# Running Head: DECISION-MAKING IN CHILDREN WITH ADHD

# Affective Decision-Making in School-Aged Children with Attention Deficit/Hyperactivity Disorder (ADHD)

by

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Presented to the Faculty of Graduate Studies of Mount Saint Vincent University in Partial

Fulfillment of the Requirements for the Degree of

# Master of Arts in School Psychology

September 15, 2011

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### Acknowledgements

My utmost gratitude goes to my thesis supervisor, Dr. Shannon Johnson, for allowing me to join her team, and for her expertise and kindness. My thanks and appreciation goes to my thesis committee members, Dr. Shannon Johnson and Dr. Frederick French. I thank my colleague, Jillian Filliter in the Clinical and Cognitive Neuropsychology Lab, for her support and readiness to help, which made my work so much smoother. Above all, I thank my partner, Neal Woodman, who stood beside me and encouraged me constantly. My thanks also to my family (my father, Wayne Baker; brother, Christopher Baker; and sister, Jacquelyn Baker) for being absolutely wonderful and providing continuous support and interest in what I do. Also, I would like to individually thank my mother, Sandra Baker, whose love and support is boundless and who has instilled in me the confidence and perseverance to follow my dreams.

### Abstract

Children and adolescents with Attention Deficit/Hyperactivity Disorder (ADHD) have been found to make a variety of poor life decisions in comparison to typically developing children and adolescents. To date, it is difficult to fully understand decisionmaking and draw firm conclusions from the literature given mixed findings and the limited application of a variety of decision-making tasks to this clinical population. The purpose of the present study was to examine the performance of school-aged children with ADHD in comparison to their typically developing peers on three affective decisionmaking tasks, the GDT, IGT and BART. The GDT was used to assess probabilistic discounting and risky decision-making, and the IGT and BART were used to assess both decisions under ambiguity and risk. As such, the current study asks three questions, (1) Do children and adolescents with ADHD make risky choices on a probabilistic discounting decision-making task (i.e., GDT)?, (2) Do children and adolescents with ADHD choose disadvantageously when making decisions with ambiguous outcomes (i.e., BART and IGT)?, and (3) Are comorbid symptoms of anxiety and depression in children and adolescents with ADHD associated with better performance on the GDT, IGT and BART? Eighteen high functioning individuals (IQ score > 80) between the ages of 8-16 meeting the clinical diagnosis of ADHD, as well as 18 typically developing comparison participants matched to the clinical sample on age, sex, and IQ participated in the study (N = 36). Overall, results suggest that school-aged children with ADHD make similar decisions to typically developing children and adolescents on probabilistic discounting tasks and tasks with ambiguous outcome, however in some areas their choices tend to be less advantageous and involve more risk.

# Affective Decision-Making in School-Aged Children with Attention Deficit/Hyperactivity Disorder (ADHD)

Decision-making is a complex cognitive ability that occurs frequently in our everyday lives. When faced with a choice, we assess the pros and cons and factor the possible rewards and punishments attached to the alternative options, often based on previous experiences. In some cases, decisions have to be made without any information pertaining to the outcome or likelihood of reward or punishment (Brand, Recknor, Grabenhorst, & Bechara, 2007). These uncertain decisions are known as "decisions under ambiguity". In other situations, although the outcome is unknown, there may be some indication of the probability of a positive versus negative outcome. These decisions with probability knowledge are known as "decisions under risk" (Brand et al., 2007).

Children and adolescents with Attention Deficit/Hyperactivity Disorder (ADHD) have been found to make a variety of poor life decisions in comparison to typically developing children and adolescents (Toplak, Jain, & Tannock, 2005). They engage in risky behaviours that lead to a higher rate of accidental injuries as children (Farmer & Peterson, 1995), and, as adolescents and young adults, more motor vehicle accidents (Thompson, Molina, Pelham, & Gnagy, 2007). Risky sexual behavior is also more common in adolescents and adults with ADHD, relative to same age peers (Flory, Molina, Pelham, Gnagy, & Smith, 2006).

In recent years, some researchers have conceptualized areas of cognitive control as "hot" and "cool" (Zelazo, Muller, Frye, & Marcovitch, 2003; Geurtz, van der Oord, & Crone, 2006). The executive ability aspects of cognitive control are known as the "cool" cognitive abilities (Kerr and Zelazo, 2004), whereas, the affective or motivational aspects of cognitive control are known as the "hot" cognitive abilities (Zelazo et al., 2003). Neuropsychological research has indicated that these different areas of cognitive control are associated with distinct brain networks that are assumed to differentially affect decision-making. For instance, neuroimaging studies have shown that performance on behavioural inhibition measures related to the "cool" cognitive aspects of executive functioning is partly mediated by the ventral lateral prefrontal cortex (VLPFC) (Aron, Fletcher, Bullmore, Sahakian, & Robbins, 2003). Patients with lesions in VLPFC show difficulties on behavioural inhibition measures such as the stop-signal paradigm, indicating executive dysfunction (Oosterlan, Logan, & Sergeant, 1998). Alternatively, "hot" cognition has been associated with the ventral medial prefrontal cortex (VMPFC). Patients with lesions in this area of the brain have difficulties anticipating future consequences and therefore have difficulty making affective decisions based on knowledge about potential rewards and punishments (Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Tranel, & Damasio, 2000).

The neuropsychological subdivision of cognitive control is in line with the dual pathway model of ADHD, suggesting that two different neurological pathways, the executive dysfunction pathway and motivational dysfunction pathway, may each lead to the disorder (Sonuga-Barke, 2003). Poor decision-making in ADHD has been explained theoretically by a variety of executive function deficits typically reported in this group. Previous research has demonstrated that deficits in attention, inhibition, working memory, and task switching are significant areas of difficulty in ADHD (Barkley, 1997; Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Sergeant, Geurts, & Oosterlan, 2002). In fact, one of the leading models of ADHD highlights executive dysfunction as

the core deficit of the disorder (Barkley, 1997). These reported executive control deficits would be defined as "cool" cognitive deficits (Kerr and Zelazo, 2004).

Although most decision-making research on ADHD has focused on executive functioning deficits, it has also been suggested that impaired decision-making in children and adolescents with ADHD may also be due, in part, to their affective or motivational style (Toplak et al., 2005), or difference in "hot" cognition (Kerr & Zelazo, 2004). Research in this area suggests that individuals with ADHD are motivated by different systems of reinforcement than their typically developing peers (Garon, Moore, & Waschbusch, 2006). For instance, there is evidence that children with ADHD have difficulty learning complex forms of reinforcement (Luman, Oosterlaan, & Sergeant, 2005; Tripp & Alsop, 2001). By the time most typically developing children reach the ages of 11 - 12 years, they are able to delay gratification by balancing immediate rewards against long-term consequences (Ernst, Grant, London, Contoreggi, Kimes, & Spurgeon, 2003). This ability allows them to make decisions that will lead to long-term rewards, an important process in learning to set and work toward future goals. This ability has been found to be impaired in individuals with ADHD. In particular, relative to typically developing peers, those with ADHD tend to be more motivated by immediate rewards and have difficulty delaying rewards (Garon, Moore, & Waschbusch, 2006; Sonuga-Barke, Taylor, Sembi, & Smith, 1992; Tripp & Alsop, 2001). In other words, individuals with ADHD may focus more on immediate gratification and be less able to consider future consequences.

