Decision Making in Adults With ADHD

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Abstract
Objectives: This study examined decision-making competence in ADHD by using multiple decision tasks with varying demands on analytic versus affective processes. Methods: Adults with ADHD and healthy controls completed two tasks of analytic decision making, as measured by the Adult Decision-Making Competence (A-DMC) battery, and two affective decision tasks (the Balloon Analog Risk Task and the Iowa Gambling Task). Results: Although a majority of the ADHD participants were tested under medication, they showed impairments in both types of task. However, logistic regression analysis showed that the applying-decision-rules task of the A-DMC battery was the only significant predictor of ADHD status. Conclusions: These findings suggested that ADHD is associated with impaired decision making in tasks involving a significant degree of cognitive control. Although both deliberative and affective neurocognitive systems probably contributed to ADHD-related problems in decision making, the findings underlined the involvement of prefrontally mediated executive functions. (J. of Att. Dis. 2012; 16(2) 164-173)

Keywords
decision making, executive functioning, ADHD

Inappropriate decision making and unnecessary risk taking in everyday situations have been described as major characteristics of children and adults with attentional disorders (e.g., Barkley, 1997; Cox, Merkel, Kovatchev, & Seward, 2000; Toplak, Jain, & Tannock, 2005). Among children, the ADHD is associated with an increased risk for accidents (e.g., DiScala, Lescohier, Barthel, & Li, 1998; Jensen, Shervette, Xenakis, & Bain, 1988), and adolescents with ADHD are 2 to 4 times more likely to experience a motor vehicle accident (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993; Barkley, Murphy & Kwasnik, 1996).

However, it is less clear whether ADHD-related problems in risk taking and decision making should be attributed to cognitive or motivational-emotional causes. Recent theories have claimed that ADHD originates from multiple factors and their underlying neural pathways, namely, a motivational-emotional pathway with a predominant dysregulation of the reward system and one or several cognitive pathways that cause impairments of executive functions, including working memory, and response inhibition (e.g., Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Sonuga-Barke, 2003, 2005; see also Barkley, 1997; Blum et al., 2008; Casey, Getz, & Galvan, 2008; Steinberg, 2008).

According to this dual-pathway model of ADHD, it is reasonable to assume that ADHD-related decision problems reflect either deficits in executive control functions or inappropriate functioning of the reward system (or a combination of these factors). This hypothesis is even more relevant in the context of dual-process models of judgment and decision making. Specifically, the cognitive and affective pathways of Sonuga-Barke’s model of ADHD reflect William James’ (1890/1950) suggestion that human thinking involves two distinct processing systems—one that is quick and intuitive and another that is slow and analytic.

More recent psychological models of judgment and decision making have elaborated these ideas by distinguishing between a rapid, effortful, affective, and intuitive set of processes and a slower, analytic, deliberate, and effortful set of processes (see Evans, 2008, for a review). Different authors have proposed a variety of names and labels for these two sets of processes, including intuitive versus analytic (Hammond, 1996), heuristic versus analytic (Evans, 1989), reflexive versus reflective (Lieberman, 2003), and System 1 versus System 2 (Kahneman, 2003; Kahneman & Frederick, 2005; Stanovich 1999). Furthermore, some authors have also explicitly linked intuitive processes with affect and emotions (e.g., Epstein, 1994; Slovic & Peters, 2006; Slovic, Peters, Finucane, & MacGregor, 2005).
Although dual-process models suffer from various limitations (e.g., De Neys & Glumicic, 2008; Keren & Schul, 2009), they may represent a useful generalization at a meta-level analysis.

According to the dual-process models, human judgment and decision making is assumed to reflect either analytic and deliberative or intuitive and affective evaluations. According to the default interventionist view (e.g., Kahneman, 2003; Kahneman & Frederick, 2005), intuition and rapid affective judgments can often provide us with fast and reasonably appropriate problem solutions, but, in some cases, they can also systematically bias our evaluations. For example, when asked whether taking the plane is safer than taking the car, individuals generally overestimate the risks of flying because of the frightening images of crashing planes they spontaneously think of (De Neys & Glumicic, 2008). In this view, intuitive judgments (e.g., affective “gut feelings,” fast evaluations based on the most accessible information) will sometimes cue erroneous responses that conflict with factually appropriate responses. To resolve this conflict it is necessary to block inappropriate intuitive or emotional responses temporarily (e.g., Evans, 2003; Sloman, 1996; Stanovich, 2009; Stanovich & West, 2000), resorting to deliberation and to a systematic assessment of the situation. Consequently, inhibitory processes are considered as one of the cornerstones of the human reasoning ability (e.g., Stanovich, 2009; Stanovich & West, 2000, 2008; see also Evans, 2008; Weber & Johnson, 2009, for reviews).

