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Social and Delay Discounting in Autism Spectrum Disorder

Katherine Rice Warnell[1,*], **Sydney Maniscalco**[2], **Sydney Baker**[3], **Richard Yi**[4], **Elizabeth Redcay**[2]

[1]Department of Psychology, Texas State University, San Marcos, TX 78666

[2]Department of Psychology, University of Maryland, College Park, MD 20742

[3]Department of Psychology, John Jay College, New York, NY 10019

[4]Cofrin Logan Center for Addiction Research and Treatment, University of Kansas, Lawrence, KS 66045

Abstract

Current literature is divided over whether and how processes such as perspective taking and reward sensitivity differ between individuals with autism spectrum disorder (ASD) versus neurotypical individuals. Discounting tasks may provide novel insight into how these processes operate. In delay discounting tasks, participants choose between smaller immediate rewards and larger delayed rewards, and in social discounting tasks, participants choose between a smaller monetary reward for themselves versus a larger reward for partners of varied social distance (e.g., a close friend versus an acquaintance). Delay and social discounting tasks thus implicitly measure the subjective value of rewards given to one's future self and to others, capturing constructs such as perspective taking, reward processing, and social closeness, all of which have been discussed as core cognitive mechanisms underlying ASD. Despite extensive research on discounting in other clinical populations, few studies have examined delay discounting in ASD and no research has examined social discounting in ASD. The goal of the current study was to assess delay and social discounting for monetary rewards in a single sample of adolescents and adults with ASD compared to a matched neurotypical sample. Overall, adults and adolescents with ASD valued both future rewards and rewards given to others less than their typical counterparts did, but rates of discounting were not significantly correlated across temporal and social domains. These results extend an important behavioral paradigm for understanding both perspective taking and reward processing to autism.

Lay Summary:

Discounting tasks—which experimentally measure the subjective value of different rewards—have been used with a variety of clinical populations, but are underexplored in ASD. We found that, compared to neurotypical individuals, individuals with ASD showed diminished subjective value for future rewards (compared to immediate rewards) and rewards for others (compared to rewards

[*]Corresponding author: Katherine Rice Warnell, Department of Psychology, Texas State University, San Marcos, TX 78666, Tel.: 512-245-5564, warnell@txstate.edu.

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for self). This finding has implications for understanding perspective taking, reward processing, and social closeness in ASD.

Keywords

reward; perspective taking; autism; social discounting; delay discounting; temporal discounting

INTRODUCTION

There is great variability in the degree to which humans value rewards that are delayed or given to another person. Such variability is often assessed via discounting tasks, in which individuals make choices between a smaller amount of money now versus a larger amount at a future time point (delay discounting tasks; Green & Myserson, 2004), or between a smaller amount of money for themselves versus a larger amount to another person (social discounting tasks; Jones & Rachlin, 2006). Although delay discounting tasks have been widely used to better understand psychiatric disorders such as ADHD, depression, and substance use disorders (reviewed in Lempert et al., 2018), only recently have researchers also begun to examine social discounting in clinical groups (e.g., Sharp et al., 2012; Yi et al., 2012). Delay/social discounting constructs may be particularly useful frameworks to examine psychiatric disorders where perspective taking deficits and atypical reward processing appear to be manifest. Moreover, the well-characterized neural correlates of discounting make such tasks a promising tool for understanding neurobiological mechanisms spanning disorders (MacKillop, 2013; Lempert et al., 2018). As the limited existing research on delay discounting in autism spectrum disorders (ASD) is mixed as to whether individuals with ASD show normative (e.g., Antrop et al., 2006; Demurie et al., 2012) or atypical discounting (e.g., Carlisi et al., 2017; Chantiluke et al., 2014; Murphy et al., 2017), and no studies have assessed social discounting in ASD, simultaneously investigating delay and social discounting in a single sample with autism could yield novel insight into cognitive processes underlying ASD.

Discounting tasks involve multiple cognitive mechanisms, including reward processing. Extensive neuroimaging research has implicated the brain's reward network in delay discounting, with individual differences in reward system activation related to behavioral differences in delay discounting and to atypical discounting behaviors in clinical groups (see Peters and Buchel, 2011 and Lempert et al., 2018 for reviews). Thus, discounting tasks may help inform current debates in the literature about the extent to which ASD is characterized by atypical reward processing (Clements et al., 2018). Additionally, although delay and social discounting tasks both involve reward processing, only social discounting involves the reward of giving to another, which may involve social-cognitive brain networks outside of the reward system (Morelli et al., 2015b). There is some limited evidence for atypical processing of others' rewards in autism (Mosner et al., 2017), but the construct remains understudied in ASD despite its core role in human social relationships (Morelli et al., 2015a).