Areas of affective decision-making that have been studied empirically in the ADHD population involve temporal discounting, probabilistic discounting, and decisionmaking under ambiguity. Studies examining the temporal discounting of rewards in adolescents with ADHD found that these individuals tend to choose smaller rewards that are presented sooner, over larger rewards that are presented later (Luman, Oosterlaan, & Sergeant, 2005; Tripp & Alsop, 2001). This temporal discounting has been suggested to represent an aversion to delay (Sonuga-Barke, Taylor, Sembi, & Smith, 1992) as well as an impulsive drive for immediate reward (Marco et al., 2009; Tripp & Alsop, 2001; Scheres, Dijkstra, Ainslie, Balkan, Reynolds, Sonuga-Barke, & Castellanos, 2006).

A few studies have employed probabilistic discounting paradigms in samples with ADHD (e.g. Drechsler, Rizzo, Steinhausen, 2010; Drechsler, Rizzo, & Steinhausen, 2008; Scheres et al. 2006). In probabilistic discounting tasks the subjective value of a reward decreases due to its decreasing probability. In other words, a large reward should become less attractive as the likelihood of obtaining it is reduced. During these tasks, participants are faced with having to decide between selecting small rewards delivered at high probabilities and large rewards delivered at small probabilities. Cautious decision makers will deduct that the more advantageous selection is to choose the small reward delivered at the higher probability rather than take the risk of selecting the large reward at the lower probability. Using the Game of Dice Task (GDT) (Brand et al., 2005, & Brand et al., 2007), a computerized gambling task that provides explicit probabilities for winning and losing, Drechsler, Rizzo, and Steinhausen (2008) found that adolescents with ADHD became more risky in their decision-making (leading to frequent losses) by selecting the lower probability/higher reward options over the course of the task, whereas adolescents from the control group selected the higher probability/lower reward options (leading to frequent gains). In a sample of young school aged children (ages 7 - 10),

Drechsler, Rizzo, and Steinhausen (2010) also found support for dysfunctional reward processing in children with ADHD. The Make-a-Match game, used by Drechsler et al. is a simple probabilistic discounting task that required participants to guess which card amongst multiple facedown cards would match a face-up target card. Before each trial, the child was instructed to choose the amount of facedown cards they want to play with. They were informed that the higher the number of cards they select, the more candy they can be rewarded, but only if they correctly make the match. Selecting fewer cards is a "safer" choice, as it is more probable way of making a match and therefore collecting more candy overall, whereas the selection of more cards is riskier as there is a lower probability of making a match and therefore resulting in fewer candy rewarded overall. The children with ADHD tended to select less likely, but larger, rewards (risking higher losses) than their typically developing peers. In contrast, Scheres et al. (2006) did not find differences in decision-making between children and adolescents (ages 6 - 17) with ADHD and aged matched controls on a probabilistic discounting task. In this study, there was no evidence of greater risk taking behaviour as all participants made choices that maximized their total gains (Scheres et al., 2006).

Though temporal discounting has been well documented and some studies have examined probabilistic discounting in children and adolescents with ADHD, less is known about how those with ADHD make decisions under ambiguity in comparison to their typically developing peers. A commonly used task for examining affective decisionmaking under ambiguous and risky outcome is the Iowa Gambling Task (IGT) (Bechara, Damasio, Damasio, & Anderson, 1994; Bechara et al., 2000). The original task requires participants to select cards from one of four decks. At the beginning of the task individuals blindly select cards, but over the course of the task optimal decision makers learn that some decks are better than others. Advantageous decks contain cards that yield consistent small monetary gains versus disadvantageous decks that yield consistent large gains accompanied by inconsistent large losses. The task requires a balancing of immediate rewards against long-term consequences. Studies using the IGT to examine decision-making in individuals with ADHD have revealed mixed results. Some have found children and adolescents with ADHD to be impaired on the IGT (Ernst et al., 2003; Toplak et al. 2005; Garon et al. 2006), whereas others did not (Geurts, van der Oord, & Crone, 2006). In particular, Garon et al. (2006) examined decision-making in three groups of children between the ages of six and thirteen using a child version of the IGT. The groups compared were typically developing children, children with a diagnosis of ADHD, and children with ADHD along with comorbid internalizing symptoms (depression and anxiety). The investigators found impaired decision-making in the ADHD-only group relative to the other two groups. The ADHD-only group tended to make riskier, less advantageous, choices and failed to show learning as they progressed through the task. Interestingly, decision-making improved during the task for the subgroup of children with both ADHD and comorbid internalizing symptoms, suggesting that the accompanying internalizing symptoms may be protective, allowing more sensitivity to reinforcements, particularly losses, and therefore resembling decisionmaking similar to controls (Garon et al., 2006). A study by Geurts et al. (2006), however, failed to find any group differences in decision-making between children aged eight to twelve with ADHD and typically developing children of the same age on a child-adapted version of the IGT. It is possible that the ADHD group comprised some participants with

comorbid internalizing disorders and some without, thus watering down any potential group differences according to Garon's findings. In adolescents, Toplak et al. (2005) found less advantageous decision-making on a standard IGT in adolescents with ADHD in comparison to their typically developing peers. Similarly, Ernst et al. (2003) found deficits in decision-making in a group of adolescents with behavioural disorders consisting mainly of a diagnosis of ADHD, but only in a second testing session administered one week after the first. During the first administration of the IGT, decision-making by participants with behavioural disorders was not significantly different from that of controls. The authors contributed this finding to a learned understanding of the task during the second administration by the control group, which was not observed in the clinical group.

A more recently developed task for examining affective decision-making under ambiguous and risky outcome is the Balloon Analogue Risk Task (BART; Lejuez, Read, Kahler, Richards, Ramsey, Stuart, Strong, & Brown, 2002). This task requires participants to earn as much money as they can by inflating a computer-simulated balloon with the optimal number of pumps before it explodes. Participants earn one cent per pump, but lose the money accrued for that balloon if it explodes. For balloons where the participant decides to stop pumping prior to the explosion, the money accrued is transferred to a secure "account" which is later rewarded to the participant. Therefore, participants must increase their risk by continuously inflating as close to where they believe the balloon will explode in order to get the highest reward. To date, only one study has been reported in which the BART was used to assess risky decision-making in ADHD (Mantyla et al., 2010). The authors compared decision-making in adults with ADHD to typically developing adults by using multiple measures. The Adult Decision-Making Competence (A-DMC) battery measured analytic decision-making processes, whereas, the IGT and BART were used to measure affective decision-making processes. It was found that, even while taking medication for attention problems, the adults with ADHD showed impairments on both types of tasks. Specifically, on the affective decision-making tasks, the ADHD group adopted a less efficient strategy then the control group on the IGT and during the BART, took greater risks by producing more balloon pumps than the controls, but only on the first block of three. The latter finding suggests that control participants were more cautious initially, but increased their risk taking to the same level of the ADHD group after completing one-third of the task.

