

# ADHD symptoms in non-treatment seeking young adults: relationship with other forms of impulsivity

Samuel R. Chamberlain,<sup>1,2</sup> Konstantinos Ioannidis,<sup>1,2</sup> Eric W. Leppink,<sup>3</sup>  
Faiza Niaz,<sup>1,2</sup> Sarah A. Redden,<sup>3</sup> and Jon E. Grant<sup>3\*</sup>

<sup>1</sup> Department of Psychiatry, University of Cambridge, Cambridge, UK

<sup>2</sup> Cambridge and Peterborough NHS Foundation Trust, Cambridge, UK

<sup>3</sup> Department of Psychiatry & Behavioral Neuroscience, University of Chicago, Chicago, Illinois, USA

**Objective.** Attention-deficit hyperactivity disorder (ADHD) has been associated with various manifestations of impulsivity in adults, including elevated rates of other impulsive disorders, substance use, questionnaire-based impulsivity scores, and inhibitory dysregulation on neurocognitive tests. The relationship between ADHD and all these other forms of impulsivity has yet to be explored within the context of a single comprehensive study.

**Methods.** A total of 423 young adults, who gambled  $\geq 5$  times in the preceding year, were recruited using media advertisements and undertook detailed assessment including structured psychiatric interview, questionnaires, and neurocognitive tests. Participants with ADHD symptoms were identified using the Adult ADHD Self-Report Scale Screener (ASRS-V1.1) and were compared to controls using multivariate analysis of variance (MANOVA).

**Results.** ADHD symptoms were found in 20.3% of the sample, but only 7.3% of these subjects had ever received a formal diagnosis. ADHD symptoms were associated with significantly lower quality of life, lower self-esteem, higher emotional dysregulation, higher impulsivity questionnaire scores, more problematic Internet use, greater occurrence of psychiatric disorders, and impaired stop-signal reaction times. Of these variables, stop-signal reaction times and Barratt attentional impulsiveness were the strongest predictors of group classification.

**Conclusions.** ADHD symptoms are common and under-diagnosed in young adults who gamble, and are most strongly linked with certain other types of impulsivity (questionnaire- and cognitive-based measures) and with emotional dysregulation, suggesting that these are each important considerations in understanding the pathophysiology of the disorder, but also potential treatment targets. It is necessary to question whether treatment for adult ADHD could be enhanced by considering self-esteem, emotional reactivity, and impaired inhibitory control as specific treatment targets, in addition to the core diagnostic symptoms of the disorder.

Received 14 July 2015; Accepted 30 September 2015; First published online 29 September 2016

**Key words:** ADHD, cognition, gambling, impulsivity, inhibition.

## Introduction

Attention-deficit hyperactivity disorder (ADHD) is a neuropsychiatric disorder characterized by impulsivity-hyperactivity and/or inattention, and marked functional

impairment.<sup>1</sup> ADHD is the most common psychiatric condition in children, and persists into adulthood in approximately 60% of cases.<sup>2</sup> Adult ADHD is associated with a variety of untoward consequences, including unemployment, criminality, interpersonal problems, and driving accidents.<sup>2–4</sup> The prevalence of ADHD in adults globally is estimated to be 3.4%, with some variability across geographical locations (range 1.2–7.3%),<sup>5</sup> but considerably higher rates have been reported in young adults. For example, one study in university students reported ADHD symptoms in 21.8% of the sample.<sup>6</sup>

ADHD is considered by many to represent an archetypal disorder of impulsivity, as impulsive behaviors are central to the diagnostic criteria and in terms of

\* Address for correspondence: Jon E. Grant, JD, MD, MPH, Professor, Department of Psychiatry & Behavioral Neuroscience, University of Chicago, Pritzker School of Medicine, 5841 S. Maryland Avenue, MC 3077, Chicago, IL 60637, USA.  
(Email: jongrant@uchicago.edu)

This study was funded by a Center in Research Excellence in Gambling grant from the National Center for Responsible Gaming (NCRG to Dr. Grant). Dr. Chamberlain's involvement in this research was supported by a grant from the Academy of Medical Sciences (AMS, UK).

understanding the disorder's pathophysiology.<sup>7</sup> The term impulsivity refers broadly to behaviors or acts that are inappropriate, premature, and that often result in undesired outcomes.<sup>8–10</sup> Thus, an individual with ADHD may be more prone to interrupting others or undertaking reckless acts without due consideration of the consequences. Impulsivity can also manifest in other ways, such as predisposition toward substance misuse (or higher frequency of substance use), co-occurrence with other disorders of impulsivity (eg, impulse control disorders), and impulsivity on self-report questionnaires and on neurocognitive tests. Despite its relative importance in ADHD phenomenology, only 3 out of 18 diagnostic symptoms are explicitly directed as assessing impulsivity in the current diagnostic and classification systems, and the full-blown disorder can be present despite the absence of all these 3 symptoms, both in children and adults.<sup>1</sup>

Studies conducted in adults with ADHD have found higher occurrence of substance use disorders (including alcohol) compared to control samples.<sup>2,11</sup> In a meta-analysis, 1 in 4 patients with a substance use disorder met criteria for comorbid ADHD.<sup>12</sup> Interestingly, some data indicate that cocaine use is associated with a lower rate of ADHD as compared to other drugs of abuse.<sup>13</sup>