Although the dual-path model of ADHD and the dual-process models of judgment and decision making present conceptual similarities, our current knowledge of decision making in ADHD exposes several limitations. First, empirical research on this topic is still too sparse and fragmentary to allow robust conclusions about decision-making capacities in ADHD and related attentional disorders. The few existing studies do not provide univocal conclusions about the reality and the degree of ADHD-related decline in decision making. Furthermore, the majority of studies have not provided a satisfying account of the mechanisms underlying ADHD-related differences in judgment and decision making, possibly due to the adoption of a very narrow set of decision measures. This is probably related to the fact that valid instruments for performance-based evaluation of decision-making competence have not been available till the recent years (see also Bruine de Bruin, Parker, & Fischhoff, 2007; Del Missier, Mäntylä, & Bruine de Bruin, in press).

Most studies have examined risk taking in ADHD by using the Iowa gambling task (IGT; for example, Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Damasio, Tranel, & Damasio, 1997; see also Maia & McClelland, 2005). In this task, which has been generally used as a measure of intuitive and affective decision making, participants draw cards from four decks associated with different (unknown) probabilities of winning or losing. In particular, they are asked to choose cards repeatedly from two “good” decks (associated with small gains and cumulatively smaller losses, with a positive expected value in the long run) and two “bad” decks (associated with large gains and recurrent larger losses, with a negative expected value in the long run). Normal individuals quickly learn which decks to select from to maximize outcomes, whereas patients with damage to the orbitofrontal cortex continue to select cards from the two disadvantageous decks.

According to the somatic marker hypothesis (Damasio, 1994, 1996), participants’ initial experience with the IGT allows them quickly to develop somatic markers, which anticipate their affective reactions to outcomes associated with the different decks (e.g., negative feelings associated with losses in the bad decks). Somatic markers would guide decision making before a conscious and clear appraisal of the value of the decks is acquired (for a critical position see, e.g., Maia & McClelland, 2005). Somatic markers would prevent normal respondents from choosing unfavorable gambles and lead them to make decisions that are advantageous in the long run, guided by the somatic experience of anticipated wins and losses. In line with this view, the failure of affective regulation mechanisms related to orbitofrontal cortex is deemed to be one of the reasons of the poorer performance of frontal patients in risky games (e.g., Weber & Johnson, 2009).

Children and adults with ADHD have been found to be impaired on the IGT (Ernst et al., 2003; Garon, Moore, & Waschbusch, 2006; Toplak et al., 2005), but results are inconsistent. For example, Garon et al. (2006) found that impaired decision making in ADHD is confined to children without symptoms of depression. Ernst et al. (2003) found group differences between participants with ADHD and controls, but only in a second test session, and Geurts, van der Oord, and Crone (2006) failed to find group differences at all.

The aim of the present study was to extend past work by examining decision competence in adults with ADHD by using a more complete and differentiated set of decision-making measures. A more specific aim was to examine whether adults with ADHD can be distinguished from normal controls by their performance on decision tasks that are usually assumed to differ in demands on analytic versus affective decision processes. Although most decision tasks are certainly “process impure” in that they involve both cognitive and affective (and other) processes, demands on specific processes are likely to be accentuated in some decision tasks (e.g., Del Missier et al., in press; Weber & Johnson, 2009). Furthermore, using multiple tasks of different type may not only reduce measurement problems but also reveal interesting patterns of decision-making competence in ADHD.
To this end, adults with ADHD and healthy controls completed two sets of decision tasks. Analytic decision performance was assessed by using two subtask of the Adult Decision-Making Competence (A-DMC) battery (Bruine de Bruin et al., 2007; see also the Method section). We chose these two tasks, referred to as the applying-decision-rules and under/overconfidence tasks, respectively, because earlier work has identified them as reliable measures of different facets of cognitively laden decision making (Bruine de Bruin et al., 2007; Del Missier et al., in press; Parker & Fischhoff, 2005). In particular, applying decision rules is a cognitively demanding, multiatribute choice test and under/overconfidence measures metacognitive ability related to knowledge calibration. These two components of decision-making competence were found to be sensitive to individual differences in executive functioning (Del Missier et al., in press), and they both correlate significantly with measures of fluid intelligence (Bruine de Bruin et al., 2007; Parker & Fischhoff, 2005). In particular, applying decision rules generally showed the highest correlations with executive functioning and fluid intelligence in past A-DMC work.

