A Meta-Analytic Review of Gender Differences on Delay of Gratification and Temporal Discounting Tasks in ADHD and Typically Developing Populations

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Abstract

Individuals with Attention-Deficit/Hyperactivity Disorder (ADHD) tend to prefer smaller immediate rewards over larger delayed rewards compared to Typically Developing (TD) individuals. Currently it is unknown if males and females with ADHD differ in their preferences for delayed rewards, although females and males with ADHD appear to manifest differences in symptoms as well as in other cognitive and emotional domains. We used meta-analytic methods to examine gender differences on delay of gratification and temporal discounting tasks in both TD and ADHD samples. We identified 28 papers with 52 effect sizes for children and adults, and calculated the average effect size for gender comparisons within TD and ADHD samples. There were no differences between TD males and TD females, but males with ADHD were more likely to choose the larger delayed rewards than females with ADHD. Meta-regressions were used to examine moderators of task type, age, and reward type, which did not significantly predict gender differences. These findings indicate a dissimilar pattern of gender differences for those with ADHD compared with TD samples. Implications of our findings are also discussed.

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Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is defined as a neurodevelopmental disorder relating to impulsivity, inattention, self-regulation, and executive functioning (Seidman, 2006; Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Barkley, 2010). ADHD is also one of the most commonly assessed neurodevelopmental disorders and the diagnosis rate has been increasing among children and adults (Visser et al., 2014; Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). Researchers have found that those with ADHD have important differences in brain activity and brain structures compared to Typically Developing (TD) individuals (Konrad & Eichhoff, 2010; Castellanos & Proal, 2012; Yu-Feng et al., 2007; Cubillo, Halari, Smith, Taylor, & Rubia, 2012). On tasks that involve choosing between a small immediate reward and a larger reward with a delay, for which we will use the term *Delayed Reward Paradigms/Tasks*, those with ADHD tend to prefer an immediate smaller reward more often than do individuals without ADHD (Coghill, Seth, & Matthews, 2014; Solanto et al., 2001). While researchers in the ADHD field acknowledge that there are differences between ADHD and TD populations in terms of their preferences to delay rewards, little attention has been paid to how males and females with ADHD differ in their preferences to delay rewards or whether the differences are similar to results seen in TD males and females without ADHD.

In this thesis, we reviewed two paradigms that measure the preference for choosing delayed rewards: delay of gratification tasks and temporal discounting tasks. We then conducted a literature search and used meta-analytic methods to evaluate the magnitude of differences between TD males and females, and the magnitude of differences between ADHD females and males, across delayed reward studies. Potential moderators between males and females were then examined. Lastly, meta-analytic methods were used to compare TD males to ADHD males and to compare TD females to ADHD females, to replicate past findings that TD individuals prefer delayed rewards more than ADHD individuals. As far as we know, this study is the first meta-analysis to analyze gender differences[1] on delayed reward tasks using both ADHD and TD populations.

The Rationality of Delaying Rewards

People face many decisions in everyday life between smaller immediate rewards and larger delayed rewards. At times, choosing a smaller immediate reward can be seen as having elements that relate to rationality, since people will often choose the immediate rewards reflexively or quickly, and unconsciously, often at the expense of their long-term interests (Metcalfe & Mischel, 1999; Stanovich & Toplak, 2012). People also approach choices with delayed rewards in a way that is not consistent across time, and these time trends can often be best represented with a hyperbolic curve as opposed to a more gradual exponential curve (Ainslie, 2003), meaning the further the rewards are delayed in the future, the more greatly the subjective value accelerates downwards (Basile & Toplak, 2015). Preference in choosing a smaller immediate reward is associated with more impulsive decision-making as well as a slower perception of time passing (Reynolds, Ortengren, Richards, & de Wit, 2006; Richards, Zhang, Mitchell, & de Wit, 1999; Rubia, Halari, Christakou, & Taylor, 2009).

The inability to delay reward can have important consequences, as studies have found it to strongly correlate with later life success in social interactions, the ability to cope with stress, and body mass index (BMI) (Mischel, Shoda, & Peake, 1988; Mischel, Shoda, & Rodriguez, 1989; Shoda, Mischel, & Peake, 1990; Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013). Also,

[1] Although we do not intend to confound “sex differences” with “gender differences,” for brevity and ease of presentation we will use the term "gender differences" throughout the paper.

the ability to delay gratification can predict future life success as early as the preschool years (Mischel et al., 1989; Shoda et al., 1990).

In laboratory settings, the preference for delayed rewards is associated with predispositions in natural settings such as achieving long-term goals and having better executive functioning and working memory (Basile & Toplak, 2015; Shamosh et al., 2008). It takes time to develop the ability to choose a delayed reward; for example, younger children choose immediate rewards more often than older children (Toplak, Hosseini, & Basile, 2016). But as we develop, the preference to delay a larger reward for some future date is also correlated with higher grades in college and with higher intelligence (Kirby, Winston, & Santiesteban, 2005; Shamosh et al., 2008; Shamosh & Gray, 2008; Basile & Toplak, 2015).

ADHD and Delayed Reward Tasks

While it is difficult for most people to prefer delayed rewards when they can have an immediate reward, compared to TD samples, adults and children with ADHD have been found to prefer smaller immediate rewards on experimental delayed reward tasks at even higher rates (Patros et al., 2016; Jackson & MacKillop, 2016; Marco et al., 2009). Researchers have attempted to explain why those with ADHD prefer immediate rewards more than controls on delayed reward tasks. Those with ADHD appear to have a different sensitivity to both reward and punishment, which may contribute to their willingness to make more impulsive short-term reward decisions (Tripp & Alsop, 2001; Luman, van Meel, Oosterlaan, & Geurts, 2012). Those with ADHD appear to be more averse to delays compared to TD populations; when those with ADHD make choices under conditions where delays can be averted they prefer the immediate reward, but in situations where the delay cannot be avoided they will not necessarily choose the immediate reward (Wilbertz et al., 2013; Paloyelis et al., 2009; Sonuga-Barke, Taylor, Sembi, & Smith, 1992).

The preference for smaller immediate rewards in experimental settings also appears to be paralleled in naturalistic situations where, compared to normal controls, those with ADHD engage in riskier impulsive decisions that are centered around short-term rewards in activities such as driving, sexual behaviour, and gambling (Thompson, Molina, Pelham, & Gnagy, 2007; Flory, Molina, Pelham, Gnagy, & Smith, 2007; Faregh & Derevensky, 2011). In addition, ADHD is often comorbid with other disorders that are linked to riskier impulsive decisions such as conduct disorder (CD) and oppositional defiant disorder (ODD) (Connor, Steeber, & McBurnett, 2010).

Delay of Gratification and Temporal Discounting Paradigms

There are two important types of tasks that involve choosing between immediate short-term rewards and delayed long-term rewards, in which those with ADHD appear to prefer short-term rewards more than TD populations: delay of gratification tasks, and temporal discounting tasks. Some researchers use these terms interchangeably or have suggested that these tasks measure the same process (Shamosh & Gray, 2008), while others distinguish these tasks (Reynolds & Schiffbauer, 2005). This meta-analytic review will define and distinguish these paradigms.

The first paradigm, delay of gratification tasks, was made famous by the “marshmallow test” conducted by researcher Walter Mischel (Mischel, Ebbesen, & Raskoff Zeiss, 1972). Participants were presented with a choice of either a smaller immediate reward (such as a marshmallow), or a larger reward (such as two marshmallows) for which they were required to wait a longer time and would need to delay or inhibit their immediate gratification (Mischel & Ebbesen, 1970; Mischel et al., 1972). Choosing the larger delayed reward is more difficult during this wait because the immediate smaller reward is available in front of the participant, which makes the immediate reward conspicuous and tempting (Metcalfe & Mischel, 1999). The participant must therefore devote serious energy and willpower to "sustain" their choice while waiting for the delayed reward (Shamosh & Gray, 2008; Metcalfe & Mischel, 1999; Reynolds & Schiffbauer, 2005).

The range of rewards for the delay of gratification tasks includes money, prizes, food, and hypothetical points (Patros et al., 2016; Bidwell, Willcutt, DeFries, & Pennington, 2007). Although delay of gratification tasks were often developed as single trial tasks, in recent years they have become more elaborate, including computerized games where the participants are given the same rewards and the same delay periods throughout the whole task (Patros et al., 2016; Paloyelis et al., 2009). For example, the *Choice Delay Task* is a delay of gratification task[2] in which participants play a computer task and on numerous trials, participants choose between a small reward presented as a green square labelled 1 point on the computer screen resulting in a 2-second reward delay, or a large reward shown as a blue square labelled 2 points with a 30-second delay (Lambek et al., 2010). The task score is either the percentage of trials for which the larger, delayed reward is selected, or the percentage of trials the smaller immediate reward is selected (Lambek et al., 2010; Sjöwall, Roth, Lindqvist, & Thorell, 2013). For other gratification paradigms, in addition to percentages of trials for choosing either the large or small reward, the amount of time a participant can wait for the delayed reward can often be used as the operational measure of delay of gratification (Patros et al., 2016; Shamosh & Gray, 2008; Mischel et al.,

[2] The Maudsley Index of Delay Aversion Task (MIDA) which is comprised of different conditions, has a condition that is the same as the Choice Delay Task known as the *No-post-reward delay* condition (Banaschewski et al., 2012; Paloyelis, Asherson, & Kuntsi, 2009). For the MIDA only the *No-post-reward delay* condition is considered a delay of gratification task (Patros et al., 2016).

1972).

The second delay paradigm is known as temporal discounting tasks.[3] Temporal discounting is the tendency to choose smaller rewards that are closer to the present time, and conversely, give less value or “discount” larger delayed rewards in the future (Shamosh & Gray, 2008; Rachlin, Raineri, & Cross, 1991). For example, a participant might be offered $2.00 today or $4.00 in a month; many people would choose the option of $2.00 today, and “discount” the larger $4.00 in a month because temporally it is too far off.

On temporal discounting tasks, experimenters manipulate and vary the amount of immediate rewards and delayed rewards between trials, as well as the duration of delays (Patros et al., 2016). For example, a temporal discounting task typically consists of over 90 trials in which participants have to choose between small amounts of hypothetical money or a larger reward of $10.00 after different delays ranging from 7, 30, 90, or 180 days (Costa Dias et al., 2013). On temporal discounting tasks, researchers are more interested when participants start to consistently switch their “commitments” from the immediate reward to the delayed reward across trials (Reynolds & Schiffbauer, 2005).

