AN EVALUATION OF TEMPORAL DISCOUNTING IN NEUROTYPICAL INDIVIDUALS AND INDIVIDUALS WITH AUTISM SPECTRUM DISORDERS

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MIKALA RAE HANSON

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APPROVED: ______________________________
Robert LaRue, Ph.D., BCBA-D

____
Kimberly Sloman, Ph.D., BCBA-D

DEAN: ______________________________
Francine Conway, Ph.D.

Abstract

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterized by impairments in social interaction, communication, and restricted and repetitive interests and activities. While not a defining characteristic of ASD, many individuals with this diagnosis display impulsive responding. The presence of impulsivity can be pervasive and dramatically affect the intervention process. In the scientific literature, impulsivity is often conceptualized as *temporal discounting*. Temporal discounting refers to the decrease in the value of reinforcers as a function of the delay of their receipt. Researchers have outlined some procedures for evaluating temporal discounting in human populations. However, much of this research is limited to hypothetical choices with typically developing populations. Additionally, research has yet to be conducted comparing impulsivity of individuals with ASD who are lower functioning to typically developing controls using real as opposed to hypothetical choices. The purpose of the current investigation was to measure temporal discounting in neurotypical individuals and individuals diagnosed with ASD. In the study, participants were given choices between an impulsive choice and a self-controlled choice. Indifference points were plotted, forming discounting curves. The results suggest that individuals diagnosed with ASD respond more impulsively overall than neurotypical peers. Furthermore, it was found that in neurotypical participants, both children and adults display more impulsive responding than adolescents, while participants diagnosed with ASD remain impulsive throughout adulthood, showing no effect for age. These findings offer preliminary data on research comparing impulsivity in individuals with ASD and their neurotypical peers. Important implications of our findings are further discussed.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

An Evaluation of Temporal Discounting in Neurotypical Individuals and Individuals with Autism Spectrum Disorders

Autism Spectrum Disorders

Autism Spectrum Disorder (ASD) is a pervasive developmental disorder characterized by persistent deficits in social interaction, deficits in language and communication, and the appearance of restricted, repetitive and stereotypical behavior (American Psychiatric Association, 2013). It is the third most common developmental disability (May Institute, 2010). The symptoms of ASD can affect the overall daily life functioning of these individuals and present a multitude of negative outcomes in school, home, and personal realms.

Prevalence

According to recent reports from the Centers for Disease Control and Prevention (CDC), 1 in 59 children are diagnosed with ASD in the United States, with approximately 2 million people diagnosed with the disorder (CDC, 2018). It is estimated that approximately 100 people are given an ASD diagnosis each day in the United States (Autism Speaks Inc., 2017). The worldwide incidence of ASD is reported to approach 1% to 2% of the population (CDC, 2018). ASD is more common in males than females (4:1), with prevalence rates for males reported as being 1 in 37, and females, 1 in 151 (Baio et al., 2018). The prevalence rate of ASD in New Jersey is among the highest in the country with 1 in 34 children having an ASD diagnosis.

Symptoms of ASD usually arise within the first 18 months, with the average onset occurring before the age of 3. Some studies have shown that it is possible to diagnose ASD in toddlers as young as 12 to 24 months (Kim & Lord, 2012). About 90% of parents first report recognizing abnormalities in language development and socio-emotional responding by 24 months (Volkmar, Chawarska, & Klin, 2005). By the age of 30 months, children with ASD begin to present with social deviance, problems with communication, and unusual responses to nonsocial environments (Volkmar et al., 2005).

Symptoms

Individuals with ASD present with core deficits in social interaction, language and communication, and restricted and repetitive behavior. These symptoms can appear in a variety of ways and are highly heterogeneous in expression. The extent to which these deficits are present may vary significantly (mild to severe), allowing for a wide spectrum of symptom presentation. This heterogeneity poses a challenge when developing treatment interventions for this population.

Social deficits. Individuals with ASD often have difficulty with social-emotional reciprocity, including abnormal social approach. They frequently misunderstand social cues, and may have difficulty adjusting their behaviors to suit various social contexts. This inflexibility can make it difficult for these individuals to attend public events (e.g. church sermons or movies). Additionally, they typically struggle with sharing their feelings with others or empathizing with the emotions of others. They are unlikely to share their interests with others, and have difficulty initiating or responding to social interactions. For example, they often fail to respond to their name or fail to respond to peer initiation during social interaction (e.g. during play). Furthermore, this population may present with overall deficits in developing, maintaining, and understanding relationships (American Psychological Association, 2013).

Language and communication deficits. Individuals with ASD also commonly present with deficits in language and communication, including a lack of facial expressions and impairments with nonverbal communication. They often have delayed speech and language skills. Their speech ability can range from being completely nonverbal to being fluent, but awkward or socially inappropriate at times (National Institutes of Health, 2015). Individuals with ASD may engage in "scripting," which involves the repetition of words or sentences from past contexts, such as a conversation they overheard or a movie they watched. They also frequently exhibit abnormalities in eye contact and body language, difficulty using gestures, and poor integration of verbal and nonverbal communication.

Repetitive and ritualistic behavior. Another core symptom of ASD includes restricted and repetitive behavior patterns, interests, or activities. These behaviors often include motor stereotypy, which consists of repetitive and stereotyped motor movements (e.g., hand flapping, twirling, and rocking back and forth). This repetitive behavior can also extend to vocalization (e.g. repeated non-contextual phrases or sounds). Other classes of ritualistic behavior commonly observed include non-functional use of objects (e.g. lining up toys). People diagnosed with ASD typically present with an insistence on sameness, have difficulties with transitions, or display inflexible adherence to routines. They may therefore become distressed when there is an unexpected change in their routine. Additionally, these individuals frequently display ritualized patterns of verbal or nonverbal behavior (e.g. needing items to be organized a specific way or needing to complete actions in a specific order). Individuals with ASD oftentimes exhibit highly fixated and restricted interests (e.g. a particularly strong interest in baseball or trains). Hyper- or hypo-reactivity to various types of sensory input are commonly reported concerns as well. This population may also present with an unusual interest in sensory aspects of the environment (American Psychological Association, 2013). This can include adverse responses to sounds, textures, and lighting, as well as excessive smelling or touching of objects.

Severity levels. The Diagnostic Statistical Manual of Mental Disorders, 5th Edition (DSM-5) breaks down the diagnosis of ASD by severity level (American Psychological Association, 2013). These severity levels are based on the amount of support the individual is likely to need. An individual with a Level 1 classification is someone who "requires support." These individuals often exhibit average to above average intelligence and speak in full sentences. However, they might have difficulties with initiating social interactions and understanding social cues. Those with a Level 1 diagnosis can also present with some behavior inflexibility and rigidity with routines as well as difficulties with organization. Furthermore, they may need various supports in place to help sustain independent living. The Level 2 classification describes individuals who require "substantial support." Those classified as Level 2 often present with marked deficits and challenges and would therefore require more support in order to engage in daily living skills and complete other everyday tasks. An individual classified as a Level 3 requires "very substantial support." They present with significant intellectual impairments, displaying severe deficits in social interaction and communication. They are likely to have extremely limited verbal ability, and may present with a higher inflexibility of their behavior. They typically exhibit repetitive and restrictive behaviors that severely impact daily life functioning and performance. These individuals frequently require more intensive supportive services, and engage in more dangerous levels of problem behavior that threaten their personal safety as well as the safety of others.

Autism Spectrum Disorder: Associated Features

While ASD is most commonly associated with social and communicative deficits, restrictive interests, and repetitive behavior, there are a number of associated features that frequently co-occur with ASD. Among the most common associated features are intellectual disability, maladaptive behavior, and impulsivity.

Intellectual Disability

Intellectual Disability is characterized by deficits in both intellectual and adaptive functioning. Intellectual functioning deficits include difficulties with general reasoning, learning, problem solving, and an IQ score less than 70. Adaptive functioning deficits generally involve difficulties in the acquisition of independent living skills (e.g. self-help, social, and communication skills) (Parekh, 2017). ASD often co-occurs with intellectual disability, with prevalence rates between 16.7% and 84.0% (Postorino et al., 2016). The wide range in prevalence is likely due to the unreliability of IQ assessments for this population. Goldberg Edelson (2006) noted that language difficulties, attention deficits, and processing delays characteristic of individuals diagnosed with ASD can make standardized measures of intellectual disability challenging and inappropriate to use with this population. A potential discrepancy between intelligence and developmental or adaptive functioning in some individuals may resultantly underestimate overall intelligence.

Maladaptive Behavior

Individuals with ASD frequently present with maladaptive behavior. Maladaptive behavior in this population can take many forms. Among the most commonly reported forms of challenging behavior are physical aggression, self-injury, disruption, property destruction, elopement, and pica (mouthing or eating inedible objects). These behaviors may be physically dangerous to the self or others, socially unacceptable, and/or behaviors that negatively impact learning (Jang, Dixon, Tarbox, and Granpeesheh, 2011). The failure to address challenging behaviors in this population often leads to a number of negative outcomes, including impaired social relationships and placement in more restrictive school and residential settings (Fitzpatrick et al., 2016; Wachtel et al, 2009). According to a prevalence study by Jang, Dixon, Tarbox, and Granpeesheh (2011), about 94% of people diagnosed with ASD exhibit some form of challenging behavior. Hill and colleagues (2014) posited that due to various impairments of the ASD population, particularly those related to communication, maladaptive behaviors may arise as a form of communication.

Impulsivity

Impulsivity is another associated feature of individuals with ASD (Ozonoff, Pennington, & Rogers, 1991, Aman et al., 2008). Behaviorally speaking, impulsive responding involves selecting a smaller, more immediate consequence over a larger, more delayed consequence (Reed & Martens, 2011). In other words, a person can be described as impulsive when they select a smaller quantity of a reward immediately as opposed to waiting longer for a larger reward.

Vollmer and colleagues (1999) investigated the relationship between impulsivity and problem behavior in the context of reinforcement schedules. They suggested that the reinforcement schedule for problem behavior may be denser than the schedule maintaining appropriate adaptive behaviors. This denser schedule means that engaging in problem behavior results in access to reinforcers more often than engaging in appropriate behaviors. Therefore, problem behaviors can be conceptualized as being an impulsive choice, where engaging in the problem behavior would allow an individual to gain access to reinforcement sooner rather than having to wait longer to access rewards.

Though impulsivity defined as above may be a more efficient means for individuals to get access to preferred outcomes sooner than engaging in more adaptive behavior, the presence of impulsivity can be pervasive, and dramatically affect the intervention process. Impulsive behavior may slow academic progress and disrupt community integration. Thus, further exploration of impulsivity in individuals diagnosed with ASD could potentially help address these issues and inform intervention. This examination of impulsivity in this population is the primary focus of the current investigation.

Temporal Discounting

Impulsivity is often conceptualized and measured in the context of temporal discounting. Temporal discounting occurs when the value of a reinforcer decreases as the length of time one has to wait for it increases (Reed, Niileksela, & Kaplan, 2013). For example, if given a choice of receiving $100 immediately or waiting one week for $500, one might choose to wait a week for the larger amount. Imagine being given the same choice, but the wait time for the $500 increases to 6 months. The value of the $500 choice may decrease due to the length of time one would need to wait (i.e., $500 may not be worth a 6 month wait time). Thus, one might choose the smaller, sooner $100 reward. In this scenario, the value of the larger reward decreased as a function of how long one had to wait to receive it. This relationship is described as temporal discounting.

General Procedures and Data Analysis

In experimental preparations of temporal discounting, participants are often given a series of selections wherein they have to choose between receiving a smaller reward sooner (impulsive choice) and receiving a larger reward later (self-controlled choice). Researchers typically vary the amount of the smaller, sooner reward while the amount of the larger, more delayed reward remains constant. In this arrangement, the delay times for the receipt of larger rewards also differ. For example, a person is presented with two options: receiving $100 immediately or waiting 2 weeks to receive $500. After making a choice, the person is then presented with another pair of options: receiving $200 immediately, or waiting 2 weeks to receive $500 and so on. Researchers then compare the 2-week delay to a 5-week delay using the same amounts to further measure any differences in response dependent on time delay to the receipt of the larger reward. Usually, researchers present choices that are hypothetical—the participant chooses which reward they would like, but they do not receive a tangible reward, such as the monetary amount used in the above example.

In temporal discounting procedures, researchers quantify impulsivity by calculating indifference points based on the choices made. An indifference point is the point at which one switches to choosing the smaller, sooner reward over the larger, delayed reward (the more impulsive choice). For example, if a person was given the option to receive $700 now or $1,000 in a week, the person may choose to wait a week. If given the choice to receive $700 dollars now or $1,000 in a month, the person might choose to wait a month for the $1,000. If then given the option to receive $700 now or $1,000 in 6 months, the same person might choose to receive the $700 now instead of waiting for 6 months. The point at which the person switches to the impulsive choice ($700 now) is the *indifference point*. These choices can then be repeated using other values for the smaller reward (e.g., $100, $200, $300). To further clarify the concept of indifference points, the indifference point in the example above can be found in Table 1 (see Appendix). This table displays representative trials and hypothetical data from a temporal discounting protocol created by Critchfield and Kollins (2001). The indifference point for the $700 immediate reward is indicated by the capital letter I with an asterisk (I*) and is located in the 6-month column. In this table, hypothetical data are also presented for other immediate reward values.

Once indifference points are established (in this example, $700 is equivalent to $1,000 with a 6-month delay) they are usually plotted on a graph in relation to the subjective value of the larger reward ($1,000) to create a discounting curve (Reed, Niileksela, & Kaplan, 2013). A model discounting curve is depicted in Figure 1 (see Appendix). In interpreting discounting curves, steeper curves represent more impulsive responding (the value of the larger reward decreases as delays to its receipt increase). Shallow curves are representative of less impulsive responding (the value of the larger reward decreases to a lesser extent as delays increase).

Non-Human Discounting Research

Much of the early discounting research began in basic laboratories using animal models. These early studies laid the framework for human applications of temporal discounting research. In Mazur (1987), pigeons were provided with concurrent choices between a smaller, sooner reward, and a larger, more delayed reward. The pigeons selected choices by pecking at an illuminated key. Richards, Mitchell, Wit, and Seiden (1997) employed similar discounting procedures with rats, where the rats pressed a lever in order to select their choices. Both studies yielded the same results—the value of the larger reinforcer decreased the longer the pigeons or rats had to wait for that reinforcer. Mazur (2000) and Green, Myerson, Holt, Slevin, and Estle (2004) implemented discounting procedures with both pigeons and rats. Their results supported the results of the prior studies and also depicted a species difference, wherein pigeons discounted more steeply than rats, exhibiting more impulsive responding. The findings of Mazur (2000) further indicated that humans discounted less steeply than both of these animals, displaying less impulsivity overall.

Human Discounting Research

The most commonly used procedures in human discounting research involve hypothetical choices, similar to those outlined in the study by Rachlin, Raineri, and Cross (1991). The procedure used by Rachlin and colleagues involved having participants make choices between two hypothetical outcomes (one immediate and one delayed) involving money. To date, researchers have conducted studies with a number of different clinical populations (e.g., individuals diagnosed with ADHD, gamblers, alcoholics, substance abusers, and individuals with intellectual disabilities).

Temporal Discounting Research in Clinical Populations

Attention Deficit Hyperactivity Disorder (ADHD)

Research has been conducted with individuals diagnosed with ADHD, a disorder that is characterized by the occurrence of impulsive behavior (Dai, Harrow, Song, Rucklidge, and Grace, 2016; Scheres, Lee, and Sumiya, 2008; Wilson, Mitchell, Musser, Schmitt, and Nigg, 2011). In most of these studies, discounting was measured using hypothetical choices across monetary amounts (cents or dollars) and various delay times (seconds, days, or years). Scheres, Lee, and Sumiya (2008), however, used real rewards as opposed to hypothetical rewards. In their procedure, participants were asked to choose between a larger, delayed reward that was kept constant at 10 cents, and a smaller, immediate reward, which varied between 2, 4, 6, or 8 cents. Delay times were 5, 10, 20, 30, or 60 seconds. All studies found that the participants with ADHD discounted more (were more impulsive) as compared to typical individuals.