In addition to substance use disorders, ADHD may also show comorbid overlap with other disorders relating to impulsivity.<sup>14</sup> Adolescents screening positive for ADHD had higher rates of gambling behavior and problem gambling,<sup>15</sup> and similar findings were reported in young adults longitudinally.<sup>16</sup> In a sample of adults with pathological/problem gambling, 1 in 4 reported a history of ADHD.<sup>17</sup> Internet addiction also appears to be strongly associated with ADHD.<sup>18</sup> In a meta-analysis, compulsive Internet use was associated with elevated risk of comorbid ADHD, with an odds ratio of 2.9.<sup>19</sup> In a survey of sexual behaviors and their consequences, elevated rates of ADHD were found in subjects with compulsive sexual behavior, as compared to those without.<sup>20</sup> ADHD has also been linked with eating disorders. One large-scale study reported that 5.7% of people with a lifetime diagnosis of ADHD had a lifetime diagnosis of bulimia nervosa, and the figure for binge-eating disorder was higher still at 9.3%.<sup>21</sup> It has been postulated that binge eating may represent a mediating “missing link” between co-occurring ADHD and obesity.<sup>22,23</sup>

Considerable research has been conducted in ADHD in relation to impulsivity as measured using self-report questionnaires and neuropsychological tasks. Of those questionnaires developed in order to quantify maladaptive impulsivity, the Barratt Impulsiveness Scale (BIS) is one of the most widely used.<sup>24,25</sup> Compared to controls, adults with ADHD typically show heightened scores on all 3 subscales of the BIS.<sup>26</sup> Similarly, while various cognitive tasks have been developed to explore impulsivity, the stop-signal task is one of the most widely used.<sup>27–29</sup>

Multiple meta-analyses confirm the existence of stop-signal inhibitory control deficits in patients with ADHD as compared to controls, albeit the majority of data are from clinical settings.<sup>30–32</sup> Studies in healthy controls indicate that Barratt impulsiveness and stop-signal impulsiveness are partially overlapping constructs.<sup>33,34</sup>

Adults with ADHD frequently experience difficulties in regulating their emotions.<sup>35</sup> Emotional dysregulation contributes to functional impairment in ADHD above and beyond impairment attributable to the core classic symptoms of hyperactivity-impulsivity and inattention.<sup>36</sup> Data from a study in ADHD sibling pairs indicated that ADHD plus emotional dysregulation may represent a familial subtype of the disorder.<sup>37</sup> In one adults study, 55% of ADHD patients showed emotional dysregulation that was of greater severity than >95% of control subjects.<sup>38,39</sup>

Much of the above research investigating relationships between ADHD and other aspects of impulsivity has tended to focus on restricted aspects rather than comprehensively examining a broad range of impulsive variables, using validated instruments, within the confines of a single study. This has made it difficult to ascertain those measures of impulsivity most strongly related with ADHD, and the inter-relationships between different types of impulsivity in this disorder.

Therefore, we quantified multiple types of impulsivity in young adults with ADHD symptoms recruited from the community compared to controls recruited from the same source using the same methodology. All participants gambled 5 times or more in the preceding year; hence this was an enriched sample for studying impulsivity. We hypothesized that ADHD symptoms would be associated with higher rates of impulse control disorders, substance use (alcohol and nicotine), problem gambling, problem Internet use, heightened questionnaire-based impulsivity scores, emotional dysregulation, and impaired response inhibition. We further predicted that heightened questionnaire-based impulsivity and cognitive impulsivity (stop-signal performance) would be particularly strongly related to ADHD symptoms.

## Methods

### Subjects

A total of 423 non-treatment-seeking young adults aged 18–29 years were recruited from the general community using media advertisements. The only inclusion criterion was that participants had gambled at least 5 times in the past year (ie, proxy for some level of baseline impulsive behavior); this nominal inclusion criterion was used, as the funding for this study was from the National Center for Responsible Gaming, and the research was conducted as part of a broader program focusing on gambling behaviors. Gambling was defined very broadly, as an

episode of putting something of value at risk in the hope of obtaining reward (adapted from Wilber and Potenza<sup>40</sup>). Large-scale U.S. studies suggest that around 70–80% of young adults gamble at least once in a given year.<sup>41,42</sup> According to the University of Calgary Addiction Behaviors Laboratory (Canada), 51% of males and 54% of females gamble more than 5 times per year (<http://www.addiction.ucalgary.ca>). Thus, our threshold of gambling 5 or more times per year is likely to be reasonably representative of most adults, but with some degree of sample enrichment.

Exclusion criteria were an inability to understand/undertake the procedures and an inability to provide written informed consent (or refusal of consent).

Individuals with ADHD symptoms were identified using the 6-item Adult ADHD Self Report Scale (ASRS v1.1) developed by the World Health Organization.<sup>2,43</sup> The ASRS 6-item screen was developed for community-based studies and exhibits strong concordance with clinician diagnoses as well as sound psychometric properties. For each item, the individual rated the frequency of a given difficulty or behavior (eg, difficulty wrapping up the final details of a project) on a scale of 0 (never) to 4 (very often) based on their experiences over the preceding 6 months. Each response of sometimes or greater (2 or more) on screening items 1–3 equated to 1 point; each response of often or greater (3 or more) on screening items 4–6 resulted in a point. A total score of 4 or more indicated that ADHD is highly likely. We therefore used this recommended definition to identify probable ADHD cases in our sample. Previous data suggest that this approach has a sensitivity of 68.7% and specificity of 99.5% for detection of true ADHD cases.<sup>2</sup>

Individuals with psychiatric and substance use comorbidity, as well as those taking psychotropic medications, were allowed to participate, since we wished this to be a naturalistic sample.

The Institutional Review Board of the University of Chicago approved the study, and all procedures were carried out in accordance with the Declaration of Helsinki. After an explanation of procedures, participants provided written informed consent, and were compensated with a \$50 gift card for a local department store after participation.