Overall, given the mixed findings in the current literature and the limited application of a variety of decision-making tasks to this clinical population, there is a need to further examine affective decision-making in children and adolescents with ADHD. This is especially important, as research on this topic is still limited and therefore remains inconclusive. Furthermore, findings from multiple decision making measures may lead to a better understanding of affective decision making patterns which have important implications for clinical and school interventions. Therefore, the purpose of the present study was to extend past work by examining the performance of children and adolescents with ADHD in comparison to their typically developing peers on three decision-making tasks, the GDT, IGT and BART. The GDT was used to assess probabilistic discounting in risky decision-making and the IGT and BART were used to assess both decisions under ambiguity and under risk (Brand et al., 2007).

Based on previous literature, discussed above, there were three central research questions for the current study: (1) Do children and adolescents with ADHD make risky choices on a probabilistic discounting decision-making task (i.e., GDT)?, (2) Do children and adolescents with ADHD choose disadvantageously when making decisions with ambiguous outcomes (i.e., BART and IGT)?, and (3) Are comorbid symptoms of anxiety and depression in children and adolescents with ADHD associated with better performance on the GDT, IGT and BART? Given the dysfunctional executive and motivational processing theories, it was expected that children and adolescents with ADHD would differ significantly from their typically developing peers on affective decision-making; making riskier choices on the GDT, taking more risks on the BART, as well as selecting more frequently from disadvantageous decks on the IGT. Furthermore, since internalizing symptoms have been suggested to be a protective factor for children with ADHD on their decision-making on the IGT, it was expected that better decisionmaking on all three tasks would be correlated with ratings of comorbid internalizing symptoms in the ADHD group.

#### Method

#### **Participants**

Eighteen high functioning individuals (IQ score > 80) between the ages of 8-16 meeting the clinical diagnosis of Attention Deficit/Hyperactivity Disorder (ADHD) as determined by qualified health care professionals using diagnostic criteria from the DSM-IV (APA, 2000), as well as 18 typically developing comparison participants matched to the clinical sample on age, sex, and IQ were recruited for participation in the current study (N = 36). Typically developing participants were recruited via letters, flyers,

handbills, and announcements in relevant websites and newsletters. Recruitment materials for children and adolescents with a diagnosis of ADHD were distributed to the Colchester-East Hants ADHD Clinic, as well as other hospital-based and private practice clinicians that specialize in ADHD evaluations. Clinicians were asked to make recruitment materials available to participants in person by means of hanging flyers or placing handbills in their clinic or office waiting area.

### Measures

As the current study was part of a larger study investigating decision-making, it consisted of a large battery of questionnaires and decision-making tasks to be completed by all participants, as well as a series of questionnaires to be completed by the participant's parent or guardian.

### Questionnaires.

Questionnaires were used to gather information about social functioning, behaviour, and symptoms, as well as information about family history and possible comorbid disorders. These included a demographic and history questionnaire, the State-Trait Anxiety Inventory (STAI; Speilberger et al., 1970), the Conners' Rating Scales-Revised (CRS-R; Conners, 1997), the Behavioural Assessment System for Children – 2<sup>nd</sup> Edition (BASC-2; Reynolds & Kamphaus, 2002), the Screen for Child Anxiety Related Emotional Disorders (SCARED; Birmaher, 1997), the Autism Spectrum Quotient (AQ; Baron-Cohen, 2001), the BIS/BAS Scales (Carver & White, 1994), the Childhood Anxiety Sensitivity Index (CASI; Silverman, Fleisig, Rabian, & Peterson, 1991), the Early Adolescent Temperament Questionnaire-Revised (EATQ-R; Capaldi & Rothbart, 1992), and the Social Responsiveness Scale (SRS: Constantino, et al. 2003). For the purposes of the current study, the BASC-2 was used to examine associations between decision-making performance and internalizing symptoms.

### Intellectual ability assessment.

General level of cognitive ability was assessed with the four-subtest version (Vocabulary, Similarities, Block Design, Matrix Reasoning) of the Wechsler Abbreviated Scale of Intelligence (WASI, ages 6 - 89). This measure was necessary to ensure that the clinical and control group met the high functioning cognitive ability criteria and were matched for cognitive ability.

### Decision making tasks.

### Iowa gambling task (IGT).

The IGT (Bechara et al., 1994) is a computerized card task that was designed to simulate the uncertainties of real life decision making, involving the ability to balance immediate rewards against long-term penalties. Particularly, the IGT examines how people learn to make choices that will maximize reward, on the basis of their experiences with positive and negative outcomes. It is an assessment of learning, motivation, and decision-making tendencies.

At the start of the task, participants were instructed to accumulate as much play money as possible by picking one card at a time from any of four decks (A, B, C, and D). The decks varied with regard to the level of immediate gain and risk of penalty. Two of the decks were "disadvantageous" as they are composed of cards with high gains and high losses, and therefore result in less money accrued overall. The other two decks were "advantageous" as they are composed of cards having low gains and low losses, and therefore result in an overall accruement of more money. Also, two decks (one advantageous and one disadvantageous) had frequent, smaller penalties while the other two decks had infrequent, but large penalties. To maximize winnings, the optimal strategy was to avoid the short-term gratification of the disadvantageous decks in favor of the slower, but overall larger gain that will accrue from selecting from the advantageous decks.

Prior to starting the IGT, participants were informed that they would receive their winnings at the end of the testing session if the overall total is positive, but they would not lose anything from their overall winnings if the total were negative. This task included 150 trials and was completed in approximately 20 minutes on average.

### Game of dice task (GDT).

The GDT is a computerized gambling task that assesses risky decision making by providing explicit probabilities regarding gains and loses. Therefore, there is no requirement for the participant to learn response contingencies. The goal of this task is for the participant to predict the outcome of a rolling die. The participant may choose to select from sets of 1, 2, 3, or 4 numbers, each with a known probability of being correct. The lower probability choices (i.e., higher risk) are associated with potentially larger wins, as well as larger losses, whereas higher probability choices (i.e., lower risk) are associated with smaller wins, as well as smaller losses. For example, if the participant chooses just one number and is correct, the winning amount is very high, but if incorrect the same loss is applied. If multiple number combinations are selected, the amount of the potential reward (as well as the potential loss) is small. The larger the combination of numbers selected, the greater the chances of being correct but the lower the prize won. In

this task, there are two "safe" choices (3 or 4 numbers) and two "risky" choices (1 or 2 numbers).

For each trial, the participant viewed four options of dice selections on the screen (sets of 1, 2, 3, or 4 number combinations) and was asked to select one by touching the corresponding image. Once the selection was made, the computer "rolled the die". The outcome was shown, along with the corresponding increase or decrease in winnings.

Prior to starting the GDT, participants were informed that they would receive their winnings at the end of the testing session if the overall total is positive, but they would not lose anything if the total is negative. Participants completed 18 trials in approximately 5 - 10 minutes.