Affective decision making was measured by using two different tasks that are thought to require a proper regulation of the affective reward system, namely, the IGT and the balloon analogue risk task (BART; Lejuez et al., 2002). The BART is a more recent behavioral measure of risk taking that seems to be sensitive to individual differences in affective processing (Maner et al., 2007). Past psychometric work suggests that the BART has reasonable measurement properties, including construct validity and test–retest reliability (Lejuez et al., 2007; White, Lejuez, & De With, 2008). Increased risk taking on the BART was found to be significantly related to alcohol and drug use, cigarette smoking, gambling, theft, aggression, and unprotected sexual intercourse in both adolescent and adult samples (e.g., Aklin, Lejuez, Zvolensky, Kahler, & Gwadz, 2005; Lejuez, Aklin, Zvolensky, & Pedulla, 2003; Lejuez et al., 2003). However, to the best of our knowledge, the BART has not been previously used to assess risk taking in ADHD.

Our basic strategy was to collect these two sets of decision measures in the same study to better understand whether ADHD-related difficulties in decision making reflect selective impairments. Specifically, following the notion that ADHD is associated with impairments in reward system regulation (Blum et al., 2008; Steinberg, 2008), ADHD patients might show lower performance in the two affect laden tasks than the healthy controls. Alternatively, specific differences in the analytic (A-DMC) tasks would support the hypothesis that ADHD is associated with impairments in cognitive control. Finally, patients might show impairment in both types of decision tasks, suggesting that both cognitive and affective processes are compromised in ADHD.

Table 1. Participant Characteristics (With Standard Deviations in Parenthesis)

<table>
<thead>
<tr>
<th></th>
<th>ADHD</th>
<th>Control</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (male/female)</td>
<td>31 (17/14)</td>
<td>32 (17/15)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>30.8 (12.58)</td>
<td>29.84 (10.81)</td>
<td>0.33</td>
</tr>
<tr>
<td>Education</td>
<td>11.56 (2.28)</td>
<td>13.17 (1.41)</td>
<td>-3.38**</td>
</tr>
<tr>
<td>BDI</td>
<td>12.00 (11.04)</td>
<td>6.81 (7.08)</td>
<td>2.21*</td>
</tr>
<tr>
<td>Stroop (in ms)</td>
<td>366 (212)</td>
<td>264 (133)</td>
<td>2.20*</td>
</tr>
</tbody>
</table>

Note: BDI = Beck Depression Inventory.
* p < .05; **p < .01 (based on independent t tests).

Method

Participants

A total of 63 adults aged between 18 and 65 years participated in the study. The ADHD group consisted of 31 adults aged between 18 and 62 years and the non-ADHD control group consisted of 32 adults aged between 20 and 65 years (see also Table 1 for participant characteristics). A majority of the ADHD participants (n = 22) were consecutive attendees to one of six ADHD outpatient clinics in Northern Sweden. To recruit these participants, we first contacted the clinic head of each outpatient clinics in Northern Sweden. After approval, each clinic informed their patients about participation in the study and booked time for testing for those individuals who were interested. The remaining 9 ADHD participants were recruited through professional contacts with a national ADHD association and local clinics. Following a standardized procedure, all the ADHD participants were diagnosed by experienced psychologists. Furthermore, all the ADHD participants met the criteria for ADHD according to Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association [APA], 1994). Due to clinical and practical restrictions, it was not possible to prevent medication during the test period. Consequently, 23 of the ADHD participants were tested under their ordinary medication (except for one individual, all the ADHD participants were under methylphenidate medication).