Addiction

Temporal discounting research has also been extended to other populations with disorders characterized by high impulsivity, such as gamblers and substance abusers (Dixon, Marley & Jacobs, 2003; Madden, Bickel, & Jacobs, 1999; Mitchell, 1999; Petry & Casarella, 1999; Vuchinich & Simpson, 1998). Discounting procedures used were similar to those described above and involved hypothetical monetary choices. Vuchinich and Simpson (1998) found that both problem drinkers and heavy social drinkers were more impulsive in their responding than light social drinkers. Results from Mitchell (1999) indicated that regular smokers were more impulsive in their responding than nonsmokers. Petry and Casarella (1999) found that substance abusers discounted more steeply, and thus were more impulsive in their responding than controls. Results also suggested that substance abusers, who were also problem gamblers, were more impulsive in their responding than those participants who were substance abusers, but did not gamble. Similarly, Dixon, Marley and Jacobs (2003) found that gamblers discounted rewards more (displayed more impulsive responding) than control populations. Madden, Bickel, and Jacobs (1999) also used hypothetical heroin rewards in their discounting procedure with opioid-dependent participants. Their results indicated that opioid-dependent individuals were more impulsive in their responding for the hypothetical heroin rewards as opposed to the hypothetical monetary rewards.

Intellectual Disabilities

Researchers have also investigated impulsivity in populations with deficits in intellectual functioning (Shamosh and Gray, 2008; Willner, Bailey, Parry, and Dymond, 2010). The discounting procedures used hypothetical rewards. Shamosh and Gray (2008) found that across studies, participants with lower intelligence levels discounted at a steeper rate, thus displaying more impulsive responding than participants with higher intelligence levels. Willner, Bailey, Parry, and Dymond (2010), in their investigation of individuals with intellectual disabilities, found that subjects with intellectual disabilities tended to discount more than controls (were more impulsive). Though not using temporal discounting procedures, Kopp (1990) and Cuskelly, Zhang, and Hayes (2003) further examined impulsivity patterns in young adolescents with Down Syndrome by investigating delayed gratification patterns. Delayed gratification, or the ability to resist getting access to a smaller immediate reward in order to receive a larger, more delayed reward, is another method used to examine impulsivity. Both studies found that the children with Down Syndrome displayed more impulsive responding, waiting less time than the control group when it came to getting access to preferred items.

Autism Spectrum Disorders

While researchers have explored discounting in a number of populations, relatively few have investigated impulsivity in individuals with ASD. Of the studies that have focused on impulsivity in this population, most have involved higher-functioning participants with ASD. The following is a brief overview of the research to date where researchers have examined temporal discounting, comparing other clinical populations to populations with an ASD diagnosis.

Antrop, Stock, Verte, Wiersema, Baeyens, and Roeyers (2006) compared impulsivity in 23 children and adolescents with high functioning autism (HFA), 25 typically developing children and adolescents, and 25 children and adolescents with ADHD. Participants were aged 6-14 (mean age 9 and 10). Antrop and colleagues used hypothetical choices in a single-repeated choice procedure. Each participant completed a task consisting of 20 hypothetical choices wherein they were instructed to choose between a small, immediate reward (1 point in 2 seconds) and a large, delayed reward (2 points in 30 seconds) on a computer. They found that the participants with ADHD displayed more impulsive responding than those participants with HFA and the neurotypical controls.

Demurie, Roeyers, Baeyens, and Sonuga-Barke (2012) extended Antrop et al.'s (2006) study using a standard temporal discounting paradigm. They examined 38 children with ADHD, 34 children diagnosed with ASD, and 46 typically developing controls, aged 8-16 (mean age 11 and 12). Participants completed a computerized task using hypothetical monetary rewards. They were instructed to choose between receiving different amounts of a small reward delivered immediately and receiving a large reward delivered after a variable delay. The large reward remained at a constant 30 Euros and the small rewards were 0, 5, 10, 20, and 30 Euros. The delays until the receipt of the larger reward were now, tomorrow, the day after tomorrow, 1 week, or 2 weeks. There was a total of 100 choice trials. Similar to Antrop and colleagues' (2006) results, they found that participants with ADHD displayed more impulsive responding (a steeper discounting curve) than the participants with ASD and the neurotypical controls. Despite the slightly steeper discounting curve displayed by individuals with ASD, accompanying statistics confirmed that there was no significant difference in impulsive responding between the participants with ASD and the neurotypical controls.

Chantiluke et al. (2014) extended this temporal discounting research to older participants. They compared 18 neurotypical boys, 18 boys with ADHD only, 15 boys with ASD only, and 12 boys with both ADHD and ASD. Participants were aged 11-17 years with the mean ages of participants being 14 and 15 years old. In the discounting task, the authors presented participants with hypothetical monetary choices. Participants were instructed to choose between a smaller amount of money received immediately (ranging from 0-100 Euros) and a larger monetary amount (100 Euros), that would be available after 1 week, 1 month, or 1 year. They found that the ASD and comorbid groups displayed more impulsive responding than typically developing controls and boys with ADHD only, which were contrary to the findings of previous studies.

Chantiluke and colleagues posited that the disparate findings may have been a function of participant age.

Chantiluke and colleagues' findings highlight an area in need of additional research regarding the influence of age on impulsivity in individuals with ASD. Perhaps younger children with ASD show a similar pattern to younger neurotypical peers wherein they both present with high levels of impulsive responding. However, perhaps during adolescence, there is differentiation in impulsivity within diagnoses. Herein, older individuals with ASD remain impulsive, but older neurotypical counterparts display lower levels of impulsive responding. To further investigate this hypothesis, it is important to consider existing research comparing age differences in impulsivity. Below is an overview of the current research conducted where investigators have explored age differences in impulsivity.

Temporal Discounting Across Ages

Green, Fry, and Myerson (1994) compared discounting behavior in 12 typically developing children (sixth graders), 12 older typically developing young adults (college-age), and 12 older typically developing adults. Participants were presented with various choices between hypothetical monetary amounts. They were instructed to choose between a constant larger reward delivered at delays of 1 week, 1 month, 6 months, 1 year, 3 years, 5 years, 10 years, or 25 years; and a smaller immediate reward ranging from 0.1% to 100% of the delayed constant large reward amount. The amount of the larger reward was $1,000 or $10,000 for the college-aged and older adult participants, and $100 or $1,000 for the sixth graders. Their findings indicated that children were the most impulsive group while the older adults were the least impulsive.

Similarly, Steinburg, O'Brien, Cauffman, Graham, Woolard, and Banich (2009) studied 935 individuals between the ages of 10 and 30 years using a temporal discounting procedure. In the temporal discounting task, participants chose between hypothetical monetary choices. The amount of the larger delayed reward was held constant at $1,000, and the time to the delay varied (1 day, 1 week, 1 month, 3 months, 6 months, and 1 year). The amount of the smaller, sooner reward was either $200, $500, or $800, and was randomly determined for each participant. Participants were then asked to choose between a smaller, sooner reward and a larger ($1,000) delayed reward. Indifference points were then computed. They found that younger adolescents (ages 10-15) were more impulsive in their responding than the older individuals (ages 16-30).

Scheres, Dijkstra, Ainslie, Balkan, Reynolds, Sonuga-Barke and Castellanos (2006) examined the effect of age on discounting and also compared impulsivity across diagnoses. They included 22 individuals diagnosed with ADHD and 24 neurotypical individuals (ages 6-17 years). They used both real and hypothetical choices in the discounting preparation. In the study, the participants played a computerized game wherein they were asked to make choices between a small variable reward that was delivered immediately and a large constant reward (10 cents) that would be delivered after a delay (0 seconds, 5 seconds, 10 seconds, 20 seconds, or 30 seconds). The amounts of the small immediate reward were 0 cents, 2 cents, 4, cents, 6 cents, 8 cents, or 10 cents. There was a total of 60 choice trials, and participants received the total amount of money that they won after each trial was completed. They found that children (ages 6–11) were more impulsive in their responding (discounted delayed rewards more steeply) than adolescents (ages 12–17) regardless of diagnosis. Taken together, these results indicate that younger participants engaged in more impulsive responding than older participants.

Purpose of the Current Investigation

To date, there has been limited and conflicting evidence regarding the nature of temporal discounting in the ASD population. Of the research that does exist, none has evaluated impulsivity in individuals diagnosed with ASD and severe intellectual disability. Additionally, conflicting evidence found in Chantiluke et al. (2014) calls into question the factor of age on impulsivity in the ASD population. Though there has been some research comparing impulsivity across ages in neurotypical populations, little research has been conducted evaluating the effect of ages across diagnoses. A comparison of impulsivity across ages of individuals with ASD has yet to be explored. Moreover, much of the temporal discounting research on humans has been conducted using hypothetical choices—often with hypothetical money—rather than using real choices. Thus, the purpose of this study is three-fold: (1) to expand upon current literature by evaluating temporal discounting using real rewards in neurotypical individuals and lower-functioning individuals diagnosed with ASD, (2) to determine if discounting varies as a function of age, and (3) to examine any interaction between the two (age and diagnosis).

It was hypothesized that lower functioning participants with ASD would respond more impulsively than neurotypical peers overall. It was further predicted that due to developmental delays, individuals diagnosed with ASD would remain more impulsive than their neurotypical peers in adolescence and adulthood. It was posited that neurotypical participants would be more impulsive when they are younger and then display less impulsivity when they are older.

Method

Participants and Setting

Eighteen individuals between ages 3 and 40 years old participated in the current investigation. There were 9 females and 9 males. Eight participants were diagnosed with ASD

(Arthur, Adrien, Abraham, Austin, Alexis, Abigail, Alexander, and Allen). All attended Douglass Developmental Disabilities Center (DDDC) at Rutgers University. The DDDC is a center-based program that serves individuals diagnosed with ASD aged 3 to 21. The center also has an adult program that serves adults over the age of 21. Students and adult clients at the DDDC are referred for intensive supports that cannot be provided in facilities within their own community. Most of the students were considered low-functioning, or “untestable” for determination of IQ or other neuropsychological data. While one participant in the ASD group was of East-Asian descent, all other subjects in the ASD group were Caucasian. The study also included 10 neurotypical individuals (Neil, Noah, Noelle, Nathan, Nancy, Naomi, Natasha, Nikki, Natalie, and Nina). The young neurotypical participants were drawn from an inclusion classroom at the DDDC. Older neurotypical participants were drawn from people in the community that were affiliated with DDDC staff members via recruitment letters. Seventy percent of neurotypical group were Caucasian, 20% were Asian, and 10% were Hispanic. All participants were familiar with timers and demonstrated an ability to choose more over less.

All sessions took place at the DDDC. For subjects who attended the DDDC, sessions were conducted in their classrooms. For subjects recruited from the community, sessions were conducted in an empty research room or office containing chairs, a table, and materials required for the discounting activities. Informed parental consent, adult consent, and adolescent and child assent, if applicable, were obtained for each participant. Table 2 and Table 3 (see Appendix) include a list of all participants diagnosed with ASD and all neurotypical participants, respectively, their ages, and preferred items that were used in discounting trials.

Materials

The following materials were used in this investigation: rewards (various preferred edibles and items including chips, M&Ms, cookies, skittles, pictures of famous celebrities, and dimes), two paper plates, one paper bowl, two identical silver digital timers, a data sheet containing a script for the experimenter to follow along during the session (Figure 2), one video camera, one video camera stand, food scissors to cut rewards into smaller pieces (if needed), and a pen or pencil.

Procedure

Preference assessments. Multiple Stimulus without Replacement (MSWO) preference assessments were conducted with learners diagnosed with ASD to establish high preference edibles or items for each participant with ASD prior to the implementation of the temporal discounting procedures. In this preference assessment, the participant was allowed to choose between multiple stimuli presented in an array of 4 to 8 items. These items used in the preference assessment were determined by teacher interview. At the start of the MSWO assessment, the instructor told the participant to "pick one" from the array. After an item was chosen from the array, the participant was provided with access to the item for a predetermined period of time (i.e., 30-second access or as long as it took to consume the edible). The stimulus was then removed from the array and the remaining items were re-presented and the prompt, "pick one," was provided once again. The order in which the stimuli were selected was recorded. For the neurotypical participants, self-report was used to determine high preference edibles or items in place of an MSWO preference assessment. The most highly preferred item(s) were used in the discounting procedure. For older adult neurotypical participants, dimes were used as it was determined that money would function as a generalized conditioned reinforcer that was more age-appropriate.

Discounting procedure. The procedures used in this study were modeled after those used by Rachlin, Raineri, and Cross (1991). Participants were given a series of choices between an impulsive choice (a smaller amount of reinforcement delivered immediately) and a self-controlled choice (accepting a constant larger, delayed amount of reinforcement). A trained therapist conducted all discounting sessions. Prior to running the discounting procedures, the participant was given a short two-choice pretest to ensure that they understood the concept of more over less and now versus later. They were presented with the choices to have 4 units of the preferred item now (e.g., 4 Skittles) or 1 unit of the preferred item now (e.g., 1 Skittle), and the choice to have 1 unit of the item now or 1 unit of the item in 30 seconds. If participants made an “illogical” choice, e.g. they rather have less over more and/or choose to have the preferred item later rather than now, the session was terminated. Upon choosing the more “logical” choice, the formal discounting protocol was implemented.

In the formal temporal discounting procedure, the trained therapist would present the participant with choices between an immediate amount of reinforcement and a fixed delayed amount (i.e. “you can have 1 potato stick now, or 7 potato sticks in 30 seconds”). The instruction used in the formal protocol was modified for Abraham, the 13-year old participant diagnosed with ASD, due to his reported biased choosing. Staff noted that he often selected the last option that staff presented, across all academic tasks. Since he demonstrated the ability to visually discriminate between amounts and the times presented on the timers within his academic environment, his verbal instruction for the formal discounting protocol was either “choose one,” or “pick one.”

Choices were presented in an ascending order, with the amounts of the smaller immediate reward increasing each successive trial. Presenting choices in a randomized order was not utilized in the procedure because it was believed that switching delays and values with each trial could be confusing for participants diagnosed with ASD who may have difficulty with understanding the concept of time. The order that the options were presented as well as the side the larger, delayed reinforcer was on was alternated in order to control for any side biases or biased choosing (e.g. based on the last option the staff member may have presented). Staff and participants were asked to restrict access to the reinforcers used in the discounting session for at least 30 minutes before the start of the session. The choices were presented on two identical paper plates placed approximately 6-12 inches from the participant. The plates were placed an equal distance (approximately 3 inches) apart from each other. Identical plastic silver digital timers were used to display the time of delay and were placed above or below each plate depending on what timer location was more salient for the learner. A bowl used for holding the reinforcers after the participant made a choice was placed to the side of the plates. There were four delay lengths: 1 second, 5 seconds, 30 seconds, and 180 seconds. There were three immediate reinforcer magnitudes: 1, 4, or 6 units (the size of the rewards varied depending on the ages of participants). The magnitude for the larger later reward remained constant at 7 units. Participants contacted each magnitude pairing and each delay—12 pairings total. Indifference points (the point at which the individual switched from the smaller-sooner to larger-later reinforcement) were plotted on a graph to measure the level of impulsivity.

In the event that the participant did not consume the reinforcers, they were provided with the option of saving their rewards (banking items) for later use in the bowl that was placed next to the plates. Additionally, in the event that the participant exhibited an unclear response (e.g.

verbally expressing one choice but pointing to the other choice) or did not fully attend to the array when the choice of options was presented, the experimenter reset the layout. Resetting involved pushing the items away from the participant and waiting for about 10 seconds, resetting the items, waiting for the participant to appropriately attend to the experimenter, and then presenting the same options for choices in the same order as before. The discounting protocol was run at least 4 times for each participant and lasted no longer than 30 minutes for each session.

