity to engage in “impulsive” or problem behavior to access less preferred outcomes often remains available in the interim. Further, if impulsive choices result in a higher overall rate of reinforcement (despite the obtained reinforcer being relatively less preferred), a pattern of impulsive responding is likely to emerge to maximize total reinforcement. Thus, Experiment 3 assessed the degree to which the timing of a delay interval and the continued availability of an alternative response during that interval affects response allocation.

**Experiment 3**

**Delay Exposure in Initial vs. Terminal Link**

Participants were exposed to choices between responding for immediate access to an LP stimulus or access to an HP stimulus after various delay intervals. Two conditions were alternated in a reversal design.

**Terminal Link Delay.** Procedures in this condition were identical to those in Experiment 2. Participants were presented with a choice between two identical tasks. Selection of the task associated with the LP stimulus resulted in immediate access to that task. Following task completion, all task materials were removed and immediate access to the associated LP stimulus was delivered. For Brian and Meg, a post-reinforcement delay period (i.e., an inter-trial interval)
equal to the delay value for the HP stimulus was then initiated prior to presentation of the next trial. Selection of the task associated with the HP stimulus also resulted in immediate access to that task. Following task completion, a delay interval (specified prior to the trial) was initiated prior to delivery of the associated HP stimulus. For all participants, the HP reinforcement interval was immediately followed with initiation of the subsequent trial.

**Initial Link Delay.** In this condition, participants were presented with the task associated with the LP stimulus and given the choice between completing that task or waiting a specified delay interval prior to accessing the (identical) task associated with the HP reinforcer. That is, the delay interval took place prior to task completion (i.e., initial link) as opposed to following task completion (i.e., terminal link). Responding toward the LP stimulus continued to result in immediate access to that task. Following task completion, all task materials were removed and the participant received immediate access to the associated LP stimulus. Failure to respond immediately toward the LP stimulus resulted in initiation of the specified delay interval. During the delay interval, the task associated with the LP stimulus remained present and the participant could choose to complete the task at any point. If the participant chose to complete the task associated with the LP stimulus at any point during the delay interval, the LP reinforcer was delivered immediately. This reinforcement interval was then followed by an inter-trial interval (equal to the balance of time remaining in the delay interval) prior to initiation of the next trial for Brian and Meg. For Stewart and Chris, the next trial was initiated immediately following the reinforcement interval. If participants chose to wait the duration of the delay interval, the task associated with the HP stimulus was presented and the participant was presented with a choice between completing the tasks associated with the LP and HP stimuli respectively. Reinforcement was then provided immediately following task completion on both alternatives.
Results and Discussion

Figure 7 shows results of Experiment 3 for Brian, Chris, Stewart, and Meg, respectively. The results of Experiment 2 represent the first phase of each panel in the Figure (to facilitate comparisons across experiments). In sum, three of four participants allocated nearly exclusive responding toward their respective HP reinforcers at all delay values. Although Stewart’s preference was clearly disrupted, he continued to allocate his responding equally toward the HP and LP stimuli in this condition.

When the delay interval occurred prior to accessing the HP task option (phase 2), Brian’s responding toward the HP stimulus decreased to 25% of trials at all delay values (relative to 100% of trials in the previous phase). When this phase was reversed and the delay occurred subsequent to task completion, he allocated his responding toward the HP stimulus on 100% of trials at a delay of 60 s and 75% of trials at delays of 120 s and 240 s. When the delay was again inserted prior to accessing the HP task option, he allocated his responding toward the HP task on 100% of trials at a delay of 60 s, 50% of trials at 120 s, and 25% of trials at 240 s.