Participants of the control group were recruited through informal contacts with different work places. When recruiting these individuals, we attempted to match their demographic background (including age, gender, level of education, and living arrangements) with that of the ADHD group. Furthermore, the two groups were also matched in terms of geographic background in that an equal number of controls and patients were recruited from the same city. None of the controls had any obvious health problems, including psychiatric symptoms. To obtain additional information about demographic background and health status, each participant was interviewed before the test session. Furthermore, to assess individual differences in executive
functioning and depression, both groups completed the color Stroop task (see the Method section, for details) and the Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996). Table 1 summarizes the background characteristics of both groups. As expected, there were significant group differences in education, depression, and response inhibition, respectively.

**Task Characteristics**

Decision-making competence was assessed by using two subtasks of the A-DMC battery and two commonly used decision-making tasks that are thought to be more affective and intuitive. The A-DMC battery is composed of six tasks relevant to normative theories of decision making: applying decision rules, resistance to framing, under/overconfidence, resistance to sunk costs, consistency in risk perception, and recognition of social norms. Bruine de Bruin et al. (2007; see also Parker & Fischhoff, 2005) showed that the A-DMC battery has good internal consistency, in terms of correlations among component tasks, and acceptable validity, in terms of correlations with real-world decision outcomes. The original A-DMC questionnaire was initially translated into Swedish, and it underwent a psychometric evaluation involving a large sample of young and middle-aged adults (Marklund & Mäntylä, 2008).

The applying-decision-rules task of the A-DMC battery (here referred to as DMC 1) evaluates participants’ ability to apply decision rules of varying complexity. The ability to apply decision rules has been traditionally associated with working memory (e.g., Payne, Bettman, & Johnson, 1993), and recent research showed that performance in this task is related to response inhibition and fluid intelligence (Del Missier et al., in press). The participant is presented with 10 different multiattribute decision problems involving choices among DVD players with different features. The subtest score is the proportion of responses across items that reflect normatively correct answers that would have been obtained from an errorless application of the prescribed decision rules.

The under/overconfidence task of the A-DMC (referred to as DMC 2) measures the accuracy of participants’ confidence judgments. Thus, this task requires metacognitive abilities. Participants are asked to answer 34 true–false factual questions. Immediately after answering each question, participants state how sure they are of their answer on a scale ranging from 50% (*just guessing*) to 100% (*absolutely sure*). Performance is measured in terms of absolute discrepancy from perfect calibration, varying between 0 and 1 (0 = *absolute discrepancy*, 1 = *perfect calibration*).

The Iowa gambling task (IGT) measures the capacity to take risky decisions in a gambling environment with uncertain outcomes. Participants are given a virtual US$2000 to play this gambling task. They are asked to choose cards from four decks repeatedly, two of which are “good” (associated with small gains and cumulatively smaller losses, with a positive expected value in the long run) and two of which are “bad” (associated with large gains and recurrent larger losses, with a negative expected value in the long run). Participants’ goal is to maximize their hypothetical payoffs. After each selection, feedback informs participants about the amount of money won and lost (for instance, won 50 and lost nothing, or won 100 and lost 1,250). We used a computerized version of the task, which complied with conventions on instructions, payoff schedules, and graphical interface (Bechara et al., 1994). Running totals were displayed in the upper part of the screen. The spatial position of good and bad decks was randomized within the group of participants. Performance was assessed by the final score of the game (total money earned).

The BART is a computerized risk-taking task, created for a laboratory setting but aiming at predicting risk taking in real-life contexts. The objective of the BART is to pump up balloons and to earn as much money as possible. Every pump is worth a certain amount of money. For each pump more money can be earned, but at some point the balloon pops and then the participant loses the money gained during that trial. Each pump is worth a hypothetical monetary value (e.g., US$0.25), but for each pump the risk of a pop increases. In the computer screen there is a button under the balloon to pump it up and one button “collect” to cash in the money earned for each trial. The test is administered in 2 consecutive sessions with 30 trials each. Following past studies, the primary dependent measure was the adjusted number of pumps (i.e., the average number of pumps on balloons that did not explode).