Data Collection, Interobserver Agreement, and Treatment Integrity

Data were collected on the choices the participant made using pencil/pen and paper. The choices were denoted on the data sheet containing the script. Experimenters marked the choice made with a check mark. Indifference points (the point at which the individual switched from the smaller-sooner to larger-later reinforcement) were plotted on a graph showing the subjective value of the reinforcers as a function of delay to receipt.

Interobserver agreement for choices made during the discounting task was calculated by dividing the total number of trials with agreement (experimenter and reliability observer marks the same choice) by the total number of trials (agreements and disagreements). All sessions were video recorded for additional coding or coding for later interobserver agreement. Interobserver agreement was collected for 52.5% of sessions with 99.5% agreement. Treatment integrity data were also collected for a minimum of 33% of sessions to ensure reliable implementation of the procedure. Using the recorded videos and a trained coder, treatment integrity data was completed for all recorded sessions. Treatment integrity was 90% for 53% of the sessions.

Data Analysis

Indifference points were calculated by noting the unit value of the point at which the participant first chose a smaller sooner reward for each time delay. Subjective values were then calculated using these data by expressing subjective value as a proportion of the amount of maximum delayed reward (as discussed in Myerson, Green, and Warusawitharana, 2001, and as used in Demurie et al., 2012 & 2013). Thus, the unit value of the point at which the participant chose a smaller, sooner reward was divided by the largest unit value and then multiplied by 100 in order to calculate the subjective value for each delay time for each session. For example, if the participant chose to receive 4 units of the reward now rather than wait for 7 units of the reward in 30 seconds, the smaller unit (4) would be divided by the larger unit (7) and then multiplied by 100%, resulting in the subjective value of 57.1% for the time delay of 30 seconds. Overall subjective value for the participant was then estimated by averaging the values across sessions. The average subjective values represent the average percentage of opportunities the participant chose to wait for the larger, more delayed reward instead of the smaller, immediate reward. The overall subjective values and the respective delay times were then plotted to form a discounting curve. The time delays were plotted on the x-axis and the subjective values were plotted on the y-axis. Visual inspection of the discounting curves was then used in order to determine the differences between age ranges and diagnoses. Steeper discounting curves represent higher degrees of impulsivity.

Results

Neurotypical Participants: Individual Results

The results for Neil (4 years old) are depicted in Figure 3. Neil chose the larger reward 100% of the time when there was no delay. He waited an average of 80.0% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. He waited an average of 54.3% of the total opportunities for the larger reward during the 5 second delay, 51.4% of the total opportunities for the larger reward during the 30 second delay and 62.8% of the total opportunities for the larger reward during the 3 minute delay. Neil's average subjective values are listed in Table 4.

Noah's results are depicted in Figure 4. During the condition with no delay, Noah (4 years old) chose the larger reward 100% of the time. He waited an average of 100.0% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. He also waited an average of 100.0% of the total opportunities for the larger reward during the 5 second delay. For the 30 second delay condition, Noah waited an average of 96.4% of the total opportunities for the larger reward. Additionally, he waited 75.0% of the total opportunities for the larger reward during the 3 minute delay. A list of Noah's average subjective values can be found in Table 4.

Noelle's (7 years old) results are depicted in Table 4 and Figure 5. Noelle waited an average of 100% of the total opportunities for the larger reward during the no delay and the 1 second delay conditions. She waited an average of 89.3% of the total opportunities for the larger reward during the 5 second delay, and waited 75.0% of the total opportunities for the larger reward during the 30 second delay. Noelle waited for the larger reward about 25.0% of the total opportunities during the 3 minute delay condition.

The results for Nathan (8 years old) are depicted in Figure 6 and are located in Table 4. Nathan chose the larger reward 100% of the time when there was no delay. During the 1 second delay, he waited an average of 100.0% of the total opportunities for the larger reward. He waited an average of 85.7% of the total opportunities for the larger reward during the 5 second delay.

Nathan's average subjective value was 60.7% during the 30 second delay and decreased during the 3 minute delay wherein he waited 25.0% of the total opportunities for the larger reward.

Nancy's results are also depicted in Table 4 and Figure 7. Nancy (11 years old) chose the larger reward 100% of the time when there was no delay. During the one second delay, she waited an average of 100.0% of the total opportunities for the larger reward. During the 5 second and the 30 second delay condition, Nancy's average subjective value was 100%—she waited every opportunity for the larger reward during these conditions. Lastly, she waited an average of 96.4% of the total opportunities for the larger reward during the 3 minute delay.

The results for Naomi (13 years old) are depicted in Figure 8 and Table 4. Naomi chose the larger reward 100% of the time when there was no delay. She waited an average of 92.9% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. In the 5 second delay condition, she waited an average of 89.3% of the total opportunities for the larger reward. Her average subjective value decreased during both the 30 second and 3 minute delay—she waited 78.6% of the total opportunities for the larger reward during these delay times.

Natasha's results can be found in Figure 9. Natasha chose the larger reward 100% of the time when there was no delay. During the 1 second and 5 second delay times, she waited an average of 100.0% of the total opportunities for the larger reward. She waited an average of 85.7% of the total opportunities for the larger reward during the 30 second delay and 57.1% of the total opportunities for the larger reward during the 3 minute delay. Her average subjective values can be seen in Table 4.

Average subjective values for Nikki (21 years old) are depicted in Figure 10 and Table 4. Nikki chose the larger reward 100% of the time when there was no delay, a 1 second delay, and a

5 second delay. She waited an average of 80.9% of the total opportunities for the larger reward during the 30 second delay. Her average subjective value decreased during the 3 minute delay—Nikki waited 14.3% of the total opportunities for the larger reward during this delay condition.

The results for Natalie (30 years old) are depicted in Figure 11. Natalie waited 100% of the total opportunities for the larger reward during the no delay, 1 second delay, 5 second delay, and 30 second delay conditions. She waited an average of 95.2% of the total opportunities for the larger reward during the 3 minute delay. Her average subjective values are depicted in Table 4.

Average subjective values for Nina (38 years old) are depicted in Figure 12 and can be found in Table 4. Nina chose the larger reward 100% of the time when there was no delay and a 1 second delay. She waited an average of 96.4% of the total opportunities for the larger reward during the 5 second delay and waited 85.7% of the total opportunities for the larger reward during the 30 second delay. During the 3 minute delay, Nina waited 14.3% of the total opportunities for the larger reward.

Participants Diagnosed with ASD: Individual Results

Arthur's average subjective values are depicted in Figure 13 and Table 5. Arthur (4 years old), chose the larger reward 100% of the time when there was no delay. During the 1 second delay, he waited an average of 85.7% of the total opportunities for the larger reward. Arthur waited an average of 57.1% of the total opportunities for the larger reward during the 5 second delay, 74.3% of the total opportunities for the larger reward during the 30 second delay, and 54.3% of the total opportunities for the larger reward during the 3 minute delay.

The results for Adrien (9 years old) are depicted in Figure 14. Adrien chose the larger reward 100% of the time when there was no delay. He waited an average of 64.3% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. During the 5 second delay condition, Adrien waited an average of 71.4% of the total opportunities for the larger reward. Average subjective values during the 30 second delay and 3 minute delay conditions were 78.6% and 32.3% respectively. These results are also depicted in Table 5.

Average subjective values for Abraham (13 years old) are depicted in Figure 15 and Table 5. Abraham chose the larger reward 100% of the time when there was no delay. During the no delay condition, he waited an average of 100.0% of the total opportunities for the larger reward. Adrien waited an average of 85.7% of the total opportunities for the larger reward during the 5 second delay and 35.7% of the total opportunities for the larger reward during the 30 second delay condition. Subjective value decreased during the 3 minute delay time—he waited 25.0% of the total opportunities for the larger reward during this delay condition.

The results for Austin (18 years old) are depicted in Table 5 and Figure 16. Austin chose the larger reward 100% of the time when there was no delay. He waited an average of 80.0% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. During the 5 second delay time, he waited an average of 77.1% of the total opportunities for the larger reward. He waited an average of 62.8% of the total opportunities for the larger reward during the 30 second delay and 31.4% of the total opportunities for the larger reward during the 3 minute delay.

Alexis' results are depicted in Figure 17. Alexis (19 years old) waited 100% of the time for the larger reward when there was no delay. During the 1 second and 5 second delay conditions, she waited an average of 48.5% of the total opportunities for the larger reward. Additionally, Alexis waited an average of 14.3% of the total opportunities for the larger reward during the 30 second delay and the 3 minute delay. Her average subjective values are located in Table 5.

The results for Abigail (19 years old) can be found in Figure 18. Abigail chose the larger reward 100% of the time when there was no delay. During the 1 second delay time, she waited an average of 100.0% of the total opportunities for the larger reward. She waited an average of 95.2% of the total opportunities for the larger reward during the 5 second delay and 85.7% of the total opportunities for the larger reward during the 30 second delay. Her average subjective value decreased during the 3 minute delay—she waited 73.8% of the total opportunities for the larger reward during this delay condition. Her results are also depicted in Table 5.

Alexander's results are depicted in Figure 19 and Table 5. Alexander (37 years old) selected the larger reward 100% of the time during the no delay condition. He waited an average of 74.3% of the total opportunities for the larger reward during the 1 second delay. He waited an average of 85.7% of the total opportunities for the larger reward during the 5 second delay, 40.0% of the total opportunities for the larger reward during the 30 second delay, and 28.6% of the total opportunities for the larger reward during the 3 minute delay.

Lastly, average subjective values for Allen (40 years old) are depicted in Figure 20. Allen chose the larger reward 100% of the time when there was no delay. He waited an average of 71.4% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. During the 5 second delay time, he waited an average of 22.9 % of the total opportunities for the larger reward. For the 30 second delay and the 3 minute delay conditions, Allen waited 37.1% and 22.9% of the total opportunities for the larger reward respectively. These values are depicted in Table 5.

Neurotypical Participants: Group Results

Data for the average discounting for younger neurotypical participants vs. older neurotypical participants are displayed in Figure 21. The data for neurotypical participants were separated into older participants (ages 20 and older) and younger participants (ages 4 to 19) according to half of the age of the oldest participant (age 38). There were 6 participants in the younger group and 4 participants in the older group. On average, the younger neurotypical participants chose the larger reward 100% of the time when there was no delay. In the 1 second delay condition, they waited an average of 95.5% of the total opportunities for the larger reward. They waited an average of 86.4 % of the total opportunities for the larger reward during the 5 second delay. Average subjective values for the 30 second delay and the 3 minute delay for the younger neurotypical participants were 77.0% and 60.5% of the total opportunities for the larger reward respectively. On average, the older neurotypical participants chose the larger reward 100% of the time when there was no delay. They waited an average of 100.0% of the total opportunities for the larger reward during the 1 second delay condition. Additionally, they waited an average of 99.1% of the total opportunities for the larger reward during the 5 second delay, 90.8% of the total opportunities for the larger reward during the 30 second delay and 48.2% of the total opportunities for the larger reward during the 3 minute delay.

Data for the average discounting for child, adolescent, and adult neurotypical participants are depicted in Figure 22. To further investigate age differences, ages of neurotypical participants were divided into children (9 and younger), adolescents (10-19), and adults (20+). On average, the neurotypical child participants chose the larger reward 100% of the time when there was no delay. During the 1 second delay condition, they waited an average of 95.0% of the total opportunities for the larger reward. During the 5 second delay condition, average subjective value for the neurotypical child participants was 82.0%—they waited an average of 82.0% of the total opportunities for the larger reward. They waited an average of 70.9% of the total opportunities for the larger reward during the 30 second delay and 47.0% of the total opportunities for the larger reward during the 3 minute delay. On average, the neurotypical adolescent participants chose the larger reward 100% of the time when there was no delay. Average subjective value for the 1 second delay condition was 96.5%—they waited an average of 96.5% of the total opportunities for the larger reward. They waited an average of 94.7% of the total opportunities for the larger reward during the 5 second delay. During the 30 second and 3 minute delays, the neurotypical adolescent participants waited 89.3% and 87.5% of the total opportunities for the larger reward respectively. For the no delay and 1 second delay conditions, the neurotypical adult participants chose the larger reward 100% of the time. They waited an average of 99.1% of the total opportunities for the larger reward during the 5 second delay, and 90.8% of the total opportunities for the larger reward during the 30 second delay. Average subjective value decreased during the 3 minute delay condition; neurotypical adults waited and average of 48.2% of the total opportunities for the larger reward during this delay condition.

Lastly, the overall average discounting curve for the neurotypical participants are depicted in Figure 23. On average, the neurotypical participants chose the larger reward 100% of the time when there was no delay. They waited an average of 97.3% of the total opportunities for the larger reward during the 1 second delay. The average subjective value was 91.5% during the 5 second delay. Neurotypical participants on average waited 82.5% of the total opportunities for the larger reward during the 30 second delay and 55.6% of the total opportunities for the larger reward during the 3 minute delay.

Participants Diagnosed with ASD: Group Results

Data for the average discounting for younger participants diagnosed with ASD vs. older participants diagnosed with ASD are displayed in Figure 24. Similar to the neurotypical group, the data for participants diagnosed with ASD were separated into older participants (ages 21 and older) and younger participants (ages 4 to 20), according to half of the oldest participant (age 40). There were 5 participants in the younger group and 3 participants in the older group. On average, the younger participants diagnosed with ASD chose the larger reward 100% of the time when there was no delay. During the 1 second delay condition, they waited an average of 75.7% of the total opportunities for the larger reward. They waited an average of 68.0% of the total opportunities for the larger reward during the 5 second delay. Average subjective values for the 30 second and 3 minute delay conditions were 53.1% and 31.5% of the total opportunities for the larger reward respectively. On average, the older participants diagnosed with ASD chose the larger reward 100% of the time when there was no delay. They waited about 81.9% of the total opportunities for the larger reward during the 1 second delay condition. Average subjective value during the 5 second delay was 67.9%—they waited an average of 67.9% of the total opportunities for the larger reward. During the 30 second and 3 minute delay conditions, older participants diagnosed with ASD waited 54.3% and 41.8% of the total opportunities for the larger reward respectively.

Data for the average discounting for child, adolescent, and adult participants diagnosed with ASD are depicted in Figure 25. Similar to the neurotypical group, ages of the participants diagnosed with ASD were divided into children (9 and younger), adolescents (10-19), and adults (20+). On average, the child participants diagnosed with ASD chose the larger reward 100% of the time when there was no delay. During the 1 second delay condition, they waited an average of 76.2% of the total opportunities for the larger reward. They waited an average of 64.3% of the total opportunities for the larger reward during the 5 second delay, 76.5% of the total opportunities for the larger reward during the 30 second delay and 43.3% of the total opportunities for the larger reward during the 3 minute delay. The adolescent participants diagnosed with ASD chose the larger reward an average of 100% of the time when there was no delay. They waited an average of 76.2% of the total opportunities for the larger reward when choosing between having the smaller reward sooner or waiting 1 second for the larger reward. During the 5 second delay condition, they waited an average of 70.4% of the total opportunities for the larger reward. Average subjective value decreased during the 30 second and 3 minute delays; adolescent participants diagnosed with ASD waited 37.6% of the total opportunities for the larger reward during the 30 second delay and 24.0% of the total opportunities for the larger reward during the 3 minute delay. On average, the adult participants diagnosed with ASD chose the larger reward 100% of the time when there was no delay. They waited an average of 81.9% of the total opportunities for the larger reward during the 1 second delay condition. On average, they waited 67.9% of the total opportunities for the larger reward during the 5 second delay. During the 30 second delay, average subjective value was 54.3%. They waited 41.8% of the total opportunities for the larger reward during the 3 minute delay.

Lastly, the overall average discounting curves for the participants diagnosed with ASD are depicted in Figure 26. The participants diagnosed with ASD chose the larger reward an average of 100% of the time when there was no delay. During the 1 second delay condition, they waited an average of 78.0% of the total opportunities for the larger reward. On average, they waited 68.0% of the total opportunities for the larger reward during the 5 second delay. They waited 53.6% of the total opportunities for the larger reward during the 30 second delay and 35.2% of the total opportunities for the larger reward during the 3 minute delay.

