Spring 2014

The Relationship Between the Development of Time Perception and Delay of Gratification

Anjela Sargent

University of Colorado Boulder

Follow this and additional works at: http://scholar.colorado.edu/honr_theses

Recommended Citation


This Thesis is brought to you for free and open access by Honors Program at CU Scholar. It has been accepted for inclusion in Undergraduate Honors Theses by an authorized administrator of CU Scholar. For more information, please contact cuscholaradmin@colorado.edu.
The Relationship Between the Development of Time Perception and Delay of Gratification

Anjela Sargent

University of Colorado at Boulder

Department of Psychology and Neuroscience

Senior Honors Thesis

March 17\textsuperscript{th}, 2014

Honors Committee:

Dr. Yuko Munakata, Department of Psychology and Neuroscience (Thesis Advisor)

Dr. Richard Olson, Department of Psychology and Neuroscience (Honors Representative)

Dr. Robert Rupert, Department of Philosophy

Karin Boerger, Department of Speech, Language and Hearing Sciences
Abstract

Delaying gratification is the ability to resist immediate rewards for larger or more desirable delayed rewards, and is important to individual and societal success. Many factors involved in delaying gratification have been well established, but the role of time perception is not well understood. Given that individuals experience time differently, these differences may influence choices regarding temporal delays. To explore how the development of time perception plays a role in willingness to delay gratification, 20 7-year-old children participated in time perception tasks, a snack delay task, a hypothetical temporal discounting task, and a behavioral motor inhibition task. Children who had a tendency to underestimate the length of temporal durations were more willing to delay gratification than children who had a tendency to overestimate. This represents the first demonstration that tendencies to over- versus underestimate time can influence decisions about delayed rewards. This work has implications for the emphasis of measuring and controlling for time perception in future delay of gratification studies, as well as teaching strategies regarding temporal education.

Keywords: Delay of Gratification, Temporal Discounting, Time Perception, Duration Judgment, Behavioral Motor Inhibition, Internal Clock Speed
The Relationship Between the Development of Time Perception and Delay of Gratification

Delaying gratification is difficult. Children might be tempted to opt for a small pre-dinner treat rather than holding out for a larger dessert, and adults might be inclined to accept a moderately-paying job rather than pursuing an advanced degree that will eventually yield a higher income. However, delaying gratification is crucial to success. The ability to delay gratification during childhood predicts important later life outcomes such as SAT scores, financial income, and physical health (Green, Myerson, & Ostaszewski, 1999; Mischel, Ebbesen, & Raskoff Zeiss, 1972; Mischel, Shoda, & Peake, 1988; Mischel, Shoda, & Rodriguez, 1992; Schlam, Wilson, Shoda, Mischel, & Ayduk, 2012; Shoda, Mischel, & Peake, 1990; Wood, 1998).

Many factors that are important to delaying gratification have been well established, including executive functions (e.g., inhibitory control), social factors (e.g., social trust), attention, and motivation (Barkley, 1997; Michaelson, de la Vega, Chatham, & Munakata, 2013; Mischel & Gilligan, 1964; Munakata et al., 2011; Rodriguez, Mischel, & Shoda, 1989). However, other factors have yet to be explored.

Delaying gratification requires avoiding immediate temptations and instead waiting a certain period of time to receive a larger or more desirable reward. Given that this period of time is a central aspect of the delayed reward, how might individual differences in the perception of time relate to individual differences in delaying gratification? One prominent theory suggests that impulsivity, which broadly refers to a tendency to act without forethought, is linked to both decision-making and individual experiences of time (Wittmann, Leland, & Paulus, 2007; Wittman & Paulus, 2008). Impulsivity in individuals is often the result of deficient inhibitory control, which is the ability to suppress automatic behaviors in order to arrive at a goal, and is closely related to the ability to hold out for delayed rewards (Schachar & Logan, 1990). Another
prominent theory outlining animal and human timing behavior similarly suggests that accuracy in the discrimination of temporal durations relates to decision-making via influences from individual differences in how the speed of passing time is perceived (Church & Broadbent, 1991; Church & Meck, 2003; Church, Meck, & Gibbon, 1994; Matell & Meck, 2000; Meck, 1996; Zakay & Block, 1997). These theories predominately hypothesize that accuracy of temporal judgments should predict delay decisions.