Although these two paradigms are slightly different, both have been used as measures of impulsivity (Patros et al., 2016), a key symptom domain of ADHD. Delay of gratification tasks are seen as a measure of willpower and motivation since these tasks tend to offer participants fixed intervals of delays and rewards throughout the trials, during which the participants have to actually wait (Reynolds & Schiffbauer, 2005; Patros et al., 2016). In contrast, temporal discounting tasks are more learning-based cognitive processes, which often involve choices where the amounts of rewards and delays in the future are constantly varied (Reynolds &

[3]Temporal discounting tasks have also been called “commitment choice” tasks (Shamosh & Gray, 2008; Reynolds & Schiffbauer, 2005), and “delay discounting” tasks (Wilbertz et al., 2012).

Schiffbauer, 2005; Rubia, Halari, Christakou, & Taylor, 2009; Patros et al., 2016). Furthermore, the delay periods for delay of gratification tasks usually consist of seconds, or minutes, but in temporal discounting the delays can range from seconds and minutes to much longer periods, such as days, weeks, months, and years.

Another key distinction between these tasks is that temporal discounting requires more complex calculations that take different delays and reward amounts into account to come up with a discount rate (Shamosh & Gray, 2008; Patros et al., 2016). For temporal discounting tasks, there can be multiple scores calculated from temporal discounting tasks. The area under the curve (AUC) is one such score that plots the participant's subjective value of a delayed reward against the duration of delay; a score closer to one indicates less discounting, while a score closer to zero means a person is more willing to choose the smaller immediate reward and discount the larger reward (Peper et al., 2013). Another temporal discounting score is the k-value, which is a special parameter that measures a person's sensitivity to delay (Myerson, Green, & Warusawitharana, 2001; Basile & Toplak, 2015). A k-value takes into account the indifference point, which is where subjectively for the participant, the immediate reward has equal value to the long-term reward (Reynolds et al., 2006; Richards et al., 1999). The k-value is calculated at each delay with the equation: $V = A / (1 + kD)$, where V is the indifference point at a given delay (where a person considers the delayed reward of equal subjective value to the short-term reward), while A is the amount of the delayed value and D is the delay period itself (such as a day, month, year) (Mostert et al., 2015; Mazur, 1987). Usually, all the k-values for each delay are combined to produce an average k-value, where greater k-values theoretically represent greater discounting of the long-term reward for short-term gain (Lawyer & Schoepflin, 2013).

Often, k-values are positively skewed and then log-transformed (Antonini, Becker, Tamm, & Epstein, 2015).

Differences Between TD Males and TD Females in Choosing Delayed Rewards

Currently, studies on delayed reward tasks have reported mixed findings on gender differences in the broader population. In the TD population, some research suggests that females tend to delay gratification slightly longer than males on a variety of different delay of gratification tasks (Silverman, 2003; Bembenutty, 2007; Mischel & Underwood, 1974), while other studies have not found female-male differences (Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Funder & Block, 1989). On temporal discounting tasks, some studies have suggested that females discount at a greater rate than males and therefore males have a slight advantage (Reynolds, Ortengren, Richards, & de Wit, 2006; Beck & Triplett, 2009; Weafer & de Wit, 2014), while other studies have found no gender differences on temporal discounting (Cross, Copping, & Campbell, 2011; Prencipe et al., 2011), or a female advantage (Stanovich, West, & Toplak, 2016; Dittrich & Leipold, 2014). Therefore, the true gender difference in the TD population remains unclear when viewed from the perspective of the two paradigms.

Differences Between ADHD Males and ADHD Females

Adults and children with ADHD have been reported to prefer smaller immediate rewards compared to TD individuals (Patros et al., 2016; Jackson & MacKillop, 2016), but whether the participant is a male with ADHD or a female with ADHD is rarely viewed as a potential moderator of delayed reward preferences. Yet, gender may be an important moderator because males and females appear differentially affected by ADHD. Boys with ADHD have also been shown to have higher ratings of inattention, impulsivity, and hyperactivity than girls with ADHD

(Arnett, Pennington, Willcutt, DeFries, & Olson, 2015; Newcorn et al., 2001, Gershon, 2002; Gaub & Carlson, 1997). The presence of hyperactive symptoms for males can explain why teachers notice ADHD more often in males in class settings (Derks, Hudziak, & Boomsma, 2007). Male hyperactivity is often regarded as prototypical of ADHD (Bruchmüller, Margraf, & Schneider, 2012), which may explain why males are diagnosed with ADHD at a much greater rate than females, whereas females with ADHD tend to get diagnosed with the inattentive-subtype more often than males (Weiss, Worling, & Wasddell, 2003). Some researchers describe this difference as a ratio of 2.28 males to every female, while other researchers suggest a ratio of 9 males to every female (Ramtekkar, Reiesen, Todorodoc, & Todd, 2010; Gershon, 2002).

In reality, the rate of the disorder among males and females may be closer to equal because some researchers have suggested that current diagnostic tools fail to adequately address the role of gender (Rucklidge, 2010; Bruchmüller et al., 2012). Since ADHD in females may be underdiagnosed or misdiagnosed, many females are unaware they may have ADHD and thus they often go untreated (Bruchmüller et al., 2012; Quinn, 2005; Taylor & Klenters, 2002). Furthermore, the underdiagnosis of females has implications for many studies, since most studies on ADHD tend to recruit and refer many more males than females, and thus cannot make conclusions as generalizable for females with ADHD.

Differences between ADHD females and males do not only manifest in different types of symptoms but in other cognitive and emotional domains. Girls with ADHD have higher rates of language and verbal difficulties compared to boys with ADHD (Gershon, 2002; Berry, Shaywitz, & Shaywitz, 1985). Females with ADHD appear to have greater rates of mood disorders like major depression compared to males with ADHD (Gershon, 2002; Groß-Lesch et al., 2016). Females with ADHD also have higher rates of anxiety compared to males with ADHD (Groß-

Lesch et al., 2016; Skogli, Teicher, Anderson, Hovik, & Øie, 2013). Girls with ADHD have also been found to have lower IQs than boys with ADHD (Gershon, 2002; Biederman et al., 2002; Gaub & Carlson, 1997). Conversely, boys with ADHD have higher rates of ODD and CD compared to girls and display greater motor function deficits (Biederman et al., 2002; Cole, Mostofsky, Larson, Denckla, & Mahone, 2008).

Such gender differences are also apparent in adulthood. Women with ADHD are more than twice as likely to be admitted into a psychiatric institution compared to men with ADHD (Dalsgaard, Mortensen, Frydenberg, & Thomsen, 2002). Females have also been found to have poorer coping and social skills than males with ADHD (Rucklidge & Tannock, 2001). However, males with ADHD are more likely to use illegal substances and engage in criminal activity compared to females with ADHD (Groß-Lesch et al., 2016; Rasmussen & Levander, 2009).

Thus, differences between males and females with ADHD may indicate slightly different paths of progression in ADHD. While researchers and clinicians are aware of the different diagnosis rates of ADHD in males and females, relatively less work has been done in evaluating how these differences in symptoms and cognitive domains manifest in delay tasks between males and females with ADHD, and if this gender difference is similar to TD populations.

Summary of the Current Study

Despite the many studies using delay of gratification tasks and temporal discounting tasks, only a small proportion of studies report gender differences in TD samples. There is also a need to investigate the findings between ADHD males and females on delayed reward paradigms. This study examined whether ADHD males and females perform in a similar manner to TD males and females on delay tasks, while being the first meta-analysis to examine a direct gender comparison on delay tasks for the ADHD population.

This study had a number of aims: 1.) To use meta-analytic methods to characterize gender differences on delayed reward tasks to determine the size of the gender difference in both ADHD and TD populations using both children and adult samples. This meta-analysis provided an estimate of the overall effect size for the gender differences obtained in these studies and then examined whether ADHD moderated the overall gender difference. This study also conducted separate meta-analytic comparisons between TD females and TD males, and between ADHD males and ADHD females, which allowed us to measure whether the effect sizes were in the same direction and magnitude for both TD samples and ADHD samples; 2.) To use meta-regression to examine moderators, such as delay paradigm type, reward type (hypothetical or real), and age, of these gender difference effect sizes; 3.) To conduct separate meta-analytic comparisons based on a subset of the studies that contain both ADHD and TD samples, in which we sought to replicate past findings that TD samples prefer delayed rewards more than ADHD samples by looking at a comparison of ADHD males to TD males and a comparison of ADHD females to TD females. The implications of these findings on research and clinical work relating to ADHD and TD populations are discussed.

Methods

Inclusion and exclusion criteria

A systematic literature search was conducted using PubMed, Web of Science, and PsycINFO up until July 14, 2016 as well as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher, Liberati, Tetzlaff, & Altman, 2009).

PRISMA guidelines have been used for meta-analyses that examine ADHD and TD populations on decision-making tasks (Jackson & MacKillop, 2016; Groen, Gaastra, Lewis-Evans & Tucha, 2013; Dekkers, Popma, van Rentergem, Bexkens, & Huizenga, 2016). PRISMA guidelines also require documenting each stage of the search, including initial studies found, duplicates, number of eligible studies, and number of studies included in the meta-analysis; each of these stages are documented here.

The initial inclusion criteria for this meta-analytic review were any published study or dissertation in English that reported comparisons of male and female participants meeting diagnostic criteria for ADHD or comparisons of TD males and females on delayed reward tasks. Including dissertations was a way of potentially minimizing publication bias because studies are more likely to be published if they have significant effects. Records were excluded if they were review or theoretical papers. Studies had to have a minimum of 15 participants total and at least five males and five females for each sample to be sufficiently large.[4]

For the ADHD samples, participants were required to have been diagnosed with ADHD. In addition, ADHD samples that had participants on medication were included along with non-medicated ADHD samples. However, for every participant who was medicated, it was mandatory to be off the medication 24 hours prior to testing. The average age of participants in both TD and ADHD samples was restricted to a range from 6 years to 50 years. We also chose to only use children who were school age because temporal discounting tasks tend not to use children who are in kindergarten or younger (e.g. Scheres et al., 2013).