Neurotypical Participants versus Participants Diagnosed with ASD

The results for the overall average discounting for the neurotypical group versus overall average discounting for ASD group are displayed in Figure 27 to show a side-by-side comparison of the discounting curves of the two groups. As discussed earlier, on average, the neurotypical participants chose the larger reward 100% of the time when there was no delay. They waited an average of 97.3% of the total opportunities for the larger during the 1 second delay, 91.5% of the total opportunities for the larger reward during the 5 second delay, 82.5% of the total opportunities for the larger reward during the 30 second delay and 55.6% of the total opportunities for the larger reward during the 3 minute delay. On average, the participants diagnosed with ASD chose the larger reward 100% of the time when there was no delay. During the 1 second delay condition, they waited an average of 78.0% of the total opportunities for the larger reward. Average subjective value was 68.0% during the 5 second delay and 53.6% during the 30 second delay. Average subjective value decreased during the 3 minute delay—they waited 35.2% of the total opportunities for the larger reward during this delay condition.

Discussion

Impulsivity is a common concern in individuals diagnosed with ASD. The presence of impulsivity can manifest in a number of different ways in this population. For example, impulsivity often plays a significant role in the prevalence of challenging behaviors in academic and community settings. In these instances, individuals are likely to engage in problem behavior to access smaller amounts of reinforcement immediately, rather than waiting for larger rewards. Ultimately, this impulsivity results in disruption of programming and thus interference with skill acquisition. Failure to effectively address impulsivity in this population may negatively impact community integration and possibly lead to poor outcomes (e.g., residential placements). This research serves as a stepping stone to better inform treatment and programming by revealing particular patterns of impulsivity that may be unique to individuals with ASD.

Unfortunately, few researchers have investigated impulsivity in the ASD population. Research to date has been limited to participants with high functioning autism (HFA). There has been no prior research comparing the impulsivity of lower functioning individuals diagnosed with ASD to neurotypical populations. Additionally, researchers have yet to explore impulsivity across ages of those diagnosed with ASD. Furthermore, most of the temporal discounting research on human populations has been conducted using hypothetical choices—often with hypothetical money—rather than using real choices. Gaps in temporal discounting research still remain. Thus, the purpose of this study was to begin to fill in these gaps and expand on the existing literature.

The current study is unique in that we explored temporal discounting across two populations—neurotypical individuals and individuals diagnosed with ASD and severe intellectual impairment. Additionally, we used real choices rather than hypothetical choices. As part of the present analysis, we also investigated impulsivity across ages to determine if discounting varies as a function of age, and to examine any interaction between the two (age and diagnosis). Taking previous literature into account, it was hypothesized that participants with ASD would respond more impulsively than neurotypical peers overall. It was further posited that neurotypical subjects would be more impulsive when they are younger and display less impulsivity when they are older. Individuals diagnosed with ASD, however, were predicted to remain impulsive across ages. Considering the individual results of the neurotypical participants and the participants diagnosed with ASD, it is evident that each subject's response was variable. However, when examining the overall group results, group differences in responding were evident.

Impulsivity Across Diagnosis

The results from the current investigation suggest that lower functioning individuals diagnosed with ASD were generally more impulsive in their responding than their neurotypical counterparts. When interpreting the discounting curves, responding patterns of participants diagnosed with ASD denoted a steeper curve than that of their neurotypical peers. This steeper curve indicated more discounting and higher impulsivity. On average, subjects diagnosed with ASD waited less for the more delayed reward and chose the smaller, more immediate reward more often than the neurotypical participants during every delay time. This supports our hypothesis and the findings of Chantiluke et al. (2014).

Effect of Age on Discounting

Across ages for the neurotypical participants, our results indicated that neurotypical child subjects displayed more impulsive responding than neurotypical adolescents and adults for delays up to 30 seconds. Interestingly, adult neurotypical subjects were more impulsive at longer delays (3 minutes), displaying similar responding to the child subjects. Overall, children and adult neurotypical participants were more impulsive than adolescent neurotypical participants. This was contrary to our hypothesis and the findings of Green, Fry, Myerson (1994), Scheres et al. (2006), and Steinburg et al. (2009). Individuals diagnosed with ASD, demonstrated impulsive responding across ages. When breaking down the data for younger versus older participants diagnosed with ASD, younger individuals were slightly more impulsive in their responding during the 3 minute delay. Breaking the ages down further, however, revealed that both adolescents and adults actually displayed more impulsive responding than the children, with adolescents being the most impulsive for the 3 minute delay. These results support our hypothesis that individuals diagnosed with ASD remain impulsive as they get older (across ages).

Our finding that neurotypical adults were more impulsive than adolescents may be due to the value of the reward as a reinforcer. In our study, the adolescent participants earned preferred food items, whereas the adult participants earned dimes as the reward. Dimes were chosen for the neurotypical adult participants, as money tends to be a powerful generalized conditioned reinforcer. Use of money was deemed a more age-appropriate reinforcer for this older group. In our preparation, the number of dimes presented could have been perceived as less reinforcing to the adults, and preferred food items, such as candy, could have been perceived as more reinforcing to adolescents. Thus, for adults, motivation to wait longer (3 minutes) for dimes may have been less than the adolescent group's motivation to wait for similar units of candy.

The finding that the neurotypical adults were more impulsive than the neurotypical adolescents warrants further investigation about how different categories of rewards may influence their strengths as reinforcers and thus influence motivation to wait longer for particular types of rewards. This concept has been explored through comparing domain-general versus domain-specific aspects of discounting rewards. Domain-generality refers to how discounting patterns remain the same across different types or classes of rewards. Domain-specificity refers to how rewards can be discounted at different rates based on the type or class of the reward. Charlton and Fantino (2008) termed this domain-specificity as the "domain effect." They noted that there may be many factors of a reward that influence discounting rates, including primary versus secondary reinforcing qualities of rewards, possibility for immediate consumption of the reward, and the degree of satiability and perishability of the reward. Interestingly, past research has found that monetary rewards are usually discounted less than food rewards due to the fact that it is non-perishable and has secondary reinforcing qualities (Charlton and Fantino, 2008; Green, Myerson, and McFadden, 1997; Odum, 2011), which does not support our current findings. However, Green, Myerson, and McFadden (1997) investigated the domain effect of the *amount* of reward on discounting patterns. The authors used similar discounting procedures as previous studies, and used hypothetical monetary choices. They compared discounting rates for different amounts of the larger, more delayed reward. Reward values for the constant larger reward were $100, $2,000, $25,000, and $100,000. The delay times were 3 months, 6 months, 1 year, 3 years, 5 years, 10 years, and 20 years. They found that smaller amounts of the reward were discounted more steeply. This may help explain our finding that dimes (a smaller amount of money) as a reward, were discounted more by the neurotypical adults.

Additionally, results may be due to a small subject pool. With 10 total neurotypical participants and 8 participants diagnosed with ASD, results show information for only a small portion of neurotypical individuals and individuals diagnosed with ASD with significant impairment. Attaining a larger participant pool would be desired for future protocols as it would help to confirm if the age differences in our discounting protocol were indeed a factor of the type of commodity or specific amount of monetary reward.

Implications and Future Directions

The current study expanded on the present research, investigating a novel population (lower functioning individuals with ASD and severe intellectual impairments) using real versus hypothetical rewards. Though past reviews of discounting research have suggested that hypothetical choices yield comparable results to real-world choices (e.g., Lagorio and Madden, 2005), the literature does not include any group differences for lower functioning individuals diagnosed with ASD who have severe intellectual deficits. When working with the lower functioning ASD population, presenting hypothetical choices introduces challenges due to cognitive delays and executive functioning difficulties. The hypothetical choices may not be as motivating for them as a real reward delivered in real-time. Thus, using real rewards allows for further generalizability of the study of impulsivity to include lower functioning individuals with developmental disabilities and cognitive delays.

Our procedure was also unique in that it provided a practical discounting model using real choices that was effective and efficient for implementing with lower functioning individuals diagnosed with ASD. In our procedures, we presented the choices in ascending order instead of presenting choices in randomized or both ascending and descending order to account for the potential cognitive deficits of our participants diagnosed with ASD in which the concept of time may be too abstract. To ensure the efficiency of our protocol, we aimed to make sessions last no more than 30 minutes.

Our procedural approach was different than the procedures used in other studies (e.g. Rachlin et al., 1991; Mazur, 1987; Richards et al., 1997). Rachlin et al. (1991) presented choices in both ascending and descending order and averaged the indifference points from both to determine the average subjective values. Mazur (1987) used an adjusting delay procedure in which participants first completed two forced-choice trials that introduce them to both the larger, more delayed reward and the smaller, immediate reward. Subjects were then given two free-choice trials where they chose between a smaller, immediate reward and a larger, delayed reward. If the participant chose the smaller, sooner reward, indifference was not reached and the larger reward's delay time was decreased in subsequent trials. If the participant chose both larger, more delayed rewards in the free-choice trials, the delay to the larger reward was then increased in subsequent trials. Thus, the delay time of subsequent choices given to participants were adjusted based on the participants' prior decisions. When responses between larger and more delayed rewards and smaller, sooner rewards became equal, an indifference point was determined, and the trial ended. Richards et al. (1997) conducted this same procedure, adjusting amounts of rewards as opposed to delay times. Green et al. (2007) compared the adjusted amounts versus adjusted delay procedures and found that both yield the same estimates of discounting.

These methods, though appropriate to use for neurotypical individuals or individuals diagnosed with ASD who are higher functioning, may be time-consuming and less efficient when working with lower functioning individuals diagnosed with ASD and utilizing real as opposed to hypothetical rewards. Future study could examine how to make these different discounting protocols more efficient and feasible to use when using real rewards with the lower functioning ASD population.

Our study also utilized different types of rewards—food, money, and preferred pictures, as determined primarily by participant preference. Additionally, the number or units of the reward were kept constant (e.g. 1, 4, 6, and 7 pieces of chips, cookies, skittle, pictures, dimes, etc.). Sizes of units were adjusted according to age of participant in order to control for satiation (e.g. pieces of cookie instead of whole cookies for 4 year old participants). All of these modifications helped to make our protocol more practical and efficient to use with lower functioning individuals diagnosed with ASD and when using real rewards. However, as our results indicate, 7 dimes may not be equivalent in value as a reinforcer to 7 pieces of food items, which may help to explain our finding that adult neurotypical participants discounted more than the adolescent neurotypical group.

In previous studies that compared discounting of different types of rewards (Odum, 2006; Charlton & Fantino, 2008), monetary values were converted to quantities of food, book, CD, or DVD rewards. Furthermore, these studies used the participants' *own* estimates to determine the conversions. Participants would estimate the average cost of a book, CD, DVD, or one serving of the food item. Using the participants' estimates, each pair of the monetary choices was divided by the cost estimate in order to standardize the amount of the reward. For example, a participant may estimate that a DVD costs $10. If the amount of the smaller and larger monetary reward for a specific trial was $10 and $100 respectively, then in the same trial for the DVD, the participant would have to choose between 1 DVD ($10 divided by $10) and 10 DVDs ($100 divided by $10) for the smaller and larger reward respectively.

This method would be interesting to utilize in future study by incorporating it into the current study's protocol. It is important to note that our specific participant group of lower functioning individuals diagnosed with ASD would make using participants' own estimates difficult since this concept would be too abstract. But, using standard estimates of monetary values for the non-monetary rewards would be interesting to explore. This method would also be beneficial to use in future study as it would ensure more standardized amounts for the types of rewards used in the protocol.

The results of the present study also indicate that participants diagnosed with ASD displayed more impulsive responding as compared to their neurotypical peers, and remained more impulsive across ages. These findings are significant, as they suggest that impulsivity may be a trait in lower functioning individuals diagnosed with ASD. That is, higher impulsive responding endured overtime into adolescence and adulthood, signifying that impulsivity could be an inherent characteristic of this population. Future examination of other trait variables and their effect on impulsivity in this population would help to determine if higher impulsivity is indeed unique to the ASD population. Our results are also notable as they provide a basis for how one can understand this increased impulsivity in the ASD population. This greater impulsivity in individuals diagnosed with ASD is indicative of a general difficulty with waiting that may persist into adolescence and adulthood. When working with older adolescents and adults diagnosed with ASD, waiting is often not considered as a target for intervention. Our results thus highlight the need for further investigation of strategies to decrease impulsivity in intervention and skills programming with this population. This can be addressed through exploration of various state variables that could influence impulsivity.

Past research has shown evidence that impulsivity is usually considered a trait variable. A trait variable refers to a preexisting characteristic of an individual that is stable and affects behavior (Odum, 2011). This is contrary to a state variable, an environmental manipulation that can influence behavior in relatively short time frame (Charlton & Fantino, 2008; Odum, 2011). Charlton and Fantino (2008) found evidence of impulsivity as a trait. They noted that metabolic processes unique to a person's enduring makeup and cognitive processing determined higher impulsivity, thus higher impulsivity persisted regardless of type of reward (i.e. food, music, money, etc.). Odum (2011) also found evidence for impulsivity being a trait. Their analysis indicated that individuals who were generally more impulsive remained more impulsive across reward type.

Contrary to these findings, other research has shown evidence for impulsivity as having both state and trait influences (Odum & Baumann, 2010). In Odum and Baumann's review, they noted that certain state variables, such as amount of outcome (higher reward amounts vs. lower reward amounts), context (settings associated with more impulsive responding vs. neutral settings), and the number of other tasks a person is doing simultaneously, have been found to influence impulsivity. They noted that trait variables, such as IQ and gender, also influence impulsivity (Odum & Baumann, 2010). Odum (2011) further emphasized that despite support for impulsivity as a trait variable, impulsivity can undoubtedly be subject to change due to certain state variables.

Trait Variables: Functioning Level and IQ

To examine the effects of trait variables on impulsivity, future research could investigate temporal discounting in other populations with severe intellectual impairments and low IQ (e.g. individuals with Down Syndrome). Exploration of other populations with intellectual disabilities could further determine if increased impulsivity is related to an overall deficit in cognitive and/or developmental functioning or if it is indeed unique to an ASD diagnosis.

Another possible avenue could be to examine impulsivity *within* the ASD population. Researchers could compare participants classified with Level 1 ASD (“higher functioning”) to participants classified with a Level 2 or Level 3 ASD diagnosis (“lower functioning”). The current study focused on individuals who would likely fall into the low functioning category. Comparing the results obtained from individuals of differing levels of cognitive impairment with a diagnosis of ASD could contribute to our understanding of discounting processes on a deeper level in this population.

Ultimately, this exploration of temporal discounting in other populations with developmental delays and intellectual disabilities, as well as higher functioning individuals with ASD as compared to lower functioning individuals with ASD, could offer important treatment implications. The findings could provide further insight into target areas for intervention in order to decrease impulsivity in the ASD population and promote more self-controlled behavior.

Trait Variables: Gender

Our study included 18 total participants. There were 3 males and 7 females in the neurotypical group, and there were 6 males and 2 females in the group diagnosed with ASD. Due to disproportionate gender representation within in each group, gender differences in impulsivity within these populations would be difficult to clarify. Future study could thus include a more balanced representation of gender for each group. This would help examine if impulsivity in this population differs as a factor of gender. If there are gender differences, treatment to reduce impulsivity could be further individualized.

The research to date is limited with regards to gender differences in neurotypical populations (Kirby & Marakovic, 1996; Logue & Anderson, 2001; Silverman, 2003; Steinburg et al., 2009). Findings are variable, showing either support for males as exhibiting more impulsive responding or showing no significant gender differences. At the present time, there have been no research studies investigating gender differences in discounting patterns in ASD populations.

State Variables: Environmental Cues (Signaled Delays)

Our study results warrant an examination of the impact of various state variables on impulsivity to determine the extent to which impulsivity can be changed. A starting point could be to extend on studies by researchers who have explored the effectiveness of a modification of environmental cues using a signaled delay to reduce problem behavior. This approach involved the use of environmental cues to signal the delivery of reinforcement. Testing these procedures within a temporal discounting protocol could further inform how impulsivity may be addressed in treatment.