Some evidence in clinical populations, healthy adults, and typically developing children supports the concept that accuracy predicts delay decisions. In clinical populations, individuals with Attention Deficit Hyperactivity Disorder (ADHD) and with Borderline Personality Disorder (BPD) have less accurate time perception compared to healthy controls (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001a; Barkley, Murphy, & Bush, 2001b; Bauermeister et al., 2005; Gooch, Snowling, & Hulme, 2011; Houghton, Durkin, Ang, Taylor, & Brandtman, 2011; Meaux & Chelonis, 2003; Smith, Taylor, Warner Rogers, Newman, & Rubia, 2002; Toplak, Rucklidge, Hetherington, John, & Tannock, 2003; Yang et al., 2007; Zentall, 1993), and also tend to struggle with delaying gratification (Marco et al., 2009; Luman, Oosterlaan, & Sergeant, 2005; Barkley et al., 2001a, Antrop et al., 2006; Tripp & Alsop, 2001; Lawrence, Allen, & Chanen, 2010). In healthy adults, individuals with less accurate time perception discount the value of later rewards more steeply (i.e., find less subjective value in a delayed reward) than those with more accurate time perception (Corvi, Juergensen, Weaver, & Demaree, 2012; Stolarski, Bitner, & Zimbardo, 2011). In typically developing children, individuals with less accurate time perception have worse behavioral inhibition than those with more accurate time perception (Meaux & Chelonis, 2005; White et al., 1994).
Despite existing support for the idea that accuracy predicts delay decisions, the direction of temporal judgment errors has been largely ignored. As such, it remains unclear whether a tendency to over- versus underestimate time is predictive of delay decisions. It is possible that the form that inaccuracies in temporal judgments take matters. For example, when considering a choice between an immediately available reward and a larger reward that will be delivered after a delay, individuals with a tendency to overestimate time might feel that the delay period is longer than individuals with a tendency to underestimate time. This may make such individuals more likely to choose immediate rewards. Likewise, individuals with a tendency to underestimate time might feel that the delay period is shorter than individuals with a tendency to overestimate time. This may make such individuals more likely to hold out for delayed rewards.

Exploring the direction of time perceptions errors is important when considering this alternative possibility that over- and underestimations of time might predict delay decisions. The concept of an Internal Clock Speed (ICS) provides a possible cognitive framework for considering such differences. Differences in ICS, or the rate of the internal timing mechanism that registers that time has passed (Meck, 1996; Wittmann et al., 2007; Wittman & Paulus, 2008; Zakay & Block, 1996, 1997), could be related to differences in decision-making. In accordance, the tendency to overestimate time (e.g., to think seven minutes have passed after only five minutes) due to having a fast ICS could increase preferences for immediate rewards, while the tendency to underestimate time (e.g., to think only 3 minutes have passed after 5 minutes) due to having a slow ICS may increase willingness to wait across a temporal delay for more desirable rewards. Exploring ICS as a spectrum also introduces the intriguing possibility that people who are less accurate in their over- or underestimations might differ in their delay decisions. For example, people who tend to greatly overestimate time might be less willing to delay than people
who only slightly overestimate time. Examining these previously unexplored divergences may reveal a more complex role of time perception during delays.

The present study tests these possibilities that accuracy and direction of error in temporal judgments predict delay of gratification, and also explores the possibility that impulsivity (as measured by inhibitory control) drives both temporal judgments and delay of gratification. This work adds to prior theories by examining the relationship between over- versus underestimations in time perception and delay of gratification. One hypothesis is that overall time perception accuracy predicts delay decisions, regardless of tendencies to over- versus underestimate. Another hypothesis is that individual differences in the perception of time may lead some to over- or underestimate the length of time periods when making delay choices, resulting in corresponding differences in willingness to delay gratification. In any case, an improved understanding of the role of time perception and inhibitory control in delay of gratification could not only be informative from a basic science perspective, but could also point to new intervention strategies for populations that struggle to delay gratification.

Method

Participants

Participants were 20 (9 male, 11 female) 7-year-old children ($M = 7.68$ years; $SD = 0.25$ years). We tested 7-year-olds because the first-grade curriculum in the state of Colorado includes content intended to teach children how to tell time and familiarize children with temporal expressions, thus allowing us to test children using terminology such as seconds, minutes, and hours (The Colorado Department of Education [CDE], 2013). All subjects were recruited from the University of Colorado Boulder, Cognitive Development Center (CDC) database. Children with a diagnosis of ADHD and/or dyslexia, and children who had not
completed the first grade in school, were not recruited for this project. Five participants were dropped for various reasons, including changes in study procedures (n = 3), lack of preference for larger amount of reward in the snack delay task (n = 1), and failure to meet eligibility criteria due to not completing the first grade (n = 1). Results from the remaining 15 children are reported below. Parental consent and minor assent were obtained at the time of the visit, prior to child testing. Children received small prizes (e.g. balls, bracelets, stickers) and a certificate at the end of the session. Parents received a travel compensation of $5.