To minimize potential methodological variability, studies were also restricted to those using either temporal discounting tasks or delay of gratification tasks (including choice delay

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[4] A meta-analysis on gender differences by Cross et al., (2011) set a minimum for each group of 10 females and 10 males, but because ADHD samples tend to have fewer females, the decision was set at a minimum of 5 instead.

tasks). Studies that examined probabilistic discounting, social discounting, academic delay of gratification, or delay tasks that involved probability of a reward instead of an actual reward were eliminated due to the variability of these tasks and their measures. Tasks that also involved losing money or points or relied on reaction time were excluded. The types of rewards that were given in these tasks were also restricted to: monetary rewards, nonedible prizes such as a toys or objects, and points from computer games.

Studies that explicitly recruited smokers, overweight participants, or consumers of alcohol were excluded because these populations have been found to differ on delayed reward tasks (Weller, Cook, Avsar, & Cox, 2008; Mitchell, 1999; Mitchell, Fields, D'esposito, & Boettiger, 2005). Similarly, studies that recruited participants based on their ethnicity or certain income levels were excluded. Samples with psychiatric disorders such as schizophrenia, bipolar disorder, autism spectrum disorder, epilepsy, borderline disorder, and intellectual disabilities were also excluded. Likewise, studies that used additional, non-standard experimental manipulations relating to the delayed task were excluded.

Literature search

Search terms were comprised of descriptors of the tasks such as temporal discounting, which were paired either with the target populations (such as ADHD) or with terms relating to gender differences. Nine total searches were conducted on each database. The specific terms entered were “delay of gratification & gender differences,” “delay aversion & gender differences,” “temporal discounting & gender differences,” “delay of gratification & ADHD,” “temporal discounting & ADHD,” “delay of gratification & sex differences,” “delay aversion & sex differences,” “temporal discounting & sex differences,” and “delay aversion & ADHD.”

A total of 1,041 records were found, of which 301 were unique records after eliminating duplicates from the three databases. The 301 abstracts were reviewed, of which 165 were deemed possibly relevant. Then full-text reviews were conducted on these 165 potential studies. Of these studies, only six articles contained enough information within the study to calculate gender difference effect sizes. Most studies tended to combine the delayed reward results of both genders together and did not indicate how male and female results differed separately. Therefore, the authors were contacted by email. A total of 85 authors were sent emails; 30 responded, but only 22 had relevant information while the rest were unable to provide the requested data or they met some exclusion criteria. Using the previously mentioned criteria, 28 studies were included in the final meta-analysis with 52 distinct effect sizes (see Figure 1). Of these 28 studies, 14 studies contained both TD samples and ADHD samples and 14 studies contained only TD samples. Of these 52 effect sizes, 33 effect sizes contained TD samples and 19 effect sizes contained ADHD samples.

For the 14 studies that contained both TD samples and ADHD samples, an additional meta-analysis was conducted on the effect sizes comparing TD males with ADHD males and comparing TD females with ADHD females on delayed reward tasks. This analysis allowed a comparison of how ADHD samples differed in the degree to which they chose delayed rewards relative to their TD peers.

Handling of multiple effect sizes

Several studies contained multiple effect sizes, including the following: there were multiple measures for delay tasks; tasks were administered to multiple groups; or there were multiple time points. For one study that had multiple time points (e.g. Achterberg, Peper, van

Duijvenvoorde, Mandl, & Crone, 2016), data from the first time point was used to reduce possible practice effects. Some studies did not provide an overall average preference for each task, but gave average participant performance after a large reward and a small reward or with a large, medium, and small reward. We selected the mean for the larger reward since one study used only the large reward blocks in subsequent analyses (e.g. Mostert et al., 2015). Some studies provided multiple ADHD groups differing by subtype (e.g. Scheres, Tontsch, & Thoeny, 2013; Solanto et al., 2007) or one group was only diagnosed with ADHD and the other group had a comorbid diagnosis of ADHD and ODD (e.g. Antonini et al., 2015). In such situations, effect sizes were calculated separately for both groups. In studies that had multiple dependent measures for a task, the measure that was thought to provide the most accurate measurement of preference was chosen (e.g. Diller, Patros, & Prentice 2011); for example, for delay discounting tasks, the AUC was deemed a more accurate assessment of preference compared to k-values, since the AUC does not need to be log-transformed to deal with skewed distributions (Myerson, Green, & Warusawitharana, 2001).

In their emailed responses, some authors clarified whether multiple published studies contained overlapping samples. If the authors indicated that their multiple papers contained overlapping samples, the sample in the later paper was excluded. If studies had multiple developmental periods, authors were emailed to request separate data on children, teenagers, and adults for the purpose of moderator analyses.

In the meta-analyses that compared ADHD females to TD females, and compared ADHD males to TD males, some studies had multiple ADHD groups. In studies that had multiple ADHD groups, such as combined-subtype group and inattentive-subtype group, the larger ADHD sample was used to compare to TD peers in order not to double-count samples.

Sample Characteristics

Individual study task and sample characteristics are available in Appendices A-B. The total number of participants was N = 4,540 (n = 2,017 females and n = 2,523 males). The number of males with ADHD was n = 733, the number of females with ADHD was n = 322, the number of TD males was n = 1,790, and the number of TD females was n =1,695.

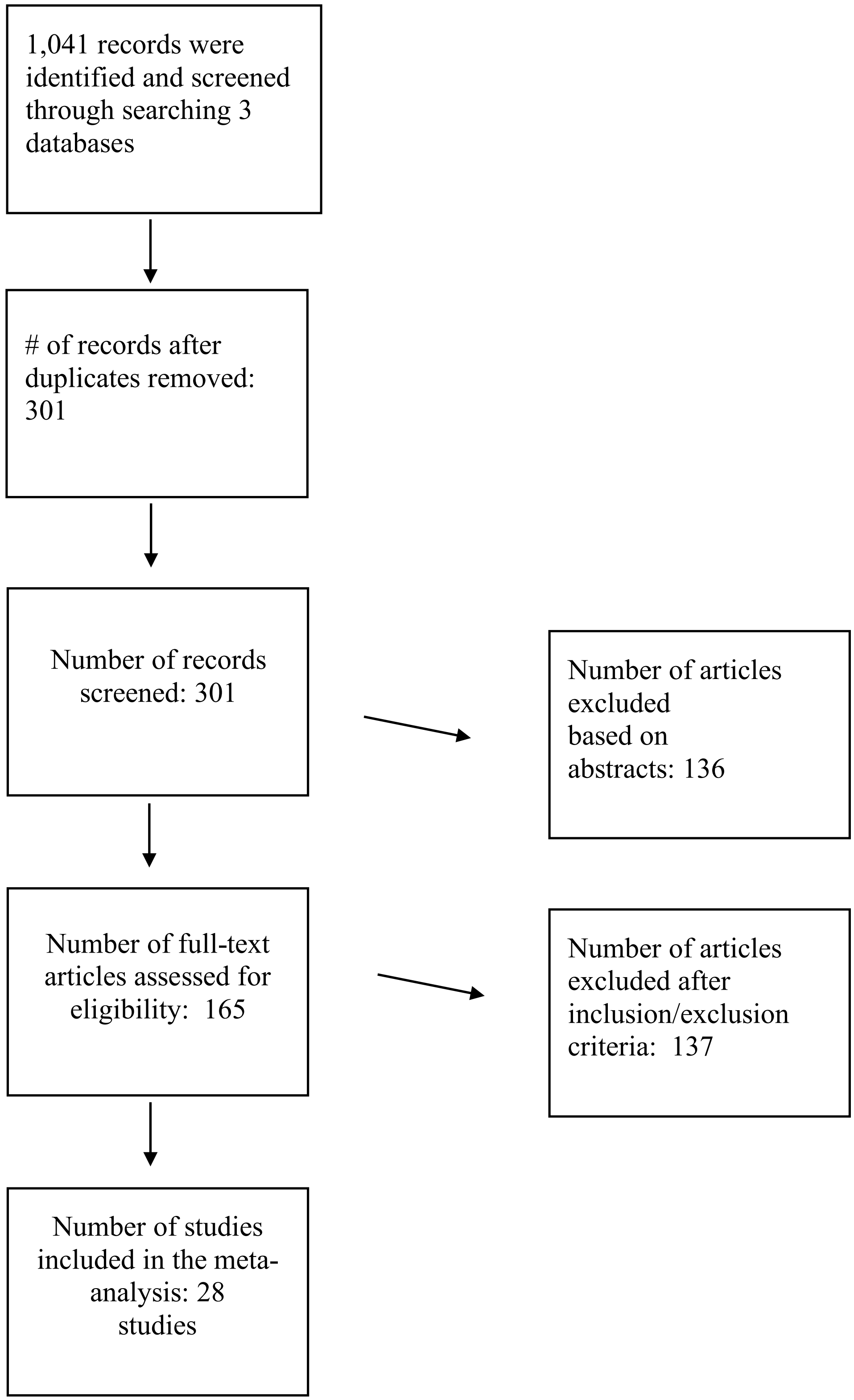

Figure 1. Preferred reporting items for systematic reviews and meta-analyses inclusion flow diagram.

Statistical-Analyses

Meta-Analyses

Hedges' *g* was the effect size statistic used in the current analyses, calculated to represent the mean difference between males and females on the delayed reward tasks outcome measure divided by the pooled standard deviation and corrected for a positive bias (Hedges & Olkin, 1985). For the first meta-analysis comparing males and females, *g* was calculated so that positive values indicated that females were better able to choose the delayed rewards while negative values indicated that males were better able to choose the delayed rewards. 95% confidence intervals (CIs) for each *g* were also calculated.

Random-effects models were used for this meta-analysis because it is assumed that the true effect can vary from study to study (i.e., studies differ in ways other than random sampling of participants) and previous meta-analyses that compared ADHD and control populations on decision-making tasks also used random-effect models (Jackson & MacKillop, 2016; Patros et al., 2016; Dekkers et al., 2016; Mowinckel, Pedersen, Eilertsen, & Biele, 2016). The meta-analyses were conducted using the metafor package (Viechtbauer, 2010) in R (R Core Team, 2013). The first meta-analysis examined the overall gender difference using both TD and ADHD samples. Next, the gender difference was examined separately for TD participants and then for participants with ADHD. Finally, the last meta-analyses examined the overall effect of TD males versus ADHD males and TD females versus ADHD females, with *g* calculated so that positive values indicated that ADHD participants were better able to choose the delayed reward compared to TD peers, while negative values indicated that TD participants were better able to choose the delayed rewards compared to ADHD peers. The effect of TD versus ADHD was also examined separately for males and females.

