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Training Tolerance to Delay Using the Escalating Interest Task

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Abstract

The present study examined the lasting effects of exposure to reinforcement that increased in magnitude as a function of time between responses in a first-person shooter video game preparation of the escalating interest task. When reinforcement density increased as a function of time, it encouraged participants to wait longer between responses (shots of a weapon). Participants exposed to such contingencies waited significantly longer to fire their weapons than participants who were exposed to linear growth, where long inter-response times were not differentially reinforced. Those with experience in conditions where reinforcement density increased as a function of time showed persistently longer wait times when the contingencies changed in the latter portion of the game where the disincentive to fire quickly was removed. The potential utility of such contingencies for training tolerance to delay of reinforcement and the broader implications of training self-control are discussed.

Keywords

Delay discounting; temporal discounting; self-control; impulsivity; tolerance to delay

When an organism is presented with two choices of differing value, the choice is often a simple one: go for the richer return. If this better option becomes temporally remote, however, at some point in time as the delay increases the organism begins to judge the better choice as being of lesser value due to its delay. This devaluation of a greater delayed outcome is described as delay (or temporal) discounting. The typical delay discounting paradigm presents an organism with two choices: a small amount of reinforcement available at a relatively proximal point in time (smaller sooner reinforcer or SSR), or a larger amount of reinforcement available at a relatively distal point in time (larger later reinforcer or LLR). This type of procedure has allowed researchers to assess individual discounting rates. Those who choose the SSR more frequently over a range of increasingly longer delays in lieu of the LLR are said to be “steep discounters,” or more impulsive. Conversely, those who

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choose the LLR more frequently over a wider range of delays are said to be “shallow discounters,” or more self-controlled.

Some of the most important findings in this line of research show that steep discounting appears to be a common phenomenon in a range of populations with different maladaptive behavioral issues. There are robust correlations between steep discounting and the presence of behavioral issues that have large impacts on quality of life; some of these behaviors are substance abuse (Madden, Petry, Badger, & Bickel, 1997; Petry, 2001), pathological gambling (Dixon, Marley, & Jacobs, 2003), and obesity (Weller, Cook, Avsar, & Cox, 2008). Many researchers have been successful in assessing the importance of procedural differences (manipulation of intertrial-intervals and session length; Logue, Peña-Correal, Rodriguez, & Kabela, 1981; Lane, Cherek, Pietras, & Tcheremissine, 2003), examining the effects of reinforcer types and amounts (e.g., Odum & Rainaud, 2003; Madden, Begotka, Raiff, & Kastern, 2003; Raineri & Rachlin, 1993), and elucidating other forms of discounting that exist (e.g., Rachlin, Raineri, & Cross, 1991; Jones and Rachlin, 2006). However, there is significantly less research with the explicit aim to improve tolerance to delays of reinforcement.

Improving tolerance to delays to reinforcement has not been untouched, but most studies have approached this research question by utilizing concurrent dichotomous choices that are akin to those used to assess delay discounting. To date, most research conducted on improving tolerance to delays of reinforcement involves manipulating delays over successive trials and/or sessions with a smaller (or less-preferred) reinforcer and a larger (or more-preferred) reinforcer that are concurrently available. This procedure has traditionally been done in one of two ways: either beginning with both the smaller and larger reinforcers at the same 0 s delay and gradually increasing the delay to the larger reinforcer (Schweitzer & Sulzer-Azaroff, 1988), or by starting both the smaller and larger reinforcers at a long delay and gradually decreasing the delay to the smaller reinforcer (Mazur & Logue, 1987). These procedures have increased tolerance to delay of reinforcement in human children identified as impulsive (Schweitzer & Sulzer-Azaroff, 1988) and with ADHD (Binder, Dixon, & Ghezzi, 2000), human adults with developmental disabilities (Dixon et al., 1998), and pigeons (Mazur & Logue, 1987; Logue & Mazur, 1981). Little research has been conducted however to identify what experiences may produce the greatest self-control, and whether or not other procedures may be more (or less) effective at creating lasting behavioral change (e.g., Young, Webb, Rung, & Jacobs, 2013).