For Chris, when the placement of the delay interval was shifted, responding was variable across the HP and LP response options. Specifically, he allocated his responding toward the HP stimulus on 25% of trials at delays of 60 s and 240 s, however he allocated responding toward the HP stimulus on 75% of trials at a delay of 120 s. When this phase was repeated, Chris allocated his responding toward the HP stimulus during 50% of trials at delays of 60 s, whereas his response allocation toward the HP stimulus decreased to 0% and 25% of trials at delays of 120 and 240 s respectively. When the delay interval occurred following task completion (fourth phase), Chris allocated his responding toward the HP task option on 50% of trials at a delay of 60 s and 100% of trials at delays of 120 s and 240 s. Finally, placement of the delay interval prior
to task access in the fifth phase resulted in a replication of the declines seen in previous phases. Specifically, responding was allocated toward the HP stimulus on 50% of trials at 60 s and 120 s and 25% of trials at 240 s. The variability in these data suggests possible carryover effects due to the ascending and descending sequence of delay presentations. In other words, a choice to wait for access to the HP stimulus on one trial may have affected choice responding on subsequent trials. Nonetheless, when delays were presented in the initial link of the concurrent-chain schedule (second, third, and fifth phases), Chris tended to allocate his responding toward the LP on a greater proportion of trials relative to sessions in which the delay was presented in the terminal link (first and fourth phases).

For Stewart, placement of the delay interval prior to task access resulted in slightly greater disruption of preference than seen in the previous phase. In the second phase, Stewart allocated 50% of his responding toward the HP stimulus at delays of 60 s and 120 s and 0% of his responding toward the HP stimulus at a delay of 240 s (relative to 50% in the previous phase). When this phase was reversed and the delay occurred subsequent to task completion, Stewart’s response allocation toward the HP task option remained stable at a delay of 60 s but increased to 75% at delays of 120 s and 240 s. Finally, when the delay was again placed in the initial link of the schedule (phase 4), responding toward the HP stimulus occurred at 0 levels for delays of 120 s and 240 s. In other words, responding shifted toward the LP option on 100% of trials at these delay values.

For Meg, placement of the delay interval prior to task access resulted in a slight decrease in response allocation toward the HP stimulus. Specifically, she responded toward the HP stimulus on 75% of trials at delays of 60 s and 240 s and 50% of trials at 120 s (relative to 100%, 75%, and 100% respectively in the previous phase). However, when this phase was reversed and
the delay interval occurred following task completion, she demonstrated a complete shift in preference toward the LP stimulus. Thus, results for Meg are more indicative of a generalized change in preference rather than an artifact of the choice preparation per se. Indeed, when daily preference assessments were initiated for a follow-up investigation, the item previously designated as her HP stimulus (SpongeBob video) was consistently ranked at the bottom of her most preferred reinforcers.

To summarize, three of four participants showed relatively greater shifts in preference toward the LP reinforcer when delays occurred prior to accessing the HP task option (initial link) relative to when delays occurred following task completion (terminal link). Average response allocation for all participants is shown in Figure 8.

In this analysis, two methods of choice delivery were presented in a reversal design. The first method used procedures identical to those in Experiments 1 and 2 in which differential outcomes occurred following task completion. In the second condition, differential outcomes occurred prior to task completion and participants retained the opportunity to switch between schedules at any time during the delay interval. Results indicated that participants were more likely to choose the task associated with the HP stimulus (i.e., engage in self-control responding) when given a single opportunity to choose between tasks prior to exposure to the associated reinforcement contingencies. When choices were presented in the alternative format, three out of four participants were more likely to shift their responding toward the task associated with the LP reinforcer. Thus, Experiment 3 provides empirical support for behavioral models of impulsivity that conceptualize self-control as a choice response on the initial link of a concurrent-chain schedule. It also provides an applied demonstration of findings from animal research suggesting differential delays in the initial link of a concurrent-chain arrangement to be
associated with greater impulsivity and shifts in preference relative to delays in the terminal links of these schedules (Davison 1988).