### *Clinical and cognitive assessments*

Psychiatric assessment included the Mini-International Neuropsychiatric Interview (MINI)<sup>44</sup> to identify major psychiatric disorders, the ASRS (described above) to identify ADHD symptoms, and the Minnesota Impulsive Disorders Interview<sup>45</sup> to screen for impulse control disorders (gambling disorder, trichotillomania, kleptomania, pyromania, intermittent explosive disorder, compulsive buying disorder, compulsive sexual

behavior, skin picking disorder, and binge eating disorder). As part of the interview, participants were asked about the number of alcoholic beverages they consumed per week, and the frequency of cigarette smoking (packs per day equivalent). Problem gambling behaviors were quantified using the Structured Clinical Interview for Gambling Disorder (SCI-GD; adapted from Grant *et al*<sup>46</sup> to consider *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition [DSM-5] gambling disorder) and problem Internet behaviors with Young's Internet Addiction Test.<sup>47</sup>

The Barratt Impulsivity Scale, Version 11 (BIS-11),<sup>25</sup> was used to measure personality facets relating to impulsivity: attentional impulsivity (inability to concentrate attention), motor impulsivity (acting without thinking), and non-planning impulsivity (being present in the moment, lack of future thinking). Quality of life was indexed using the Quality of Life Inventory (QOLI),<sup>48</sup> and self-esteem was assessed using the Rosenberg Self Esteem questionnaire (RSE).<sup>49</sup> We also included the Difficulties in Emotional Regulation Scale (DERS)<sup>50</sup> because problems regulating emotion are commonly implicated in the pathophysiology of ADHD.<sup>51</sup>

Neurocognitive testing was undertaken using the Cambridge Neuropsychological Test Automated Battery (CANTAB),<sup>52</sup> in a quiet testing room supervised by a trained assessor. We focused on response inhibition, working memory, and set-shifting, as these are commonly affected cognitive domains across clinical ADHD studies.<sup>8,53</sup>

Response inhibition was measured with the stop-signal task.<sup>54</sup> Participants observed a series of directional arrows appearing one per time on-screen, and made quick motor responses depending on the direction of each arrow (left button was pressed for a left arrow, and vice versa). On a minority of the trials, an auditory stop-signal occurred (a “beep”), which indicated to the participants that they should attempt to suppress their button press response for the given trial. By using a tracking algorithm, the task estimated the “stop-signal reaction time” for each subject, which is a measure of the average time taken to suppress a response that would normally be undertaken (longer values equated to worse inhibition control). Median reaction times for “go” trials were also recorded (longer values indicate relative psychomotor slowing).

On the Spatial Working Memory task,<sup>55</sup> participants attempted to locate tokens hidden underneath boxes on-screen while avoiding returning to boxes that previously yielded such tokens. The key outcome measure was the total number of errors made on the task, with higher scores equating to worse memory performance.

On the set-shifting task, for each trial 2 pictorial stimuli were displayed on-screen, and volunteers attempted to work out an underlying rule about which stimulus was “correct.” After making a choice, the computer provided feedback (“correct” or “incorrect”). Once the individual

had learned the underlying rule governing the correct stimulus, the rule was changed by the computer. The key outcome measure on the task was the number of errors made at the crucial extra-dimensional set-shifting stage, in which it was necessary to shift attention to a previously irrelevant stimulus dimension.

### Data analysis and power estimate

Salient demographic, clinical, and cognitive variables were tabulated for the 2 groups: ADHD symptom group and controls. We first considered whether these variables differed significantly between the groups overall using multivariate analysis of variance test (mANOVA). If this global test was significant, individual results were explored using follow-up ANOVA tests (or equivalent nonparametric tests were used as appropriate, where indicated in the text). Where significant group differences were found, effect sizes were reported (Cohen's D, or equivalent nonparametric statistic as indicated in the text).

Binary logistic regression was used to identify significant independent predictors of group classification (method "enter," probability for stepwise entry  $p = 0.05$ , removal  $p = 0.10$ , maximum iterations 20).

In secondary analysis, possible influences of gender on variables that differed significantly between ADHD

symptom group and controls were examined using t-tests (for each group, and in all subjects pooled). Statistical significance was defined as  $p < 0.05$ , 2-tailed, uncorrected.

Our original target sample size of 400 participants was based on the assumption of approximately 20% prevalence of ADHD symptoms in the general community; this would have yielded group sizes of 80 and 320, respectively. We calculated that such group sizes would yield >95% power to detect a statistically significant difference between groups on each measure of interest, assuming medium effect size (Cohen's D of 0.5 or greater), and  $\alpha = 0.05$  uncorrected, 2-tailed.

### Results

Demographic, clinical, and cognitive measures of the 2 groups are presented in Table 1. The composite MANOVA test was significant ( $p < 0.001$ ), indicating that the 2 groups differed significantly on these variables overall; post-hoc ANOVA tests are displayed. ADHD symptoms were identified in 20.3% of the total sample, and only 7 individuals (8.3%) within the ADHD symptom group had ever received a diagnosis of ADHD.