During the visit, children completed a measure of behavioral motor inhibition (Stop Signal; included to test the possibility that impulsivity drives both differences in time perception and delay of gratification), two time perception measures (time estimation and production tasks), and two delay of gratification tasks (a snack delay task and a hypothetical temporal discounting task). While children completed their tasks in the testing room, parents completed two surveys and an optional demographic form in the observation room, where study procedures were displayed on a computer monitor via a webcam that was mounted on the testing room wall.

**Questionnaires (completed by parent)**

*“It’s About Time” questionnaire.* Parents were asked to complete a 25-item multiple-choice questionnaire titled, “It’s About Time” (Barkley, 1998; Table 1.) which tapped children’s general timeliness and punctuality, as well as tendencies to talk about past and future events (e.g., “When you give your child a task or chore to do that has a time limit, how often is he or she likely to get the task done within that time period?”). Parents responded on a 4-point Likert scale, with answers ranging from “Rarely” to “Almost always”. This questionnaire served as an externally valid measure of time perception, as well as an indication of each child’s organization of their behaviors with respect to time.
Salience, Organization, and Management of Time Scale. Parents were asked to complete a 12-item questionnaire titled “Salience, Organization, and Management of Time Scale” (SOMTS; Houghton et al., 2011; Appendix A). This survey tapped general timeliness and punctuality in everyday life (e.g., “My child does not follow set routines, for example, when getting ready for school in the morning.”). Parents responded on a 4-point Likert scale, with answers ranging from “Definitely not true” to “Definitely true”. This survey, also a measure of time perception, gathered additional information regarding each child’s behavioral organization regarding time.

Behavioral tasks (completed by child)

Stop Signal task. Children completed a computerized measure of behavioral motor inhibition in which they had to occasionally refrain from executing a prepotent motor action based on a visual cue (adapted from Chevalier, Chatham, & Munakata, 2014). The task included No Signal and Stop Signal phases. In the No Signal phase, planes appeared on either the left or right side of the screen, and children had to press the corresponding left or right button as quickly as they could to make each plane land (Figure 1). After a demonstration by the experimenter and
a block of 24 No Signal practice trials, the experimenter gave children alternative instructions for the Stop Signal phase. On Stop Signal trials, the plane appeared first, with a Stop Signal (a lightning bolt) occasionally appearing after a variable delay that increased or decreased in duration depending on accuracy in previous Stop Signal trials. Children were instructed to continue making the planes land as fast as they could, but to refrain from pressing any button (i.e., making the plane land) if a lightning bolt appeared over the plane. The majority of the planes did not appear with a lightning bolt over them, establishing button-pressing as a prepotent response. Stop Signal delays were titrated to achieve 50% accuracy for each child (as in Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003). After a demonstration by the experimenter and a block of 24 practice trials in the Stop Signal phase, children played 3 blocks of 48 trials. Feedback was provided during the practice trials only, to ensure understanding of the instructions. Encouragement was offered between blocks for all children.

![Figure 1](image)

*Figure 1.* Stop signal task. Children were taught to make planes land by pressing buttons as quickly as they could in the No Signal phase, establishing button-pressing as a prepotent response. In the Stop Signal phase, children were required to continue pressing buttons to make the planes land, but to refrain from pressing when the stop signal (a lightning bolt) appeared. Only a small proportion of the planes had a stop signal.
**Time perception tasks.** In the time perception tasks, children estimated the number of seconds a remote-controlled lantern had been turned on by the experimenter (estimation), and also turned the lantern on for a period of seconds specified by the experimenter (production). The experimenter and the child sat on opposite sides of a table with a remote-controlled lantern in the center of the table, and a silent timer facing the experimenter. A stopwatch was also used in order to ensure duration accuracy.