# Balloon Analogue Risk Task (BART).

The BART is a more recent behavioural measure of disinhibition and dynamic risk taking (BART; Lejuez et al., 2002). On the BART, risk taking leads to positive outcomes up to a particular point at which continued excessive risk taking then results in negative outcomes that override the positives. The BART requires the participant to inflate a computer-generated balloon by pressing an icon on a touch screen to earn money. The participant is awarded one cent per pump, which is summed in a tally box on the computer screen. If the balloon is pumped too many times by the participant (according to a predetermined sequence), it will explode and the sum of money for that particular balloon will be lost. At any time however, the participant has the opportunity to stop pumping the balloon before it explodes and transfer the sum of their earnings in the tally box to a permanent bank labeled "Total Earned" by pressing a "Collect \$\$\$" icon. The permanent bank holds the total amount of money accrued across all trials and is understood by the participant to be the amount of money rewarded upon completion of the task. Each time a balloon explodes or the earnings are transferred to the bank, a new balloon will appear and the process is repeated until 30 trials have been completed.

Prior to starting the BART, standardized instructions were given and participants were informed that they would receive their winnings at the end of the testing session. Participants were not provided with any information about the probability of the explosion point, with the exception of being told "It is your choice to determine how much to pump up the balloon, but be aware that at some point the balloon will explode" and "the balloon may pop at anytime, from the first pump to enough pumps to make the balloon fill the entire computer screen." Each participant completed the 30 trials in approximately 5 - 10 minutes.

### Procedure

The tasks described above were administered as part of a larger decision-making study that included additional tests and questionnaires. Upon initial contact with parents or guardians of potential participants, an overview of the study was provided and they were asked to participate in a brief screening interview to determine if their child met study inclusion requirements.

To be included in the study, control participants must have been between ages 8-17 years old, have English as their primary language, normal or corrected normal eyesight, and no history of severe head injury, psychosis, and/or a significant central nervous system disorder. History of severe head injury was defined as loss of consciousness for 30 minutes or more and/or skull fracture or cerebral bleeding. The exclusion criteria were necessary to rule out differences in performance due to the above conditions. ADHD participants had to meet the same criteria in addition to having a diagnosis of ADHD from a specialized clinician or multi-disciplinary team with expertise in this area and no current diagnosis of any other psychiatric disorder. If inclusion criteria were met, an appointment to participate in the study was scheduled. Participants being treated with psychostimulant medications were asked to discontinue medication the day of the study appointment. Parents were informed that a package would be sent out to them prior to their appointment containing directions to the study, Information and Consent or Authorization forms, as well as paper/pencil questionnaires and links to online questionnaires. This provided them with the opportunity to get started or complete this part of the study in advance if they wished to do so.

At the start of the study appointment, the researcher reviewed each item on the Information and Consent or Authorization forms with participants and families, and answered any questions that arose. Once it was ensured that parents and participants understood the information provided and both agreed to participate, signatures for informed consent and/or authorization were obtained. If families chose to complete the forms and questionnaires prior to their appointment, these were collected and reviewed again at the time of their visit, providing an opportunity to ask questions and collect signatures.

Due to the age range in this study, an appropriate form was selected based on the age and ability of the participant. Participants under age 13 were provided with the Information for Children form. This was reviewed and discussed in aural format as needed. The participant's parent or guardian was asked to review and sign the Information and Authorization form. Participants 13-17 years were asked to review and

sign the Information and Authorization form as were their parent or guardian. All participants and parents were encouraged to review the study information and to ask questions. Appropriate signatures on the authorization or consent forms were obtained, including that of a witness. If at any time a child/adolescent refused to participate, even after parents have provided authorization and consent, we did not proceed with the study.

Participants completed approximately 2.5 - 3 hours of standardized and experimental testing. The study was completed in a single session or multiple testing sessions, according to the preference of the participant or his/her family. Testing took place in the Dalhousie University Psychology Department Lab and the Colchester-East Hants ADHD Clinic; again, this was according to the preference of the participant and family.

As previously mentioned, participants and parents were given the option to answer several online and paper and pencil questionnaires at their convenience before or during the scheduled testing session. In the interest of time, as well as ethical and psychometric issues regarding repeat psychological testing, we also gave parents the option to provide consent for release of information to obtain psychological assessment results. Furthermore, with parents/participants consent we requested results of intellectual testing and questionnaires that were the same as those administered in the current study. For example, the Conners' Rating Scale-Revised is a commonly used measure at the ADHD Clinic. Intellectual testing was repeated if scores were obtained more than two years prior and the questionnaires re-administered if this data was obtained more than six months prior. The general battery of tests and measures were organized such that intellectual testing was administered first, followed by cognitive and decision-making tasks. These tasks involved question/answer-style interaction by the researcher and participant, as well as, interactive game-like tasks and computer tasks. Finally, the participant completed paper and pencil questionnaires, followed by online questionnaires.

### **Design and Analysis**

The current study used a matched-group, between subjects multi-factor design. For each decision-making task, group differences were examined using an appropriate group comparison statistic. The objectives outlined in the Introduction section were addressed as follows.

(1) Do children and adolescents with ADHD make risky choices on a probabilistic discounting decision-making task (i.e., GDT)?

In the GDT, two out of the possible four choices (the three number combination and the four number combination) were defined as "safe" since they had a winning probability of 50% or higher and were associated with low losses. The other two options (one single number and the two number combination) were considered "risky" as they had a winning probability of less than 50% and were more likely to yield high losses. To determine if children and adolescents with ADHD made risky choices on the GDT, independent samples t-tests were conducted to compare the mean number of selections (choices) made by group (control and ADHD) for "risky" options (option 1 + option 2), "safe" options (option 3 + option 4), and each of option 1, 2, 3, and 4 on the GDT. See results for findings. (2) Do children and adolescents with ADHD choose disadvantageously when making decisions with ambiguous outcomes (i.e., IGT and BART)?

Performance on the IGT was determined by obtaining a global outcome score that corresponded to the proportion of advantageous deck selections. Global outcome scores were obtained for each consecutive block of 25 cards per participant. To compare groups, a repeated measures ANOVA was conducted, with global score on blocks (1-25, 26-50, 51-75, 76-100, 101-125, 126-150) as the within subject factors and group (ADHD vs. control) as the between subject factor. Analysis of IGT performance by block was incorporated to gain information about the learning during the task as well. Performance (global scores) in learning should improve across blocks corresponding to changes in awareness or understanding of the task: guess, pre-hunch, hunch, and conceptual knowledge (Ernst et al., 2003). See results for findings.

Risky performance on the BART was determined by obtaining the average number of pumps on balloons that did not explode, with more pumps meaning greater risk. This adjusted value is superior to other variables such as the average number of pumps or number of explosions because the adjusted value includes only balloons in which the participant's behavior was not constrained by the explosion point of the balloon (Lejuez et al., 2007). A t-test was conducted to compare overall average number of balloon pumps by group and an ANOVA was also conducted, with group (ADHD vs. control) as the between subject factor and block (3 blocks of 10 trials) as the within subject factor. See results for findings.

(3) Are comorbid symptoms of anxiety and depression in children and adolescents with ADHD associated with better performance on the GDT, IGT and BART?

Associations between performance on each decision-making task and internalizing symptoms will be examined with a series of Pearson's product-moment correlations (e.g., is overall BART performance correlated with internalizing symptoms for the ADHD group?).

### Results

### **Demographic Characteristics**

The study group comprised 36 children (18 children with a diagnosis of ADHD and 18 typically developing children) with ages ranging from 8 to 16 years (M = 11.6, SD = 2.4).