Forest plots were used to show the individual effect sizes and CIs for each of the meta-analyses described above. The bottom of the forest plot shows the weighted mean effect size and its CI.

Heterogeneity

Cochran's Q and I^2 were used to measure variability among effect sizes included in the meta-analyses. Cochran's Q reflects the sum of squared differences between each individual weighted effect size and the overall effect estimate (Higgins, Thompson, Deeks, & Altman, 2003). Significant Q tests indicate substantial differences in effect sizes among studies that cannot be explained by sampling error, suggesting systematic differences between studies (Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). I^2 reflects the percentage of the total variation that is explained by the variation among studies and is used along with Q partly because I^2 is not influenced by the number of studies in the meta-analysis (Higgins et al., 2003). Values of I^2 less than or equal to 25% indicate low heterogeneity, values around 50% indicate moderate heterogeneity, and values equal to or over 75% indicate high heterogeneity (Higgins et al., 2003).

Publication Bias

Publication bias (also known as the file-drawer effect) occurs when studies that have smaller samples are more likely to be published if they attain larger effect sizes that are statistically significant (Egger, Smith, Schneider, & Minder, 1997; Duval & Tweedie, 2000; Dickersin, 1990). There are many ways to measure publication bias; one method is Egger's test, which is a regression test of asymmetry where a greater y-intercept indicates that a meta-regression model might be affected by publication bias (Egger et al., 1997)

Funnel plots, in which effect sizes are plotted against their standard errors, are good visual indicators for possible publication bias, as well as heterogeneity. Possible publication bias is indicated by asymmetry of the effect sizes from either side of the "funnel." For this study, funnel plot asymmetry was investigated with the trim and fill method (Duval & Tweedie, 2000; Duval, 2005), which is a nonparametric, rank-based procedure that is used to estimate the number of studies missing from a meta-analysis due to leaving out the most extreme effect sizes that would be on one side of the funnel plot. The funnel plot is filled in with estimates of missing effects that make the new plot more symmetric (Duval & Tweedie, 2000).

Lastly, Kendall's tau is a non-parametric rank correlation statistic used to measure the correlation between effect size and the effect size's variance estimate (Jin, Zhou, & He, 2015). A large correlation indicates the set of studies might be affected by publication bias.

Meta-Regressions

Meta-regressions were used to model moderator effects because effect sizes varied in their study characteristics (such as relating to task and reward characteristics); these study characteristics were used as effect size predictors (i.e., moderators) in the regression models.

Before moderator analyses were conducted, the overall weighted mean effect sizes comparing TD and ADHD males and females were calculated along with their 95% CIs. In the meta-regressions, we included each potential moderator separately due to the relatively small number of studies.

All studies included information about the sample age, the type of task, and whether there was some real reward given for participating in the task. Therefore, the moderator variables were: 1.) DSM diagnosis of ADHD (vs. TD); 2.) Task type, either being a delay of gratification task or a temporal discounting task; 3.) Average age of the total combined male and female samples being under or over 18 years; 4.) Task reward, being real money or prize versus hypothetical.

Results

Gender Differences on Delayed Reward Tasks

The overall weighted mean effect size, combining ADHD and TD studies, was very small, $g = -0.08$, $p = .10$, 95% CI [-.17, .02]. This result indicates that, overall, choosing a delayed reward does not differ substantially between males and females (see Table 1). There was substantial heterogeneity of effects among the studies ($Q = 84.00$, $p < .05$, $I^2 = 40.82\%$; see Table 1).

Within TD participants, the weighted mean gender difference was $g = -0.01$, $p = .81$, 95% CI [-0.13, 0.10], but variation among studies was again significant (see Table 1). This result indicates that there is practically no overall difference between TD females and TD males on these delay tasks (see Figure 2), although the effects are quite variable across studies. Within ADHD participants, the weighted mean gender difference was small in the male direction, $g=-0.23$, $p < .05$, 95% CI [-0.39, -0.07]. This result indicates that, overall, there was a difference between ADHD females and ADHD males on these delay tasks (see Figure 3), and the heterogeneity across studies was not significant (see Table 1).

Table 1.
Summary of Statistics from Meta-Analyses of Males vs Females

Comparison	g	SE	95% CI	z	Q	I^2	df
Males vs Females	-0.08	0.05	(-0.17, 0.02)	-1.63	84.00*	40.82%	51
TD Males vs TD Females	-0.01	0.06	(-0.13, 0.10)	-0.24	58.15*	48.27%	32
ADHD Males vs ADHD Females	-0.23*	0.08	(-0.39, -0.07)	-2.78	18.43	15.76%	18

Note. *g* = Hedge's *g*; negative *g* indicates a male advantage in terms of choosing the delayed reward, while positive indicates a female advantage in terms of choosing the delayed reward; Q= heterogeneity test statistic; I^2 = total heterogeneity / total variability.
* $p < .05$.

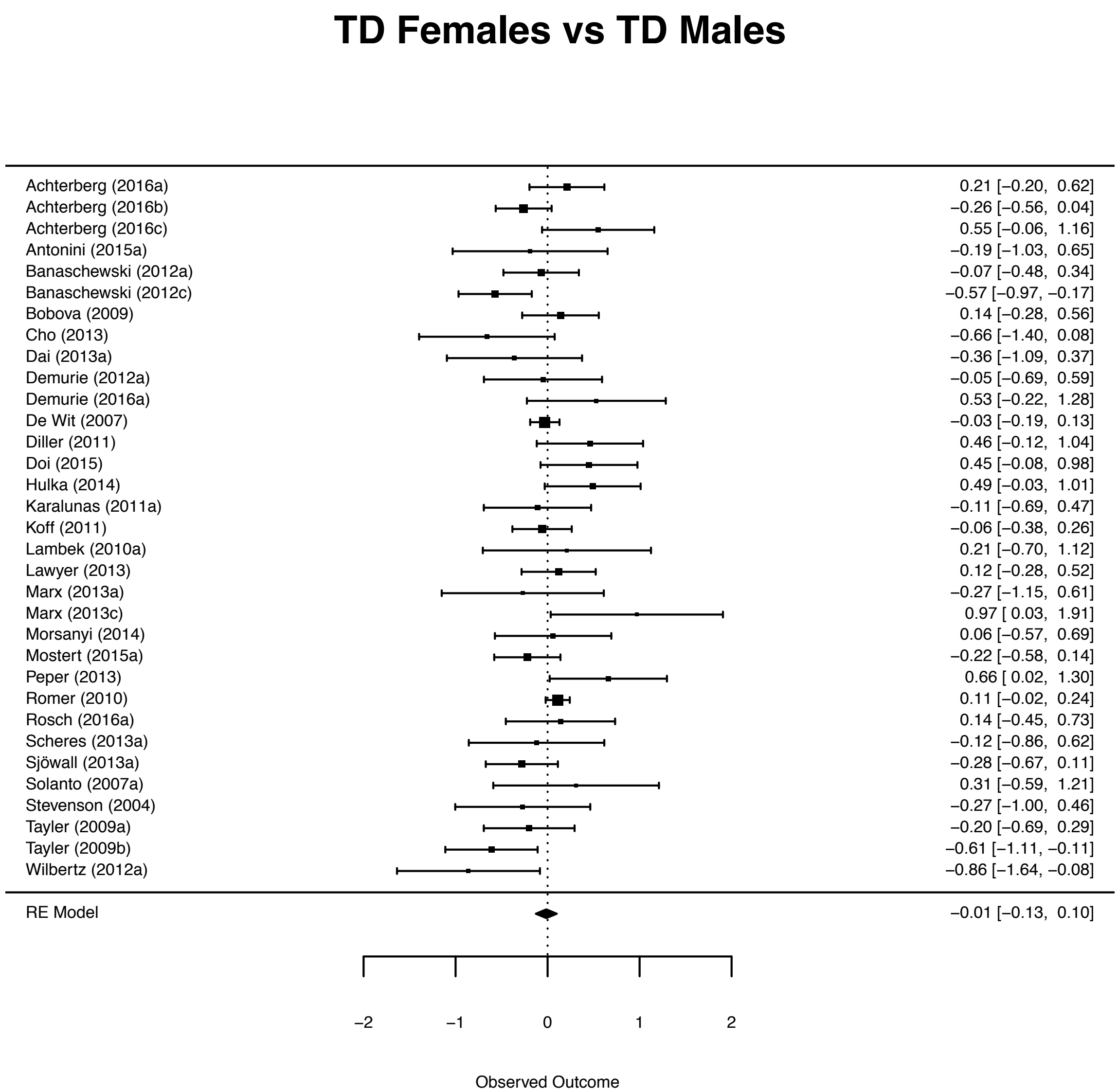

Figure 2. Forest plot providing effect sizes (standardized mean differences, *g*) and 95% confidence intervals (CI) by study for comparisons of TD males and TD females. *Note.* Effect size squares are proportional to study sample size. Effects to the right of zero and positive reflect a female advantage in terms of choosing delayed rewards compared to males, while effects to the left of zero and negative reflect a male advantage in terms of choosing delayed rewards compared to females. Study subscripts with letters refer to multiple effect sizes within the same study.