**Time estimation task.** In this task, children were asked to verbally estimate the duration of time that they saw a visual stimulus (the lantern being turned on; Bauermeister et al., 2005). The experimenter turned on the lantern with a remote control for an unstated, but predetermined, number of seconds. Then the experimenter asked children to verbally estimate the number of seconds the lantern was on. The experimenter explained, “For this game, I’m going to turn the light on, and I’ll leave it on for a little while, and then I’ll turn it off. Then it’ll be your turn to guess how many seconds the light was on. While the light is on, be quiet and make sure you pay attention!” After the experimenter demonstrated how the game was played, children were given a practice trial of 5 seconds. Children then completed 12 trials using time durations in the order of 6, 13, 25, 10, 33, 18, 33, 6, 18, 10, 13, and 25 seconds (as adapted from Bauermeister et al. 2005). Each trial began with the experimenter stating, “Ready, set, on!” and concluded with the experimenter saying, “Off! Now, how many seconds do you think the light was on?” The experimenter did not give any feedback regarding accuracy.

**Time production task.** In this task, children were instructed to produce a visual stimulus (turning on a lantern) for a duration of time instructed by the experimenter (Bauermeister et al., 2005). The experimenter provided children with the remote control to the lantern, and explained, “Okay, now it’s your turn to turn the light on and off! But this time, I’m going to tell you how
many seconds that you should turn the light on. Try to keep the light on for as many seconds as I tell you to!” After the experimenter demonstrated how the game was played, children were given a practice trial of 5 seconds. Children then completed 12 trials using time durations in the order of 13, 18, 10, 25, 33, 6, 33, 13, 6, 18, 25, and 10 seconds (adapted from Bauermeister et al., 2005). Each trial began with the experimenter stating, “Okay. Next, I want you to turn the light on for [trial duration] seconds. Ready, set, on!” The experimenter refrained from giving feedback regarding their accuracy. As a strategy check, after all tasks for the child’s visit were completed each child was asked, “How did you know how to play those games with the light?”

**Snack delay task.** In this standard self-imposed delay of gratification task, children were left alone with a small snack reward for up to 25 minutes, and told that if they could wait to eat it until the experimenter returned to the room, they would receive a larger snack instead (Rodriguez et al., 1989). The experimenter first asked if each child would rather have marshmallows or M&M’s for their snack, to ensure all children were tested with a snack that they found desirable. Once children made their snack selection, the experimenter asked children to choose between a larger and smaller amount of the snack, to confirm all children desired a larger amount. Next, the experimenter stated, “Okay! Well, I need to do something in the other room. If you wait until I come back by myself, without eating any of those M&M’s (that marshmallow), and without leaving your seat, then you can have these M&M’s (marshmallows) to eat instead. How does that sound? Stay right there in that chair, can you do that?” The experimenter then took the larger reward, leaving the smaller reward on the table in front of the children, along with a small bell. The experimenter then said, “But if you don't want to wait, you can ring the bell and make me come back anytime you want to. But if you ring the bell and make me come back, you can't have the larger pile but you can have the smaller pile. I’ll leave
those M&M's (marshmallow) here, and if you haven’t eaten any when I come back, and if you haven’t rung the bell, you can have these M&M's (marshmallows) instead!” Children were then left with the smaller reward for up to 25 minutes while the experimenter observed in another room via a webcam that was mounted on the testing room wall. If children ate an M&M, bit the marshmallow, or rang the bell, the experimenter returned and allowed them to finish the small reward. In the event that children waited 25 minutes without eating the M&M’s or marshmallow and without ringing the bell, the experimenter returned and allowed them to eat the larger reward. After the experimenter returned, regardless of performance on this task, children were asked, “How many minutes do you think I was gone?” This provided a measure of retroactive time perception in terms of a relatively larger temporal unit (minutes) than that used in the time perception tasks (seconds).

**Hypothetical temporal discounting task.** Children played a computer game in which they chose between 32 hypothetical candies later, or some smaller quantity of candies now (Figure 2). The number of candies in the immediate option ranged from one to 31 candies, and the time to receive the future 32 candies ranged from one minute to one year. The two different quantities were displayed as pictures of candies, with the delay duration displayed below each picture. The small immediate reward was always displayed on the left side, with the delayed reward on the right. For each trial the experimenter pointed to the screen and said, “Would you rather have [number] candies now, or 32 candies in one [time unit]?” as prompted on the screen. Children responded verbally, and the experimenter controlled the keyboard to log responses and advance trials. Each participant made 30 choices. This task was titrated such that the number of candies in the immediate option from trial to trial was adjusted depending on the child’s previous responses, in order to hone in on each child’s indifference point, or the point in which the smaller
immediate reward and the larger delayed reward held the same subjective value for a given delay period.