Atypical intertemporal choice paradigms have revealed improvement in delay tolerance with experience over successive trials when rewards are exposed and accumulate in real-time. Anderson, Fujita, and Kuroshima (2010) tested three variations of a delayed gratification procedure using monkeys as subjects, where food items (pieces of sweet potato) were presented to a subject one-by-one, with fixed intervals between presentations. If a monkey waited until all items were presented, it could accumulate a maximum of six pieces of sweet potato; during this accumulation period a monkey could defect at any given point and take the currently presented amount. Despite a forced-choice trial that allowed the monkeys to see the potential maximum number of items, few of the monkeys delayed. When the contingencies changed and the pieces of sweet potato increased in size with each

presentation, 2 of 4 subjects in one species began to reliably delay gratification in a higher proportion of trials. In the other species tested, one subject that was already delaying tended to accumulate more items than when the magnitude of each piece did not increase, and another subject that did not delay previously showed a substantial increase in the number of trials where delaying occurred. This increase in the ability to tolerate delays to reinforcement was still evident in the subjects of the first species when retested 8 weeks later, and even when the pieces of sweet potato used were again equivalent in magnitude.

A recently developed procedure for humans that also utilizes continuously available reinforcement that accumulates as a function of time is the Escalating Interest task (EI task; Young, Webb, & Jacobs, 2011). The EI task was developed as a first-person shooter style video game in which a participant's avatar is equipped with a weapon that charges up to a maximum damage potential over a programmed interval of time (typically 10 s). Depending upon the value of the *power* parameter within the super ellipsoid feedback function that determined the growth rate of weapon damage (see Equation 1), differential rates of firing are reinforced:

$$\text{damage} = 100 \times \left(1 - \left(\frac{(10-t)}{10} \right)^{\text{power}} \right)^{1/\text{power}} \quad (1)$$

where t is the delay since the previous shot and maximal damage is achieved after 10 s. For power values below 1.00, the curve is positively accelerating, for values above 1.00 it is negatively accelerating, and for a value of 1.00 it is linear; see Figure 1 for examples. Young and colleagues found that participants are sensitive to the various rates of increasing outcomes in the form of the equipped weapon's potential damage. For power values less than 1.00, participants tended to wait longer between shots, which maximizes reinforcement density. Conversely, for power values greater than 1.00, participants tended to fire rapidly, which also maximizes reinforcement density. Lastly, when the recharge of the weapon was a fixed linear increase (when power is 1.00), participants tended to fire rapidly even though the rate of firing has no impact on reinforcement density as long as the participant fires within 10 s of the previous shot.

Most of the experiments that have been conducted using the EI task have cycled through different power values rapidly within-session, but a more recent study exposed participants to specific power values for longer durations of time and assessed the effects of the order of the power values experienced on subsequent responding in the game (Young, Webb, Rung, & Jacobs, 2013). Overall, participants' behavior varied in accordance to the programmed contingencies, but Young et al. found an effect of order. Participants whose early game experience included power values greater than or equal to 1.00 tended to have shorter interresponse times (IRTs) overall throughout the game. Additionally, participants whose early experiences included power values that differentially reinforced long IRTs showed faster rates of behavior change (behavior came under control of the current consequences faster) when the power values changed within the session. These early experiences persisted even when other power values that differentially reinforced IRTs of the opposite length intervened.

While the two procedures utilizing accumulating and continuously available reinforcement (the EI task and Anderson et al.'s deferred gratification task) are not directly analogous, both have shown that humans and non-human animals are sensitive to increases in reinforcement density with time, and that those who are sensitive to these changes show persistent history effects when the contingencies change (Anderson et al., 2010; Young et al., 2013). However, the history effects assessed by Young et al. (2013) included rates of reinforcement that were positively accelerating, negatively accelerating, and linearly increasing, and did not isolate the effects of any one contingency in the context of a single other contingency for a prolonged period. Thus, in the present study we used the EI task to assess the lasting effects of long-term exposure (about 20 minutes) to contingencies where long IRTs were initially reinforced using one of two different power values (0.50 and 0.75), followed by an assessment phase using a power value of 1.00 that does not differentially reinforce IRT duration. Performance during this assessment phase was also compared to that of controls who only experienced the power of 1.00 throughout the entirety of the game. The presence of prolonged lasting effects from such contingencies in the assessment phase could provide evidence for the utility of contingencies that manipulate reinforcement density for training greater tolerance to delay of reinforcement in humans.