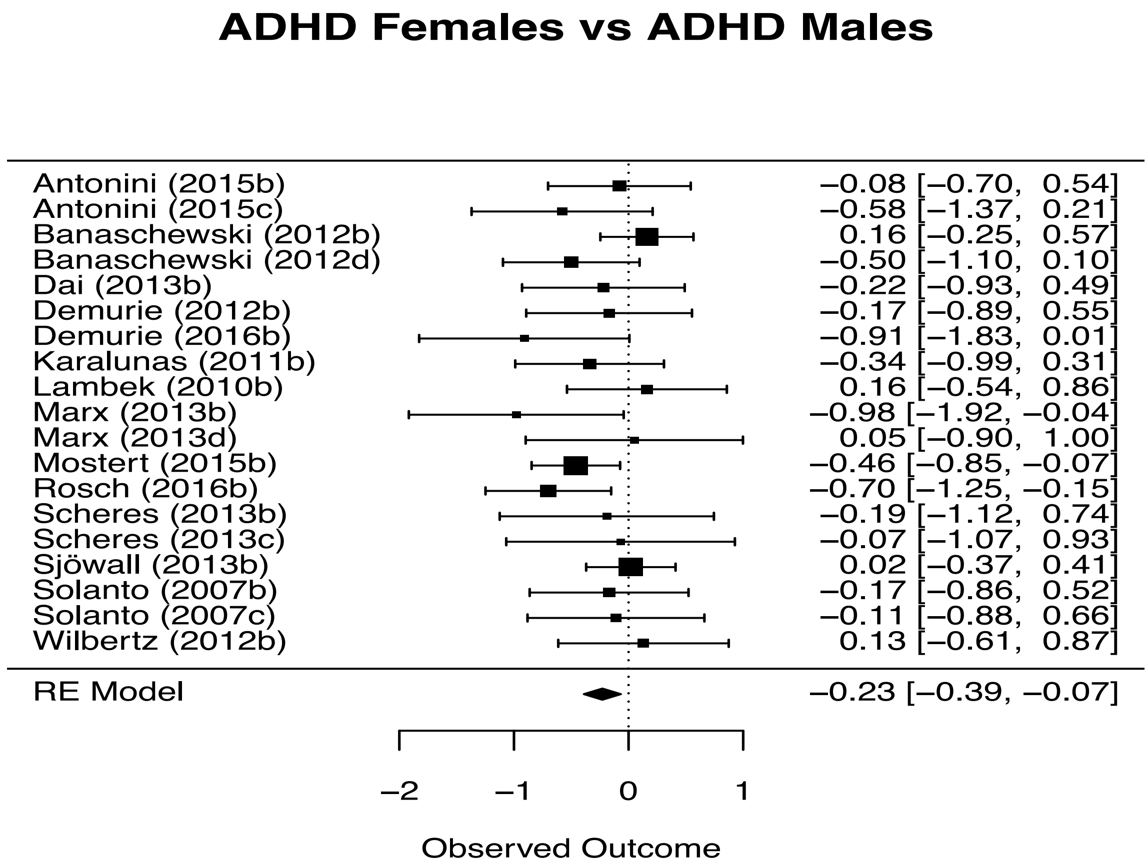

Figure 3. Forest plot providing effect sizes (standardized mean differences, *g*) and 95% confidence intervals (CI) by study for comparisons of ADHD males and ADHD females. *Note.* Effect size squares are proportional to study sample size. Effects to the right of zero and positive reflect a female advantage in terms of choosing delayed rewards compared to males, while effects to the left of zero and negative reflect a male advantage in terms of choosing delayed rewards compared to females. Study subscripts with letters refer to multiple effect sizes within the same study.

Robustness of the Overall Results

The robustness of the overall average effect was investigated in multiple ways. Egger's test (Egger et al., 1997) indicated no funnel plot asymmetry (z = -0.54, p = 0.59). Similarly, Kendall's tau also did not indicate significant publication bias, τ = -0.05, p = 0.64. Finally, the funnel plot with the trim and fill method also did not reveal publication bias (Figure 4).

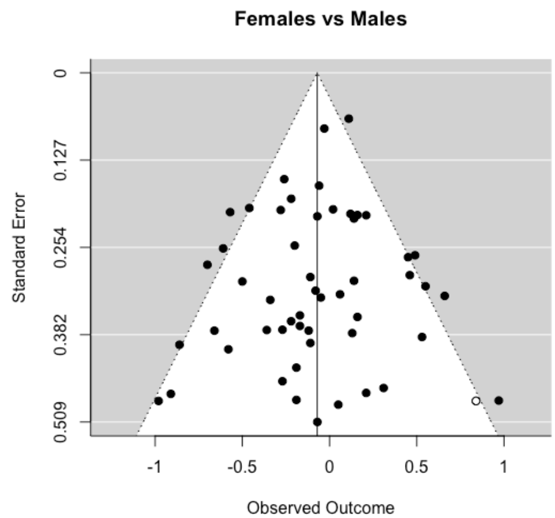

Figure 4. Funnel plot with the trim and fill method. *Note.* Points indicate female-male effect sizes from all studies. Black points are original effect sizes, white points represent filled-in effects based on the trim and fill method.

Meta-Regression Results

ADHD Diagnosis

Because we wanted to investigate if ADHD samples display gender difference on delayed reward tasks in comparison to TD samples, the gender difference effect size was regressed on ADHD diagnosis. As expected, there was a significant moderating influence of the ADHD diagnosis, $B = -0.22$, $p < .05$, 95% CI [-0.42, -0.02]. Specifically, those samples with an ADHD diagnosis had a .22 greater male advantage compared to TD samples, consistent with the result above that ADHD males have an advantage over ADHD females in delaying rewards. Thus, the magnitude of gender difference in delay of gratification tasks and temporal discounting tasks is generally greater among ADHD samples than TD samples.

Task Type

There was no moderating influence of task type on gender differences, $B = 0.08$, $p = 0.45$, 95%CI [-0.13, 0.28]. Of the 52 effect sizes, 34 contained temporal discounting measures and 18 contained delay of gratification measures.[5]

Age

Additionally, there was no moderating influence of age on gender differences, $B = 0.08$, $p = 0.39$. 95% CI [-0.11, 0.28]. Of the 52 effect sizes, 30 contained effect sizes with an average age of under 18, and 22 contained effect sizes with the average age over 18.

Type of Reward

Whether there was a real reward or hypothetical reward did not significantly predict female-male differences, $B = -0.05$, $p = 0.64$, 95% CI [-0.26, 0.16]. Of the 52 effect sizes, 34 contained hypothetical rewards while 18 contained real rewards.

ADHD vs TD Comparison Results

A subset of the studies that contained both ADHD and TD samples was used to compare the preferences between ADHD males and TD males and between ADHD females and TD females. Comparing ADHD to TD samples yielded a significant mean effect size of $g = -0.39$, $p < .05$, 95% CI [-.50, -.27]. This result indicates that, overall, TD samples perform better on delayed decision-making tasks than ADHD samples. However, variation across studies was significant, $Q = 49.53$, $p < .05$, $I^2 = 23.83\%$; (see Table 2). Among male-only samples, the average effect size was $g = -0.35$, $p < .05$, 95% CI [-.49, -.21] in the TD direction (see Table 2).

[5] Out of the 18 delay of gratification effect sizes, 13 effect sizes were from the CDT, or a condition on the MIDA.

Among female-only samples, the average effect size was g = -0.51, $p < .05$, 95% CI [-.77, -.26] in the TD direction (see Table 2). Yet, performance between genders did not significantly differ, B =-0.12, p = .36, 95% CI [-.37, .14].

Table 2.
Summary of Statistics from Meta-Analyses TD vs ADHD Samples

Comparison	g	SE	95% CI	z	Q	I^2	df
ADHD vs TD Peers	-0.39*	0.06	(-0.50, -0.27)	-6.43	49.53*	23.83%	31
ADHD Males vs TD Males	-0.35*	0.07	(-0.49, -0.21)	-4.87	17.87	19.69 %	15
ADHD Females vs TD Females	-0.51*	0.13	(-0.77, -0.26)	-3.93	31.29*	51.64%	15

Negative Hedge's g indicates TD advantage in terms of choosing a delayed reward, while positive indicates ADHD advantage in terms of choosing the delayed reward; Q=Test for heterogeneity; I^2 = total heterogeneity / total variability.
* $p < .05$.

Robustness of the Overall Results

The robustness of the overall results was investigated in several ways. Egger's test was not significant (z = -1.90, p = .06), while Kendall's τ = -0.25, p = .05, suggested possible publication bias. Similarly, the trim and fill method did reveal possible funnel plot asymmetry (see Figure 5).

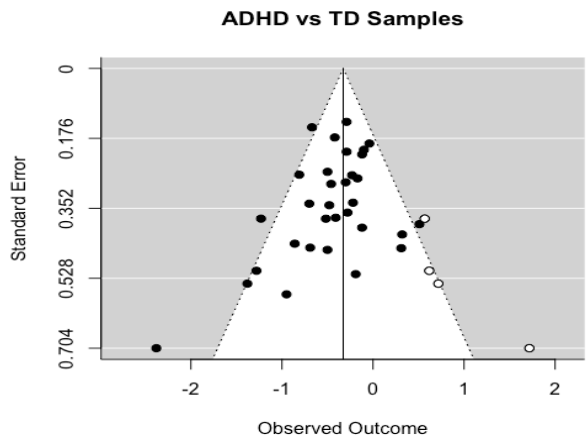

Figure 5. Funnel plot with the trim and fill method. *Note*. Points indicate ADHD-TD effect sizes from all studies. Black points are original effect sizes, white points represent filled-in effects based on the trim and fill method.

Discussion

The present meta-analyses were conducted to examine gender differences on delayed reward tasks in both TD and ADHD populations using 28 studies. Our findings revealed no differences for both the overall comparison between males and females (using both ADHD and TD samples together), as well as the separate comparison between TD males and TD females. However, there was a small significant effect comparing ADHD males to ADHD females on delay tasks, demonstrating that females with ADHD are more likely to prefer immediate smaller rewards than males with ADHD. Moderators of age, task type, and reward type, were not significant. Our findings also revealed that TD males outperformed ADHD males and TD females outperformed ADHD females. These findings indicate that across delay of gratification and temporal discounting paradigms, ADHD samples prefer immediate rewards more than TD samples.

Explaining ADHD Male to ADHD Female Differences

The novel finding of this study was that there is a significant gender difference in the ADHD samples, but not for the TD samples. This finding indicates that ADHD females prefer immediate rewards more than ADHD males on both temporal discounting tasks, and delay of gratification tasks. The findings were surprising given that males often display greater impulsivity and hyperactivity than females (Gershon, 2002).

Perhaps these findings that ADHD females prefer immediate rewards relate to the literature on how females with ADHD in many domains have worse outcomes than males with ADHD in areas such as coping abilities, internalizing distress, difficulties with organization, speech and language, and social skills issues (Gershon, 2002; Berry et al., 1985). Females with ADHD often have comorbid disorders such as anxiety, depression, and eating disorders, at a greater rate than ADHD males (Groß-Lesch et al., 2016; Skogli et al., 2013; Quinn, 2005). The presence of comorbid conditions may have an impact on ADHD females' delayed reward preferences. Studies have found that those with depression discount more than controls (Imhoff, Harris, Weiser, & Reynolds, 2014; Pulcu et al., 2014).