![Image: Hypothetical temporal discounting task.](image)

**Figure 2.** Hypothetical temporal discounting task. Children were asked to make choices on whether they would prefer 32 candies later, or some smaller number of candies in the immediate. The hypothetical delay period ranged from one minute to one year. This task was titrated such that the number of candies in the immediate option from trial to trial were adjusted based on the child’s previous response in order to hone in on their point of indifference for the given delay period.

**Results**

**Preliminary Analyses and Descriptive Statistics**

Data from the computerized tasks were automatically logged into a spreadsheet. Performance on the two time perception tasks and the snack delay task were coded from video by two research assistants. All analyses were conducted using the R statistical package (R Core Team, 2013).
**Time perception questionnaires and tasks.** In the time perception questionnaires, the “It’s About Time” ($M = 41.33$, $SD = 9.95$) and the Salience, Organization, and Management of Time scale ($M = 43$, $SD = 4.63$) scores were the sum of their ratings on all 4-point Likert scale questions, with higher scores reflecting greater temporal awareness in everyday life (Barkley, 1998; Houghton et al., 2011). While scores on these scales were highly correlated with one another ($r = 0.76$, $p = .002$), they did not relate to performance on any of the time perception behavioral tasks or the delay of gratification tasks, thus will not be discussed further.

In the time perception tasks, error scores were calculated for each trial by subtracting actual trial durations from children’s verbal estimates of how long the lantern was on (in the estimation task) or the length of time children turned the lantern on (in the production task; as adapted from Bauermeister et al., 2005). An average estimation discrepancy score and an average production discrepancy score (reflecting overall accuracy, and the direction of accuracy) was calculated for each child. Consistent with prior work using the present time perception measures, children displayed task-specific patterns of over- and underestimations on the estimation and production tasks, such that if children tended to overestimate on the estimation task, then they tended to underproduce on the production task, and vice versa (Bauermeister et al., 2005). Thus, discrepancy scores on the estimation and production tasks were significantly anticorrelated with one another ($p = 0.00018$), so we did not combine performance on the two tasks to create a composite discrepancy measure that took direction of error into account. However, an absolute composite discrepancy score, reflecting accuracy regardless of direction of error, was calculated.

**Delay of gratification tasks.** In the snack delay task, coders recorded the number of seconds before each child’s first taste of the marshmallow or M&M’s – lick or bite – occurred
Based on choices made in the hypothetical temporal discounting task, a $k$ parameter was estimated for each participant (as in Ballard and Knutson, 2009), with lower $k$-values reflecting increased preferences for delayed rewards ($M = 1.16, SD = 1.21$). Indifference points were calculated at each delay using logistic regression to determine the later value at which there was an equal probability of each response. Discounted value (DV) was calculated at each delay and a hyperbolic discounting function was fit to all DVs using non-linear least squares: $DV = 1/(1 + k \times \text{delay})$, where $k$ is the unknown discounting parameter. Given that $k$-values were not normally distributed, all values were log transformed for subsequent analyses ($M = -1.18, SD = 2.1$). Wait times from the snack delay task were not significantly correlated with $k$-values from the hypothetical temporal discounting task ($r = .16, p = .58$).

**Behavioral motor inhibition task.** Performance on the Stop Signal task was converted to a Stop Signal Response Time for each participant (SSRT; as in Aron et al., 2003) by subtracting the average Stop Signal delay (SSD; titrated to 50% accuracy on Stop Signal trials) from the median No Signal reaction time. Higher SSRT scores thus correspond to worse behavioral motor inhibition. SSRT values were not correlated with measures of time perception or delay of gratification, nor did results change when controlling for SSRT in the regression models (all $ps > .1$); thus, performance on this task will not be discussed further.

**Time perception accuracy and delay of gratification**

First, to evaluate the hypothesis that overall time perception accuracy relates to delay of gratification, we examined absolute discrepancy scores as a continuous measure, ignoring the direction of time perception errors. Absolute discrepancy scores from the production and
estimation tasks (both the separate and composite measures) did not relate to either of the delay of gratification measures (all $ps > .1$). The absolute composite discrepancy measure showed a marginal negative relationship with $k$-values, such that higher composite discrepancy scores predicted lower $k$-values ($F_{1,13} = 3.24, p = .10$). However, given a strong relationship between $k$-values and age ($F_{1,13} = 7.89, p = .02$), with older children demonstrating an increased preference for immediate rewards relative to younger children, we tested a multiple regression model predicting $k$-values from the absolute composite measure while controlling for age. A main effect of age persisted in this model ($F_{1,13} = 7.32, p = .02$) but the absolute composite measure was no longer significant, nor was there an interaction between age and absolute composite discrepancy scores ($ps > .4$).