The ADHD symptom group did not differ from controls in terms of age, education, gender, problem gambling behaviors (SCI-GD), or amounts of nicotine

TABLE 1. Comparison of the study groups on demographic and clinical variables

Variable	ADHD symptoms (N = 86)	Controls (N = 337)	p-value	Effect size
Age, years	22.3 (3.7)	22.3 (3.6)	0.942	
Gender, male, N [%]	54 [62.8%]	213 [63.2%]	0.920c	
Education score #	3.3 (0.7)	3.3 (0.9)	0.662	
Quality of life t-score	42.7 (11.7)	46.9 (11.7)	0.003	-0.36 **
Problem gambling score (SCI-SG)	1.5 (2.0)	1.2 (1.8)	0.181	
Internet addiction score (IAT)	2.9 (2.0)	2.2 (2.1)	0.031	0.34 *
Alcohol consumption, drinks per week	1.5 (1.2)	1.3 (1.4)	0.360	
Nicotine consumption, packs per day (equivalent)	0.1 (0.3)	0.1 (0.3)	0.639	
Self-esteem (RSE) total score	20.2 (6.0)	22.4 (6.3)	0.005	-0.36 **
Emotional dysregulation (DERS) total score	81.1 (20.0)	71.3 (17.3)	<0.001	0.52 ***
Any current MINI psychiatric disorder, excepting impulse control disorders, N [%]	45 [52.3%]	109 [32.3%]	<0.001c	0.17 ***
Any current impulse control disorder, N [%] #	14 [16.3%]	33 [9.8%]	0.0875c	
BIS-11				
Attention	19.9 (3.9)	16.2 (3.9)	<0.001	0.95 ***
Motor	26.0 (5.1)	23.1 (4.7)	<0.001	0.59 ***
Non-planning	26.8 (4.4)	23.3 (5.6)	<0.001	0.70 ***

All scores are mean  $\pm$  SD unless otherwise noted. Statistic: ANOVAs except where indicated with "c" for chi-square. y: Yates' correction applied. Effect sizes are Cohen's D except for chi-square, which are phi.

# education scores: 1 = did not complete high school, 2 = high school graduate, 3 = some college, 4 = college graduate, 5 = beyond college level education. SCI-GD = Structured Clinical Interview for Gambling Disorder; IAT = Young's Internet Addiction Test; RSE = Rosenberg Self-Esteem scale; DERS = Difficulties in Emotional Regulation Scale; MINI = Mini International Neuropsychiatric Inventory; BIS-11 = Barratt Impulsivity Scale.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

MINI: The count N [%] of each type of disorder in the ADHD and control groups, respectively, were: any mood disorder: 6 [7.0%], 10 [3.0%]; any anxiety disorder: 10 [20.9%], 44 [13.1%]; any substance use disorder: 32 [37.2%], 60 [17.8%]; any eating disorder: 4 [4.7%], 7 [2.1%]. MID: The count N [%] of each disorder, in the ADHD and control groups, respectively, were: Compulsive buying disorder: 5 [5.8%], 14 [4.2%]; Kleptomania: 1 [1.2%], 0 [0%]; Trichotillomania: 0 [0%], 2 [0.6%]; Intermittent explosive disorder: 3 [3.5%], 6 [1.8%]; Pyromania: 0 [0%], 1 [0.3%]; Pathological gambling: 16 [18.6%], 64 [19%]; Compulsive sexual behavior: 5 [5.8%], 7 [2.1%]; Binge-eating disorder: 3 [3.5%], 4 [1.2%]; Skin picking disorder: 3 [3.5%], 3 [0.9%].

TABLE 2. Comparison of the study groups on cognitive variables

Variable	ADHD symptoms (N = 86)	Controls (N = 337)	p-value	Effect size	
SST SSRT	205.1 (78.1)	176.1 (58.0)	<0.001	0.42	***
SST median correct RT on GO trials	515.3 (196.9)	482.8 (176.4)	0.138		
SWM total errors	18.9 (18.4)	18.2 (19.1)	0.763		
IED ED errors	9.1 (9.7)	10.2 (9.9)	0.366		

All scores are mean  $\pm$  SD unless otherwise noted. Statistic: ANOVAs. Effect sizes are Cohen's D. SST = Stop Signal Task; SSRT = Stop-Signal Reaction Time; IDED = Intra-Dimensional/Extra-Dimensional Set-Shift Task; SWM = Spatial Working Memory task.  
\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

and alcohol consumed. Compared to controls, the ADHD symptom group showed significantly lower quality of life, lower self-esteem (RSE questionnaire), higher emotional dysregulation (DERS), more psychiatric disorders besides impulse control disorders, and higher questionnaire-rated impulsivity (Barratt questionnaire). The ADHD symptom group also had higher problem Internet use scores, albeit with marginal statistical significance. Although occurrence of 1 or more impulse control disorders was numerically higher in the ADHD symptom group, the difference versus controls did not obtain statistical significance.

In terms of neuropsychological test performance, the ADHD symptom group was impaired on stop-signal reaction times, but was intact on the other cognitive domains that were examined.

The logistic regression model was statistically significant (chi-square = 49.936,  $p < 0.001$ ); group status was significantly predicted by stop-signal reaction times ( $B = 0.221$ , Wald = 13.514,  $p < 0.001$ ), and Barratt attentional impulsivity ( $B = 0.005$ , Wald = 4.063,  $p = 0.044$ ). The classification model exhibited overall correct classification of 79.6%, with high specificity (94.6%) but limited sensitivity (34.7%).

Secondary analysis of variables that differed between the ADHD symptom group and controls (identified in Tables 1 and 2) indicated that there were no statistically significant effects of gender on these variables in either group (all  $p > 0.10$ ), nor in the whole study population (all  $p > 0.10$ ).

## Discussion

Despite ADHD symptoms being relatively common, the majority of studies exploring different types of impulsivity in relation to ADHD have focused on just 1 or 2 aspects of impulsivity. We explored the relationship between ADHD symptoms and various forms of impulsivity in a sample of young adults recruited from the general community, with controls also recruited using the same methodology. All participants were selected on the basis of gambling 5 or more times in the preceding year. The key findings were that ADHD symptoms were

significantly associated with worse quality of life, lower self-esteem, more emotional dysregulation, higher questionnaire-based measures of impulsivity (Barratt questionnaire), more psychiatric disorders (besides impulse control disorders), higher problem Internet use, and worse response inhibition. When binary logistic regression was used to identify independent predictors of group classification, stop-signal reaction times and Barratt attentional impulsiveness were significantly predictive variables, albeit the model displayed limited fit (high specificity but relatively low sensitivity).