Yet the findings could be explained if there were actually differences in ADHD symptoms between females and males. Since ADHD females are more often underdiagnosed, or diagnosed when they only have severe impairments (Bruchmüller et al., 2012; Hinshaw, 2002), this can make recruiting ADHD females for studies much more difficult. If ADHD females in our meta-analysis had more severe symptoms, this may have led ADHD females to choose the immediate reward more frequently compared to ADHD males.

Another possible explanation is that the findings relate to differences in intelligence between ADHD males and females. Higher intelligence in TD samples is associated with a preference of delayed rewards on both delay of gratification and temporal discounting tasks (Shamosh & Gray, 2008). Girls with ADHD have been found to have lower intelligence than boys with ADHD (Gershon, 2002; Biederman et al., 2002; Gaub & Carlson, 1997). In the current study, if there were IQ differences, this might explain ADHD females' preference for immediate rewards on delayed reward paradigms.

Our findings are slightly different than the recent meta-analyses by Patros et al. (2016) that looked at gender differences between TD and ADHD samples on delay of gratification tasks and temporal discounting tasks. They found that for male-only samples, the difference between the ADHD and TD groups was larger than the comparison of ADHD and TD samples that included both males and females. But there were key differences between our meta-analyses and the Patros et al. meta-analytic review. First, Patros et al. did not directly compare ADHD male scores to ADHD female scores, or TD male scores to TD female scores. Second, they included studies of child samples (including kindergarten), and they only looked at children and adolescents with ADHD, while our meta-analyses included studies that looked at a wider range of development from school age children to adults**.** Third, studies that included only male samples in their meta-analysis were omitted from our meta-analyses because we wanted a direct comparison between males and females. Because our study did a direct comparison between ADHD males and females and between TD males and females, our results offer a more direct comparison of gender differences.

Explaining TD Male and TD Female Differences

Another important finding was that there was a near-zero difference between TD males and females. On delay of gratification tasks, our findings seem contrary to the findings of the

Silverman (2003) meta-analysis that found that on delay of gratification tasks, females performed slightly better than males. A few factors can explain the different results. First, Silverman looked at studies that used food as a reward, such as candy, marshmallows, and candy bars (e.g. Moore, Clyburn, & Underwood, 1976; Ritchie & Toner, 1984), whereas the studies in our meta-analyses involved monetary rewards, points, and non-edible prizes like pens (e.g. Stevenson & Cate, 2004). Second, in Silverman's meta-analysis there were older studies that often were slightly different in design, other studies comprised of a smaller number of trials, as well as some that did not involve computers (e.g. Mischel & Underwood, 1974), in contrast to modern delay of gratification tasks, which are similar to playing a computer game with more trials (e.g. Solanto et al., 2007; Banaschewski et al., 2012). Lastly, it is also possible that gender differences have decreased over time. Other cognitive gender differences have decreased over time, such as in memory, numeracy, and risk taking (Weber, Skirbekk, Freund, & Herlitz, 2014; Byrnes et al., 1999). Whereas every study included in our meta-analyses was published in the 21st century, many of the studies in Silverman's meta-analyses are over 40 years old.

In terms of the temporal discounting tasks, while there were no significant gender differences for TD samples, the results were consistent with the only other meta-analysis we could find on the subject, conducted by Cross et al. (2011), which also found a non-significant gender difference. Although it is not clear why there was a complete lack of gender differences for TD samples included in our study, there does tend to be greater variability among males in terms of cognitive ability (Strand, Deary, & Smith, 2006).

Moderators and Heterogeneity

The moderator of delay paradigm was not significant in our study. Our results are similar to those of Shamosh and Gray (2008), who found no differences between delay of gratification and temporal discounting studies in a meta-analysis they conducted on TD samples, as well as the Patros et al. (2016) meta-analytic comparison of TD and ADHD samples, which found that their effect sizes were similar on both delay of gratification and temporal discounting tasks.

One of the important findings in the current study was the lack of developmental differences in TD and ADHD samples. It is surprising that age was not a significant moderator, given that in certain cognitive domains, there are gender differences in adults and adolescents but not children (Byrnes, 2005) and that some differences between males and females with ADHD change depending on developmental stage (Rucklidge, 2008).

Perhaps because we were only able to test a binary age effect as average age over versus under 18, our analysis may not have caught any difference from childhood to adolescent years or from young adulthood to middle adulthood. Yet, our results are consistent with a meta-analysis by Jackson and MacKillop (2016), which looked at the moderator of age being over versus under 18 and found no significant age effects in the comparison of ADHD and TD groups that had both males and females.

Similarly, real or hypothetical reward type was not a significant moderator. This result was also consistent with other studies (Jackson & MacKillop, 2016; Johnson & Bickel, 2002).

Heterogeneity between studies was expected. Outcome measures varied greatly depending on the study, whether it was the number of trials, delay amount, or immediate amount, which may explain heterogeneity between studies. Study delays varied considerably, ranging from seconds and minutes, to days, months, and years. Yet, we believe that the overall conclusions made in our study are credible because other meta-analyses on delay paradigms also included tasks with various delays, trials, and rewards (Patros et al., 2016; Jackson & MacKillop, 2016; Shamosh & Gray, 2008).

ADHD vs TD Comparison

For the comparison of ADHD males to TD males and ADHD females to TD females, our findings replicated previous findings in which TD samples outperform ADHD (Jackson & MacKillop, 2016; Rosch & Mostofsky, 2016). We were able to replicate the finding of Patros et al. (2016) where TD samples outperform ADHD samples using child and teenage samples (g=.47). Our findings in which TD males outperformed ADHD males, and TD females outperformed ADHD females, are not surprising because by definition, impulsivity and inattention are core symptoms of ADHD and so those with ADHD are expected to perform more poorly (APA, 2013). Although a meta-analysis by Mowinckel et al. (2015) found a non-significant difference between ADHD adults and TD adults on temporal discounting tasks, they only used six effect sizes including only adults and it is unclear whether they classified delay of gratification tasks as temporal discounting tasks. But our results are also consistent with the ADHD to TD comparison of Jackson and MacKillop (2016) that used only monetary delay discounting tasks. This study used 25 effect sizes and found a small but significant difference between TD and ADHD samples.

Limitations and Future Directions

Our study had some limitations. One limitation was that many of the studies found in the literature search did not report male and female means separately on delay tasks so there was limited information within the studies. Even if the number of males and females were reported, most of the data were not in the actual articles and needed to be requested through email, and several authors did not respond. In addition, many studies did not provide the number of males and females that had comorbid disorders, as well as differences between females and males in terms of symptoms such as impulsivity and hyperactivity.

Future research should examine both comorbidity and symptom severity as potential moderators, over and above ADHD diagnosis, of gender differences on delayed reward tasks. Further research should also examine how ADHD female preferences on these delay tasks are related to other important ADHD gender differences in terms of speech and language difficulty, and internalizing difficulties such as anxiety and depression (Groß-Lesch et al., 2016; Gerson, 2002). Other possible variables relating to the samples, such as age as a continuous moderator, medication status, as well as intelligence and other measures of executive functioning such as working memory should also be examined. Lastly, future projects should also look at variables such as the number of trials, payoff amounts, and delay periods on both temporal discounting tasks and delay of gratification tasks.

Implications

These findings have a number of potentially important implications. To start, a clear implication is that there is a small gender difference in ADHD groups that is not found in TD groups. The finding that females with ADHD prefer immediate rewards more than males with ADHD may have clinical significance, as ADHD females may be at risk for making poorer life choices compared to ADHD males, since delayed reward tasks are significantly correlated with success in many life domains (Daugherty & Brase, 2010; Petry, 2003; Mischel et al., 1989;

Shoda et al., 1990).

The gender differences found in our study between ADHD males and females, if replicated, may highlight a further need to differentiate how we diagnose and assess ADHD females and ADHD males in the future. Boys in Canada are 3 times as likely to get diagnosed with ADHD compared to girls despite the fact that in many domains girls can have worse outcomes (Vasiliadis et al., 2017; Gershon, 2002; Rucklidge & Tannock, 2001). These differences in symptoms and diagnosis also can lead to differences in how ADHD males and female receive treatment. For example, males with ADHD are medicated at a much higher rate than females (Vasiliadis et al., 2017). Thus, females who are at risk for ADHD may in the future benefit from assessments that are more tailored to the symptoms and issues associated with ADHD females, such as preferences for immediate gratification and discounting future rewards.

Similarly, this study has implications for the treatment of both males and females with ADHD who show preference for short-term rewards, since interventions for increasing tolerance for delays have been suggested for those with ADHD (Sonuga-Barke, 2004). Studies in which children with ADHD were given meta-cognitive strategies to create plans for delaying reward, as well as self-control training, found that children with ADHD who used these treatments increased their preferences for delayed rewards (Gawrilow, Gollwitzer, & Oettingen, 2011; Neef, Bicard, & Endo, 2001). Likewise, researchers offered the meta-cognitive strategy known as *contrasting* (where someone imagines a positive future and relates it to their present goal, as well as possible obstacles to that goal), in addition to creating *if-then* plans to those at risk of ADHD (Gawrilow, Morgenroth, Schultz, Oettingen, & Gollwitzer, 2013). The study found improvements in school performance that related to setting goals and planning for future rewards (Gawrilow et al., 2013). However, it is not understood whether males and females with ADHD would both benefit to the same degree from different meta-cognitive strategies that can change a person's preference for delayed rewards. Thus, further research that looks at the implementation of possible treatments should also examine the preferences of ADHD females and males separately if our findings of quantitative differences can be replicated.

Finally, understanding why those with ADHD prefer immediate rewards on temporal discounting and delay of gratification paradigms may shed light on how they make rational decisions, especially if we view the brain as having two sets of systems of processing. Type 1 processing is the quick, emotional, multifarious set of systems that share the defining feature of autonomous processes, while Type 2 processing is a slow, analytic set of systems that share the defining feature of conscious processing (Stanovich, 2012; Stanovich & Toplak, 2012; Evans & Stanovich, 2013). Because those with ADHD tend to have both executive functioning deficits relating to inhibition and an increased intolerance for delays compared to TD populations (Sonuga-Barke, 2004), those with ADHD may be more likely to rely on Type 1 processing and choose immediate rewards. Future studies should explore whether ADHD gender differences in delayed reward paradigms are correlated with differences in Type 1 and Type 2 processing.