Finally, to assess group differences in response inhibition participants completed the *Stroop* task (Stroop, 1935). In this task, a series of 96 word triples were presented on the computer screen (see also Del Missier et al., in press; Mäntylä, Carelli, & Forman, 2007). The central word of the triple (stimulus word) was printed in color (blue, green, yellow, or red) at the center of the screen. In half of the trials, the color of the printed word was congruent with the stimulus word (e.g., the word “red” was printed in red), whereas in the other half it was incongruent (e.g., the word “red” was printed in blue). The two adjacent words also referred to color names (blue, green, yellow, red) but were always printed in black. Participants were asked to identify the color in which the central word was printed by pressing one of two keys to respond. The first key was on the right side of the computer keyboard and marked with a right arrow, and the second, on the left side of the keyboard, was marked...
with a left arrow. Participants were instructed to press the right arrow to indicate that the color of the central word corresponded to the word presented in the right side of the screen, whereas pressing the left arrow meant that the color of the central word was designated by the black word presented in the left side of the screen. We asked participants to be both fast and accurate, and they underwent a short series of training trials before starting the test. We used two dependent measures, namely, mean difference in response time between incongruent and congruent items, and a more stringent measure that combined speed and accuracy. Specifically, each error corresponded a 10-ms increment in response time (i.e., Stroop $1 + 10 \text{ ms} \times \text{number of errors}$). As the two measures showed virtually identical group differences, only the data based on the stringent scoring are reported here (see Table 1).

**Procedure**

Participants were tested in quiet rooms under similar conditions at the outpatient clinics or at the university. During the first phase of the test session, participants were informed that the aim of the study was to examine individual differences in decision competence and that they would be asked to complete a series of cognitive tasks. For both groups, the tasks were administered in the following fixed order: BART, IGT, Stroop, DMC2, and DMC1. In addition to the BDI, participants completed questionnaires related to cognitive style and temporal orientation, but these data are not reported here. All participants were given oral instructions before each task, followed by a practice phase with examples and feedback. The computerized tasks were completed by using a laptop computer with a 14-inch display. The whole test session took about 90 min to complete, including a background interview and short breaks.

**Results**

The decision-making data were first analyzed by examining group differences on each of the four decision tasks, followed by a more detailed (Group × Test Session) analysis of variance (ANOVA) on the IGT and BART data, respectively. Finally, we examined the relative power of the four decision measures to predict ADHD status in a logistic regression analysis, with age, gender, level of education, and depression as covariates.

Table 2 shows simple correlations among the four decision tasks. In these analyses, the DMC 1 score of one control participant was replaced by the group mean, as this result was extremely poor ($< 3 \text{ SD}$), probably due to misunderstanding of task instructions. Consistent with previous studies, the two DMC tasks showed a significant correlation. It should also be noted that the associations between the BART and the remaining tasks, including IGT, were nonsignificant and close to zero, whereas the DMC 1 and IGT showed a significant correlation.

**ADHD in Analytic Decision Making**

Following A-DMC standard scoring, the proportion of correct responses constituted the dependent variable of the DMC 1 task and the absolute discrepancy from perfect calibration was the primary measure of the DMC 2 task (see Bruine de Bruin et al., 2007 for more details). As shown in Table 3, the analyses of the overall decision data with independent-samples $t$ tests highlighted significant group differences in DMC 1 but not in DMC 2. This result suggests that ADHD was associated with impairments in the more cognitively laden decision task. By contrast, the two groups showed similar levels of metacognitive decision performance, as measured by DMC 2.

**ADHD in Affective Decision Making**

As shown in Table 3, the overall analyses of the IGT and BART data indicated selective group differences. In particular, the IGT data suggest that the ADHD group adopted a less efficient gambling strategy than the control group as measured by total money earned. More detailed analyses of the IGT showed similar patterns of performance across the

### Table 2. Pearson Correlations Among the Decision Tasks

<table>
<thead>
<tr>
<th></th>
<th>DMC 1</th>
<th>DMC 2</th>
<th>BART</th>
<th>IGT</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMC 1</td>
<td>—</td>
<td>.43**</td>
<td>.07</td>
<td>.28*</td>
</tr>
<tr>
<td>DMC 2</td>
<td>.43**</td>
<td>—</td>
<td>.16</td>
<td>.20</td>
</tr>
<tr>
<td>BART</td>
<td>.07</td>
<td>.16</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>IGT</td>
<td>.28*</td>
<td>.20</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: DMC 1 = applying decision rules; DMC 2 = under/overconfidence; BART = balloon analog risk task; IGT = Iowa gambling task.