In addition to reward processing, discounting tasks also involve perspective taking. How participants assign subjective reward value in discounting tasks involves, in part, taking the perspective of either one's future self (delay discounting; Peters & Buchel, 2010) or another person (social discounting; Yi et al., 2016). For example, prospective episodic thinking about oneself increases the willingness to wait for rewards (e.g., Daniel et al., 2013; Lin & Epstein 2014; Peters & Buchel, 2010), and brain regions linked to perspective taking are consistently implicated in both delay (Lempert et al., 2017; Soutschek et al., 2016) and social discounting (Strombach et al., 2015). The use of discounting measures in ASD is especially relevant as there is currently disagreement about the degree and universality of perspective-taking deficits in ASD, when either taking the perspective of one's future self (e.g., Ciaramelli et al., 2018; Terrett et al., 2013; Crane et al., 2013) or of others (Tager-Flusberg, 2007). As delay and social discounting tasks are both well-matched on task demands, if individuals with ASD show more discounting on both tasks when compared to typically-developing (TD) individuals, it would provide new evidence for equivalent difficulties in perspective-taking across self and other contexts. In contrast, an asymmetrical pattern of results could suggest larger difficulties with perspective-taking in particular situations.

In light of these potential insights into ASD, the current study is the first to investigate delay and social discounting in a single ASD sample. We recruited adolescents and young adults, age ranges that have successfully completed discounting tasks in prior studies (e.g., Murphy et al., 2017; Carlisi et al., 2017), and compared their results to a TD group matched on age, sex, and IQ. Given inconsistencies in prior ASD delay discounting studies and the lack of research on social discounting in ASD, three potential hypotheses could be advanced: first, there might be no group differences on either social or delay discounting; second, there might be equivalent group differences on both tasks; and third, there might be an interaction between group and task type, such that one task might show larger group differences than the other. Each potential finding would inform understanding of ASD, laying the groundwork for more targeted studies examining the specific mechanisms underlying ASD performance.

METHODS

Participants

All procedures were prospectively reviewed and approved by the local Institutional Review Board. Participants between the ages of 14 and 32 were recruited via a database of local families, community listervs, targeted flyers, on-campus recruitment, and word of mouth. Adult participants provided written informed consent and participants under the age of 18 provided written assent with a parent/guardian providing written informed consent. All participants had normal or corrected-to-normal hearing and vision. Out of thirty-two recruited participants with ASD, two were excluded due to verbal IQs below 70 on the KBIT-2 (Kaufman & Kaufman, 2004), one was excluded because of a lack of IQ data, and two were excluded due to failure to complete the discounting tasks. Thus, the final ASD sample consisted of 27 individuals (21 males). Diagnosis was confirmed via the Autism Diagnostic Observation Schedule, 2nd Edition (ADOS-2; Lord et al., 2008) combined with

clinical judgement by a research-reliable clinical psychology Ph.D. student resulting in a sample with an average ADOS calibrated severity score of 6.6 (out of 10, SD=2.13; Gotham, Pickles, & Lord, 2009; Hus & Lord, 2014). From a larger sample of typical individuals, a subset (n=27) was selected that was matched to the ASD sample on sex (21 males) and mean-matched on age (M_{TD}=19.81y, M_{ASD}=20.98y, $t(52)=-1.0$, $p=.32$), verbal IQ (M_{TD}=100.7, M_{ASD}=98.11, $t(52)=.58$, $p=.56$), non-verbal IQ (M_{TD}=102.4, M_{ASD}=101.1, $t(52)=.76$, $p=.76$), and full-scale IQ (M_{TD}=101.9, M_{ASD}=99.6, $t(52)=.48$, $p=.63$).

Experimental Tasks

Participants completed a computer-administered social discounting task followed by a delay discounting task (modified from Yi et al., 2016). In the social discounting task, participants were asked to make a list of four different individuals: the person with whom they were closest (P_1), a person with whom they were still close but not as close (P_2), a person who they knew "kind of well" (P_3), and a person they had met personally, but did not know well at all (P_4). To assist with comprehension, participants were also shown a graphic with concentric circles (with themselves in the middle) representing increasing social distance. To minimize memory demands, participants wrote down the initials of each P_X. Participants were told that no actual money was given out during or after the game. We used hypothetical rewards given evidence that real versus hypothetical rewards do not alter neurotypical participant behavior in in delay (Johnson & Bickel, 2002) or social (Locey et al., 2011) discounting.