Contrary to our expectations, ADHD symptoms were not significantly associated with higher rates of impulse control disorders, more problem gambling, or cognitive impairments in domains other than inhibitory control (working memory, set-shifting).

### Quality of life, self-esteem, and emotional dysregulation

The finding that the group with ADHD symptoms manifested lower quality of life than controls (small to medium effect size) confirms that our method of identifying this group was clinically meaningful, ie, the participants were significantly negatively impacted by the symptoms. Beyond the lower quality of life, the ADHD symptom group also showed lower self-esteem (small to medium effect size). Reduced self-esteem has been reported both in child/adolescent ADHD<sup>56,57</sup> and in adult patients,<sup>58</sup> recruited from clinical settings. Problems with self-esteem in ADHD play an important role in how these individuals adapt psychosocially in adolescence and in later life.<sup>58–61</sup> The association we found between emotional dysregulation and ADHD symptoms (medium effect size) supports the view that the former is an important component in understanding ADHD in adults.<sup>62</sup>

### Comorbidity, including with other impulsive symptom types

ADHD symptoms were associated with greater risk of psychiatric disorders in general as quantified by the MINI assessment, but with small effect size, and this appeared to have been mostly driven by substance use disorders, suicidality, and antisocial personality disorder (see



footer, Table 1), which are indeed common in clinical ADHD settings.<sup>2,63–66</sup> Interestingly, the ADHD symptom group showed higher occurrence of problem Internet use. Previous research has found that, in a sample of outpatients with Internet addiction, ADHD occurred in 14% of the sample.<sup>18</sup> Compulsive Internet use was associated with elevated risk of comorbid ADHD in a meta-analysis, with an odds ratio of 2.9.<sup>19</sup> Contrary to expectation,<sup>67</sup> however, our study groups did not differ on overall occurrence of impulse control disorders as indexed by the Minnesota Impulse Disorders Inventory (MIDI), nor in terms of problem gambling scores. This may in part reflect the relative scarcity of impulse control disorders, but could also suggest that relationships between ADHD symptoms and formal impulse control disorders are quite subtle in young adults recruited from the community.

### Questionnaire and cognitive types of impulsivity

Questionnaire-based composite measures of impulsivity and compulsivity are useful in that they are quick to administer, convenient, and well-suited for population based studies. We found that ADHD symptoms were associated with higher scores on all 3 subscales of the BIS, with medium to large effect sizes. Consistent with our data, elevated BIS scores have been previously documented in ADHD.<sup>26</sup>

The identification of impaired response inhibition in people with ADHD (small to medium effect size) accords well with previous meta-analyses, which reported impaired response inhibition across ADHD clinical studies.<sup>32,68</sup> Weak relationships have been found between neuropsychological functioning and severity of ADHD symptoms.<sup>69,70</sup> Our findings suggest that impaired response inhibition extends to individuals with ADHD symptoms who have not generally sought treatment, likely reflecting the milder end of the disease spectrum. Stop-signal impairment represents a particularly promising cognitive marker for ADHD risk,<sup>71</sup> given that other cognitive domains we assessed (working memory, set-shifting) were intact in our sample. Impaired response inhibition appears to represent a trait marker for ADHD, which is significantly heritable,<sup>72</sup> rather than being particularly related to current symptom severity. Response inhibition is dependent on the integrity of neural circuitry, including the right inferior frontal gyrus and anterior cingulate cortex.<sup>54</sup> Patients with ADHD show hypoactivation of fronto-striatal circuitry when undertaking functional imaging versions of such inhibitory control tasks.<sup>73,74</sup>

### Limitations

While this study has positive features, such as inclusion of a broad set of impulsivity measures and the use of a

community sample, several limitations should be considered. All participants were recruited on the basis of gambling 5 or more times in the preceding year according to self-report. While it could be argued that our findings may not therefore generalize to the background population, it is likely that the majority of individuals in the background population gamble at least 5 times or more per year (see <http://www.addiction.ucalgary.ca>), and so we believe our sample, while somewhat enriched in terms of impulsivity, is informative. We intentionally focused on ADHD symptoms rather than formally diagnosed ADHD. It should be noted that the clinical diagnosis of ADHD requires detailed assessment, including use of gold-standard measures besides the ASRS. As such, our results may differ from those found in formally diagnosed patients, who are likely to present with a more severe form of pathology, and hence may well present with higher rates of psychiatric comorbidities, including impulse control disorders and substance use, than observed here. According to previous data, the method we utilized of identifying ADHD symptoms detects true ADHD cases with around 68.7% sensitivity and 99.5% specificity.<sup>2</sup> Thus, while nearly all of the “ADHD symptom” group would have been expected to actually have ADHD, some cases of underlying clinical ADHD would have been overlooked and included in the control group. Missed cases in the control group are likely to be on the lesser severity end of the spectrum, and this is also supported by Kessler *et al.*,<sup>3</sup> where those cases that screened positive on ASRS were likely to have a higher average symptom severity score compared to those who scored negative. This being an exploratory study, and based on our a priori power calculation, we did not correct our findings for multiple comparisons; as such, replication studies would be warranted before firm conclusions are drawn. That being said, the overall composite MANOVA test was highly significant, and the majority of significant group differences would have survived correction for multiple comparisons. While our sample size had >95% power to detect a statistically significant difference between study groups of medium (0.5) or greater effect size, the ability to detect smaller effects would have been more limited. We did not record current medication usage, eg, stimulants; however, the overwhelming majority of subjects with ADHD symptoms in our study (91.7%) had never been diagnosed for ADHD, and therefore is unlikely to have been receiving treatment for their symptoms. Last, we did not record information about neurological symptoms or history of head trauma.