In attempts to explore any possible relationships that would explicate whom such contingencies may be more effective with and if there are individuals who would be more or less likely to exhibit prolonged history effects, we administered a self-report questionnaire of impulsivity, the Barratt Impulsiveness Scale (BIS-11; Patton, Stanford, & Barratt, 1995), and a behavioral measure of rapid-response impulsivity, the Immediate Memory Task (IMT; Dougherty 1999). Previous research using the escalating interest task has found moderate correlations between BIS scores and IRT length, but has failed to find relationships between performances on other impulsivity tasks and behavior in the video game (Young et. al, 2011; but see Young et. al, 2013 for a recent report of a relationship between discounting rate and IRT length). The IMT was chosen since it was a task not previously assessed in conjunction with behavior in the video game.

Method

Participants

Seventy-three students (43 females and 30 males) from the Introduction to Psychology course at Southern Illinois University at Carbondale participated in the study. Students were compensated with course credit for approximately one hour of research participation.

Procedure

Upon entering the laboratory, participants provided informed consent, were seated at one of four computers and completed a set of questionnaires, the Immediate Memory Task (the IMT, a continuous performance task; Dougherty 1999), and the video game task. Half of the participants completed the questionnaires and the IMT prior to the video game, and half completed them after. All tasks, including the questionnaires, were completed on a computer. The questionnaires and IMT were completed via a program created in PsyScope (Cohen, MacWhinney, Flatt, & Provost, 2003). The tasks are described below.

Video Game—The video game was a customized first-person-shooter style game. All participants received verbal instructions from the experimenter regarding navigation, a static stimulus on the players' screens (a weapon charge bar), and their objective in the task. Participants were told they would be placed in a virtual village that is being attacked by monsters (orcs) and were instructed to "destroy all the orcs in each level as effectively as possible." They were also notified of the function of an orange charge bar near the center of the screen. The charge bar indicated how much of the potential maximum damage their weapon would currently produce if fired; the closer the charge bar was to being full, the more damage a shot would produce.

The video game task utilized the Torque Game Engine as the platform for development (obtained from www.garagegames.com). The video game consisted of four identical levels, with 14 orcs grouped in pairs in seven different regions throughout the environment. Upon eliminating all enemies in a game level, the game reset to the same landscape with all of the orcs replaced such that each level was visually identical with the exceptions that the player began in a randomly selected location and the growth rate of weapon charge may (0.50 and 0.75 conditions) or may not (1.00 condition) have changed depending on the current level a participant was in.

In order to make the goal within the video game more realistic and to ensure that participants' behavior in the game was primarily affected by the weapon's programmed contingencies (instead of firing in order to protect the player's own health), the orcs were stationary and did not fire at players. Each pair of orcs was oriented toward a unique target building and fired their equipped weapons at the targeted buildings throughout the village every 4 s on average.

Participants were randomly assigned to one of three conditions that varied by the value of the power parameter (see Equation 1 and Figure 1) in the first two levels of the video game (henceforth called the "exposure phase"). For the 0.50 condition, a participant's weapon recharged based on a power of 0.50, for the 0.75 condition based on a power of 0.75, and for the 1.00 (or control) condition based on a power of 1.00. Once the exposure phase was completed, the assessment phase, or the last two levels of the game, began. During this phase, a participant's weapon recharged based on a power of 1.00 for all three conditions.

BIS—The Barratt Impulsiveness Scale (BIS; Patton et al., 1995) is a 30 item self-report questionnaire that is an internally consistent ($\alpha = .82$) measure of trait impulsivity. Responses on the questionnaire were used to generate a total score in addition to individual scores for the three second-order factors: motor impulsiveness, nonplanning impulsiveness, and attentional impulsiveness. The questionnaire involves a series of statements that the participant must rate as one of the following responses: "Rarely/Never, Occasionally, Often, Almost Always/Always." The resulting responses are converted to a numeric score and summed so that high scores correspond to a high level of self-rated impulsive behavior (possible range 30 to 120).

Demographics—Participants completed a demographics questionnaire that asked participants' sex and frequency playing nine categories of video games over the last 4 years (see Young et al., 2011 for details).