**Over- versus underestimating time and delay of gratification**

Next, to evaluate the hypothesis that the direction of error in time perception relates to delay of gratification, we examined signed discrepancy scores, which took over- versus underestimations into account. As a basic continuous measure of over- versus underestimations, we first analyzed average discrepancy scores on the time estimation and production tasks. Signed discrepancy scores on both time perception tasks showed no relationship with delaying gratification on neither the snack delay task (estimation task: $r = -.22, F_{1,13} = 0.67, p = .43$; production task: $r = .11, F_{1,13} = 0.16, p = .7$; Figure 3) nor the hypothetical temporal discounting task (controlling for effect of age; estimation task: $F_{1,13} = 1.82, p = .2$; production task: $F_{1,13} = 0.31, p = 0.59$).
However, this basic continuous measure could be influenced by extreme values (e.g., if a child underestimates on all trials except one, but that one overestimation was very large, their average signed discrepancy score might make them look like an over-estimator). Additionally,
these data were not normally distributed, as indicated by a Shapiro-Wilk test of normality ($W = 0.87, p = .04$). To address these issues, we normalized each discrepancy score by the overall duration of the trial for the time perception tasks. Specifically, raw signed error for each trial was divided by the overall duration for the trial, yielding a proportion error score (e.g., if a child estimated that a 10 second estimation trial lasted for 5 seconds, their weighted error would be $-5/10 = -0.5$). The normalized discrepancy scores from the production task did not relate to snack delay times ($r = .14, F_{1,13} = 0.26, p = 0.62$; Figure 4) or $k$-values (controlling for effect of age; $F_{1,13} = 0.19, p = .66$). Similarly, the normalized discrepancy scores from the estimation task did not relate to snack delay times ($r = -.09, F_{1,13} = 0.1, p = .75$; Figure 5) or $k$-values (controlling for effect of age; $F_{1,13} = 2.05, p = .18$).

**Figure 4.** In order to normalize the distribution, raw signed error for each time production trial was divided by the overall duration for the trial, yielding a proportion error score. Weighted proportion accuracy scores did not predict wait times in the snack delay task ($r = .14, F_{1,13} = 0.26, p = 0.62$).
Next, as a coarser measure of time perception task tendencies, we examined counts of over- versus under-estimations by trial counts, ignoring overall time perception accuracy. For both the production and estimation tasks, the number of trials on which a child overestimated was subtracted from the number of trials on which a child underestimated, yielding an overall time perception tendency score, with positive values reflecting a tendency to underestimate. This coarse measure of over- versus underestimation tendencies did not predict wait times in the snack delay task ($F_{1,13} = 0.9, p = .36$; production task: $F_{1,13} = 0.57, p = .46$) or k-values on the hypothetical temporal discounting task (controlling for effect of age; estimation task: $F_{1,13} = 0.32, p = .58$; production task: $F_{1,13} = 1.68, p = .22$).

As a final, exploratory analysis, we categorized children as over- or under-estimators based on whether they had a positive or negative value for the coarse trial count measure. Using this method, 14 children were categorized as over-estimators in the production task, and 12

---

**Figure 5.** In order to normalize the distribution, raw signed error for each time estimation trial was divided by the overall duration for the trial, yielding a proportion error score. Weighted proportion accuracy scores did not predict wait times in the snack delay task ($r = -.09, F_{1,13} = 0.1, p = .75$).
children were categorized as over-estimators in the estimation task. First examining the production task, no differences in snack delay wait times ($p > .1$) or $k$-values ($p > .9$) were observed between over- and under-estimators. Next examining the estimation task, no differences in $k$-values were observed between over- and under-estimators ($p > .9$). However, we did group differences on the snack delay task, with under-estimators waiting significantly longer ($M = 24.77$ minutes, $SD = 0.39$) for a delayed reward relative to over-estimators ($M = 16.6$ minutes, $SD = 10.7$) as measured by a Wilcoxon signed rank test with a continuity correction ($W = 91, p = 0.0012$; Figure 6).