A few studies have shown support for the use of signaled delays to help increase self-control in ASD populations (e.g., Kelley et al., 2011; Vollmer, Borrero, Lalli, and Daniel, 1999). These researchers have examined the impact of signaled delays on the reduction of impulsive responding in children with developmental disabilities. After teaching a functional communication response, the authors increased delays to reinforcement while evaluating the effects of signals on the participants' ability to wait. The results from both studies indicated that the participants were able to wait longer with signaled delays as compared to non-signaled delays.

State Variables: Modification of Reinforcement Schedules

Another state variable that can be explored involves modifying reinforcement schedules, which could impact overall motivation to wait. One method to modify reinforcement schedules involves using satiation to influence motivation to gain access to a particular reinforcer. For instance, researchers could evaluate the extent to which pre-session access to the reward (satiation) impacts impulsivity. To date, no studies on the impact of motivating operations on temporal discounting patterns have been investigated by researchers. Thus, future study of the impact of satiation on impulsive responding could further inform and contribute to research on treating impulsivity in this population.

Conclusion

The current study is an important stepping stone to promote exploration of temporal discounting and impulsivity in individuals diagnosed with ASD. Our study extended the existing discounting literature in a number of ways. First, we investigated impulsivity in participants diagnosed with ASD with significant intellectual disabilities ("low functioning" populations). To this point, this population has been largely neglected in the discounting literature. In addition, we examined impulsivity using real choices, rather than hypothetical choices. While the existing literature suggests that hypothetical choices are a viable alternative, they may not be salient to individuals diagnosed with ASD who have significant cognitive impairments. The present study provides a practical discounting model using real choices that was effective in this population. This study was also unique in that we explored discounting across ages and diagnoses, using a neurotypical comparison group.

The results of this investigation suggest that participants diagnosed with ASD were more impulsive in their responding as compared to their neurotypical counterparts and remain impulsive across ages. This finding has important implications with regards to treatment and skills programming. It highlights the importance of identifying strategies to reduce impulsivity and increase self-control in this population. With an improvement in the ability to wait for more delayed rewards, a decrease in potential problem behavior may resultantly increase the rate of skill acquisition and improve treatment outcome.

In conclusion, the present study is an important first step to understanding and treating impulsivity in individuals diagnosed with ASD to ensure better outcomes for this population. The findings provide valuable information about the nature of impulsivity in these individuals and emphasize the necessity for further study that could inform treatment methods and modifications that would ensure a higher quality of living.

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Appendix

Table 1

Hypothetical Discounting Data

Table 1

Representative trials and hypothetical raw data from a portion of a temporal discounting experiment involving choices between imaginary money gains. Columns represent different delays to receipt of a large gain (in this case, $1,000). For each delay, the large delayed gain remains constant, and the amount of an alternative immediate gain (leftmost column) varies systematically across in ascending sequence. A complete experiment would also include a descending sequence of small gains for each delay (see text). A hypothetical response to each trial is indicated with a D (delayed money option selected) or an I (immediate money option selected). For each of the delays, switches from delayed to immediate options are highlighted with an asterisk.

Amount of immediate reward	Delay to large reward (in months)								
	0.25	1	6	12	36	60	120	180	300
1	D	D	D	D	D	D	D	D	D
5	D	D	D	D	D	D	D	D	I*
10	D	D	D	D	D	D	D	D	I
20	D	D	D	D	D	D	D	D	I
40	D	D	D	D	D	D	D	I*	I
60	D	D	D	D	D	D	D	I	I
80	D	D	D	D	D	D	I*	I	I
100	D	D	D	D	D	D	I	I	I
150	D	D	D	D	D	I*	I	I	I
200	D	D	D	D	D	I	I	I	I
250	D	D	D	D	D	I	I	I	I
300	D	D	D	D	D	I	I	I	I
350	D	D	D	D	D	I	I	I	I
400	D	D	D	D	D	I	I	I	I
450	D	D	D	D	D	I	I	I	I
500	D	D	D	D	I*	I	I	I	I
550	D	D	D	I*	I	I	I	I	I
600	D	D	D	I	I	I	I	I	I
650	D	D	D	I	I	I	I	I	I
700	D	D	I*	I	I	I	I	I	I
750	D	D	I	I	I	I	I	I	I
800	D	D	I	I	I	I	I	I	I
850	D	I*	I	I	I	I	I	I	I
900	D	I	I	I	I	I	I	I	I
920	D	I	I	I	I	I	I	I	I
940	D	I	I	I	I	I	I	I	I
960	D	I	I	I	I	I	I	I	I
980	D	I	I	I	I	I	I	I	I
990	D	I	I	I	I	I	I	I	I
1,000	I*	I	I	I	I	I	I	I	I

Note. Reprinted from *Temporal discounting: Basic research and the analysis of socially important behavior,* by Critchfield, T. S., & Kollins, S. H. (2001). *Journal of applied behavior analysis*, *34*(1), 101-122.

Table 2

Participants Diagnosed with ASD, Ages, and Preferred Items

Participant Name	Age	Preferred Items
Arthur	4	M&Ms, cookies
Adrien	9	Tortilla Chips
Abraham	13	Lays Potato Chips
Austin	18	Oreos, Cheez-its, Doritos
Alexis	19	Lays Potato Chips
Abigail	29	Popcorn, fruit snacks, Potato Chips
Alexander	37	Fruit Snacks, Pretzels
Allen	40	Pictures of Madonna, Tina Turner, & Shania Twain

Table 3

Neurotypical Participants, Ages, and Preferred Items

Participant Name	Age	Preferred Items
Neil	4	Animal Crackers, Lucky Charms, Pretzels
Noah	4	Potato Chips
Noelle	7	Doritos, Oreos, M&Ms
Nathan	8	Potato Chips
Nancy	11	Skittles, M&Ms
Naomi	13	Skittles, M&Ms
Natasha	20	Dimes
Nikki	21	Dimes
Natalie	30	Dimes
Nina	38	Dimes

Note: Dimes were used for adult neurptypical participants due to money being a generalized conditioned reinforcer and more age-appropriate

Table 4

Average Subjective Values for Neurotypical Participants

Delay Time (s)	Average Subjective Value (% of Total Value)									
	Neil	Noah	Noelle	Nathan	Nancy	Naomi	Natasha	Nikki	Natalie	Nina
0	100	100	100	100	100	100	100	100	100	100
1	80	100	100	100	100	92.9	100	100	100	100
5	54.3	100	89.3	85.7	100	89.3	100	100	100	96.4
30	51.4	96.4	75	60.7	100	78.6	85.7	80.9	100	85.7
180	62.8	75	25	25	96.4	78.6	57.1	14.3	95.2	14.3

Table 5

Average Subjective Values for Participants Diagnosed with ASD

Delay Time (s)	Average Subjective Value (% of Total Value)							
	Arthur	Adrien	Abraham	Austin	Alexis	Abigail	Alexander	Allen
0	100	100	100	100	100	100	100	100
1	85.7	64.3	100	80	48.5	100	74.3	71.4
5	57.1	71.4	85.7	77.1	48.5	95.2	85.7	22.9
30	74.3	78.6	35.7	62.8	14.3	85.7	40	37.1
180	54.3	32.3	25	31.4	14.3	73.8	28.6	22.9

Figure Captions

Figure 1. Hypothetical Discounting Data from data in Table 1. *Note*. Reprinted from *Temporal discounting: Basic research and the analysis of socially important behavior,* by Critchfield, T. S., & Kollins, S. H. (2001). *Journal of applied behavior analysis*, *34*(1), 101-122.

Figure 2. Sample Temporal Discounting Data Sheet for both pre-session and regular discounting session protocols.

Figure 3. Summary of the assessment results for Neil. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 4. Summary of the assessment results for Noah. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 5. Summary of the assessment results for Noelle. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 6. Summary of the assessment results for Nathan. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 7. Summary of the assessment results for Nancy. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 8. Summary of the assessment results for Naomi. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 9. Summary of the assessment results for Natasha. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 10. Summary of the assessment results for Nikki. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 11. Summary of the assessment results for Natalie. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 12. Summary of the assessment results for Nina. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 13. Summary of the assessment results for Arthur. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure14. Summary of the assessment results for Adrien. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 15. Summary of the assessment results for Abraham. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 16. Summary of the assessment results for Austin. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 17. Summary of the assessment results for Alexis. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 18. Summary of the assessment results for Abigail. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 19. Summary of the assessment results for Alexander. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 20. Summary of the assessment results for Allen. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 21. Summary of the assessment results for the average discounting for NT group split by younger vs. older. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 22. Summary of the assessment results for the average discounting for NT group split by children, adolescents, and adults. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 23. Summary of the assessment results for the overall average discounting for NT group. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 24. Summary of the assessment results for the average discounting for ASD group split by younger vs. older. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 25. Summary of the assessment results for the average discounting for ASD group split by children, adolescents, and adults. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 26. Summary of the assessment results for the overall average discounting for ASD group. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

Figure 27. Summary of the assessment results for the overall average discounting for NT group vs overall average discounting for ASD group. Percentage of subjective value is depicted on y-axis. Time delay (seconds) of larger reward is depicted on x-axis.

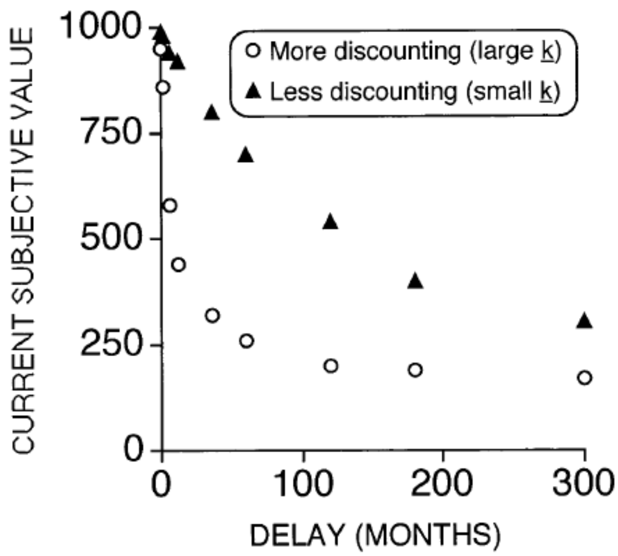

Figure 1. Hypothetical temporal discounting data, showing current subjective value of $1,000 as a function of delay to its receipt. See text for details.

Figure 1. Hypothetical Discounting Data from data in Table 1

Note. Reprinted from *Temporal discounting: Basic research and the analysis of socially important behavior,* by Critchfield, T. S., & Kollins, S. H. (2001). *Journal of applied behavior analysis*, *34*(1), 101-122.

Date: ___________ **Time:** ___________ **Student:** ___________ **Food:** ___________
Condition: ___________ **Session:** ___________ **Staff:** ___________

Pre-session

More v. Less Challenge

1. One ___________ now or four ___________ now. Mark the choice made.

Now v. Later Challenge

2. One ___________now or one ___________in 30 seconds. Mark the choice made.

Discounting Sessions

Step 1: 1-Second Delay

3. One ___________ now or seven ___________ in one second. Mark the choice made.
4. Four ___________now or seven ___________in one second. Mark the choice made.
5. Six ___________ now or seven ___________in one second. Mark the choice made.

Step 2: 5-Second Delay

6. One ___________ now or seven ___________ in five seconds. Mark the choice made.
7. Four ___________now or seven ___________in five seconds. Mark the choice made.
8. Six ___________ now or seven ___________in five seconds. Mark the choice made.

Step 3: 30-Second Delay

9. One ___________ now or seven ___________ in 30 seconds. Mark the choice made.
10. Four ___________now or seven ___________in 30 seconds. Mark the choice made.
11. Six ___________ now or seven ___________in 30 seconds. Mark the choice made.

Step 4: 300-Second Delay

12. One ___________ now or seven ___________ in 180 seconds. Mark the choice made.
13. Four ___________now or seven ___________in 180 seconds. Mark the choice made.
14. Six ___________ now or seven ___________in 180 seconds. Mark the choice made.

Figure 2. Sample Temporal Discounting Data Sheet used in discounting session protocols