Conclusion

In conclusion, we conducted the first known meta-analysis to directly compare hundreds of ADHD males and females, as well as thousands of TD males and females, using school age children, teenagers, and adults on delay of gratification and temporal discounting tasks. Our findings indicate a dissimilar pattern of female-male differences in those with ADHD compared to those without ADHD. The results obtained from our study suggest that differences between ADHD females and ADHD males may not only be found in certain symptoms, but in other cognitive, emotional, and psychiatric domains, as well as on decision-making tasks.

Our findings also add to previous meta-analytic findings that ADHD samples prefer immediate rewards more than TD samples. Lastly, considering the substantial number of ADHD studies that have been published on delayed reward paradigms, few examined gender differences, which calls attention to the need for further investigation of possible gender differences on delayed reward tasks.

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Appendix A. Task Characteristics

Study	Temporal Discounting or Delay of Gratification Paradigm	Task Description	Outcome measure	Reward Type
Achter-berg et al. (2016)[6]	Temporal discounting	A computerized version of a temporal discounting task based on the task in Richards et al. (1999). The task had 4 hypothetical delays: 2, 30, 180, or 365 days, and $10 was the amount used as a delayed reward. If a participant chose the immediate reward, the amount of immediate reward was decreased on the next trial, whereas if the delayed reward was chosen, the amount of immediate reward was increased on the next trial.	AUC discount rate	Hypothe-tical Money
Antonini, Becker, Tamm, & Epstein (2015)	Temporal discounting	The temporal discounting task was a computerized task that was approximately 10 minutes in length. The immediate reward varied from $0 to $10.00 in $0.50 increments, while the delayed reward was always $10. There were four hypothetical delays: 7, 30, 90, or 180 days. The task involved 88 trials.	AUC discount rate	Hypothe-tical money
Bana-schewski et al. (2012)	Delay of gratification	The Maudsley Index of Childhood Delay Aversion (MIDA) was used in this study. In this task the participant chose between getting 1 point with a 2-second delay or 2 points with a 30-second delay. Each participant was given 2 conditions: *No-post-reward condition*: Choosing the smaller reward led to the immediate next trial, reducing the overall length of the task delay; *Post-reward delay condition:* Choosing the smaller reward led to a 30-second delay.	Time preference for immediate reward [7]	Hypothe-tical points
Bobova, Finn, Rickert, & Lucas (2009)	Temporal discounting	The temporal discounting task consisted of 22 choices. The delayed amount was $50 and the delay periods were: 1 week, 2 weeks, 1 month, 3 months, 6 months, 1 year. On some trials, the immediate reward value began with $0.05, followed by $1.25 and was then increased from $2.50 to $50 in 20 increments of $2.50. On other trials, the immediate reward	K-value discount rate[8]	Two conditions 1. Chance payoff 2. Real

[6] This study had two time points. Only the first time point was used.
[7] Only the no-post-reward delay condition of the MIDA was used as the outcome measure.
[8] Log10 transformed k values were used.

		was reduced from $50 to $2.50 in 20 reductions of $2.50. Participants made choices on both increasing and decreasing immediate reward trials. At each delay, the increasing and decreasing of reward trials were administered in order no matter the participant's choice.		money
Cho et al. (2013)	Temporal discounting	A computerized temporal discounting task based on the Kirby, Petry, & Bickel (1999) delay task, which consisted of 27 trials with two options that did not change based on the participant's response. Delays ranged from 7 days to 186 days. The immediate reward ranged from $11 to $80 while the large reward ranged from $25 and $85.	K-value discount rate[9]	Hypothe-tical money
Dai et al. (2013)	Temporal discounting	Participants completed a computer-based delay task. The immediate delay had two blocks of trials that started with either a $50 or $5,000 amount. The delays were 1 or 6 months, 1 or 3 years, or 5 or 10 years. The computer program would adjust the amounts in an attempt to get to the indifference point where the immediate reward would become of equal value to the delayed reward.	AUC discount rate	Hypothe-tical money
Demurie, Roeyers, Baeyens, & Sonuga-Barke (2012)	Temporal discounting	The temporal discounting task consisted of 100 trials, and the choice between small rewards available immediately of €0, €5, €10, €20, and €30, or a large fixed delayed reward of €30. The delay periods were: tomorrow, in two days, 1 week, and 2 weeks. The amounts were shown on the computer screen as euro notes. Each small immediate reward was paired with one of the four delay times of the large reward. All combinations of immediate reward and delay period were presented to participants in a pseudo-randomized order.	AUC discount rate	Hypothe-tical money
Demurie, Roeyers, Wierse-ma & Sonuga-Barke (2016)	Temporal discounting	The temporal discounting task consisted of 100 trials, and the choice between small rewards delivered immediately ranging from, €0, €5, €10, €20, and €30 or a large constant reward of €30. The delay periods were: now, tomorrow, two days, 1 week, and 2 weeks. Reward amounts were shown on the computer screen as euro notes. Each small immediate reward was paired with one of the four delay times of the large reward. All combinations of immediate reward and delay period were presented to participants in a pseudo-randomized order.	AUC discount rate	Hypothe-tical money

[9] Natural Logarithms of k were used.

Diller, Patros, & Prentice (2011)	Temporal discounting	A computerized delay task was used. The delayed amount was $1,000 delivered at one of seven delays ranging from one week to 25 years. The immediate reward was one of 27 amounts ranging from $1 to $1,000, which were presented first in descending order and then in ascending order for the 7 delay periods.	AUC discount rate[10]	Hypothe-tical money
Doi, Nishitani, & Shinohara (2015)	Temporal discounting	A computerized delay task was used. The amount of delayed reward was unchanged throughout a block of either 1,000,000 yen or 100,000 yen. Seven levels of delays were: 1, 4, 12, 36, 96, 240, and 480 days; each delay was used twice, producing a total of 70 trials for both the delayed reward blocks. If the participant chose the delayed reward over the immediate reward, then the amount of the immediate reward was increased on the next trial; but if the participant preferred the immediate reward, the amount of the immediate reward was decreased on the next trial. This ascending and/or descending was repeated until the participant had made their fifth choice.	K-value discount rate[11]	Hypothe-tical money
de Wit et al. (2007)	Temporal discounting	This task involved the same delay procedure that was used in Mitchell, 1999. The immediate rewards ranged from $0.10 to $105 for the same day, or a delayed reward of $100 after a delay of 0, 7, 30, 90, 180, 365 days or 5 years. All trials with different immediate rewards and delay periods were presented in a randomized order.	K-value discount rate[12]	Hypothe-tical money
Hulka et al. (2014)	Temporal discounting	This was the same task that was used in Kirby et al. (1999). The task was composed of 27 trials based on two options that did not change based on the participant's response. Delays ranged from 7 days to 186 days. The immediate reward ranged from $11 to $80 while the large delayed reward ranged from $25 to $85.	K-value discount rate	Hypothe-tical money
Karalunas & Huang-Pollock (2011)	Delay of gratification	In this computerized task, called the Choice Delay Task (CDT), and based on Sonuga-Barke et al. (1992), children chose between two rewards each requiring a different waiting period. They would get a 1-point reward after 2 seconds, or a 2-point reward after 30 seconds. A new trial would start immediately after the reward was received from the	Time preference for the delayed reward	Points could be exchanged for a real prize

[10] Multiple discount rates were presented in the study but AUC was chosen as the discount rate since this was used in all other analyses in the paper.
[11] Logarithms of k were used only for the larger reward blocks.
[12] Natural Logarithms of k were used.

		previous trial. Children had 20 trials, as well 5 practice trials.		
Koff & Lucas (2011)	Temporal discounting	This task involved the Monetary Choice Questionnaire (MCQ), described by Kirby and Maraković (1996), where participants had 21 trials with the delay periods ranging from 10 days to 75 days. Each trial presented a choice between a smaller immediate reward and a larger delayed reward. Both the immediate reward and delayed reward amounts varied, while the different reward amounts and delay periods were presented in random order.	K-value discount rate[13]	Chance payoff
Lambek et al. (2010)	Delay of gratification	This computerized task, called Choice Delay Task (CDT), was based on Sonuga-Barke et al. (1992). Participants chose between a green square which was equivalent to 1 point with a 2-second delay, or a blue square equivalent to 2 points after 30 seconds. This task consisted of 20 trials.	Time preference for delayed reward	Points could be exchanged for real money
Lawyer & Schoep-flin (2013)	Temporal discounting	A computerized task based on Richards et al. (1999). In this task, participants chose between an immediate smaller amount of money that was adjusted or a delayed for an amount of $10. There were five delays: 1 day, 1 week, 1 month, 6 months, 1 year. If the delayed amount was chosen, then on the next trial the immediate amount would be decreased randomly from the pool of possible amounts of $0.50. If the immediate reward was chosen, then for the next trial the immediate amount would be increased randomly from the pool of possible amounts of $0.50.	AUC discount rate	Hypothe-tical money
Marx et al. (2013)	Delay of gratification	A computerized task based on Müller, Sonuga-Barke, Brandeis, & Steinhausen (2006), in which a donkey deposited gold into a basket. Participants were asked to collect as much gold as they could; the gold being delivered decreased over the trial and stopped after 60 seconds. Participants decided when to complete the trial and move on to the next trial. The whole task contained 22 trials, and after each trial, participants were informed of the number of trials left.	Mean trial duration	Two conditions 1. Real money offered 2. No money offered

[13] Logarithms of k were used.