IMT—The immediate memory task (IMT) is a continuous performance task that measures brief attentional capacity, or immediate memory, and is typically administered in conjunction with the delayed memory task (DMT), which measures the ability to retain and then identify stimuli presented over a longer delay (Dougherty 1999; Dougherty, Marsh, & Mathias, 2002). In the IMT, a series of five numbers is presented for 500 ms followed by the presentation of either the same or a different set of numbers after a 500 ms blackout period. Participants are instructed to respond (in this preparation, with the press of the spacebar) when the currently displayed series of numbers is identical to the one that immediately preceded it. Participants with high false alarm rates (responding when the number sequence is different from the preceding sequence) are judged to potentially have greater response-initiation, or rapid-response impulsivity (Acheson, Richard, Mathias, & Dougherty, 2011; Swann, Bjork, Moeller, & Dougherty, 2002). Due to time constraints on session length and previous research findings that measures of performance on the IMT correlate significantly with a broader range of psychiatric and behavioral complications than its counterpart, only the IMT was administered (Swann et al., 2002).

Results

Of the 73 students who participated in the experiment, three participants did not complete the video game task. This resulted in missing/incomplete data for the third and fourth levels of the 1.00 condition for one participant, and incomplete data for one participant in the fourth level of the 0.75 condition. Both of these participants' data were retained in the analyses. The remaining participant who did not complete the video game task was dropped from the analyses and replaced with data from an additional participant who was placed in the same experimental condition. The dropped participant's data was excluded due to a failure to adhere to instructions on each task in the experiment and completion of less than half of the video game. This resulted in each condition containing data from 24 participants, with half completing the demographics questionnaire, BIS, and IMT first, and half completing these last.

Similar to previous experiments utilizing the EI task, IRTs produced a bimodal distribution and thus were dichotomized and analyzed as a binomial outcome variable (see Figure 2 for a graphical depiction of the distribution of IRTs in each condition). IRTs less than 5 s were categorized as short and those greater than or equal to 5 s were categorized as long. All IRTs greater than 20 s were not analyzed because they likely reflect inattention or extensive travel time in the game. This procedure resulted in 2.24% of IRTs being dropped.

The data were analyzed with a generalized linear mixed effects model in *R* with the outcome variable specified as binomial (i.e., a repeated measures logistic regression). Condition and phase were entered as categorical predictors, and proportion of time in phase was entered as a continuous predictor of dichotomized IRT. All interactions were included in the model. Figures 3 and 4 show the model fits for the conditions and individual subjects, respectively.

The proportion of time in phase was centered so that the intercept estimates for condition correspond to the mean IRT in the middle of the phase; this aids in interpretation of the effects of both the contingencies in Phase 1, and the lasting effects of order in Phase 2, in that they correspond to a point in each of the phases at which participants have had a fair amount of exposure to the current contingencies. Centering also serves the function to reduce multicollinearity between the interactions involving time in phase and its main effect. The best fitting model as judged by AIC allowed both intercepts and slopes to vary across participants for the main effect of phase, as well as the slope effects of proportion of time in phase. Table 1 shows the best fitting parameter estimates for the centered intercepts and slopes for each condition by phase.

During the exposure phase (the first phase) of the game, participants' IRTs varied in accordance with the assigned condition. Participants in the 0.50 and 0.75 conditions showed sensitivity to the change in growth rate of weapon damage during the 10 s charge interval, in that participants in these conditions tended to have a higher proportion of long IRTs, while those who were assigned to the 1.00 condition tended to have a higher proportion of short IRTs. Participants assigned to the 0.50 and 0.75 conditions had a significantly higher likelihood of producing long IRTs than those in the 1.00 condition (z s = 7.89 and 4.78, p s < .05, respectively). In the 0.50 condition where the consequences for firing quickly were the greatest, participants had a significantly higher likelihood of producing a long IRT than those in the 0.75 condition (z = 3.11, p < .05).

When the contingencies changed in the assessment phase (the second phase), participants in the 0.50 and 0.75 conditions showed a decrease in the proportion of long IRTs. This resulted in a significant decrease in the mean likelihood of producing a long IRT from the exposure phase for the 0.50 condition, but not the 0.75 condition (z = 2.11, p < .05, and z = 0.48, p > .05, for the 0.50 and 0.75 conditions respectively). There remained a higher likelihood of producing long IRTs in the 0.50 condition compared to the 0.75 condition, but this difference was not significant (z = 1.49, p > .05). Despite this decrease in the proportion of long IRTs from the exposure to the assessment phase, both of these groups exhibited a higher proportion of long IRTs than participants in the 1.00 condition (z s = 6.26 and 4.77, p s < .05, for the 0.50 and 0.75 conditions, respectively). The proportion of long IRTs in the 1.00 condition remained low in the assessment phase of the experiment.