**General Discussion**

This series of studies evaluated a direct method of assessing delay sensitivity in individuals with developmental disabilities. Specifically, evaluated the effects of choices for high and low preferred toys were evaluated when access to HP items was delayed at various time intervals. Results of Experiment 1 suggested that individuals who were referred for impulsive behavior allocated choices to the more highly preferred item when presented with delays up to 60 s. Results of Experiment 2 suggested that increasing the delay values by a factor of 4 did not appreciably affect response allocation for three of four participants. In Experiment 3, the placement of the delay interval was systematically alternated between the initial and terminal links of the concurrent-chain arrangement. Results of this evaluation demonstrated differential changes in preference between the two conditions for three out of four participants. For these participants, more “impulsive” responding was observed in sessions when they were required to wait for access to a task option as opposed to sessions in which identical delay intervals occurred following task completion.

Despite minor disruptions of preference, the methodology employed in Experiments 1 and 2 (i.e., delays in the terminal link of the concurrent-chain schedule) did not reveal substantial shifts in response allocation at delay values equal to or less than 240 s. One participant did demonstrate disruption of preference at delays between 60 and 240 s, although preference was not observed to shift completely from one stimulus to the other. While this study did not directly compare choice responding using single choice and concurrent-chain arrangements, past research suggests responding in the latter schedules to be characterized by relatively greater self-control
than responding on the former (Davison & Smith, 1986). Future research should directly assess differences in self-control responding in children with developmental disabilities when exposed to delays in single choice and concurrent-chain arrangements. Also, for two of the four participants, HP stimuli consisted of edible reinforcers. Past research indicates that, for some children, edible items consistently displace non-edible leisure items in preference hierarchies (DeLeon, Iwata, & Roscoe, 1997). Thus, for Chris and Stewart, LP (nondible) stimuli may not have served as viable substitutes for HP stimuli at extended delay values. Further research is needed to assess the degree to which reinforcer substitutability impacts responding in a self-control paradigm.

Limitations

The methodology used in these studies (ascending and descending sequences of delay values) is commonly used for assessing the discounting of reinforcer value under hypothetical delays (e.g., Dixon, Jacobs, & Sanders, 2006). When hypothetical delay scenarios are presented using this method, participants typically demonstrate linear (logarithmic) and negatively sloped patterns of preference for HP stimuli. In the current series of studies, response allocation was not observed to shift in such a fashion. Rather, all participants displayed seemingly idiosyncratic responding at various delay intervals (e.g., responding toward the HP stimulus at 25% of trials at a delay of 60 s and 75% of trials at a delay of 120 s). One explanation for these results is that participants did not discriminate the differences in delay values. While all participants were exposed to pre-assessment tests of delay sensitivity, no measures were collected to assess their ability to discriminate varying lengths of delay. Thus, stimuli may have signaled the availability of highly preferred reinforcers without facilitating discrimination between associated delay values. A second explanation may be that, when exposed to actual delays (as opposed to
hypothetical ones), a participant’s choice on one trial (and exposure to the associated delay) may affect his or her choices on subsequent trials. For instance, several participants demonstrated patterns of responding in which preferences shifted from the HP stimulus to the LP stimulus within sessions. In such cases, it is possible that extended exposure to delays reduced participants’ tolerance for delays (often of shorter duration) on subsequent trials. While past research has demonstrated an improvement in delay tolerance when relative delay values are progressively and gradually increased (Mazur & Logue, 1978; Dixon, Hayes, Binder, Manthey, Sigman, & Zdanowski, 1998), it is possible that more dramatic increases in delay value across trials interfere with delay training. Future research is needed to identify the conditions under which delayed access to reinforcement is likely to enhance and/or diminish tolerance for future delays.