For each P_X, participants completed six trials in which they chose between giving \$100 to P_X versus receiving a variable amount for the self (beginning at \$50 on T rial 1). The amount for the self was titrated based on the response in the previous trial, increasing if they selected other and decreasing if they selected self (see Supplementary Material for task details). The resulting amount for the self following six trials was indicated as the indifference point—the value for the self that is subjectively equivalent to giving \$100 to P_X.

After the social discounting task, participants completed the delay discounting task. In this task, participants chose between receiving \$100 at a future time point or a smaller amount immediately. Again, participants were informed that the money was hypothetical and verbal comprehension checks ensured that all participants understood the task instructions. Participants made decisions about four time points in the future: one day (T_1), one month (T_2), one year (T_3), and 25 years (T_4). For each T_X,participants completed six trials in which they chose between receiving \$100 at T_X versus a variable amount immediately (beginning at \$50 on T rial 1). The immediate amount was titrated using the same algorithm of the social discounting task, and the resulting immediate amount following six trials was indicated as the indifference point—the immediate value that is subjectively equivalent to receiving \$100 at T_X.

Data Analysis

There are two primary ways of analyzing discounting data using indifference points: to calculate the discounting slope by fitting a theoretically informed discount function, or to calculate the area under the curve (AUC). Given that social discounting tasks have not been

previously conducted with ASD populations, we opted for the method (AUC) that does not assume an underlying model. Specifically, we used ordinal distances between social and temporal points in our AUC analysis (Figure 1), as proposed by Borges and colleagues (2016). In both delay and social discounting tasks, smaller AUC values indicate that rewards are steeply discounted as a function of delay and social distance, respectively. One ASD participant and one TD participant failed to complete the task at the 25 year time point, and so their delay discounting data was excluded from AUC analysis.

RESULTS

Both TD and ASD participants showed greater discounting for increased temporal and social distance (Figure 2). There was no relation between the degree of discounting (measured via AUC) and age or verbal IQ for either group nor were there any gender effects (*ps*>.05). For the ASD group, ADOS severity was not correlated with delay AUC ($r(24)=.12$, $p=.55$) or social AUC ($r(25)=.08$, $p=.69$). Rates of social discounting and delay discounting were not related in either TD ($r(24)=.18$, $p=.37$) or ASD ($r(24)=-.03$, $p=.89$) groups, indicating that discounting in one domain did not predict discounting in another.

Using AUC values, ASD individuals showed greater discounting compared to the TD group on both delay ($t(50)=2.18$, $p=.034$) and social ($t(43.8)=2.01$, $p=.042$) tasks. The TD group showed significantly more individual variability in social discounting than the ASD group ($F(1,52)=5.270$, $p=.026$), but such a difference was not present in delay discounting.

We next examined specific indifference points in a 2 (delay, social) × 4 (distance level) repeated-measures ANOVA, using diagnosis as a between-subjects factor. There was no main effect of task type ($F(1, 150)=.858$, $p=.359$), but there were significant main effects of diagnostic status ($F(1,50)=9.60$, $p=.003$) and distance ($F(3,150)=94.30$, $p<.0001$), as well as a significant interaction between task and distance ($F(3,150)=10.13$, $p<.0001$), such that the effect of distance was greater for the delay task. No interactions with diagnosis, however, were significant. Post-hoc comparisons indicated that, for the delay task, the only significant difference between groups was at 1 day ($t(52)=2.23$, $p=.030$), with non-significant differences for each subsequent time point (1 month: $t(52)=1.89$, $p=.065$; 1 year: $t(52)=1.94$, $p=.058$; 25 years: $t(50)=.86$, $p=.39$). For the social task, the difference between groups was significant for the closest ($t(52)=2.18$, $p=.034$) and next closest person ($t(52)=2.20$, $p=.035$), but not for the two more distant people (3rd person: $t(52)=.214$, $p=.83$; 4th person: $t(52)=.73$, $p=.47$).