The ADHD group consisted of 12 boys and 6 girls with a mean age of 11 years (M = 11.6, SD = 2.5), a mean full-scale IQ score of 108 (M = 108.3, SD = 13.0), a mean verbal IQ score of 106 (M = 106.3, SD = 14.8), and a mean performance IQ score of 108 (M = 108.3, SD = 10.7). The control group also consisted of 12 boys and 6 girls with a mean age of 11 years (M = 11.6, SD = 2.3), a mean full-scale IQ score of 111 (M = 111.1, SD = 11.7), a mean verbal IQ score of 112 (M = 112.1, SD = 10.9), and a mean performance IQ score of 107 (M = 107.3, SD = 13.3). Independent samples t-tests revealed that there were no significant differences in demographic characteristics between the ADHD and control group for age and IQ. Table 1 presents the general descriptive statistics for each group. Table 2 presents the number of participants with internalizing, anxiety, and depression symptoms, as well as the associated t-scores (means and ranges) for the study sample as reported on the parent- and self-reports of the BASC-2.

Table	1
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	N	Mean Age	Mean Age Ranges	Full- Scale IQ	Full-Scale IQ Ranges	Verbal IQ	Performance IQ
ADHD Group	18	11.6	8.0 - 16.1	108.3	87 – 132	106.3	108.3
Control Group	18	11.6	8.2 - 16.4	111.1	89 – 138	112.1	107.3
t-score		06		68		-1.32	.25
df		34		34		34	34
Sig. (2- tailed)		.95		.50		.20	.81

Descriptive statistics for study sample.

*Note.* df = degrees of freedom, Sig. (2 tailed) = p value, where p < 0.05.

# Table 2

Number of participants with internalizing, anxiety, and depression symptoms as reported on the parent and self-reports of the BASC-2.

		ADHD Group		Control Group		
	# of participants with t- scores > 60	Mean t- score	Ranges	# of participants with t-scores > 60	Mean t- score	Ranges
BASC (PRS)						
Internalizing	4/18	51.8	34 - 72	4/18	50.3	32 - 68
Anxiety	3/18	49.5	31 - 78	4/18	49.4	35 - 75
Depression	8/18	54.6	37 - 71	4/18	50.7	37 - 71
BACS (SRP)						
Internalizing	3/17	52.3	38 - 72	0/17	43.8	36 - 56
Anxiety	4/17	52.1	38 - 64	0/17	42.7	32 - 52
Depression	1/17	48.7	41 - 63	0/17	43.5	39 - 52

Note: T-score of 70+ indicates clinically significant problems; 60-69 means "at risk" of developing clinically significant problems; 41-59 indicates average responses that are indicative of normal behaviour; 31-40 indicates a low level of maladaptive behaviour/problems.

Do children and adolescents with ADHD make risky choices on a probabilistic discounting decision-making task?

### **Game of Dice Task**

An independent samples t-test was conducted to compare the mean number of selections (choices) between groups for "risky" (total selections from option 1 + option 2) and "safe" options (option 3 + option 4) on the GDT (Figure 1). In addition, groups were compared on the number of selections for each of option 1, 2, 3, and 4 (Figure 2).

Overall, there were no significant differences between the number of "risky" selections (options 1 + 2) made by the ADHD group (M = 6.7, SD = 5.3) and the control group (M = 6.8, SD = 4.8), t (34) = -0.06, p = 0.95. Nor were there any significant differences between the number of "safe" selections (options 3 + 4) made by the ADHD group (M = 11.3, SD = 5.3) and the control group (M = 11.2, SD = 4.8), t (34) = 0.06, p = 0.95.

When mean number of selections were compared by group per each individual option, it was found that the ADHD group selected option 2, the second most "risky" choice, (M = 2.4, SD = 2.5) significantly less than the control group (M = 4.7, SD = 3.7); t (34) = -2.19, p = 0.036. There was a trend level difference for option 1, with the ADHD group selecting this most "risky" choice, (M = 4.3, SD = 4.3) more often than the control group (M = 2.1, SD = 2.2); t (34) = 1.90, p = 0.07. There were no group differences for option 3; t (34) = -1.31, p = 0.20 nor option 4; t (34) = 0.78, p = 0.44; both of which represent "safer" choices.

# Figure 1



Mean number of "risky" and "safe" choices selected by the ADHD and control groups on the Game of Dice Task.

# Figure 2

Mean number of selections made per option by the ADHD and control groups on the Game of Dice Task.



*Note.* \* = p < 0.05

Do children and adolescents with ADHD choose disadvantageously when making decisions with ambiguous outcomes?

### **Iowa Gambling Task**

To determine if the ADHD group made disadvantageous decisions on the IGT, an ambiguous outcome task, the proportion of advantageous deck selections was calculated for each participant for each consecutive block of 25 cards. A repeated measures ANOVA was conducted to compare proportion of advantageous deck selections between groups and to examine learning across the six blocks (1-25, 26-50, 51-75, 76-100, 101-125, 126-150) of the IGT (Figure 3).

Figure 3



Mean proportion of advantageous deck selections per block for the ADHD and control group.

*Note.* \* = p < 0.05

There was no main effect of block (F(5) = 1.35, p = .25) or group (F(1) = 1.17, p = .29), but there was a significant block by group interaction (F(5) = 2.93, p = .02). Post hoc t-tests revealed that the control group made more advantageous selections (M = 0.61, SD = .19) during the final block than the ADHD group (M = 0.44, SD = .15); t (34) = - 2.81, p = 0.01. There were no group differences for any of the other blocks (1-5).

### **Balloon Analogue Risk Task**

Group differences were compared between children and adolescents with ADHD and typically developing peers on the BART; a second decision-making task with ambiguous outcomes. Adjusted values for block (3 blocks of 10 trails) and overall score were calculated by averaging the number of pumps on balloons that did not explode; more pumps are interpreted as greater risk taking. An independent samples t-test was used to compare the overall adjusted number of balloon pumps between the ADHD and control groups. A repeated measures ANOVA with a Greenhouse-Geisser correction was then used to compare adjusted number of balloon pumps between groups (ADHD vs. control) across the three blocks (1-10, 11-20, 21-30).

There was no difference between the ADHD (M = 26.5, SD = 10.3) and control (M = 28.7, SD = 12.4) groups; t (32) = -.56, p = 0.58, for the overall adjusted number of balloon pumps (Figure 4). The repeated measures ANOVA revealed no main effect of block (F(1.65) = .03, p = .96) or group (F(1) = .20, p = 66), nor a significant block by group interaction (F(1.65) = .35, p = .66) (Figure 5).

# Figure 4



Mean number of adjusted balloon pumps by the ADHD and control group on the balloon analog risk task (BART).

# Figure 5

Mean number of pumps on the three blocks of the balloon analog risk task (BART) by ADHD and control group.



# Are comorbid symptoms of anxiety and depression in children and adolescents with ADHD associated with better performance on the GDT, IGT, and BART?