While participants showed sensitivity to the contingencies in the exposure phase, most participants in all conditions initially displayed short IRTs at the beginning of the phase (see Figures 3 and 4). As the phase progressed, participants in the 0.50 and 0.75 conditions had very similar slopes, in that they began to show a higher proportion of long IRTs at a similar rate (see Table 1). This rate of behavioral change was not significantly different between the two conditions (z = .064, p > .05), but the rate of change was more consistent in the 0.50 condition than in the 0.75 condition (see Figures 3 and 4). Participants in the 1.00 condition also tended to respond more slowly as the phase progressed (z = 2.61, p < .05), but this appears to be limited to a small portion of participants in the 1.00 condition and was not a consistent trend (see Figure 4). Most participants in the 1.00 condition fired very rapidly throughout the phase or by its end.

When the contingencies changed in the assessment phase from the exposure phase, participants in the 0.50 and 0.75 conditions had negative slopes, or a decrease in the proportion of long IRTs as a function of time elapsed in the assessment phase (see Table 1). The effects of prolonged exposure to the contingencies in the exposure phase deteriorated more quickly in the 0.75 condition than in the 0.50 condition. That is, the likelihood of producing a long IRT in the 0.75 condition decreased at a higher rate than that of the 0.50 condition ($z = 2.63, p < .05$). Participants' behavior in the 1.00 condition did not significantly change as a function of time in the second phase ($z = -1.23, p > .05$).

Individual Differences Variables

Because of the small number of participants and large number of individual differences predictors, this analysis was confined to examining the main effect of each between-subject predictor. For ease of presentation, each was examined without the other predictors included, which could lead to a higher probability of Type I error. Thus, these analyses should be considered exploratory. When sex was included as a predictor in the model, the model was significantly improved ($\chi^2(1) = 5.99, p < .05$). Men tended to have a lower likelihood of producing long IRTs than women ($z = -2.53, p = .01$).

When scores on the attentional subscale of the BIS were added as a predictor (without sex), the model was again significantly improved ($\chi^2(1) = 6.36, p < .05$). Participants who scored higher on the attentional subscale of the BIS tended to have a higher likelihood of producing long IRTs ($z = 2.597, p = .009$). Total BIS score and scores on the motor and nonplanning subscales of the BIS did not significantly improve the model, nor did measures of performance on the IMT (all $ps > .05$).

When measures of video game experience were included in the model as predictors (without sex and scores on the attentional subscale of the BIS), experience playing musical/rhythm games improved the model ($\chi^2(1) = 4.33, p < .05$). Participants who had previous experience with musical and rhythm video games had a higher likelihood of producing long IRTs ($z = 2.14, p = .032$). Similarly, when experience playing puzzle and casino games was added as a predictor to the model (also without the other individual differences predictors), greater experience with this genre of games predicted a higher likelihood of producing long IRTs, but it was not a statistically significant predictor ($z = 1.90, p = .057$).

Discussion

This experiment sought to examine the long-term consequences of training people to wait under conditions where a neutral incentive (linear growth rate in reinforcement magnitude) produced little waiting. The experiment successfully replicated the finding that participants are sensitive to changes in the rate of reinforcement and will wait longer for reinforcement when outcomes increase in density as a function of time. While participants in the experimental groups (0.50 and 0.75 conditions) were only exposed to approximately 20 minutes of game play with positively accelerating growth rates of weapon damage (the exposure phase), this was sufficient to have lasting effects on behavior when these contingencies were changed in the assessment phase. When the growth rate of weapon damage was linear and there was no previous experience with power values that

differentially reinforce long IRTs (the 1.00 condition), participants tended to fire rapidly and overall continued to do so throughout the game.

A key question was whether the stronger incentive for waiting in the exposure phase (the 0.50 condition) would produce greater waiting in the exposure phase at the cost of a rapid decrease in waiting during the assessment phase. This outcome was possible because the change in contingency from a 0.50 to 1.00 power would be more salient than a change from 0.75 to 1.00. This sudden change could provide a contextual cue that would prompt a rapid shift in behavior.