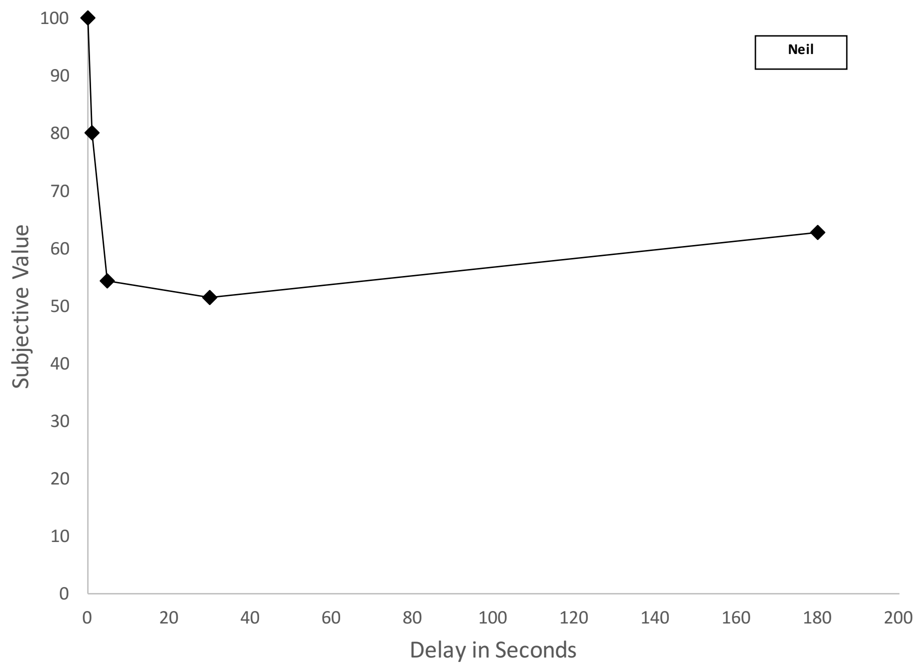

Figure 3. Summary of the assessment results for Neil

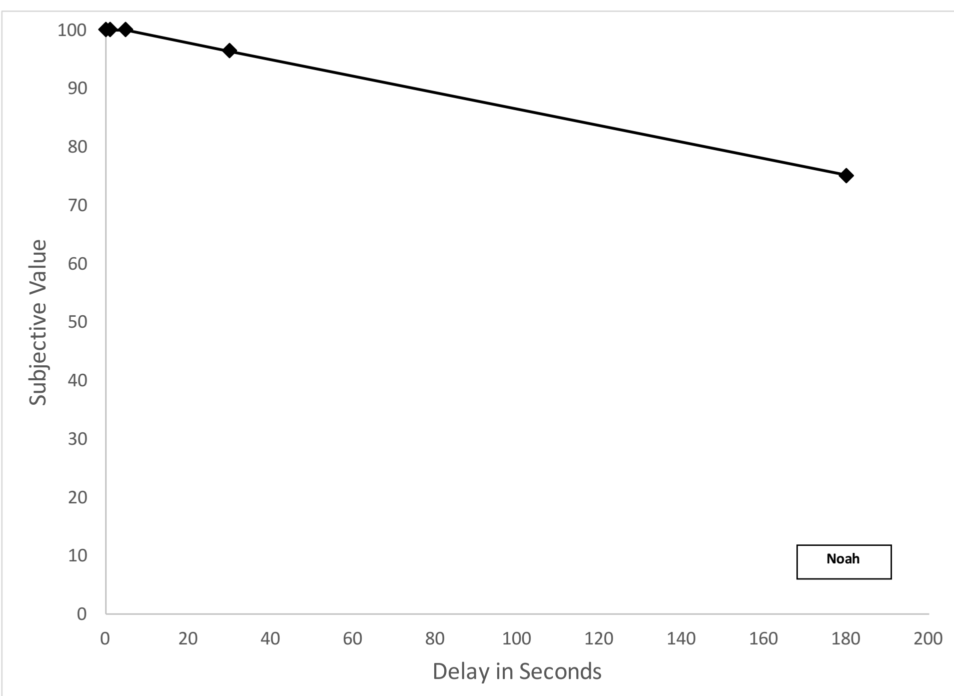

Figure 4. Summary of the assessment results for Noah

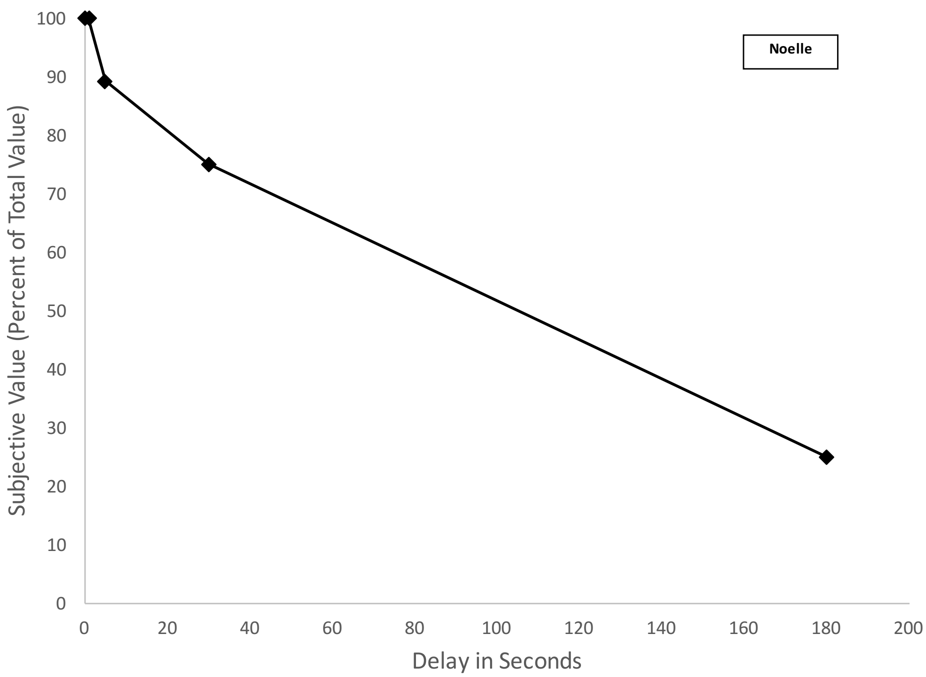

Figure 5. Summary of the assessment results for Noelle

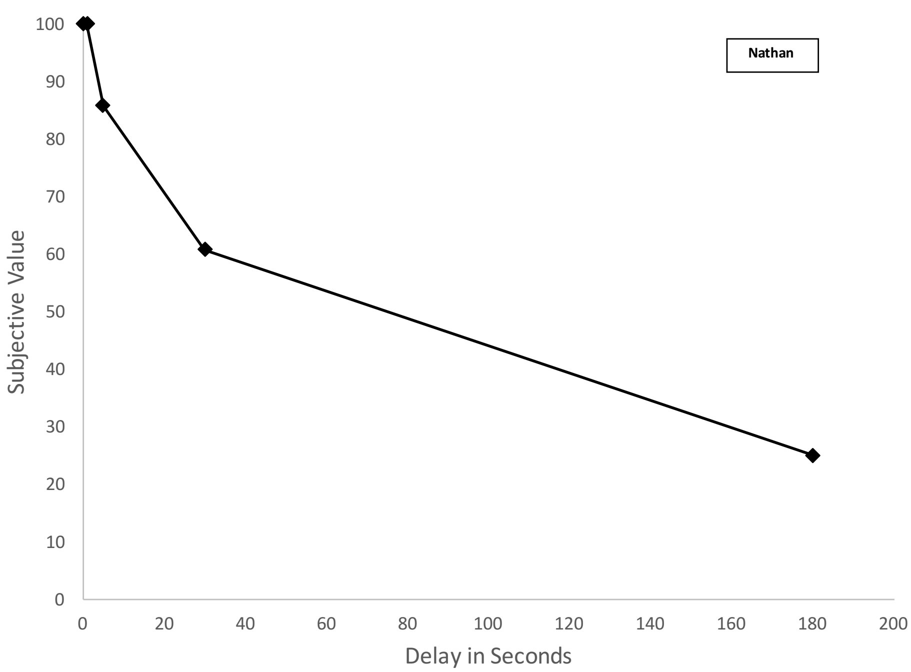

Figure 6. Summary of the assessment results for Nathan

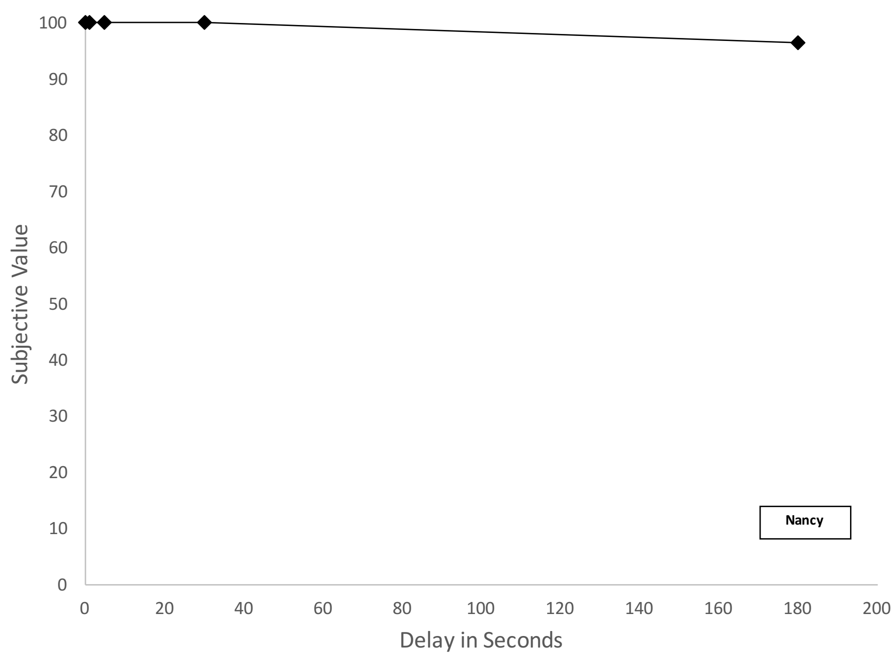

Figure 7. Summary of the assessment results for Nancy

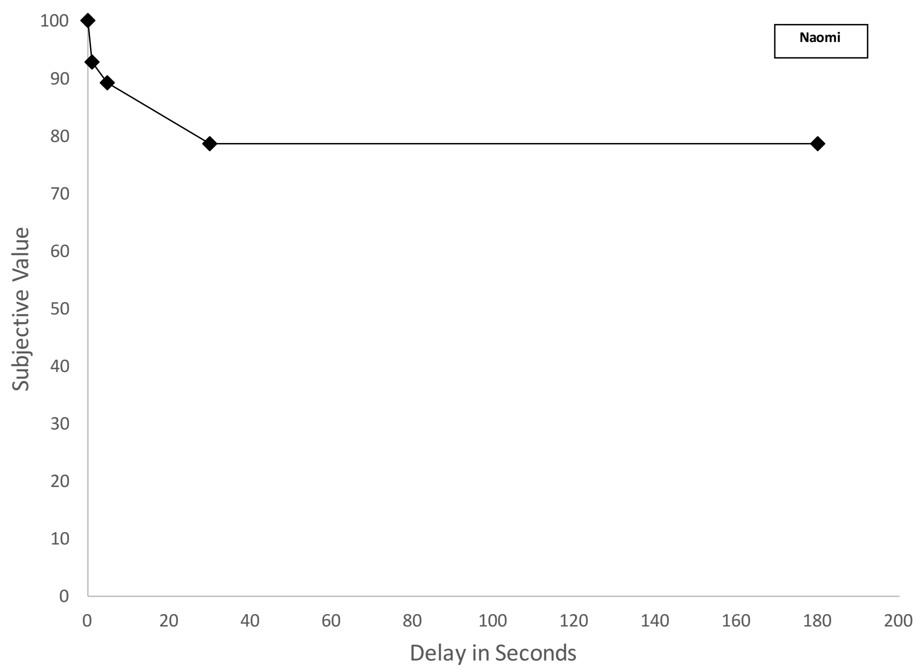

Figure 8. Summary of the assessment results for Naomi

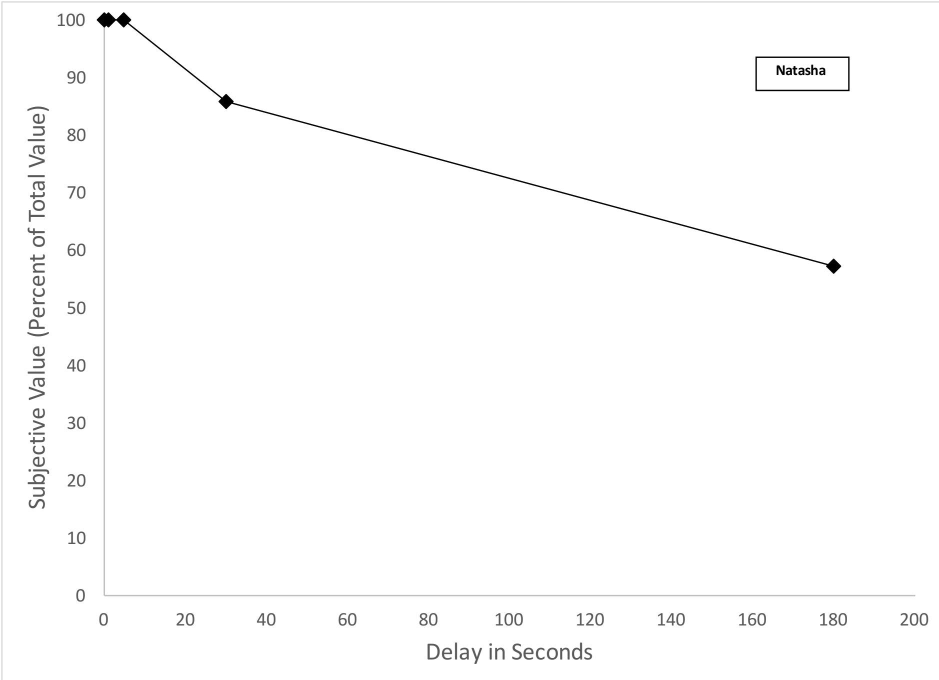

Figure 9. Summary of the assessment results for Natasha

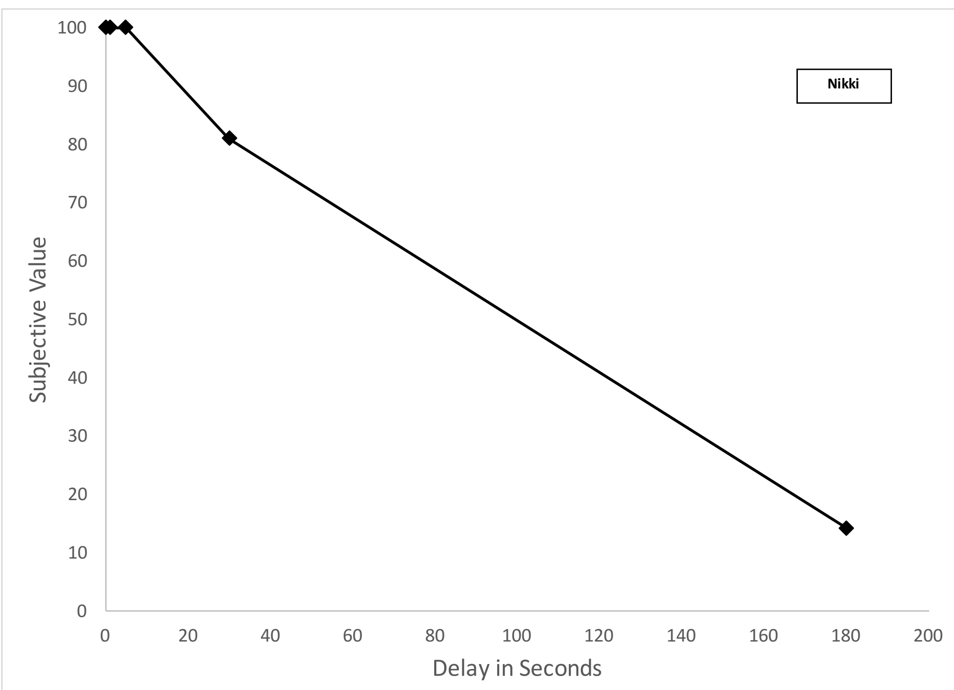

Figure 10. Summary of the assessment results for Nikki

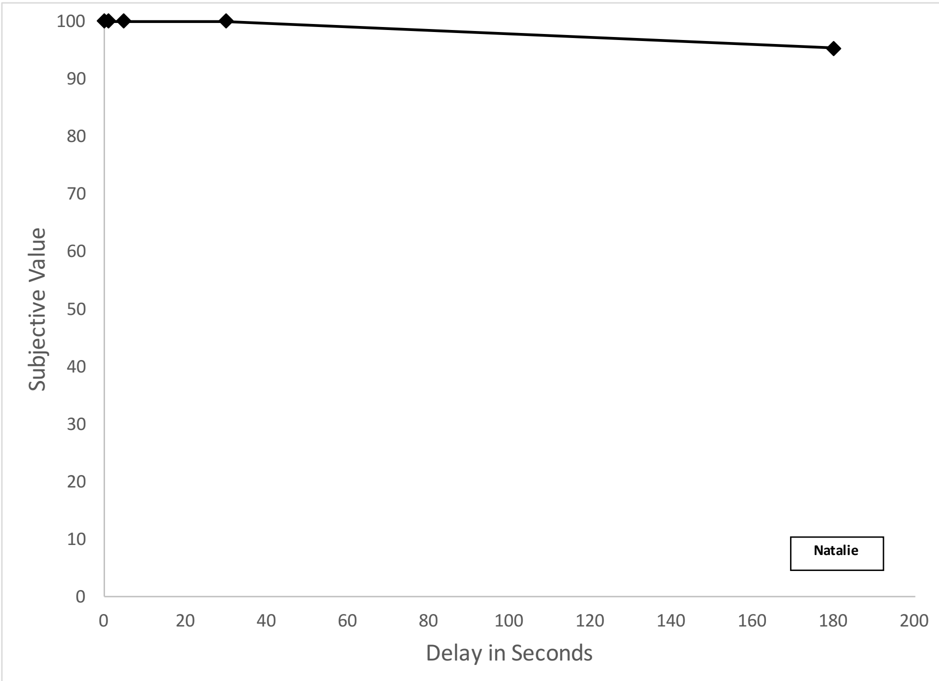

Figure 11. Summary of the assessment results for Natalie

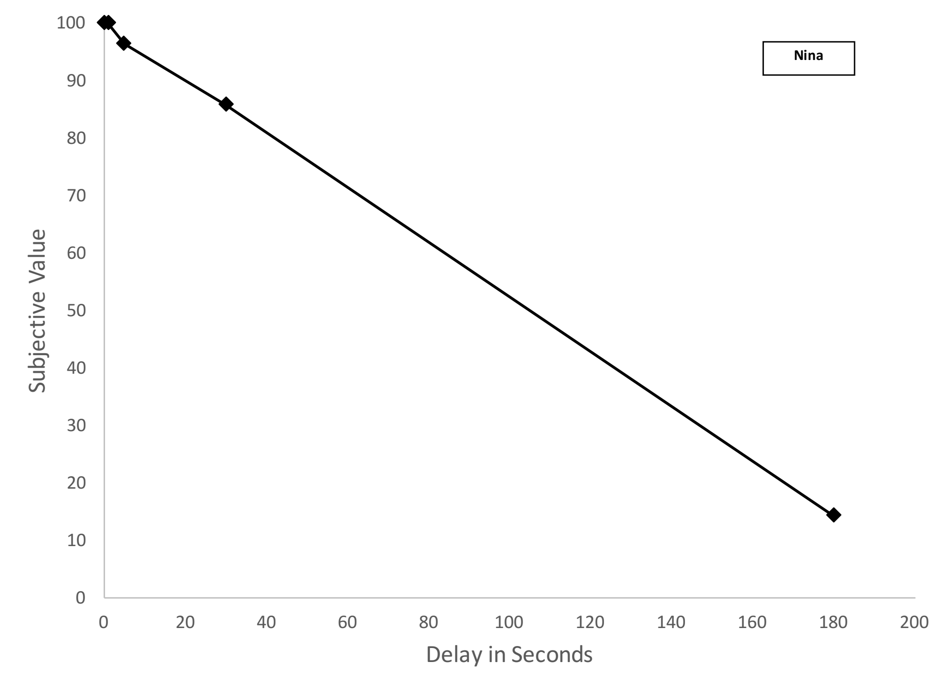