### Table 3. Decision-Making Performance as a Function of Task and Group (With Standard Deviations in Parenthesis)

<table>
<thead>
<tr>
<th></th>
<th>ADHD</th>
<th>Control</th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMC1</td>
<td>0.66 (0.12)</td>
<td>0.77 (0.13)</td>
<td>−3.53**</td>
</tr>
<tr>
<td>DMC2</td>
<td>0.90 (0.10)</td>
<td>0.92 (0.05)</td>
<td>−0.90</td>
</tr>
<tr>
<td>IGT</td>
<td>−342 (619)</td>
<td>61 (812)</td>
<td>−2.21*</td>
</tr>
<tr>
<td>BART Block 1</td>
<td>971 (398)</td>
<td>922 (309)</td>
<td>0.55</td>
</tr>
<tr>
<td>BART Block 2</td>
<td>1035 (366)</td>
<td>1038 (301)</td>
<td>−0.04</td>
</tr>
</tbody>
</table>

Note: DMC 1 = applying decision rules; DMC 2 = under/overconfidence; IGT = Iowa gambling task; BART = balloon analog risk task.

* $p < .05$; ** $p < .01$ (based on independent $t$ tests).
5 sets of 20 card selections. Specifically, a 2 (group) $\times$ 5 (set) mixed ANOVA showed a significant main effect of group but a nonsignificant interaction between group and set ($F < 1$). It should also be noted that the observed group effect was mediated by level of education. Specifically, a Group $\times$ Session ANCOVA, with age, education, sex, and BDI as covariates, showed a nonsignificant main effect of group.

The BART data indicated similar overall levels of performance, with the ADHD group producing somewhat more pumps than the controls during the first block of the task. However, as shown in Table 3, this difference in mean number of pumps was not statistically significant. More detailed analyses of the data, decomposed into 3 sets of 10 trials within both blocks, indicated that the ADHD group took greater risks than the controls during the initial phase of the task. Specifically, as illustrated in Figure 1, the ADHD group took greater risks than the control group as measured by mean number of pumps during the first set. However, after being relatively cautious during the initial phase of the task, the controls increased their pumping frequency during the following sets. Finally, as shown in Figure 1, both groups adopted similar and relatively high pumping frequency when the task was repeated in Block 2.

A 2 (group) $\times$ 2 (block) $\times$ 3 (set) mixed ANOVA, with Block (Block 1 vs. Block 2) and Set (1-3) as within-subjects factors, confirmed these observations by revealing a significant three-way interaction among group, session, and test, $F(5, 310) = 4.58$, $p < .01$. Subsequent tests of simple effects indicated that this effect was attributed to a significant group difference during Set 1 of Block 1 ($p < .05$), with nonsignificant group differences during the remaining sets.

Taken together, these data suggest ADHD-related differences in risk taking in that participants in the control group were more cautious during the first 10 trials, but they increased risk taking to the same or even higher level than that of the ADHD group from the second set of trials. It should be noted that the same pattern of data was observed even when age, education, sex, and BDI were included as covariates in a mixed ANCOVA. Specifically, again the interaction was highly significant ($p < .01$), suggesting that a significant group difference in initial risk taking was observed even when (significant) differences in education and depression were taken into consideration.

Finally, we completed a logistic regression analysis to examine the power of the decision-making variables to predict ADHD status. In this analysis, age, education, sex, and BDI were used as covariates in the first block, followed by the four decision tasks in the second block. As can be seen in Table 4, DMC 1 was the only significant predictor of group status in this analysis. These results suggest that the applying-decision-rules component of the A-DMC battery is significant.