DISCUSSION

Delay and social discounting tasks are robust and well-characterized paradigms that offer insight into cognitive processes hypothesized to be affected in ASD. The current study is the first to examine delay and social discounting in a single sample of individuals with ASD and a matched TD sample. We found that ASD participants showed both greater delay and social discounting compared to TD individuals, indicating that the subjective value for rewards that are delayed and given to others are lower amongst ASD individuals. The group differences on delay and social discounting tasks were of similar magnitude and were most pronounced

at the closest temporal and social points compared to more distant points. Although this study cannot pinpoint the specific mechanism underlying these group differences, our findings have implications for understanding discounted value in ASD and are a springboard for future research.

Currently, the literature is divided on whether ASD subjective valuation is predominately affected in contexts with social-cognitive components or is atypical across broader situations (e.g., Clements et al., 2018). The current findings make two interesting, albeit preliminary, contributions to this discussion. First, group differences in discounting were not specific to social discounting, or giving money to a social partner; individuals with ASD also showed greater discounting of delayed money for themselves. Second, although these group differences in discounting were present across contexts, findings did not indicate hyposensitivity to reward in ASD; rather, individuals with ASD valued immediate rewards to the self comparatively more than TD individuals.

Although our findings of greater delay discounting in ASD are contrary to some studies, existing literature is mixed. Some researchers have found evidence for greater discounting of future rewards in ASD (e.g., Carlisi et al., 2017; Chantiluke et al., 2014; Murphy et al., 2017), but others have found no group differences (e.g., Antrop et al., 2006; Demurie et al., 2012; Kouklari et al., 2018; & Karalunas et al., 2018). One possible explanation is that most studies finding differences, including ours, examined adolescents and adults, whereas most studies showing no differences included children as young as 7 or 8. Immediate financial gain may be more valuable to adolescents and adults with ASD, and thus, future research should include more targeted age ranges and assess financial understanding and financial independence.

The exact mechanisms behind this general increase in discounting in ASD are unknown, but there are several candidate possibilities. Individuals with ASD may have failed to understand the task, but this is countered by the fact that both groups showed greater discounting at greater temporal and social distances. Another possibility is that, although previous research with typical individuals has found that real versus hypothetical rewards affect discounting similarly, hypothetical rewards are treated differentially in ASD. Assuming equivalent task understanding and buy-in, greater discounting in ASD could be explained by increased valuation of immediate rewards to the self, a devaluation of future rewards or rewards to others (i.e., vicarious rewards), or some combination of these two. If immediate rewards (compared to delayed rewards or rewards to others) are valued more in ASD, it could be due to comorbidity between ADHD and ASD (Simonoff et al., 2008). ADHD does influence discounting (see Jackson et al., 2016 for meta-analysis) and some studies have found greater discounting in ADHD than ASD samples (Antrop et al., 2006; Demurie et al., 2013), although other research with delay of gratification suggests that ASD phenotypes are not solely attributable to comorbid ADHD (Faja & Dawson, 2015). Unfortunately, we did not systematically assess comorbidity, but future research should assess ADHD symptoms and include symptomatology measures in analyses.

Increased ASD discounting may also be explained by ASD participants assigning comparatively less value to both long-term rewards and rewards to others, perhaps due to

atypical perspective-taking. Although atypical perspective-taking in ASD is most frequently discussed in context of taking others' perspectives, there is also evidence for atypical simulation of one's future self (Ciaramelli et al., 2018; Terrett et al., 2013; but see Crane et al., 2013). Evidence from typical populations suggests that the perspective taking required in delay and social tasks may share a common neurocognitive basis (Hill et al., 2017), overlapping with that involved in theory of mind (O'Connell et al., 2018). Thus, it is possible that atypical perspective taking explains group differences on both tasks, and future studies could relate individual differences in discounting to other perspective taking measures or experimentally manipulate episodic thinking.

Interestingly, we failed to find a relation between delay and social discounting, suggesting the mechanisms underlying these tasks may be heterogeneously affected in ASD. One possibility is that first-person prospection is not related third-person perspective taking, although previous research in neurotypical adults has found commonalities between these two processes (Spreng et al., 2009). Our findings are consistent with findings that, in delay contexts, social and material rewards operate differently. Demurie and colleagues (2013) found that in TD and ASD children, willingness to wait for money was correlated with willingness to wait for non-social rewards (i.e., toys, activities), but not with willingness to wait for social feedback, consistent with neural evidence for at least some dissociation between these reward types (Ruff & Fehr, 2014). Future research should examine how performance on existing social reward paradigms (e.g., Dichter et al., 2012; Kohls et al., 2011) relates to social discounting and delay discounting for various types of rewards, including more tangible social rewards (e.g., positive feedback) not measured in the present study.