![ICS Classification and Mean Wait Times](image)

*Figure 6.* Trial count information for each child was calculated by subtracting the number of trials that they overestimated on from the number of trials they underestimated on. Negative scores corresponded with a classification as having a fast Internal Clock Speed (ICS; or a greater tendency to overestimate time), and positive scores corresponded with a classification as having a slow ICS (or a tendency to underestimate time). Children with a slow ICS ($n = 3$) on average had significantly longer wait times ($M = 24.77$ minutes, $SE = 0.23$) than children with a fast ICS ($n = 12; M = 16.6$ minutes, $SE = 3.09$), $W = 91, p = 0.0012$. Error bars reflect standard error.
Discussion

Our results demonstrate that the direction of error in individual time perception may play an important role in delay of gratification. Regardless of individual differences in behavioral motor inhibition, when using group classifications the children who tended to underestimate in their temporal judgments waited longer for desirable but delayed rewards relative to children who tended to overestimate in their temporal judgments. This study complements prior work, which provided some evidence for this relationship between time perception and behavioral inhibition in typically developing children, but did not examine willingness to delay for real rewards or address differences in over- and underestimations of time (Corvi et al., 2012; Meaux & Chelonis, 2005; White et al., 1994). Additionally, the relatively unexplored but critical period in time perception development around 7 years of age was examined in this study. The findings from this work may be informative for implementing new teaching strategies or interventions that increase temporal awareness for children that struggle with delaying gratification.

This work adds to prior literature indicating that the decision to delay gratification may be influenced by more than self-control and reward sensitivity (Michaelson et al., 2013; Mischel & Gilligan, 1964; Rodriguez, Mischel, & Shoda, 1989), and supports some existing theories that suggest time perception may be one of these factors (Church & Meck, 2003; Wittman et al., 2007; Wittman & Paulus, 2008). Such theories have focused on the importance of time perception accuracy in predicting delay of gratification decisions, and studies in ADHD populations and healthy adults have supported the idea that greater absolute accuracy in temporal judgments corresponds to greater willingness to delay gratification for monetary rewards (Barkley et al., 2001a; Corvi, et al., 2012). Although the present study did not find evidence for a relationship between time perception accuracy and delay of gratification, this relationship may
emerge with a larger sample size and greater statistical power. Also inconsistent with prior literature, behavioral motor inhibition was not related to any of our behavioral tasks, including our delay of gratification measures.

While accuracy did not predict delay of gratification in the present data, tendencies to over- versus underestimate temporal durations in the estimation task were interesting. It is somewhat surprising that we observed such a high proportion of over-estimators relative to under-estimators, and unfortunate that this prevented us from examining under-estimators in the production task. However, focusing on the estimation task (over the production task or a composite measure) seems appropriate, because the duration judgments made in these trials are arguably more similar to those made in the delay choice paradigm, relative to the production task. That is, while the production time perception task required children to generate durations of time, the estimation time perception task asked children to make judgments about temporal durations generated by others, much like in the snack delay task.

Although we did observe a significant difference in snack delay wait times between over-estimators and under-estimators, the present results should be interpreted cautiously due to our small sample size ($n = 15$), small slow ICS subset ($n = 3$), and the concern that this effect is only seen when analyzing ICS as a categorical variable. It will be important to determine whether this pattern persists in larger samples, as well as to determine if ICS as a continuous variable is predictive of delay decisions in larger samples. If so, having a fast ICS may result in the perception of a delay period as lasting far longer than it does in reality, and therefore influences decision-making in favor of immediate gratification, which could help to explain why children tend to be notoriously impulsive. Likewise, having a slow ICS may result in feeling that less
time has passed in a delay period, and therefore influences decision-making in favor of larger later rewards.

It is important to note that reevaluations of future rewards during unspecified delay periods may result in preferences for immediate gratification due to a reduced belief that the delayed reward will soon be delivered, regardless of time perception accuracy. A growing body of research suggests that beliefs about the amount of time left to wait for a delayed reward increase with wait times over the delay period, such that the longer an individual waits for a delayed reward, the longer they believe they will have to wait before the delayed reward will arrive (McGuire & Kable, 2012). In the present study, children were not told how long they would be required to wait for the experimenter to return. Thus, children who decided to either eat the small reward or ring the bell during the delay period may have reevaluated the length of time they would need to wait. This alternative interpretation of the role of individual time perception in delay of gratification suggests that future research should more closely examine this process of reevaluating time during delays in relation to the tendency to over- and underestimate temporal durations.