### Table 4. Summary of Logistic Regression Analysis Predicting ADHD Status

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>S.E.</th>
<th>Wald</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.02</td>
<td>0.04</td>
<td>0.17</td>
<td>0.98</td>
</tr>
<tr>
<td>Education</td>
<td>0.18</td>
<td>0.24</td>
<td>0.55</td>
<td>1.19</td>
</tr>
<tr>
<td>Gender</td>
<td>-0.05</td>
<td>0.81</td>
<td>0.01</td>
<td>0.96</td>
</tr>
<tr>
<td>BDI</td>
<td>-0.09</td>
<td>0.05</td>
<td>3.56**</td>
<td>0.92</td>
</tr>
<tr>
<td>BART</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
<td>1.00</td>
</tr>
<tr>
<td>IGT</td>
<td>0.01</td>
<td>0.01</td>
<td>1.81</td>
<td>1.01</td>
</tr>
<tr>
<td>DMC 1</td>
<td>9.53</td>
<td>3.81</td>
<td>6.27*</td>
<td>13739.11</td>
</tr>
<tr>
<td>DMC 2</td>
<td>-5.17</td>
<td>4.84</td>
<td>0.03</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Note: BDI = Beck Depression Inventory; DMC 1 = applying decision rules; DMC 2 = under/overconfidence; BART = balloon analog risk task; IGT = Iowa gambling task.

* $p < .01$. ** $p < .10$.
was the primary predictor of ADHD status even when differences in the background variables were taken into consideration.

**Discussion**

In this study, we examined decision-making competence in adults with ADHD. A more specific aim of the study was to examine whether adults with ADHD can be distinguished from healthy controls by their performance on decision tasks that are thought to differ in demands on cognitive versus affective decision processes. ADHD-related impairments in decision making might be selective in that they reflect deficits in either executive control functions or impairments in reward system regulation (that is usually assumed to be related with risk-taking behavior in laboratory and real-world scenarios). Alternatively, these effects might be general in that both cognitive and affective processes contribute to disadvantageous decision making in ADHD.

A central finding of the study was that ADHD was associated with impaired performance in some decision tasks. Although a majority of the ADHD participants were tested under medication (which should have reduced their problems in decision making and related higher cognitive functions), group differences were observed in three of the four decision tasks. Specifically, the ADHD group showed higher levels of risk taking than the healthy controls as measured by the IGT and BART. Participants in the ADHD group also made fewer advantageous choices in the IGT than participants in the control group. However, the two groups showed similar patterns of gambling behavior across the successive trials, and the overall group difference was mediated by formal education. In the BART task, the ADHD group showed a different pattern of gambling behavior than the controls with a higher level of initial risk taking. However, as indicated by the three-way interaction among group, set, and session, the two groups showed similar patterns of risk taking during the successive trials. Moreover, despite the higher level of initial risk taking in the BART, no significant difference emerged in the overall evaluation of risky decision-making performance between the ADHD group and the control group.

Taken together, the IGT and BART data suggest that ADHD is associated with increased levels of risk taking in decision making. However, it should be noted that the two tasks showed different patterns of gambling behavior with significant differences in the BART trials (but not in the IGT) even when level of education was included as a covariate. This result may indicate that the two tasks are based on different risk-taking processes and their underlying neural mechanisms (see also Ernst et al., 2003; Toplak et al., 2005). Consistent with this notion, the correlation between the two tasks was nonsignificant and close to zero (see also Lejuez et al., 2003; Skeel, Neudecker, & Pilarski, 2007, for similar findings). Furthermore, several studies suggest that BART (but not IGT) correlates with self-reported risk-taking behavior such as smoking, drug abuse, gambling, and stealing (Aklin et al., 2005; Lejuez et al., 2003; Skeel et al., 2007).

Task-specific differences in the payoff schedules might also contribute to these effects. For example, Weller, Levin, Shiv, and Bechara et al. (2007) suggested that decisions about potential gains and losses require different neural structures for advantageous choices. In their study, individuals with lesions to the amygdala, an area responsible for processing emotional responses, displayed impaired decision making when potential gains, rather than losses, were considered. In contrast, patients with damage to the ventromedial prefrontal cortex, an area responsible for integrating cognitive and emotional information, showed deficits in both domains. According to Weller et al. (2007) adaptive decision making for risks involving potential losses is more difficult to disrupt than decisions involving potential gains. Our findings were consistent with this notion in that ADHD was associated with more pronounced risk taking in the BART, which involves gains. By contrast, the IGT, which involves both gains and losses, showed weaker effects.