For two participants, reinforcement rate was allowed to vary as participants could potentially engage in “impulsive” responding by accessing more frequent access to LP stimuli as opposed to accessing less frequent access to HP stimuli. For the other two participants, overall reinforcement rate was held constant through the inclusion of an inter-trial interval (equal to the delay associated with the HP reinforcer) following responding toward the LP reinforcer. Controlling for overall reinforcement rate was not found to be associated with differential patterns of responding across participants. Even when total reinforcement rate was allowed to vary (for Stewart and Chris), only one of these participants showed any disruption of preference for the HP stimulus. Further, standard procedures across conditions in Experiment 3 allowed for replication of independent variable effects within subjects. Nonetheless, research is needed to further evaluate impulsivity as a pattern of responding that serves to increase overall reinforcement despite relatively less preference for obtained reinforcers (Logue, 1995).
With manipulations in the timing of delay intervals (i.e., insertion of delay intervals at various links in the reinforcement schedule), most participants’ demonstrated a shift in preference from HP reinforcers to LP reinforcers that were more immediately available. In other words, responding became more impulsive for all participants under specific conditions. However, the degree to which response allocation shifted was idiosyncratic across participants, underscoring the importance of an individualized approach towards assessment and intervention for impulsive behavior.

Although these studies did not evaluate a specific intervention *per se*, it is noteworthy that three out of four participants engaged in differential responding when delays were presented in the initial and terminal links of the concurrent-chain schedule. This finding indicates that the way in which choices are presented may have a significant effect on children’s choice behavior. It may be that differential contingencies are more salient when delays occur within the initial link relative to the terminal link. Alternatively, shifts in response allocation may be more directly influenced by continued access to the LP option. In other words, initial responding toward the more highly preferred reinforcer may serve as a ‘commitment response’ that reduces or eliminates the availability of the less preferred option. It was not intended that Experiments 1 and 2 would include a “treatment” condition. In fact, it was anticipated that responding would have shifted towards the LP stimulus in Experiment 1 (i.e., that participants would have behaved impulsively). The results of Experiments 1 and 2 were incongruent with the referral concerns, but we may have inadvertently discovered an assessment condition that produced desirable response patterns. Further research is needed to isolate better the influence of 1) differential delays at the initial link of concurrent chain schedules and 2) the continued presence of stimuli signaling the availability of reinforcement for “impulsive” responding.
Results of these analyses provide a first step in developing a data-based method for assessing impulsive responding and refining interventions for increasing self-control behavior. Understanding the conditions under which reinforcers are likely to maintain their subjective value may be critical for devising treatments with enduring effects. Indeed, individual preferences are likely to shift over time even in the absence of treatment challenges such as delayed reinforcement (as demonstrated by Meg in Experiment 3). Objective assessment of the subjective value of various stimuli can be useful in predicting their efficacy when treatment integrity is challenged. For instance, prior to instituting a treatment for “impulsive” behavior in clinic or school settings, school psychologists would be well-advised to assess the efficacy of identified reinforcers when the immediate delivery of these reinforcers may not be practical. In many cases, highly preferred stimuli may maintain their value despite delays to their receipt (as indicated in Experiments 1 and 2). However, preferences for less desired reinforcers may not be so durable, highlighting the importance of comprehensive preference assessment procedures prior to intervention development.

Further, understanding the conditions under which individuals are likely to engage in “impulsive” responding is a necessary precursor to effective intervention. The current studies increase our understanding of human delay discounting in concurrent-chain reinforcement schedules that are likely to occur in children’s home and school environments. Specifically, in one choice arrangement (delay in the terminal link), children were asked to choose between two readily available response options. In the other choice arrangement (delay in the initial link), children were asked to choose between engaging in a response to obtain a LP stimulus or refraining from responding for a specified period of time until a more preferable reinforcement contingency was established. Although children may be more likely to engage in self-control
responding in the former choice arrangement, such arrangements may not occur with great
frequency in children’s daily lives. More commonly, children are presented with choices
analogous to the latter choice arrangement in which they maintain the option to engage in
problem behavior (i.e., to behave “impulsively”) at any time. Furthermore, in school settings,
“self-control” is commonly characterized by the lack of problem behavior, which may be
analogous to children in these studies refraining from responding toward the LP task option until
such time as the HP task option was made available. The results of Experiment 3 suggest that
children have substantially greater difficulty refraining from “impulsive” behavior depending on
the manner in which the choice is presented.