Other than the main effect of increased social discounting in ASD, the specific trajectory of social discounting across social distance was roughly similar between individuals with ASD and TD individuals, but the current study did not ask participants to elaborate on their relationships or to explain their reasoning. One possible explanation for increased social discounting in ASD is that individuals with ASD feel subjectively less close to their selected reward recipients, consistent with potential differences in affiliative tendencies and social networks (e.g., Chevallier et al., 2012). Importantly, however, the ability to form close relationships is likely also related to perspective taking and reward processing, making it difficult to determine whether closeness per se entirely explains social discounting. Longitudinal investigations of the relations between these variables may help disentangle the factors leading to social discounting, factors which may be distinct in ASD versus TD groups. Additionally, as females with ASD may show increased compensatory social behaviors (e.g., Dean et al., 2017; Lai et al., in press), group differences in social discounting could be smaller among women. Although our current sample was too small to examine gender effects, this is an important direction for future research.

Overall, this study represents an important first step in using the well-characterized delay and social discounting paradigms to better understand autism and to contextualize ASD in the context of other psychiatric disorders. Both delay and social discounting show clinical utility in other disorders (e.g., predicting treatment outcomes; Bradstreet et al., 2012; stratifying disorder subtypes; Dombrovski et al., 2011) and the extension of these tasks to

ASD is consistent with an RDoC approach (Insel et al.,2014; Lempert et al., 2018). Discounting tasks may capture underlying neurocognitive mechanisms (e.g., reward processing, perspective taking) that cut across disorders, allowing for common clinical and pharmacological interventions. We caution, however, against assuming that similar manifest behaviors always spring from the same underlying mechanisms. In spite of the wealth of research on discounting in other populations, we are just beginning to investigate discounting tasks in ASD. Thus, our findings of reduced discounting in ASD may be rooted in different cognitive processes than those which underlie reduced rates of discounting in other populations. More research that pairs discounting tasks with interviews, classic social-cognitive measures, and neuroimaging can help to capture mechanisms underlying the subjective value of different experiences for those with autism.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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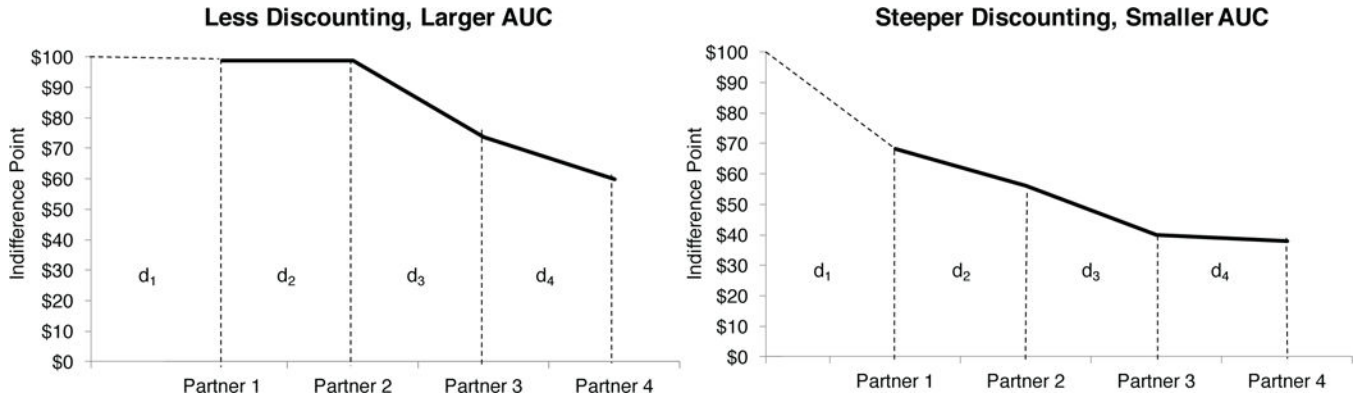

Figure 1.

Assessing discounting behavior in individual participants. To calculate each individual's rate of discounting, we calculated their area under the curve (AUC). In these calculations, the y-axis was rescaled to have a maximum value of 1. We converted the x-axis values to ordinal points, such that, rather than assuming that the distance between person 3 and person 4 was larger or smaller than between person 1 and 2, we set equal distance between all points. Thus, the values of each distance point (i.e., Partner 1, 2, 3, and 4; 1 day, 1 month, 1 year, and 25 years) were rescaled to 0.25, 0.5, 0.75, and 1 respectively, such that the maximum AUC value was 1. We then summed together the area of trapezoids d1, d2, d3 and d4 to calculate each person's AUC. Individuals who showed more discounting had smaller AUC values. The data depicted in the graphs are from two TD participants.