Morsanyi & Fogarasi (2014)	Temporal discounting	A computerized task based on Kirby & Maraković (1996), the task consisted of 18 trials between a smaller amount of money that would be available tomorrow, and a larger amount that would be available later ranging from 10 to 75 days. The value of the immediate reward ranged from $1.50 to $7.00, and the value of the delayed reward ranged from $3.00 to $8.00.	Time preference for delayed rewards[14]	Chance payoff
Mostert et al. (2015)	Temporal discounting	A computerized task based on Dom, D'haene, Hulstijn, & Sabbe (2006). Depending on the choices selected, the amount of immediate reward was adjusted across trials. For the task, five different delays were used within the range of 2, 30, 180, 365 to 730 days. For delay amounts, participants could choose between varying amounts of money between €10, €30 and €100, which became available after a delay. The number of trials was not mentioned but the Dom et al. (2006) paper consisted of over 100 questions.	K-value discount rate[15]	Hypothe-tical money
Peper et al. (2013)	Temporal discounting	A computerized task based on Richards et al. (1999). Participants had to make a choice between a small, immediately available amount of money and a delayed amount of €10 available after 2 days, 30 days, 180 days, or 365 days. When the participant chose the immediate reward, this amount was decreased on the next trial. But if the delayed money was preferred, the immediate reward was increased on the next trial.	AUC discount rate	Hypothe-tical money
Romer, Duck-worth, Sznitman, & Park (2010)	Temporal discounting	This computerized delay task was a modification of Green, Fry, & Myerson (1994). Participants were first asked if they would prefer $500 immediately or $1,000 in six months. Then participants were asked to identify an amount of money if received now (ranging from $100 to $900), which would be equal to receiving $1,000 six months later. Immediate reward amounts were adjusted based on the participant's response. Those who accepted the $500 were asked if they would accept an amount lower than $500 in $100 amounts, while those who did not accept $500 were asked if they would accept an amount greater than $500 in $100 amounts.	The final dollar offer they would accept today in lieu of $1,000 in six months.	Hypothe-tical money

[14] Logarithms of k were only used for the larger reward blocks.
[15] Logarithms of k were only used for the larger reward blocks.

Rosch & Mostof-sky (2016)	Temporal discounting[16]	During this task, participants could make nine trials after deciding whether to play their choice of a game immediately for a period of 15, 30, or 45 seconds, or instead wait 25, 50, or 100 seconds to play the game for a fixed longer amount of time (60 seconds). Participants had several game options such as playing a video game, Legos or coloring. The game of choice was placed in a clear box directly in front of participants when they made their decisions and if they decided to wait for the larger reward. This task in total consisted of 2 practice trials, and nine real trials. The immediate rewards were given in ascending order for each delay, while the delays were counterbalanced between participants.	AUC discount rate	Non-monetary reward
Scheres, Tontsch, & Thoeny (2013)	Temporal discounting	Three computerized temporal discounting tasks were used. Task 1 consisted of 80 trials; the small immediate reward was 2, 4, 6, or 8 cents, and the delayed reward was 10 cents with a delay of 5, 10, 20, 30, or 60 seconds. In Task 2, participants made 40 trials; the immediate reward was 2, 4, 6, or 8 cents, and the delayed reward was 10 cents with the same delay periods of Task One. Task 3 consisted of 80 trials; the immediate reward was 1, 2, 3, or 4 cents, and the delayed reward was 5 cents with the same delay periods of the other tasks. Trials were administered in the same pseudo-random order for all participants.	AUC discount rate	Real money
Sjöwall, Roth, Lindqvist, & Thorell (2013)	Delay of gratification	Participants did the Choice Delay Task based on Sonuga-Barke, et al. (1992). In this task participants chose between one option that offered 1 point after a 2-second delay, or a delayed option of 2 points after a 30-second delay.	Time preference for immediate rewards	Hypothe-tical points
Solanto et al. (2007)	Delay of gratification	Same task as in Solanto et al. (2001), which was the Choice Delay Task involving a computer game that took approximately 30 minutes to complete. Participants had to choose between collecting points from a green square representing 1 point with a 2-second delay, or a blue square representing 2 points after a 30-second delay.	Time preference for delayed rewards	Real money[17]

[16] In this study children also engaged in another temporal discounting task that involved longer delays, and the child only had the option of winning some of the rewards that were semi randomly selected. In order not to double count studies, we opted to only use the task with shorter delays (described above) where the children would actually be rewarded with whatever activity and choice they selected, since we thought this would be a better indicator of the children's preferences.

[17] The study did not indicate reward type. But in an earlier study by Solanto et al. (2001), a real reward was given for the task.

Stevenson & Cate (2004)	Delay of gratification	A computer game where the participant had to destroy an enemy spacecraft, similar to Kuntsi, Oosterlaan, & Stevenson (2001). For each of the 20 trials, the participant had to choose between a small immediate reward, which was equal to one point and a delayed reward equal to three points.	Researchers' ratings of the participant's behaviour as they were waiting for the delayed reward	Real prize
Tayler, Arantes, & Grace (2009)	Temporal discounting	In experiment 1, participants did a temporal discounting task similar to the task in Chapman (1996), which consisted of 16 trials. Participants were asked the amount of a delayed reward that would be equal to four immediate rewards of $500, $1,000, $2,000, and $4,000. There were four delays: 1, 3, 6, and 12 years. In experiment 2, participants did a temporal discounting task, which consisted of 16 trials. Participants were asked the amount of a delayed reward that would be equal to four immediate rewards of: $500, $1,000, $2,000, and $4,000. There were four delays: 3 months, 6 months, 1 year, and 2 years.	Annual discount rate	Hypothe-tical money
Wilbertz et al. (2012)	Temporal discounting	Computerized hypothetical temporal discounting task based on the experiment of Richards et al. (1999) that consisted of 42 trials. Participants chose between €200 that would be delayed or an immediate reward that was adjusted depending on the participant's response in order to obtain the subjective indifference point. For every trial, the delay time was changed from 1, 3, 9, 24, 60, 120, 240 months and the immediate amount option started at €100.	K-value discount rate[18]	Hypothe-tical money

[18] Natural Logarithms of k were used.

Appendix B. Sample Characteristics Comparing TD or ADHD Males vs Females on Delayed Reward Tasks

Study	Sample Type	Total Combined Samples	Number of Females	Number of Males	Percentage of Females	Developmental Period
Achterberg et al. (2016a)	TD	94	51	43	54%	Childhood
Achterberg et al. (2016b)	TD	168	82	86	49%	Adolescence
Achterberg et al. (2016c)	TD	43	22	21	51%	Adulthood
Antonini, Becker, Tamm, & Epstein (2015a)	TD	25	8	17	32%	Childhood
Antonini, Becker, Tamm, & Epstein (2015b)	ADHD	55	13	42	24%	Childhood
Antonini, Becker, Tamm, & Epstein (2015c)	ADHD and ODD	31	9	22	29%	Childhood
Banaschewski et al. (2012a)	TD sample under 12 years	101	35	66	35%	Childhood
Banaschewski et al. (2012b)	ADHD sample under 12 years	198	27	171	14%	Childhood
Banaschewski et al. (2012c)	TD sample over 12 years	136	33	103	24%	Adolescence
Banaschewski et al. (2012d)	ADHD sample over 12 years	134	12	122	9%	Adolescence
Bobova et al. (2009)	TD	89	43	46	48%	Adulthood

Cho et al. (2013)	TD	34	11	23	32%	Adulthood
Dai et al. (2013a)	TD	29	14	15	48%	Adulthood
Dai et al. (2013b)	ADHD	31	17	14	55%	Adulthood
Demurie, Roeyers, Baeyens, & Sonuga-Barke (2012a)	TD	46	13	33	28%	Childhood and adolescence
Demurie, Roeyers, Baeyens, & Sonuga-Barke (2012b)	ADHD	38	10	28	26%	Childhood and adolescence
Demurie, Roeyers, Wiersema, & Sonuga-Barke (2016a)	TD	39	9	30	23%	Childhood and adolescence
Demurie, Roeyers, Wiersema, & Sonuga-Barke (2016b)	ADHD	32	6	26	19%	Childhood and adolescence
de Wit et al. (2007)	TD	606	303	303	50%	Adulthood
Diller, Patros, & Prentice (2011)	TD	48	27	21	56%	Adulthood
Doi, Nishitani, & Shinohara (2015)	TD	57	30	27	53%	Adulthood
Hulka et al. (2014)	TD	68	21	47	31%	Adulthood
Karalunas &	TD	46	26	20	57%	Childhood

Huang-Pollock (2011a)						
Karalunas & Huang-Pollock (2011b)	ADHD	45	13	32	29%	Childhood
Koff & Lucas (2011)	TD	192	142	50	74%	Adulthood
Lambek et al. (2010a)	TD	26	6	20	23%	Childhood and adolescence
Lambek et al. (2010b)	ADHD	48	10	38	21%	Childhood and adolescence
Lawyer & Schoepflin (2013)	TD	103	66	37	64%	Adulthood
Marx et al. (2013a)	TD real reward condition	20	10	10	50%	Adulthood
Marx et al. (2013b)	ADHD real reward condition	20	9	11	45%	Adulthood
Marx et al. (2013c)	TD non-real reward condition	20	11	9	55%	Adulthood
Marx et al. (2013d)	ADHD non-real reward condition	18	7	11	39%	Adulthood
Morsanyi & Fogarasi (2014)	TD	40	16	24	40%	Adolescence
Mostert et al. (2015a)	TD	123	72	51	59%	Adulthood
Mostert et al. (2015b)	ADHD	109	64	45	59%	Adulthood
Peper et al. (2013)	TD	40	20	20	50%	Adulthood
Romer, Duckworth, Sznitman, & Park (2010)	TD	898	431	467	48%	Adolescence and young adulthood

Rosch & Mostofsky (2016a)	TD	55	15	40	27%	Childhood
Rosch & Mostofsky (2016b)	ADHD	65	19	46	29%	Childhood
Scheres, Tontsch, & Thoeny (2013a)	TD	31	11	20	35%	Children and adolescence
Scheres, Tontsch, & Thoeny (2013b)	ADHD-combined type and hyperactive/inattentive type	22	5	17	23%	Children and adolescence
Scheres, Tontsch, & Thoeny (2013c)	ADHD-inattentive type	19	7	12	37%	Children and adolescence
Sjöwall, Roth, Lindqvist, & Thorell (2013a)	TD	102	56	46	55%	Children and adolescence
Sjöwall, Roth, Lindqvist, & Thorell (2013b)	ADHD	102	56	46	55%	Children and adolescence
Solanto et al. (2007a)	TD	20	12	8	60%	Childhood
Solanto et al. (2007b)	ADHD-combined type	34	13	21	38%	Childhood
Solanto et al. (2007c)	ADHD-inattentive type	26	12	14	46%	Childhood
Stevenson & Cate (2004)	TD	30	18	12	60%	Childhood

Tayler, Arantes, & Grace (2009a)	TD	64	35	29	55%	Adulthood
Tayler, Arantes, & Grace (2009b)	TD	64	32	32	50%	Adulthood
Wilbertz et al. (2012a)	TD	28	14	14	50%	Adulthood
Wilbertz et al. (2012b)	ADHD	28	13	15	46%	Adulthood