It should also be noted that the IGT, but not the BART, correlated positively with the DMC tasks. This result illustrates the process-impurity problem discussed earlier and suggests that the two tasks reflect a different mixture of decision processes. Relying on previous research, we might hypothesize that IGT depends more on cognitive control than the BART (see also Busemeyer & Stout, 2002).

Consistent with the hypothesis that ADHD is associated with impairments in prefrontally mediated executive control functions (Barkley, 1997; Sonuga-Barke, 2005), a significant group difference was observed in the applying-decision-rules (DMC 1) component of the A-DMC battery. By contrast, the under/overconfidence (DMC 2) task indicated that ADHD was not associated with impairments in knowledge calibration. Thus, in agreement with previous findings (Knouse, Paradise, & Dunlosky, 2006), ADHD status does not seem to have a clear influence on metacognitive judgments.

Finally, the applying-decision-rules task was the only significant predictor of group status when differences in the background variables were taken into consideration. This pattern of result should be interpreted with caution due to measurement limitations, but it suggests that impairments in high-level cognitive regulation may play a central role in ADHD-related decision problems. This notion is consistent with previous research showing that, in addition to having a good reliability and validity, the DMC 1 is the most cognitively demanding and “analytical” A-DMC task (Bruine de Bruin et al., 2007).
Furthermore, Del Missier et al. (in press) reported an individual-differences study in which they examined two decision-making tasks of the A-DMC battery in relation to three executive functions (updating, shifting, and inhibition) measured as latent variables in healthy young adults (see also Mäntylä et al., 2007; Miyake et al., 2000). A central finding of their study was that the decision-making tasks were selectively related to the components of executive functioning. In particular, inhibition appeared to play a significant role in the accurate implementation of decision rules, as measured by the DMC 1. Our findings are consistent with these selective effects in that the ADHD participants (who also showed problems of response inhibition in the Stroop task) had the greatest difficulties in the DMC 1 task. Specifically, group differences in decision-making performance might have been accentuated in the DMC 1 task because the ADHD participants had greater difficulties than the controls in keeping task-relevant information active by suppressing interfering or irrelevant information while completing the multiattribute choice task.

In general, the overall pattern of the present findings is consistent with the idea that inappropriate risk-taking and poor decision making in ADHD (and related reward deficiency syndromes; Blum et al., 2008) reflect problems in both deliberative and affective neurocognitive systems. Extending this hypothesis, our findings suggest that decision problems in ADHD reflect impairments in "cool" (rather than "hot") cognitive regulation.

The results of the present study should be interpreted with caution, but our findings may suggest interesting clinical implications. To the extent that specific cognitive control functions are required for the successful accomplishment of some decision-making tasks, training in these functions may improve aspects of decision-making performance. Thus, as noted by Del Missier et al. (in press), it would be interesting to examine the effects of training and rehabilitation of executive functions (e.g., Dahlin, Stigsdotter Neely, Larsson, Bäckman, & Nyberg, 2008; Olesen, Westerberg, & Klingberg, 2004) on decision making. These training effects might be especially valuable in individuals with executive and frontal problems, including children and adults with ADHD.

Two limitations of the present study need to be acknowledged. The first limitation is related to the medication state of our ADHD participants. Due to clinical restrictions, it was not possible to prevent medication during the test period. It is reasonable to assume that stimulant medication reduced ADHD-related symptoms in our study (De Vito et al., 2008; Spencer et al., 1995). Thus, our findings may actually underestimate the magnitude of ADHD-related impairments in decision making. The four decision tasks might also show a different pattern of predictor sensitivity for nonmedicated participants.

Another limitation of the present study resides in the number and type of decision-making tasks considered. As explained earlier, the four decision-making tasks were selected because they measure different dimensions of decision competence and are assumed to pose different demands on cognitive and affective processes. Moreover, the tasks used here are commonly used to assess decision-making competence and skills in research settings that are assumed to simulate everyday decision making. However, other judgment and decision-making tasks need to be considered by future research, which will hopefully enhance our understanding of decision-making competence in ADHD and related attentional disorders.

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Note
1. The DMC 1 score of this participant was only .20, which is inconsistent with his demographic background and performance on the other cognitive tasks, including the DMC 2 and Stroop tasks. Furthermore, separate analysis indicated that the exclusion of this data point did not change the overall pattern of results.

References


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