As expected, participants' proportion of long IRTs in the 0.50 and 0.75 conditions decreased from the first phase of the game, indicating a deterioration of long waiting times when the contingencies changed. Despite this decrease, the proportion of long IRTs within these two conditions remained higher than the proportion of long IRTs in the 1.00 condition in the assessment phase. The decrease in the proportion of long IRTs from the exposure phase to the assessment phase was statistically significant only for the 0.50 condition. It is possible this occurred because of the more salient contrast in the change of the rate of weapon recharge; the change in growth rate as indicated by the charge bar may have been more discriminable. The proportion of long IRTs in the 0.75 condition decreased at a faster rate than that of the 0.50 condition, though, and this may be because the 0.75 power value does not as strongly differentially reinforce long IRTs as the 0.50 power value. There is greater incentive to wait when the growth rate is determined by a 0.50 power value than when it is 0.75. This stronger contingency may have created greater tolerance to delay or perhaps greater sensitivity to larger outcomes due to prolonged exposure in the 0.50 condition, thus being more resistant to deterioration when those contingencies are no longer present. Because a power value of 1.00 does not differentially reinforce IRTs of any length, the behavior exhibited by participants in the 0.50 and 0.75 conditions in the assessment phase cannot be called "self-controlled"; there is no limit to the number of shots that can be made in the video game, and as such, behavior throughout the assessment phase cannot be referred to as optimal regardless of the length of IRT.

The analysis of individual difference predictors examined variation in susceptibility to history effects with the types of contingencies used in the present study. Some of the relationships we found are consistent with those in other studies using the EI task and thus these main effects may be reliable, such as men having shorter IRTs (Young et al., 2011) and those who have more experience playing musical games having longer IRTs (Young et al., 2013). However, because we only looked at the main effects of each individual difference predictor, it is possible that there are differential relationships with the likelihood of producing a long IRT depending on the phase and condition that a participant was in. Some examples of such relationships would be, men tending to respond more quickly in the assessment phase only, or participants who scored higher on the attentional subscale of the BIS being more likely to have long IRTs in the 1.00 condition as a function of time (higher inattention the longer the video game task was played). As mentioned previously, the relationships between game performance and individual differences should be considered as exploratory and areas that should potentially be investigated more thoroughly in future research.

Procedural Limitations

Overall, it is promising that there was a persistent history effect when it did not matter how long a participant waited to fire in the assessment phase. This outcome parallels Anderson et al. (2011) whose experiments used primary reinforcers and a fixed number of trials. It is unknown however, if the history effects we observed would persist if participants returned for repeated testing, or if over longer assessment phases the history effect would gradually disappear. It is possible that the decrease in the proportion of long IRTs for participants in the 0.50 and 0.75 conditions would not have been observed if there were additional contingencies that made IRT length relevant when the power value was 1.00. This could be achieved in a number of ways. The procedure could be changed such that money is contingent upon how few shots are made in the game, or a limit on the number of shots a participant can make could be employed. If either of these procedural manipulations were implemented, how long participants wait to fire when the growth rate of weapon charge is linear would presumably be different than the behavior typically seen when the power value is 1.00 and could create greater incentive to wait. Additions such as these may not only decrease deterioration of history effects within-session, but could also decrease deterioration of history effects between-sessions if repeated testing was conducted. Consideration is warranted for the possibility that adding these contingencies may pose problems with the timescales used in this procedure (e.g., could create exclusive long IRTs if money was contingent on responding).

The Importance of Tolerance to Delay and Self-Control

Steep discounting of temporally distal rewards is associated with the presence of a variety of poor behavioral and health outcomes in adulthood (e.g., Madden, Petry, Badger, & Bickel, 1997; Dixon, Marley, & Jacobs, 2003). Moreover, there is evidence that poor self-control and an inability to tolerate delays to reinforcement may be a persistent behavioral trait throughout the lifespan. One such instance is from the seminal studies of delayed gratification. In the traditional procedure, the contingencies are arranged such that a child is told that if he or she waits until the experimenter returns to the room they will receive a larger reward, meanwhile a smaller reward is available and visible during the delay period but consuming it cancels the delivery of the larger reward (Mischel & Ebbesen, 1970). When follow-up studies were conducted with the participants of this early work (at approximately 18 years of age, with original testing at approximately 4 years of age), Shoda, Mischel, and Peake (1990) found positive correlations between self-imposed delay and scores on the Scholastic Aptitude Test ($r = 0.42$, $p < .05$ for verbal scores, and $r = 0.57$, $p < .001$, for quantitative scores) as well as with ratings of cognitive, self-regulatory, and coping competence. In almost all instances, there were no significant correlations between these competency measures and the amount of time delayed in differing procedures when the rewards were obscured or when the children were instructed to think in particular ways during the delay period. The most important predictor was how long the child delayed with no instruction and when the rewards were visible. When a larger pool of participants from these early studies were surveyed 30 years after the original experiments (from various experimental conditions, but first delay experience used), it was found that the participants'

ability to delay gratification at 4 years of age accounted for a significant portion of variance in body mass index (Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013).