To investigate possible associations between decision-making performance and internalizing symptoms for the ADHD group, a series of Pearson's product-moment correlations were employed to examine relationships between performance on the GDT, IGT, and BART and internalizing symptoms from the BASC parent- and self- reports. For self-report analyses, we examined the anxiety, depression, and internalizing problems t-scores form the BASC-2 Self-Report of Personality (BASC-2, SRP form) (Table 4) and for the parent-report analyses, we examined the same scales from the BASC-2 Parent Rating Scale (BASC-2, PRS form) (Table 3).

### **GDT and Internalizing Symptoms**

### Self-Reports.

A significant positive correlation was found between self-reports of depression and selection of option 1 (the most "risky" choice) on the GDT by ADHD participants, r = 0.54, p = .02. That is, riskier choices were associated with more symptoms of depression in individuals with ADHD. There were no other significant correlations between self-ratings of anxiety, depression, and internalizing problems and performance on the GDT (option 2, 3, 4, total risky and total safe).

### Parent-Reports.

There were no significant correlations between the anxiety, depression, and internalizing problems t-scores from the BASC-2, PRS and GDT performance.

### **IGT and Internalizing Symptoms**

# Self-Reports.

There were no significant correlations between performance on the final block of the IGT (proportion of advantageous selections on block 6) and self-ratings of anxiety, depression, and internalizing problems.

# Parent-Reports.

There were no significant correlations between parent-ratings of anxiety, depression, and internalizing problems and block 6 performance on the IGT.

# **BART and Internalizing Symptoms**

# Self-Reports.

There were no significant correlations between performance on the BART (total adjusted score) and self-ratings of anxiety, depression, and internalizing problems.

# Parent-Reports.

There was a significant negative correlation between parent-reports of their children's symptoms of anxiety and total adjusted scores on the BART, r = -0.53, p = .04. That is, ADHD participants whose parents rated them higher on anxiety symptoms made fewer balloon pumps (took less risk) overall on the BART.

There were no other significant correlations between parent-ratings of anxiety, depression, and internalizing problems and performance on the BART.

Table 3

		GE	IGT	BART		
	Option 1 "riskiest"	Option 2 "risky"	Option 3 "safe"	Option 4 "safest"	Block 6 Performance	Total Adjusted Pumps
BASC PRS						
Internalizing	.14	05	23	.02	30	22
Anxiety	.02	.12	30	.07	23	53*
Depression	.04	15	17	.12	.09	.11

Correlational relationships (r-values) between performance on the GDT, IGT, and BART and internalizing symptoms as rated by parents of children with ADHD.

*Note.* \* p < 0.05., BASC PRS = Behavioural Assessment System for Children  $-2^{nd}$  Edition, Parent Rating Scale.

# Table 4

Correlational relationships (r-values) between performance on the GDT, IGT, and BART and internalizing symptoms as rated by children with ADHD.

		GE	IGT	BART		
	Option 1 "riskiest"	Option 2 "risky"	Option 3 "safe"	Option 4 "safest"	Block 6 Performance	Total Adjusted Pumps
BASC SRP						
Internalizing	.32	.05	38	12	.30	.18
Anxiety	.27	.22	00	34	.28	.42
Depression	.54*	.05	34	34	11	.17

*Note.* \* p < 0.05., BASC SRP = Behavioural Assessment System for Children  $-2^{nd}$  Edition, Self-Report of Personality.

# Discussion

The primary aim of the current study was to examine affective decision-making in children and adolescents with ADHD. Specifically, the performance of children and adolescents with ADHD was compared to their typically developing peers on three

decision-making tasks measuring affective decision-making; the GDT, IGT and BART. The GDT was used to assess probabilistic discounting and risky decision-making and the IGT and BART were used to assess both decisions under ambiguity and under risk.

## **Probabilistic Discounting: The GDT**

Contrary to expectations, ADHD participants did not make a greater number of "risky" choices on the GDT than typically developing participants. Both groups selected more frequently (about 75 percent of choices) from the "safer", more likely, smaller reward option. Surprisingly, the control group selected the second most risky option significantly more often than the ADHD group. It was found at the trend level however, that the ADHD group tended to select the least likely, but largest reward option (most "risky") more often than the control group.

These findings align closely with the work of Scheres et al. (2006), who also observed similarities in decision-making between children and adolescents (ages 6 - 17) with and without ADHD on a probabilistic discounting task. In that study, there was no evidence of greater risk taking behaviour as all participants made "safe" choices that maximized their total gains (Scheres et al., 2006). In the current study however, differences between groups occurred, albeit for option 2 only, in which the typically developing children and adolescents made the "riskier" choice. At first glance, one might conclude that the above finding suggests that typically developing children make riskier decisions on a probabilistic decision making task. This conclusion is inaccurate given the trend toward favored selection of the "riskiest" option (option 1) by the ADHD group. It is possible that a more robust sample size would have strengthened this result to significance. Furthermore, when both groups took risks, the fact that the ADHD group selected most frequently from the "riskiest" option (option 1) whereas the control group, in contrast, selected most frequently from the "less risky" (option 2), suggests that the control group actually preferred to play it safer when making risky decisions. Whereas, when the ADHD group made risky decisions, they tended to prefer the "riskiest" choice.

Although the trend toward riskier decision-making by the ADHD group was uncovered when risk-taking was examined in isolation from safe choice making, as discussed above, that fact remains that overall decision-making on this probabilistic discounting task was similar for both groups. That is, the examination of all choices made by both groups which involved calculating the total number of risky choices (option 1 + option 2) versus the total number of safe choices (option 3 + option 4), revealed an overall tendency for both groups to make a similar proportion of "safe" decisions that slowly increased their chances of gaining and decreased the risk of losing. Essentially, the ADHD and control group made optimal choices overall by weighing out the positive and negative probabilities associated with increasing their reward. Therefore, the current study does not support previous studies that have found dysfunctional reward processing in children (Drechsler, Rizzo, and Steinhausen, 2010) and adolescents (Drechsler, Rizzo, and Steinhausen, 2008) with ADHD on a probabilistic discounting task. Recall, dysfunctional reward processing previously seen in individuals with ADHD, as opposed to their typically developing peers, involved the tendency to select less likely, but larger, rewards (risking higher losses). However, smaller yet more likely rewards were the overall selection of choice for both groups in the current study. Therefore, the current data suggests intact reward processing in children and adolescents with ADHD on a probabilistic discounting task.

### **Decisions Under Ambiguity and Risk:**

# The IGT

In contrast to our predictions, there were no overall differences in decisionmaking between the children and adolescents with ADHD and their typically developing peers on the IGT. Both groups made a similar proportion of advantageous and disadvantageous deck selections, selecting around half of the time from good and bad decks. This pattern of selections suggests that neither group showed a preference for advantageous or disadvantageous decks throughout most of the task.