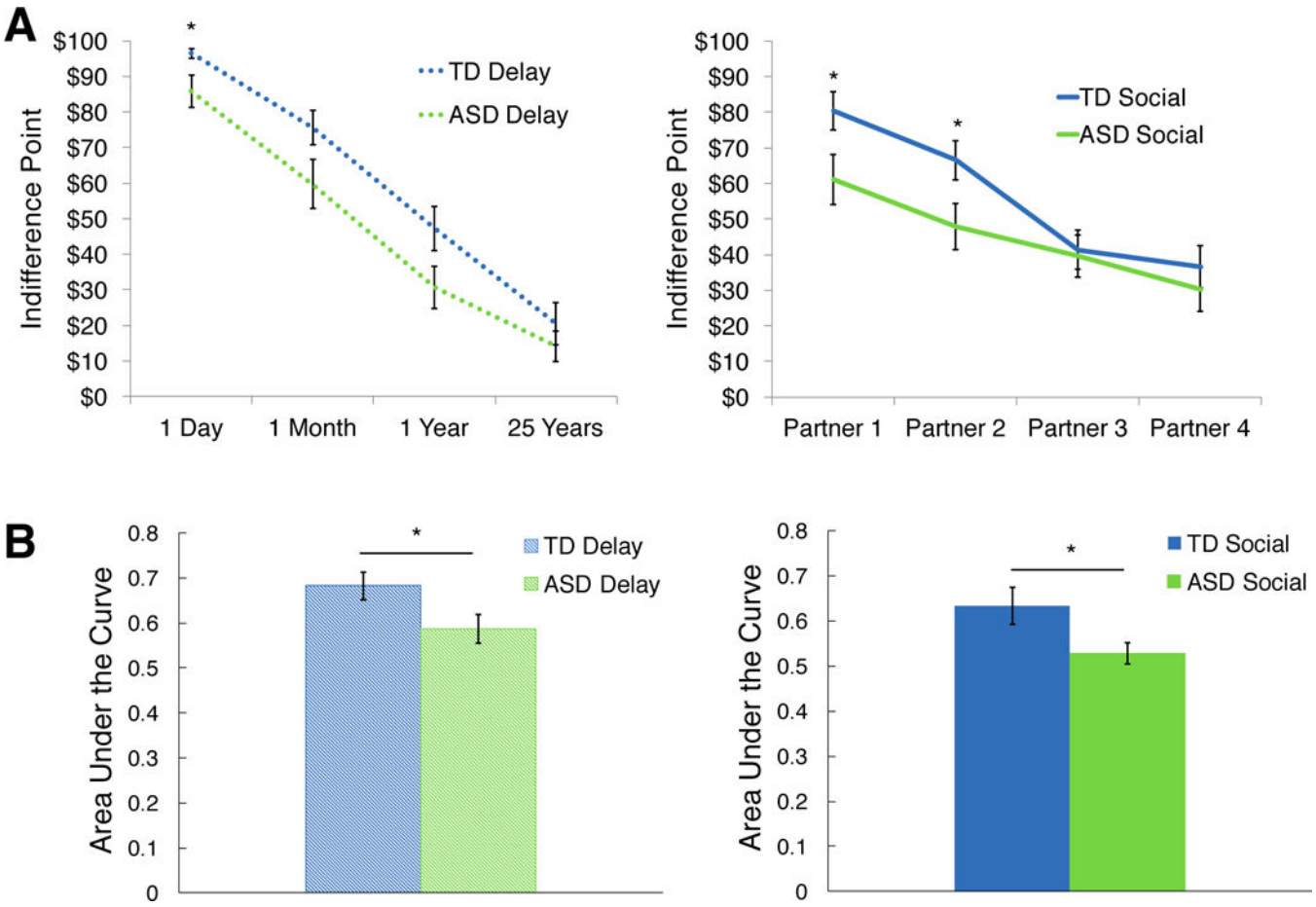

Figure 2.

Comparing delay and social discounting in typical individuals and individuals with ASD. (A) Comparing at each specific time point indicated significant group differences at temporally and socially closer time points. (B) Area under the curve (AUC) analyses indicated significantly greater ASD discounting in both delay and social conditions. *, $p<$. 05. Error bars represent +/− 1 standard error.