### Conclusion

In summary, self-report ADHD symptoms appear to be very common in young adults who gamble 5 or more

times per year, and are associated with highly specific cognitive impairment in terms of inhibitory dyscontrol, higher than expected questionnaire-based impulsivity scores, and high emotional dysregulation, along with increased prevalence of Axis I disorders in general. The majority of people with these ADHD symptoms by self-report had never received a formal diagnosis; in part, this will reflect “false positives” of this method of ADHD screening, but it is also likely that many cases of clinically significant ADHD are being overlooked. Future work should further evaluate the functional consequences of these findings relating to impulsivity longitudinally, and consider whether the specificity and sensitivity of ADHD screening instruments could be improved by incorporating cognitive or questionnaire measures. It would also be important for future studies to confirm the generalizability of these findings, and to further explore the impact of ADHD treatments<sup>75</sup> on domains of emotional dysregulation, self-esteem, and inhibitory control, as these aspects of ADHD are not well-reflected in the current core diagnostic criteria of the disorder.

## Disclosures

Jon Grant has the following disclosures: Brainsway, researcher, research support; Forest, independent investigator, research support; Roche, researcher, research support; NCRG, independent investigator, research support. Samuel Chamberlain consults for Cambridge Cognition. Konstantinos Ioannidis, Eric Leppink, Faiza Niaz, and Sarah Redden do not have anything to disclose.

## REFERENCES:

- American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*, 5th ed. Washington, DC: American Psychiatric Association; 2013.
- Kessler RC, Adler L, Ames M, et al. The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. *Psychol Med*. 2005; **35**(2): 245–256.
- Kessler RC, Adler L, Barkley R, et al. The prevalence and correlates of adult ADHD in the United States: results from the National Comorbidity Survey Replication. *Am J Psychiatry*. 2006; **163**(4): 716–723.
- Nigg JT. Attention-deficit/hyperactivity disorder and adverse health outcomes. *Clin Psychol Rev*. 2013; **33**(2): 215–228.
- Fayyad J, De Graaf R, Kessler R, et al. Cross-national prevalence and correlates of adult attention-deficit hyperactivity disorder. *Br J Psychiatry*. 2007; **190**(5): 402–409.
- Atwoli L, Owiti P, Manguro G, Ndambuki D. Self-reported attention deficit and hyperactivity disorder symptoms among university students in Eldoret, Kenya. *East Afr Med J*. 2010; **87**(5): 187–191.
- Barkley RA. Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychol Bull*. 1997; **121**(1): 65–94.
- Chamberlain SR, Sahakian BJ. The neuropsychiatry of impulsivity. *Curr Opin Psychiatry*. 2007; **20**(3): 255–261.
- Daruna JH, Barnes PA. A neurodevelopmental view of impulsivity. In: McCown WG, Johnson JL, Shure MD, eds. *The Impulsive Client: Theory, Research, and Treatment*. Washington, DC: American Psychological Association; 1993: 23–37.
- Moeller FG, Barratt ES, Dougherty DM, Schmitz JM, Swann AC. Psychiatric aspects of impulsivity. *Am J Psychiatry*. 2001; **158**(11): 1783–1793.
- Vingilis E, Mann RE, Erickson P, et al. Attention deficit hyperactivity disorder, other mental health problems, substance use, and driving: examination of a population-based, representative Canadian sample. *Traffic Inj Prev*. 2014; **15**(Suppl 1): S1–S9.
- van Emmerik-van Oortmerssen K, van de Glind G, van den Brink W, et al. Prevalence of attention-deficit hyperactivity disorder in substance use disorder patients: a meta-analysis and meta-regression analysis. *Drug Alcohol Depend*. 2012; **122**(1–2): 11–19.
- van Emmerik-van Oortmerssen K, Crunelle CL, Carpentier PJ. Substance use disorders and ADHD: an overview of recent Dutch research. *Tijdschr Psychiatr*. 2013; **55**(11): 861–866.
- Kooij JJ, Huss M, Asherson P, et al. Distinguishing comorbidity and successful management of adult ADHD. *J Atten Disord*. 2012; **16**(5 Suppl): 3S–19S.
- Faregh N, Derevensky J. Gambling behavior among adolescents with attention deficit/hyperactivity disorder. *J Gambl Stud*. 2011; **27**(2): 243–256.
- Breyer JL, Botzet AM, Winters KC, Stinchfield RD, August G, Realmuto G. Young adult gambling behaviors and their relationship with the persistence of ADHD. *J Gambl Stud*. 2009; **25**(2): 227–238.
- Grall-Bronnec M, Wainstein L, Augy J, et al. Attention deficit hyperactivity disorder among pathological and at-risk gamblers seeking treatment: a hidden disorder. *Eur Addict Res*. 2011; **17**(5): 231–240.
- Bernardi S, Pallanti S. Internet addiction: a descriptive clinical study focusing on comorbidities and dissociative symptoms. *Compr Psychiatry*. 2009; **50**(6): 510–516.
- Carli V, Durkee T, Wasserman D, et al. The association between pathological internet use and comorbid psychopathology: a systematic review. *Psychopathology*. 2013; **46**(1): 1–13.
- Odlaug BL, Lust K, Schreiber LR, et al. Compulsive sexual behavior in young adults. *Ann Clin Psychiatry*. 2013; **25**(3): 193–200.
- Kessler RC, Berglund PA, Chiu WT, et al. The prevalence and correlates of binge eating disorder in the World Health Organization World Mental Health Surveys. *Biol Psychiatry*. 2013; **73**(9): 904–914.
- Cortese S, Isnard P, Dalla Bernardina B, Mouren MC. Attention-deficit/hyperactivity disorder, binge eating, and obesity. *J Clin Psychiatry*. 2007; **68**(6): 976.
- Cortese S, Castellanos FX. The relationship between ADHD and obesity: implications for therapy. *Expert Rev Neurother*. 2014; **14**(5): 473–479.
- Congdon E, Canli T. A neurogenetic approach to impulsivity. *J Pers*. 2008; **76**(6): 1447–1484.
- Patton JH, Stanford MS, Barratt ES. Factor structure of the Barratt impulsiveness scale. *J Clin Psychol*. 1995; **51**(6): 768–774.
- Malloy-Diniz L, Fuentes D, Leite WB, Correa H, Bechara A. Impulsive behavior in adults with attention deficit/hyperactivity disorder: characterization of attentional, motor and cognitive impulsiveness. *J Int Neuropsychol Soc*. 2007; **13**(4): 693–698.
- Winstanley CA, Eagle DM, Robbins TW. Behavioral models of impulsivity in relation to ADHD: translation between clinical and preclinical studies. *Clin Psychol Rev*. 2006; **26**(4): 379–395.
- Aron AR, Robbins TW, Poldrack RA. Inhibition and the right inferior frontal cortex: one decade on. *Trends Cogn Sci*. 2014; **18**(4): 177–185.
- Logan GD, Cowan WB, Davis KA. On the ability to inhibit simple and choice reaction time responses: a model and a method. *J Exp Psychol Hum Percept Perform*. 1984; **10**(2): 276–291.