Figure 12. Summary of the assessment results for Nina

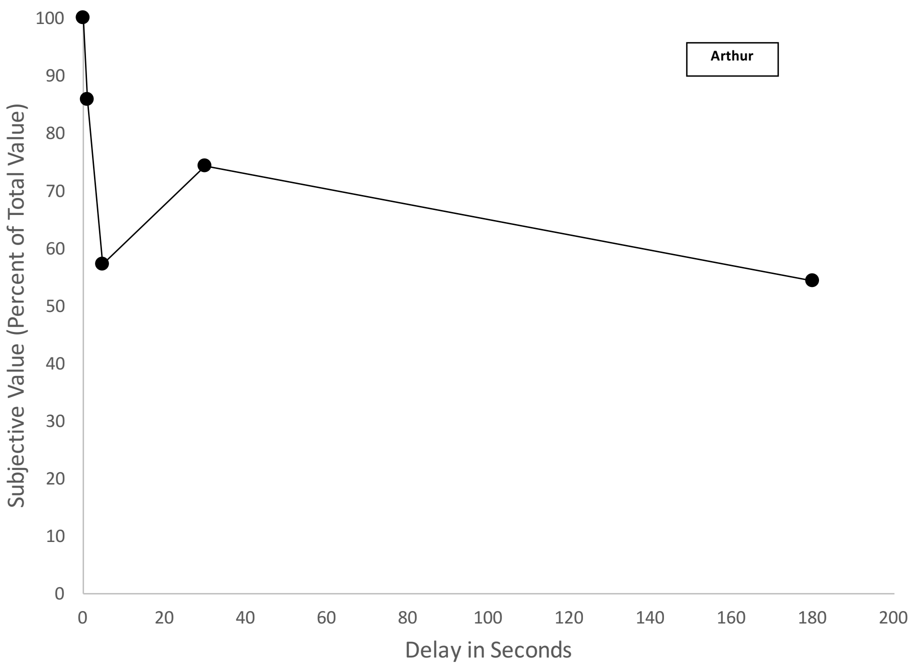

Figure 13. Summary of the assessment results for Arthur

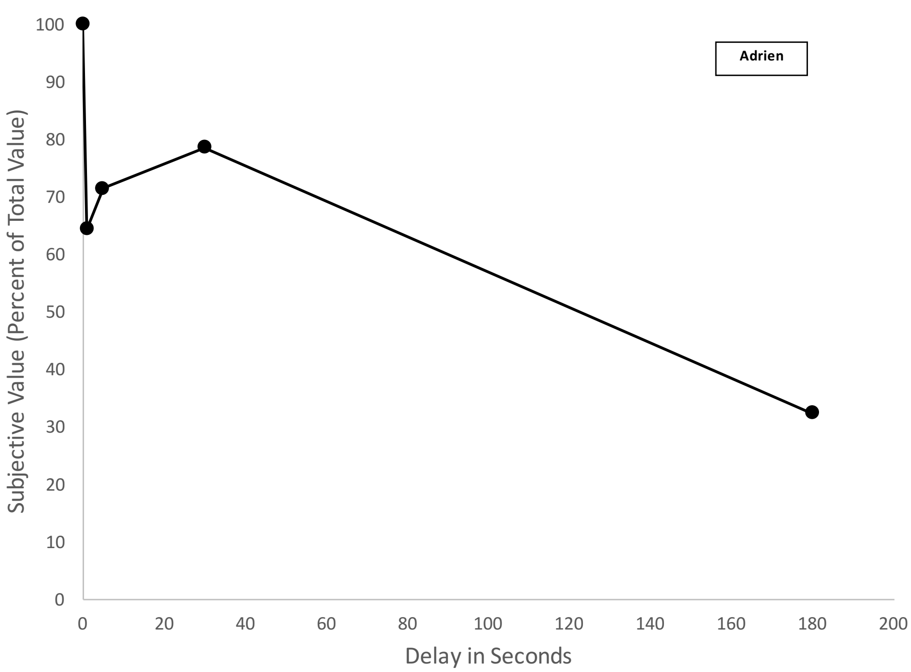

Figure14. Summary of the assessment results for Adrien

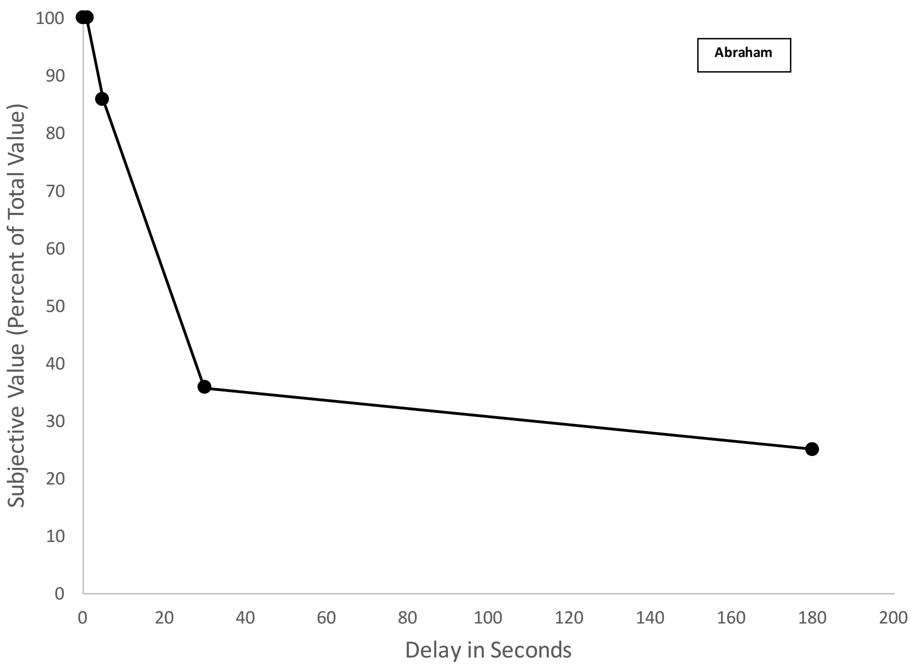

Figure 15. Summary of the assessment results for Abraham

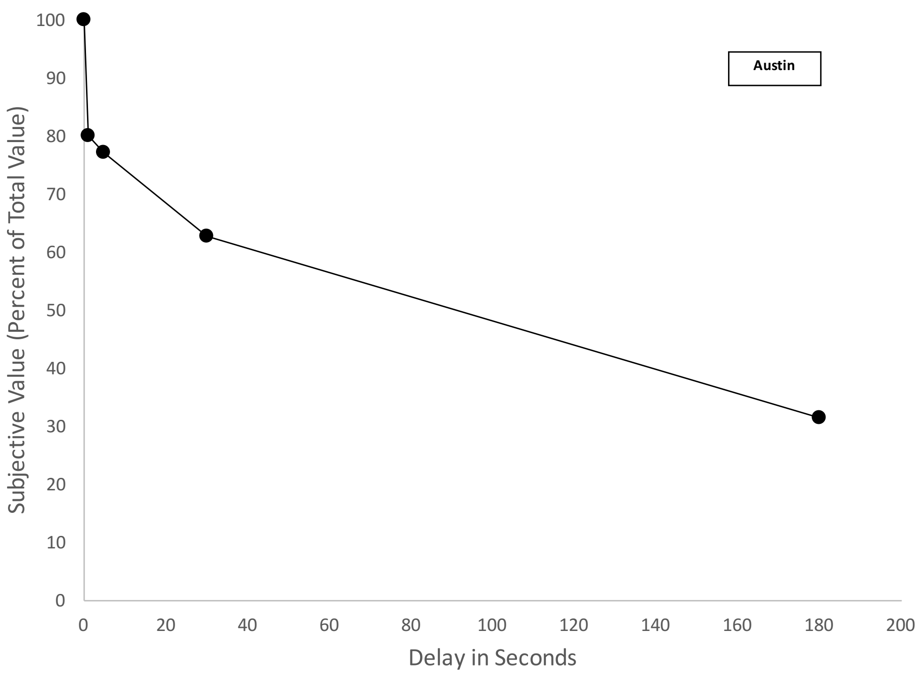

Figure 16. Summary of the assessment results for Austin

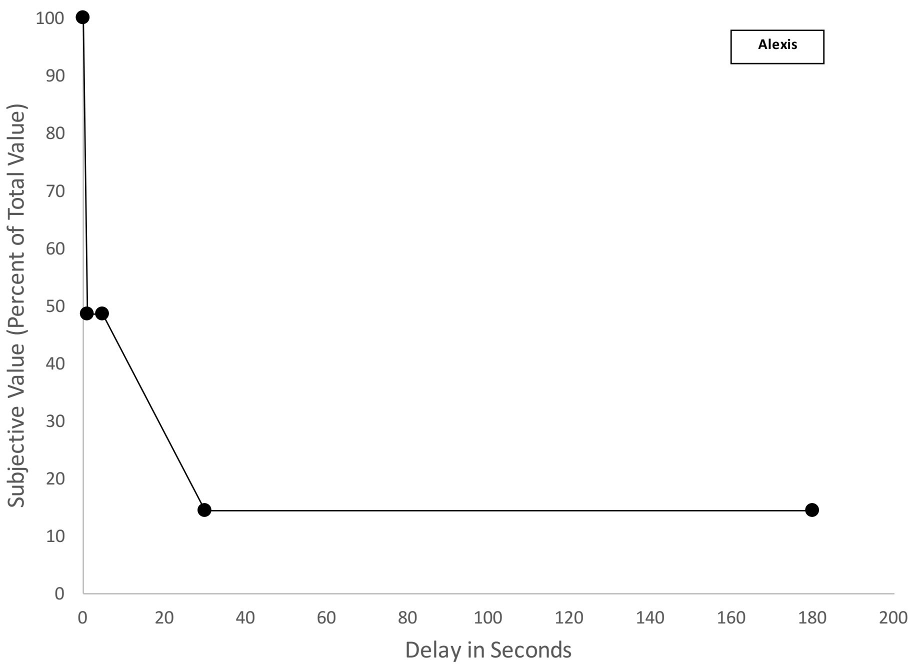

Figure 17. Summary of the assessment results for Alexis

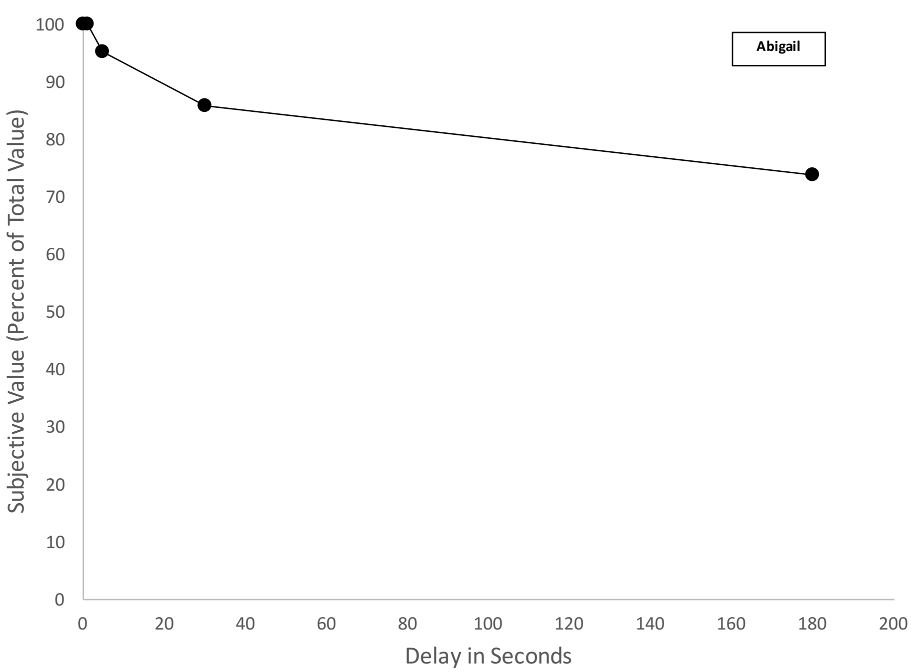

Figure 18. Summary of the assessment results for Abigail

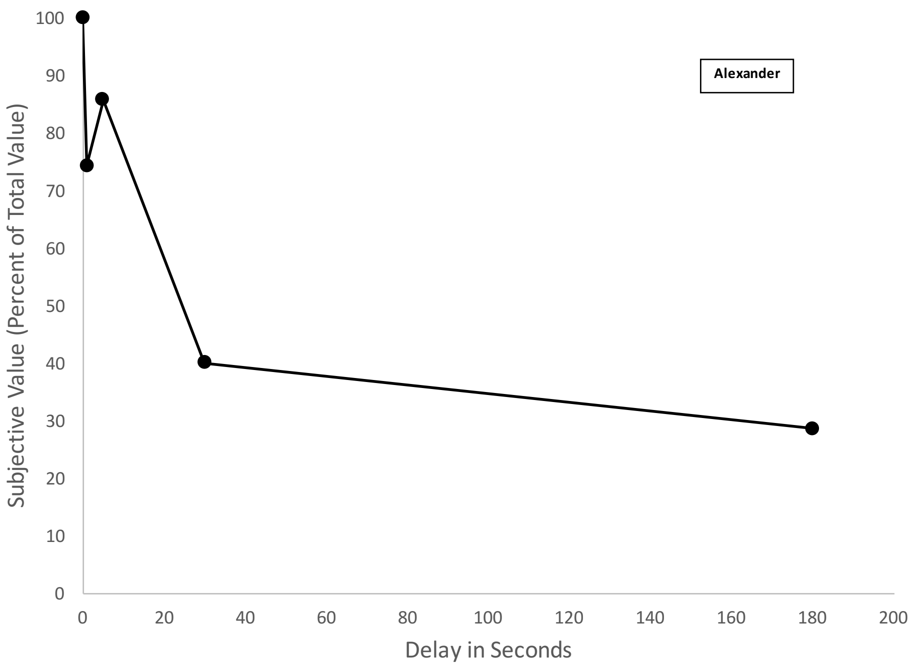

Figure 19. Summary of the assessment results for Alexander

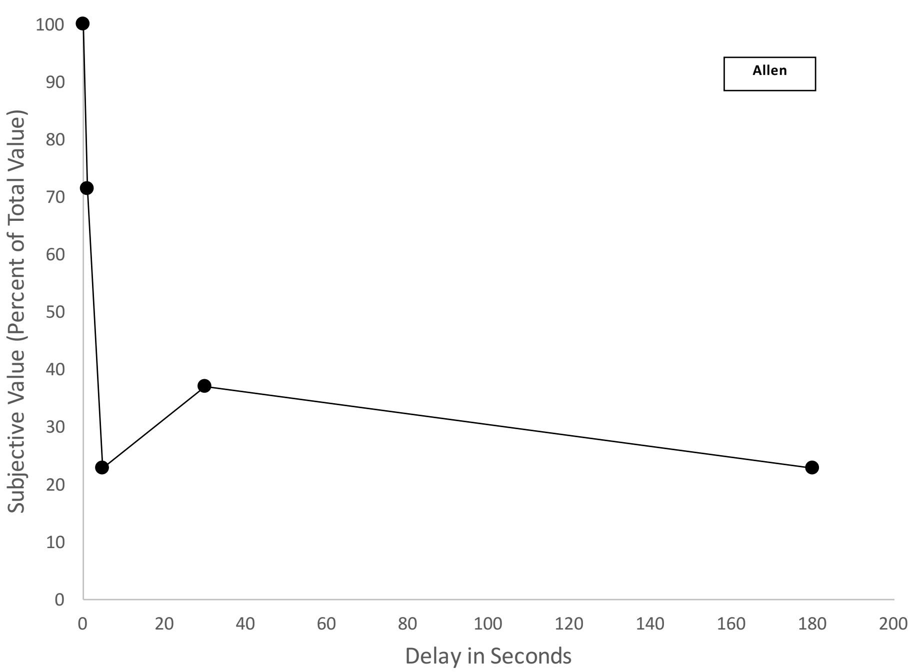

Figure 20. Summary of the assessment results for Allen

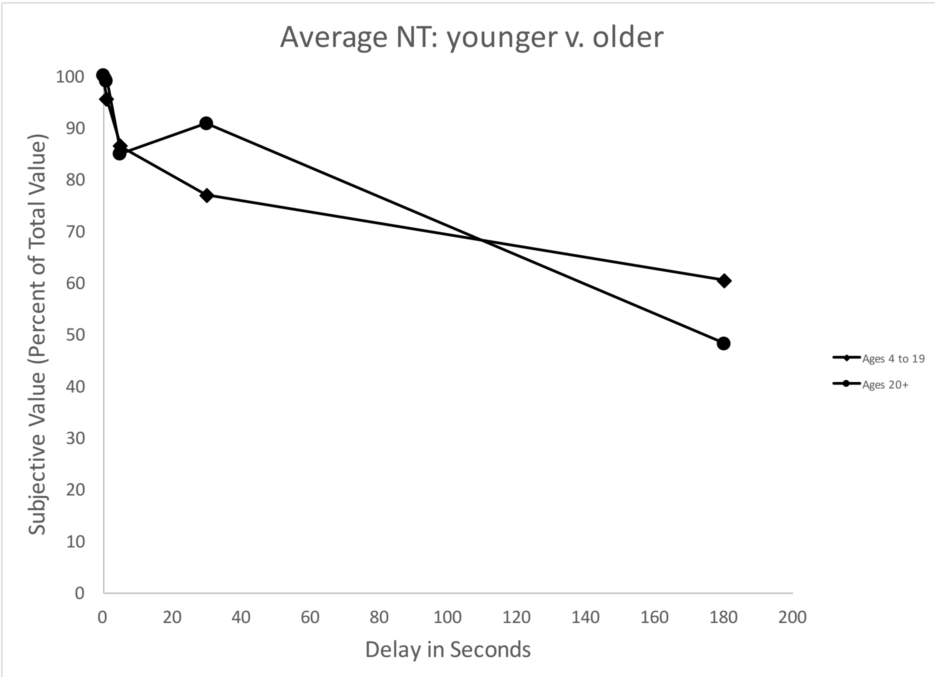