In addition, there were no overall differences in the proportion of advantageous deck selections between blocks. In other words, participants showed similar, consistent patterns of deck selections across successive trials without any clear evidence of an increase in selections from advantageous decks across the task, as would be expected. That is with the exception of the final block of the task. Interestingly, there was an interaction between group and block, which was due to the control group making more selections than the ADHD group from advantageous decks during the final block of the IGT. As mentioned above, the overall pattern of deck selections by block for the ADHD group suggests that they were very consistent in their choices throughout the task, selecting the same amount of advantageous decks as the control group. At the end however, this changed such that their choices were disadvantageous. It appears that the toward the end of the task, participants in the ADHD group may have developed a stronger preference for disadvantageous decks, which are the larger win decks, but also carry the largest losses. Not surprisingly, the control group also appeared to be drawn to the disadvantageous decks, but earlier in the task (4<sup>th</sup> block). By the end of the task

however, they appeared to shift their preference to the advantageous decks, perhaps due to more experience on the task. These different approaches by each group likely resulted in the control group being deterred by the large losses accompanying the high reward decks and therefore selecting more optimal, small reward decks by the final block, whereas the ADHD group seemed to have still been enticed to select the large win decks by the final block without regard for the associated large losses. A version of the IGT with additional trials would be useful for examining how the ADHD group would make selections with more experience on the task in comparison to the control group.

Prior studies using the IGT to examine decision-making in individuals with ADHD have revealed mixed results. The disadvantageous deck selections made by the ADHD group in the final block of the task in the current study is consistent with studies by Ernst et al. (2003), Toplak et al. (2005), and Garon et al. (2006) who also found children and adolescents with ADHD to be impaired on the IGT. In particular, Ernst et al. found that the control group showed a preference for advantageous deck selections on a second administration of the IGT, whereas the ADHD group did not. The researchers attributed the impaired decision-making by the ADHD group as a failure to learn the locations of the advantageous decks over the course of the task (2003). Garon et al. (2006) also found that the ADHD group did not demonstrate learning across the blocks of the IGT. As suggested by previous researchers, this apparent failure to learn optimal deck locations may be due to weaker "somatic" reactions in children and adolescents with ADHD (Bechara et al., 1997; Garon et al., 2006). The IGT examines choice making under ambiguous outcomes at the beginning of the task, and also how people make choices that will maximize reward, on the basis of their experiences with positive and

negative outcomes by the end of the task. Weaker somatic reactions to losing in children and adolescents with ADHD may lead this group to be less hesitant about selecting riskier decks later in the task as they have not experienced the physical sensations typically associated with negative outcomes. Another possible factor that may affect learning across the task for the ADHD group would be symptoms of hyperactivity and lack of focus. If participants with ADHD have trouble concentrating on the task, they are less likely to observe feedback, thus leading them to overlook the infrequent high penalty associated with the appealing high reward decks. Paired with impulsive choice making, it is no surprise that a seemingly high reward deck would entice those participants who do not slow down to consider all of the information, such as potential and actual losses. Research by Toplak et al. (2005) supports this hypothesis, as disadvantageous deck selections by the ADHD group were associated with symptoms of impulsivity and hyperactivity. Thus, it would be interesting to examine the severity of symptoms or type of ADHD in relation to decision-making.

#### The BART

Contrary to expectations, no significant differences were found in the overall number of adjusted balloon pumps between the ADHD and control participants on the BART. That is, the ADHD group did not engage in more "risky" behaviour than the control group. This finding corresponds to that of Mantyla et al. (2011) who also did not find a difference in the overall evaluation of risky decision-making performance on the BART in adults with ADHD in comparison to control participants.

In addition, the number of adjusted balloon pumps made by participants over the course of the task (three blocks of 10 trials) was steady and not significantly different,

indicating that the pattern of performance by both groups was consistent throughout the task. The findings of Mantyla et al. (2011) however, found differing results. Higher levels of risk-taking on the first block of the BART by adult ADHD participants were reported in that study. At this stage, it is difficult to ascertain why the disparity in findings between studies occurred. The most obvious explanation pertains to group differences. Participants in the Mantyla study were adults whereas the current study was composed of children and adolescents. Clearly differences in age due to maturity may impact decision-making on the BART. For instance, it is possible that adults without ADHD in the Mantyla study were less risky in their selections than the children and adolescents without ADHD in the current study. As such, differences were not observed between the ADHD and control children in the current study as both groups took similar risks. However, in the Mantyla study adults without ADHD were more cautious at the start of the task then the adults with ADHD, which resulted in the reported differences.

Furthermore, an important factor that may have contributed to the lack of difference between groups on the BART in the current study was identified upon analysis of the raw data of the BART. Intermittent strings of zero balloon pumps were found in a number of ADHD participant's data. Initial speculation by the researchers explaining a lack of balloon pumps on trials was that since the BART is a computer task, and common computer usage often requires a "double-click" on the mouse or icons, it was thought that perhaps participants were habitually double-tapping the "collect \$\$\$" icon at the end of one trial, causing them to skip to the next balloon trial without pumping. This hypothesis was dismissed however, because there were no zero response trials within the control group data. That is, every typically developing participant made at least one balloon-

pump on each trial. Therefore, some participants within the ADHD group only, skipped on to the next balloon trial without making any balloon pumps at all. Therefore, habitual "double-tapping of the icon is not likely since it would be expected to be observed within the control group as well. Given the reward associated with each pump it is surprising that anyone, even the most conservative of risk takers, would deliberately choose not to make at least one balloon pump, essentially wasting a balloon. Therefore, the belief remains that this was not a deliberate choice by participants. Instead, zero response trials are likely due to either an impulsive tapping of the "collect \$\$\$" icon or a lack of awareness that a new trial had started by some ADHD participants. Both of these scenarios are plausible, as children and adolescents with ADHD characteristically experience symptoms of impulsivity and lack of attention and focus. This is a flaw in the task for testing with an ADHD population or any group that exhibits such symptoms. A better task design would ensure that participants were not able to move to another balloon without making at least one pump. Furthermore, it might be helpful to alert participants that a new trial has begun by way of a brief change in screen colour. Due to this glitch in the BART, it was important to correct for this in our analysis. The adjusted BART scores were re-calculated by removing the zero response trials from the denominator for the ADHD participants. Again, independent samples t-test was used to compare the overall newly adjusted number of balloon pumps between the ADHD and control groups and a repeated measures ANOVA was then used to compare the newly adjusted number of balloon pumps between groups (ADHD vs. control) across the three blocks (1-10, 11-20, 21-30).

Although the new scores for the ADHD group were slightly higher (i.e. more risk), there was still no difference between the ADHD (M = 30.0, SD = 11.3) and control (M = 28.7, SD = 12.4) groups; t (32) = -.34, p = 0.75, for the overall adjusted number of balloon pumps. The repeated measures ANOVA revealed no main effect of block (F(2) = .88, p = .42) or group (F(1) = .11, p = 75), nor significant block by group interaction (F(2) = .16, p = .86).

The BART is a newer behavioural measure of disinhibition and dynamic risk taking. To our knowledge, only one previous study employed the BART to examine an ADHD population. Therefore, with the correction for the zero responses, findings are preliminary and although they provide a contribution to the current literature, more studies are needed in order to gather enough reliable information to draw any firm conclusions on risky decision-making in children with ADHD using this task.