Although this series of studies did not evaluate a treatment of impulsivity per se, high
levels of self-control responding demonstrated in Experiments 1 and 2 point to several
interventions that professionals in school psychology might employ. One such intervention
involves the identification of adaptive behaviors that are functionally equivalent to problem
behaviors. Put simply, children may be more likely to exhibit specific pro-social behaviors than
to refrain from “impulsive” behavior for any given period of time. A related approach may
involve teaching a child to engage in a specific response that commits him or her to one course
of action over another. For example, prior to entering into a situation that tends to evoke problem
behavior, professionals might present the child with possible courses of action and prompt the
child to select the course of action that would be associated with his or her most desired
outcome. Once a commitment is made on the part of the child, professionals should consider
means of eliminating access to competing behaviors as well as stimuli associated with
reinforcement of those behaviors. Finally, when access to competing sources of reinforcement
cannot be eliminated, professionals should identify ways of increasing the salience of the more
highly preferred stimulus or outcome. When all response options are presented with equal salience, the child may be more likely to choose his or her most highly preferred outcome despite delayed access to that outcome.

This series of studies demonstrates a useful framework for further evaluations of self-control responding in children with developmental disabilities. Continued investigation is needed to further our understanding of self-control and impulsivity in this population. Specifically, research is needed to identify the conditions under which children are likely to respond impulsively and/or demonstrate self-control. Finally, treatment evaluations are needed to assess the effectiveness of interventions related to the types of choice arrangements to which children are exposed in their natural environments.
References


Figure Captions

**Figure 1.** Traditional self-control paradigm (i.e., concurrent-chain reinforcement schedule) in which responding on the initial link of a concurrent-chain schedule results in differential outcomes in the terminal links.

**Figure 2.** Self-control paradigm (i.e., concurrent-chain reinforcement schedule) highlighting delay intervals in the initial and terminal links of a concurrent-chain schedule.

**Figure 3.** Results of paired choice preference assessments for Brian, Stewart, Chris, and Meg, respectively.

**Figure 4.** Results of pre-assessment procedures for Brian, Stewart, Chris, and Meg, respectively. Multiple–Schedule Baselines are depicted in the first phase and Concurrent-Schedule Baselines in the second phase for all participants.

**Figure 5.** Results of Delay Exposure Assessment for Brian, Chris, Stewart, and Meg, respectively. Delay values (0 s to 60 s) are depicted on the x-axis and the proportion of trials in which responding was allocated toward the HP stimulus is depicted on the y-axis.

**Figure 6.** Results of Extended Delay Exposure assessment for Brian, Chris, Stewart, and Meg, respectively. Delay values (60 s to 240 s) are depicted on the x-axis and the proportion of trials in which responding was allocated toward the HP stimulus is depicted on the y-axis.

**Figure 7.** Results of Experiment 3 for Brian, Stewart, Chris and Meg, respectively. Delay values (60 s to 240 s) are depicted on the x-axis and the proportion of trials in which responding was allocated toward the HP stimulus is depicted on the y-axis. For all clients, the first phase represents participants’ responding when the delay was presented in the terminal link of the concurrent-chain schedule. In subsequent phases, the delay was presented in the initial and terminal links in a reversal design.
Figure 8. Cumulative results of Experiment 3 across participants. Delay values (60 s to 240 s) are depicted on the x-axis. The y-axis depict the average proportion of trials with self-control responding at each time interval across participants.
Figure 1. Diagram of concurrent-chain schedule with delay in the terminal link
Figure 2. Diagram of concurrent-chain schedule with delay in initial link
Figure 3.

Brian

Stimuli

Gummy Bears | Gold Fish | M&Ms | Cheetos | Finding Nemo | Trucks | Chomper | Ball

Stewart

Stimuli

Gummy Bears | Gold Fish | M&Ms | Cheetos | Finding Nemo | Trucks | Chomper | Ball
Figure 4.
Figure 5.
Figure 6.
Figure 7.
Figure 8.