30. Alderson RM, Rapport MD, Sarver DE, Kofler MJ. ADHD and behavioral inhibition: a re-examination of the stop-signal task. *J Abnorm Child Psychol*. 2008; **36**(7): 989-998.
31. Lijffijt M, Kenemans JL, Verbaten MN, van Engeland H. A meta-analytic review of stopping performance in attention-deficit/hyperactivity disorder: deficient inhibitory motor control? *J Abnorm Psychol*. 2005; **114**(2): 216-222.
32. Lipszyc J, Schachar R. Inhibitory control and psychopathology: a meta-analysis of studies using the stop signal task. *J Int Neuropsychol Soc*. 2010; **16**(6): 1064-1076.
33. Aichert DS, Wöstmann NM, Costa A, et al. Associations between trait impulsivity and prepotent response inhibition. *J Clin Exp Neuropsychol*. 2012; **34**(10): 1016-1032.
34. Broos N, Schmaal L, Wiskerke J, et al. The relationship between impulsive choice and impulsive action: a cross-species translational study. *PLoS One*. 2012; **7**(5): e36781.
35. Corbisiero S, Stieglitz RD, Retz W, Rösler M. Is emotional dysregulation part of the psychopathology of ADHD in adults? *Atten Defic Hyperact Disord*. 2013; **5**(2): 83-92.
36. Barkley RA, Fischer M. The unique contribution of emotional impulsiveness to impairment in major life activities in hyperactive children as adults. *J Am Acad Child Adolesc Psychiatry*. 2010; **49**(5): 503-513.
37. Surman CB, Biederman J, Spencer T, et al. Deficient emotional self-regulation and adult attention deficit hyperactivity disorder: a family risk analysis. *Am J Psychiatry*. 2011; **168**(6): 617-623.
38. Surman CB, Biederman J, Spencer T, Miller CA, McDermott KM, Faraone SV. Understanding deficient emotional self-regulation in adults with attention deficit hyperactivity disorder: a controlled study. *Atten Defic Hyperact Disord*. 2013; **5**(3): 273-281.
39. Surman CB, Biederman J, Spencer T, Miller CA, Petty CR, Faraone SV. Neuropsychological deficits are not predictive of deficient emotional self-regulation in adults with ADHD. *J Atten Disord*. 2015; **19**(12): 1046-1053.
40. Wilber MK, Potenza MN. Adolescent gambling: research and clinical implications. *Psychiatry (Edgmont)*. 2006; **3**(10): 40-48.
41. Barnes GM, Welte JW, Hoffman JH, Tidwell MC. Gambling, alcohol, and other substance use among youth in the United States. *J Stud Alcohol Drugs*. 2009; **70**(1): 134-142.
42. Welte JW, Barnes GM, Wieczorek WF, Tidwell MC, Parker J. Gambling participation in the U.S.—results from a national survey. *J Gamb Stud*. 2002; **18**(4): 313-337.
43. Rösler M, Retz W, Thome J, Schneider M, Stieglitz RD, Falkai P. Psychopathological rating scales for diagnostic use in adults with attention-deficit/hyperactivity disorder (ADHD). *Eur Arch Psychiatry Clin Neurosci*. 2006; **256**(Suppl 1): i3-11.
44. Sheehan DV, Lecrubier Y, Sheehan KH, et al. The Mini-International Neuropsychiatric Interview (M.I.N.I.): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *J Clin Psychiatry*. 1998; **59**(Suppl 20): 22-33.
45. Grant JE. *Impulse Control Disorders: A Clinician's Guide to Understanding and Treating Behavioral Addictions*. W.W. Norton and Company New York; 1993.
46. Grant JE, Steinberg MA, Kim SW, Rounsaville BJ, Potenza MN. Preliminary validity and reliability testing of a structured clinical interview for pathological gambling. *Psychiatry Res*. 2004; **128**(1): 79-88.
47. Young KS. Internet addiction: the emergence of a new clinical disorder. *CyberPsychology and Behavior*. 1998; **1**(3): 237-244.
48. Frisch MB, Clark MP, Rouse SV, et al. Predictive and treatment validity of life satisfaction and the quality of life inventory. *Assessment*. 2005; **12**(1): 66-78.
49. Rosenberg M. *Society and the Adolescent Self-Image*. Princeton, NJ: Princeton University Press; 1965.
50. Gratz KL, Roemer L. Multidimensional assessment of emotion regulation and dysregulation: development, factor structure, and initial validation of the difficulties in emotion regulation scale. *Journal of Psychopathology and Behavioral Assessment*. 2004; **26**(1): 41-54.
51. Shaw P, Stringaris A, Nigg J, Leibenluft E. Emotion dysregulation in attention deficit hyperactivity disorder. *Am J Psychiatry*. 2014; **171**(3): 276-293.
52. Cambridge Cognition Limited. *CANTABclipse* version 3. Cambridge, UK: Cambridge Cognition Limited; 2006.
53. Willcutt EG, Doyle AE, Nigg JT, Faraone SV, Pennington BF. Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. *Biol Psychiatry*. 2005; **57**(11): 1336-1346.
54. Aron AR, Robbins TW, Poldrack RA. Inhibition and the right inferior frontal cortex. *Trends Cogn Sci*. 2004; **8**(4): 170-177.
55. Owen AM, Downes JJ, Sahakian BJ, Polkey CE, Robbins TW. Planning and spatial working memory following frontal lobe lesions in man. *Neuropsychologia*. 1990; **28**(10): 1021-1034.
56. Kurman J, Rothschild-Yakar L, Angel R, Katz M. How good am I? Implicit and explicit self-esteem as a function of perceived parenting styles among children with ADHD. *J Atten Disord*. In press.
57. Yen CF, Chou WJ, Liu TL, Yang P, Hu HF. The association of Internet addiction symptoms with anxiety, depression and self-esteem among adolescents with attention-deficit/hyperactivity disorder. *Compr Psychiatry*. 2014; **55**(7): 1601-1608.
58. Cook J, Knight E, Hume I, Qureshi A. The self-esteem of adults diagnosed with attention-deficit/hyperactivity disorder (ADHD): a systematic review of the literature. *Atten Defic Hyperact Disord*. 2014; **6**(4): 249-268.
59. Newark PE, Elsässer M, Stieglitz R. Self-esteem, self-efficacy, and resources in adults with ADHD. *J Atten Disord*. In press. DOI: 10.1177/1087054712459561.
60. Shaw-Zirt B, Popali-Lehane L, Chaplin W, Bergman A. Adjustment, social skills, and self-esteem in college students with symptoms of ADHD. *J Atten Disord*. 2005; **8**(3): 109-120.
61. Slomkowski C, Klein RG, Mannuzza S. Is self-esteem an important outcome in hyperactive children? *J Abnorm Child Psychol*. 1995; **23**(3): 303-315.
62. Villemonteix T, Purper-Ouakil D, Romo L. Is emotional dysregulation a component of attention-deficit/hyperactivity disorder (ADHD)? *Encephale*. 2015; **41**(2): 108-114.
63. Edwards AC, Kendler KS. Twin study of the relationship between adolescent attention-deficit/hyperactivity disorder and adult alcohol dependence. *J Stud Alcohol Drugs*. 2012; **73**(2): 185-194.
64. Impey M, Heun R. Completed suicide, ideation and attempt in attention deficit hyperactivity disorder. *Acta Psychiatr Scand*. 2012; **125**(2): 93-102.
65. Sundquist J, Ohlsson H, Sundquist K, Kendler KS. Attention-deficit/hyperactivity disorder and risk for drug use disorder: a population-based follow-up and co-relative study. *Psychol Med*. 2015; **45**(5): 977-983.
66. Wilens TE, Upadhyaya HP. Impact of substance use disorder on ADHD and its treatment. *J Clin Psychiatry*. 2007; **68**(8): e20.
67. Subramaniam M, Wang P, Soh P, et al. Prevalence and determinants of gambling disorder among older adults: a systematic review. *Addict Behav*. 2015; **41**C: 199-209.
68. Chamberlain SR, Robbins TW, Winder-Rhodes S, et al. Translational approaches to frontostriatal dysfunction in attention-deficit/hyperactivity disorder using a computerized neuropsychological battery. *Biol Psychiatry*. 2011; **69**(12): 1192-1203.
69. Barkley RA, Fischer M. Predicting impairment in major life activities and occupational functioning in hyperactive children