### Decisions Under Ambiguity: The IGT and the BART

Taken together, the disparity in risky decision-making outcomes on the IGT and BART may be due to the fact that the two tasks differ visually and take into account different risk-taking decision processes. For instance, in the current study it appeared that the ADHD group made better decisions when there were visual indicators of risk and gain. In the GDT and BART there are constant visual reminders to aid the participant in deducting the most effective way of moving through the task. For example, in the GDT, the dice and their probabilities are explicitly labeled and hierarchically displayed visually. On the BART, the balloon expands visually and the amount of money is explicitly tallied and displayed. Therefore, the participant can view and decide the amount of reward and risk with which they are comfortable. This differs from the IGT, where the contingencies have to be learned and the amount of money gained or lost is presented following each selection but is then removed before the next trial. After every trial on the IGT the screen resets so the participant is required to rely on memory more so than in the other tasks. Though the IGT and BART both measure decision making with ambiguous outcomes and risk, these visual differences may contribute to the decision making of participants. More colour and animation on the BART may attract the attention of the participants, especially those with ADHD, and may explain differences in outcome. This, in turn, provides information about real life decision-making, as decisions vary in their complexity and nature. The findings from the study may suggest that children and adolescents with ADHD can make advantageous decisions when the situation is simple and aided by visual input, but use a less advantageous decision-making strategy when the situation is more complex (i.e. relying on memory) and less interesting.

### **Internalizing Symptoms**

Internalizing symptoms have been suggested to be associated with better decisionmaking for children with ADHD on the IGT, therefore it was expected that better decision-making on all three tasks would be associated with higher ratings of internalizing symptoms in the ADHD group. Using reported symptoms of anxiety, depression, and overall internalizing problems from the BASC-2 parent- and self-rating scales, relationships were found between anxiety and risky decision-making on the BART and depression and risky decision-making on the GDT.

Specifically, higher parent reports of anxiety in children and adolescents with ADHD were associated with less risky decision-making on the BART. This finding was in keeping with our hypothesis and is consistent with previous findings from Garon et al., (2006). In that study, decision-making was found to improve over the course of the task for the subgroup of children with ADHD and comorbid internalizing symptoms. The authors interpreted this result as indicating that the accompanying internalizing symptoms may be protective, allowing more sensitivity to feedback, particularly losses, and therefore resulting in decision-making similar to controls (Garon et al., 2006).

For the GDT, higher self-ratings of depression in children and adolescents with ADHD were associated with "riskier" decision-making (more selection of option one; riskiest choice). Although not in accordance with our hypotheses or previous studies of ADHD (Garon et al., 2006), this finding can be interpreted in another manner. Individuals with symptoms of depression characteristically view things in absolutes and experience feelings of helplessness and hopelessness. When making decisions, especially those involving risk, this sense of hopelessness can lead to poor decision-making behaviours (Leykin et al., 2010). In support of this hypothesis, Leahy proposed a "portfolio theory" in which individuals with depression make sub-optimal and riskier decisions due to feelings of having less resources and lower future potential, thus causing them to minimize loss at the thought of experiencing potential pleasure from gains (Leahy, 2001).

### **Limitations and Future Directions**

Some limitations of the current study need to be considered. First, it should be noted that the age range employed in this study (8 to 16 years) is wide and may potentially cloud findings. Ideally, smaller age groups of children and adolescents would be examined so that developmental differences in learning and motivation could be examined. This would be an important consideration in future studies to help to tease apart potentially convoluted findings. Due to brain development and behavioural changes during those years, decision-making may change from childhood to adolescence. Furthermore, age may have an impact on motivation, especially in relation to the rewards associated with the decision-making tasks in the current study. The tasks in the current study used monetary rewards as an incentive to motivate behaviour in order to gather the most reliable data. Although informal questionnaires completed by participants following each task revealed that most children in the study were motivated by the monetary rewards, it is possible that younger children and adolescents would differ in the level of motivation associated with this type of reward. Examining younger children and adolescents separately may be important for controlling for potentially different levels of motivation for monetary rewards.

Another limitation in the current study is the small sample size. The group size prevented further examination of individual differences, such as subtypes of ADHD and age range as mentioned above. Analyzing subtypes of ADHD is an important consideration however, as it is possible that the decision-making of children and adolescents with the hyperactive subtype of ADHD would differ from individuals with an inattentive subtype of ADHD. A larger sample size would increase statistical power, allowing for the examination of individual differences, and would potentially lead to more robust findings between groups.

Furthermore, analysis of BASC-2 scores revealed that few ADHD participants in this study had internalizing symptoms. Again, a larger sample size might provide more heterogeneity in internalizing symptoms. Furthermore, future studies of decision-making in ADHD should consider comorbid symptoms of anxiety and depression as inclusive screening requirement. The somewhat limited range of BASC-2 scores likely limited the outcome of the correlational analyses.

Also, in the design of the current study, the addition of physiological measures, such as skin conductance, to examine the somatic responses of children would have provided important information. For instance, skin conductance could inform as to whether children and adolescents with ADHD have different or a lack of "somatic" markers than their typically developing peers, and if so, how these responses are related to decision-making could be examined more closely. In addition, both parent and selfratings were used in the design of the current study to gather information about internalizing symptoms. It would be important for future studies to carefully consider the most appropriate rater for the questionnaires since disagreement is often observed between parent and child reports of child behaviour and psychological symptoms (Achenbach, McConaughy, & Howell, 1987), as was the case in the current study. Studies suggest that self ratings are often preferred over parent ratings when investigating internalizing symptoms, as parents may not be aware of the thoughts and feelings that their child may be experiencing (De Los Reves & Kazdin, 2005). This is in contrast to externalizing symptoms, where the parents are typically the best informants on externalizing behaviours as these symptoms are observable and often downplayed by the child. There are also additional factors to consider when choosing the best informant, such as age of the child and feelings of social desirability by the child (De Los Revers & Kazdin, 2005), as well as insight and self-awareness, often an area of difficulty in clinical populations. Therefore careful consideration should be given before selecting the most appropriate informant.

Another important future direction for the examination of decision-making in ADHD involves replicating previous studies. Studies examining decision-making in ADHD populations are available. However, variation in methodological approaches, participant age, as well as, substantial variation in tasks leads to difficulty in the comparison of these studies as well as our ability to draw firm conclusions from them. For instance, choosing an affective decision-making task(s) can pose challenges. Not only are there are numerous tasks and developmentally appropriate variants available, but these tasks also tap a wide variety of decision-making components, such as cognitive versus motivational areas. Future studies must continue to focus on the replication of previous studies using the same or most optimal decision-making measures in order to identify emerging patterns in the ADHD decision-making literature.

#### Conclusions

Overall, the current study revealed some important findings that will be important contributions to the literature on decision-making in children and adolescents with ADHD. Children and adolescents with ADHD made similar choices to typically developing children and adolescents on a probabilistic discounting task, suggesting intact reward processing by the ADHD population. The only difference was that typically developing children were a little more cautious when taking risks then those with ADHD. When making decisions without any information pertaining to the outcome, children and adolescents with ADHD made less advantageous decisions than their typically developing peers, but different preferences emerged only after experience during situations where information surrounding the decision was more ambiguous. In situations with less ambiguous outcomes, children and adolescents with and without ADHD demonstrated similar patterns of decision-making. Generally, internalizing symptoms were not associated with better ("safer") decision-making in ADHD. There was one exception, on one task, where a higher level of parent-reported anxiety in ADHD participants was related to safer decision-making. In contrast, on one task, higher self-reported symptoms of depression were related to riskier decision-making. Thus, associations between internalizing symptoms and decision-making in ADHD require a closer look in future studies.

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