Similarly, in another longitudinal study conducted in New Zealand, a cohort of 1,037 individuals was followed from birth to the age of 32 years (Moffitt et al., 2011). Moffitt and colleagues rated individual's self control during their first decade of life utilizing a composite measure consisting of observational ratings of lack of control, and parent, teacher, and self-report ratings of lack of control, impulsive aggression, hyperactivity, lack of persistence, inattention, and impulsivity. The composite rating of self-control was found to be a significant predictor of the presence of health issues (e.g., periodontal disease, overweight, sexually transmitted infections), risk of substance dependence (including tobacco, alcohol, cannabis, and other street and prescription drugs), being less financially planful and having more money management and credit problems, and the likelihood of having been convicted of a criminal offense. All of these correlations were statistically significant even when controlling for socioeconomic status and intelligence quotient.

To our knowledge, there are no existing longitudinal studies that have attempted to train greater tolerance to delay of reinforcement and thereafter survey life outcomes at various stages of development. Moffitt et al.'s (2011) study did not include an intervention, but they did find that participants who became more self-controlled relative to their initial childhood measures had better outcomes in adulthood. As the authors point out, "it is not clear that natural history change of the sort [they] observed in [their] longitudinal study is equivalent to the intervention-induced change" (p. 2696), but the fact that self-control can change should raise consideration for the assessment of such interventions. It is possible that individuals who were rated as having low-self control have a genetic predisposition that may make early intervention unsuccessful—but there are some who did exhibit change and were able to improve. These differences could be due to genetic predispositions, or perhaps from learning experiences that were not afforded to all of the participants who were rated as having low self-control at a young age.

Despite the fact that the longitudinal studies discussed here are correlational in nature, they should be heeded as evidence for the importance of researching tolerance to delay of reinforcement in the face of temptation and how it can be improved; this appears to be a crucial behavior to target and develop early in life. The decisions that individuals make on a daily basis often require continued effort, where the ability to defect and choose a "smaller sooner" outcome is a constant reality. We live in a world where technology and industry have made a plethora of reinforcers that can be obtained at a moment's notice readily available—some of which are detrimental to individuals' long-term well being. If we can teach individuals from an early age to tolerate delays to larger and more efficacious reinforcers, we may be able to decrease the rates of susceptibility to many of these behavioral traps and improve the quality of life of individuals throughout their lifespan.

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Figure 1.

Percent of maximum weapon charge as a function of time with three different values of the parameter *power* as determined by the superellipsoid feedback function.

Figure 2.

Distribution of IRTs by condition and phase. The width of the contour plot for each decile of the proportion of time in phase represents the proportion of non-dichotomized IRTs between 0 and 10 s.

Figure 3.

The average likelihood of waiting more than 5 s by proportion of time in phase (in deciles), in each phase, for each condition. The curves shown are the aggregate of individual participants' likelihood of waiting by condition derived from a generalized linear mixed effects analysis that allowed slopes and intercepts to vary across participants. Error bars are one standard error from the mean.

Figure 4.

Individual participants' likelihood of waiting more than 5 s as a proportion of time in phase for each condition in both phases. The lines represent the best fitting curves derived from a generalized linear mixed effects analysis that allowed slopes and intercepts to vary across participants.

Table 1

Best Fitting Parameter Estimates for the Intercept and Centered Slope Parameters from a Generalized Linear Mixed Effects Model of Dichotomized Interresponse Times

Condition	Intercept (Exposure)	Intercept (Assessment)	Slope (Exposure)	Slope (Assessment)
0.50	1.68	0.97	3.58	−0.53
0.75	0.40	0.45	3.54	−1.47
1.00	−1.58	−1.52	0.34	0.08

Note: Parameter estimates are in a transformed logistic space; an intercept estimate of 0 corresponds to a 50% likelihood of waiting more than 5 s at the midpoint of a phase. Standard error for intercept and slope estimates are approximately 0.30 and 0.47, respectively.