- as adults: self-reported executive function (EF) deficits versus EF tests. *Dev Neuropsychol.* 2011; **36**(2): 137-161.
70. Barkley RA, Murphy KR. Impairment in occupational functioning and adult ADHD: the predictive utility of executive function (EF) ratings versus EF tests. *Arch Clin Neuropsychol.* 2010; **25**(3): 157-173.
71. Wodushek TR, Neumann CS. Inhibitory capacity in adults with symptoms of attention deficit/hyperactivity disorder (ADHD). *Arch Clin Neuropsychol.* 2003; **18**(3): 317-330.
72. Crosbie J, Arnold P, Paterson A, et al. Response inhibition and ADHD traits: correlates and heritability in a community sample. *J Abnorm Child Psychol.* 2013; **41**(3): 497-507.
73. Morein-Zamir S, Dodds C, van Harteveld TJ, et al. Hypoactivation in right inferior frontal cortex is specifically associated with motor response inhibition in adult ADHD. *Hum Brain Mapp.* 2014; **35**(10): 5141-5152.
74. Sebastian A, Gerdes B, Feige B, et al. Neural correlates of interference inhibition, action withholding and action cancelation in adult ADHD. *Psychiatry Res.* 2012; **202**(2): 132-141.
75. Knouse LE, Safren SA. Current status of cognitive behavioral therapy for adult attention-deficit hyperactivity disorder. *Psychiatr Clin North Am.* 2010; **33**(3): 497-509.