An additional limitation of the present study is the possibility that our time perception tasks (used in Bauermeister et al., 2005) may not be the most optimal method for capturing ICS. The lantern time perception tasks captured differences in accuracy and over- and underestimations of time on temporal judgments on the order of seconds; however, the vast majority of the delay decisions we make in everyday life occur on the order of minutes, hours, days, or months. Examining over- and underestimations of these longer durations in relation to delay of gratification in future research may provide a more accurate representation of this relationship in the real world.
In future work, it will be important to address questions of the present study in a larger sample. This will allow us to see if the ICS proportion in our sample persists in the general population, with most children overestimating temporal durations and relatively fewer children underestimating temporal durations. Additionally, with a larger sample (and therefore, a larger subset of underestimators) we will be able to determine if our sample’s trend of underestimators demonstrating a greater willingness to delay gratification than overestimators persists in the population. A subsequent examination of the ways in which time perception accuracy relates to delay of gratification will also allow us to determine whether our measures of time perception replicate previous findings, and how this relationship in 7-year-olds differs from older groups. As an intriguing additional possibility, it would be interesting to evaluate whether decisions in a delay of gratification task differ when children are told the amount of time they will have to wait for the delayed reward, therefore removing the uncertainty involved in the choice. Seeing how children with and without this knowledge make decisions, as well as examining their perceptions of time, could be informative for understanding delay decisions at this age.

The increasing evidence for the role of time perception in delay of gratification offers new insights to prior findings, and points to novel directions for intervention. Theoretically, the present study supports recent research showing that delay of gratification depends on factors other than just inhibition, and possibly warrants greater attention to differences in time perception in future delay of gratification studies. Individual perceptions of time may greatly impact the individual experience of time, making temporal periods feel far longer or far shorter, thereby changing the subjective value of larger later rewards. This is especially relevant in choices made when the time between the immediate choice and the delayed choice is uncertain, such as in delay of gratification. These variations in perceptions of time may be due some innate
ability (as exemplified by the time perception deficits in ADHD populations), however, accuracy in time perception and temporal awareness may be increased through interventions and practice. In school and at home, teachers and parents can give children more concrete experiences with time, rather than solely explaining the anatomy of a clock. These demonstrations could be in the context of practicing delay of gratification using specified temporal durations (e.g., promising a child a cookie after dinner is over in one hour). Gaining a more accurate understanding of time might allow for better-informed decisions on whether to wait for more desirable later rewards. Testing such possibilities for the role of time perception, and exploring how it interacts with other internal and external factors, may progress our understanding of delay of gratification from an innate ability to part of a far more complex decision-making process.
References


investments of time versus money. *Journal of Experimental Psychology: General, 134*(1), 23.

Appendix A

Salience, Organization, and Management of Time Scale
Stephen Houghton, Ph.D.

Child’s Name ___________________________________________ Date __________________

Child’s Age ___________ Date of Birth ____________________  Sex:  Male  Female

Person Completing This Form: (Circle one below):

Mother  Father  Guardian  Other (Explain) ______________________

Instructions
Please read the statements below and rate how true each statement is of your child from “Definitely not true” (1) to “Definitely true” (4). Thank you!

1. My child frequently talks about upcoming events that he/she will be involved in.

   Definitely not true                Definitely true

   1                                2  3  4

2. My child often asks about things that will happen in the future.

   Definitely not true                Definitely true

   1                                2  3  4

3. My child enjoys talking about things that he/she has done in the past.

   Definitely not true                Definitely true

   1                                2  3  4

4. My child at the end of the day will often talk about what he/she will be doing tomorrow.

   Definitely not true                Definitely true

   1                                2  3  4

5. My child at the end of the day will often talk about what has happened that day.

   Definitely not true                Definitely true

   1                                2  3  4
6. My child does not follow set routines, for example, when getting ready for school in the morning.
   Definitely not true
   Definitely true
   
   1  2  3  4

7. My child is oblivious to other people’s time deadlines.
   Definitely not true
   Definitely true
   
   1  2  3  4

8. My child is rarely ready to leave for school on time.
   Definitely not true
   Definitely true
   
   1  2  3  4

9. My child is not a punctual person.
   Definitely not true
   Definitely true
   
   1  2  3  4

10. My child has difficulty telling the time using a clock.
    Definitely not true
    Definitely true
    
    1  2  3  4

11. My child has difficulty retelling events in the order that they happened.
    Definitely not true
    Definitely true
    
    1  2  3  4

12. My child struggles to conceptualize units of time (e.g. weeks/months/terms).
    Definitely not true
    Definitely true
    
    1  2  3  4