Figure 21. Assessment results for the average discounting for NT group: younger vs. older

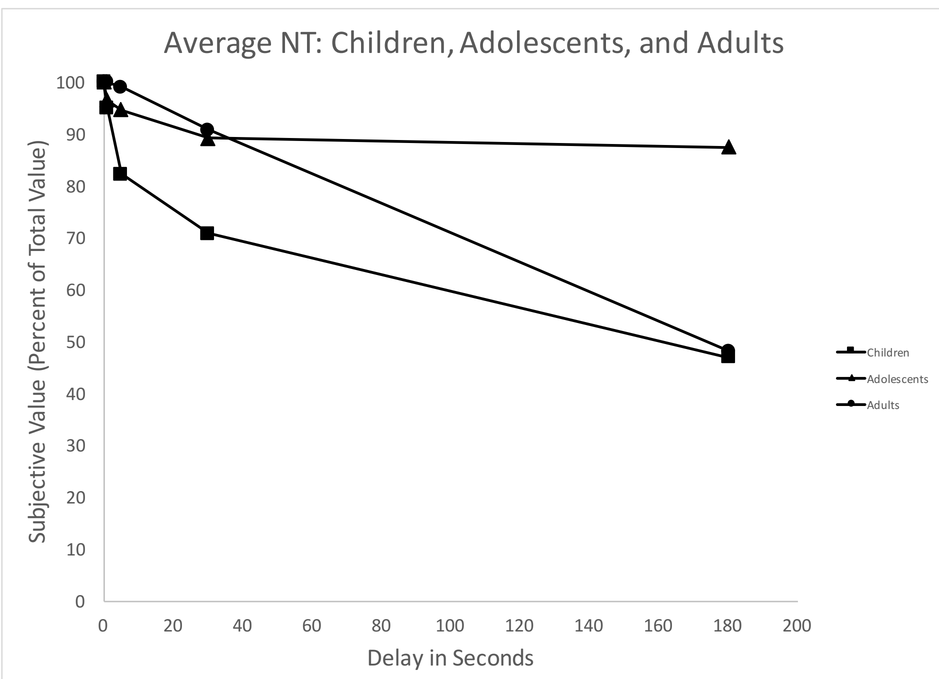

*Figure 22.*Assessment results for the average discounting for NT group: children, adolescents, and adults

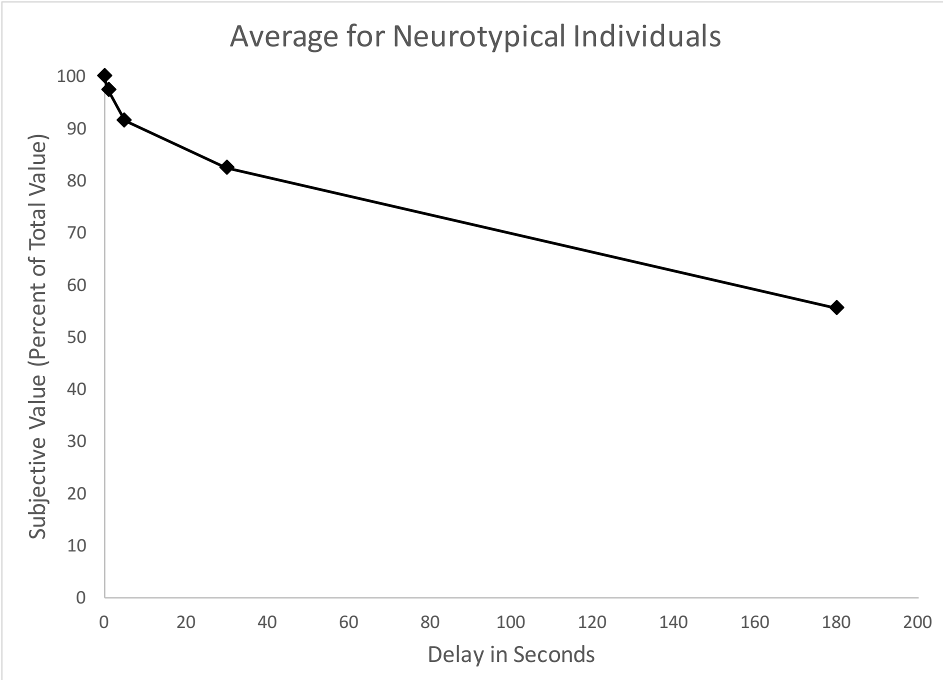

Figure 23. Summary of the assessment results for the overall average discounting for NT group

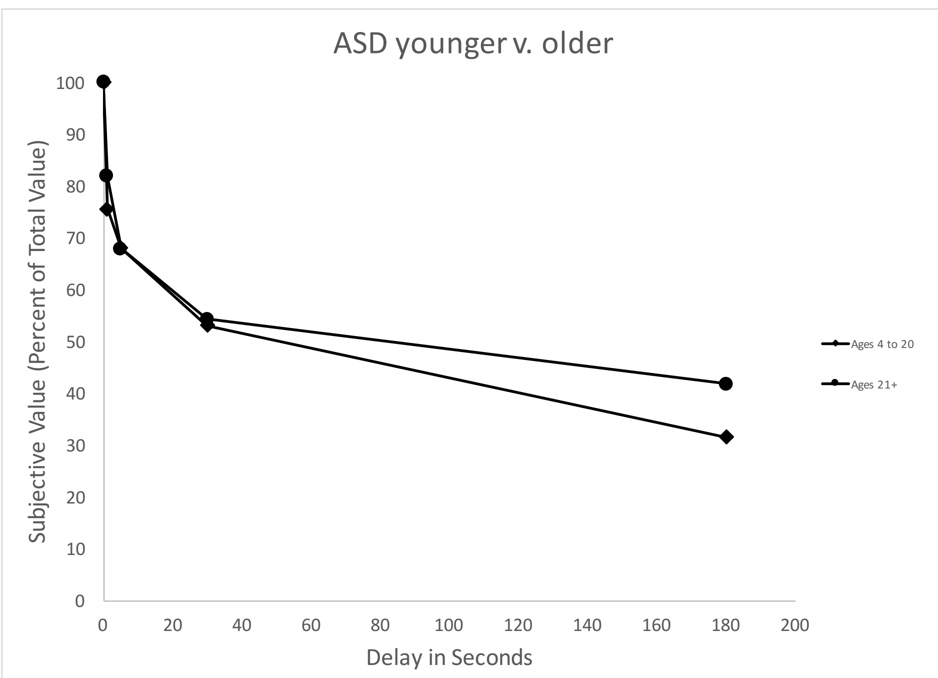

Figure 24. Assessment results for the average discounting for ASD group: younger vs. older

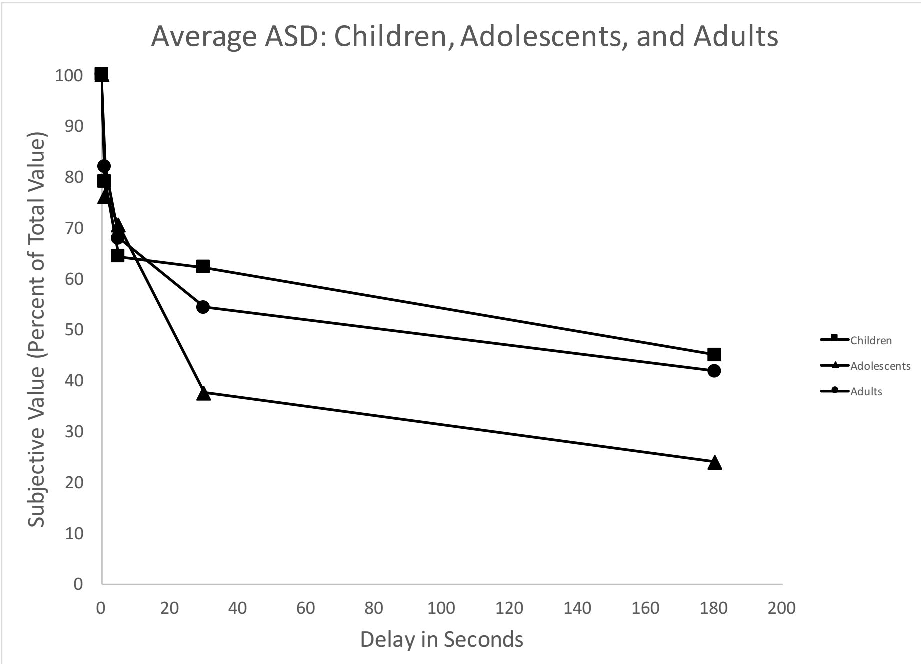

Figure 25. Assessment results for the average discounting for ASD group: children, adolescents, and adults

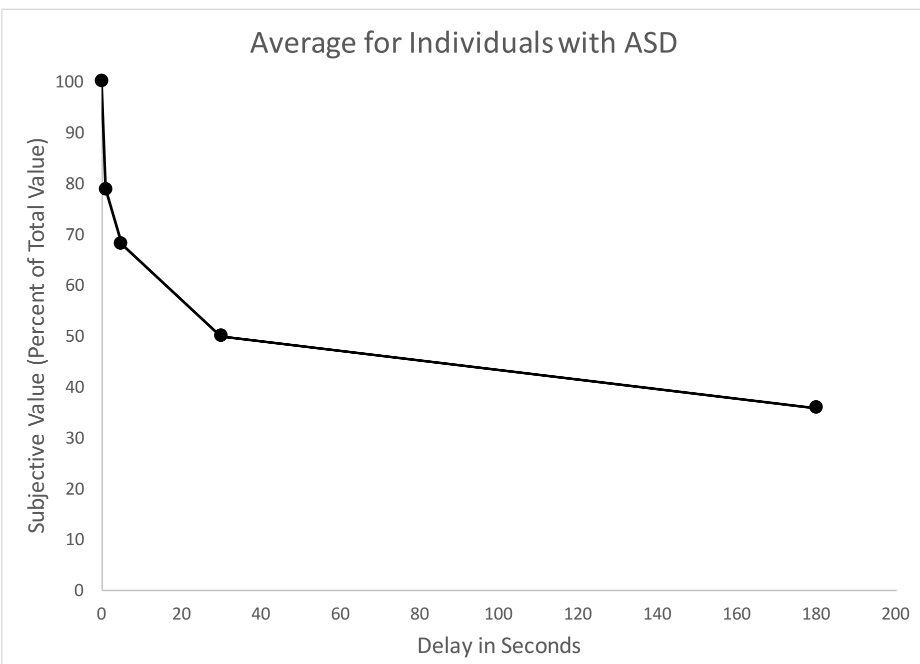

Figure 26. Summary of the assessment results for the overall average discounting for ASD group

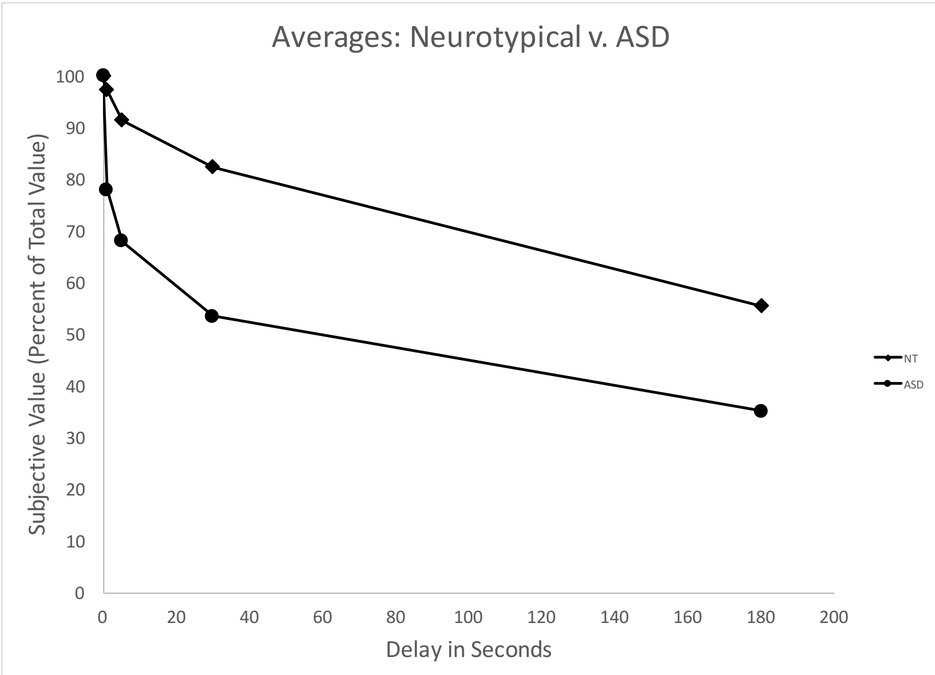

Figure 27. Assessment results for the overall average discounting for NT group vs. overall average discounting for ASD group