A Context for Normalizing Impulsiveness at Work for Adults with Attention Deficit/Hyperactivity Disorder (Combined Type)

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Abstract

Impaired executive function and impulsiveness or intolerance to boredom in adult attention deficit/hyperactivity disorder (ADHD) are thought to compromise performance at work. Several task parameters help people with ADHD to perform better on computerized cognitive tasks, namely reduced response-to-stimulus interval, discriminative feedback, or a format resembling a videogame. However, still very little is known about how these contexts might be helpful in a real work environment. We developed a computerized task resembling a fast-paced videogame with no response-to-stimulus interval and constant and diverse discriminative error feedback. The task included several measurements of high-order executive function (planning, working memory, and prospective memory) formatted as a single multitask simulating occupational activities (SOA). We also administered the Continuous Performance Test-II (CPT-II), a very simple vigilance task without discriminative feedback and with long response-to-stimulus intervals. We tested 30 adults answering to DSM-IV criteria of ADHD (combined type) and 30 IQ-matched adults without ADHD. As has been reported many times, the ADHD participants made significantly more errors of commission than the control participants on the CPT-II, whereas the two groups made the same number of errors of commission on the SOA. The ADHD group also sought discriminative feedback significantly more actively on the SOA than the control group and performed at par with the control group in all respects. There was no speed/accuracy trade-off, nor was there any evidence of other costs of normalization on the SOA. Impulsiveness in adult ADHD is compensable on a task simulating the work environment.

Keywords: Adult ADHD; Executive functions; Videogame; Motivational; Incidental retrospective memory; Errors of commission

Introduction

Adults with attention deficit/hyperactivity disorder (ADHD) have behavioral problems which compromise activities of daily living (ADL) including in family life, at school, while driving and at work (Barkley, 1997; Faraone et al., 2000; Mannuzza, Klein, & Bessler, 1993; Weiss & Hechtman, 1993). These problems of ADL may be at least partly due to brain anomalies measurable with neuropsychological tests (Parsons, Bowerly, Galen, & Rizzo, 2006). Three neuropsychological models of ADHD have been proposed by Nigg (2001).

The Dorsolateral Prefrontal/Dysexecutive Model of ADHD

Tasks of high-order executive function are failed by people with ADHD (Castellanos, Patti, Sharp, & Jeffries, 2002; Filipek et al., 1997; Hesslinger et al., 2002). Adults with ADHD present problems on specific high-order executive functions such as planning, measured, for example, by script generation tasks (Braun et al., 2004; Desjardins, Scherzer, Braun, Godbout, & Poissant, 2010), and working memory (Gallagher & Blader, 2001; Jenkins, Cohen, Malloy, Salloway, & Johnson, 1998; Kovner, Budman, Frank, Sison, & Lesser, 1998). While it is known that prospective memory is impaired in juvenile
ADHD (Clark, Prior, & Kinsella, 2000; Kerns & Price, 2001; Kliegel, Ropeter, & MacKinlay, 2006; Siklos & Kerns, 2004), it remains unknown whether this is the case in adult ADHD.

There is evidence, albeit limited, that poor working memory is specifically related to dysfunction of the dorsolateral prefrontal cortex in ADHD (Mehta et al., 2000; Oleson, Westerberg, & Klingberg, 2003).

**The Orbitofrontal/Disinhibition Model of ADHD**

Behavioral impulsivity or failure of inhibition has been proposed as the core impairment in ADHD (Rubia, 2002). An impairment of inhibition has been amply demonstrated in adult ADHD, operationalized as errors of commission on various tasks. High rates of such errors of commission have been observed in adult ADHD on the Continuous Performance Test-II (CPT-II) (Boonstra, Kooij, Oosterlaan, Sergeant, & Buitelaar, 2005; Malloy-Diniz, Fuentes, Leitem, Correa, & Bechara, 2007), stop tasks (Chhabildas, Pennington, & Willcutt, 2001), and go/no go tasks (Iaboni, Douglas, & Baker, 1995; Tucha et al., 2009). Resistance to impulsivity is not seen as a high-order or effort-demanding executive function, though it can be observed in that context as well (Nigg, 2001).

There is evidence that impulsivity is specifically caused by dysfunction of orbitofrontal cortex in ADHD, including in adults (Casey et al., 1997; Dibbets, Evers, Hurks, Marchetta, & Jolles, 2009; Durston, Mulder, Casey, Ziemans, & vanEngeland, 2006; Itami & Uno, 2002; Konrad et al., 2010; Ströhle et al., 2008).

**The Striatal-Dopaminergic Motivational Model of ADHD**

Tasks measuring impulsiveness (vigilance tasks, stop tasks, go/no go tasks) sensitive to ADHD are usually quite artificial, monotonous, slow paced, and do not provide feedback about ongoing performance. However, even tasks of high-order executive function, failed by people with ADHD, can also be so characterized (see Desjardins et al., 2010, for an opinion to that effect). In conformity with this viewpoint, a “motivational” or “energetics” theory of ADHD posits that the frontostriatal dopaminergic reward system is sparse in ADHD (Durston, 2003) and that this impairment becomes manifest on complex tasks (Phillips, Ahn, & Floresco, 2004) or on menial tasks, indifferently—on condition that they be unmotivating for people with ADHD (Sonuga-Barke, 2005). Adults with ADHD readily recognize their susceptibility to boredom as a problem (Kass, Wallace, & Vodanovich, 2003).

This susceptibility to boredom of people with ADHD has been operationalized as an intolerance to delay of reward in juvenile and adult ADHD (Barley, Edwards, Laneri, Fletcher, & Meteiva, 2001; Luman, Oosterlaan, & Sergeant, 2005; Plichta et al., 2009; Scheres et al., 2006; Tripp & Alsop, 2001).

Effective feedback in ADHD can consist of reward, money or food, for example (Drechsler, Rizzo, & Steinhausen, 2010), but need not be so. It can consist simply of immediate information clearly indicating that an error has occurred (Kohls, Herpertz-Dahlmann, & Konrad, 2009). Long response-to-stimulus intervals on vigilance tasks provoke errors of commission in adult ADHD and this commissiveness can be normalized with short response-to-stimulus intervals (Wiersema, Van der Meere, Roevers, Van Coster, & Baeyens, 2006). The dopaminergic reward circuit is inordinately primed in ADHD by a videogame environment (Han, Lee, Na, Ahn, & Chung, 2009). Children with ADHD are inordinately attracted to videogames and are more often compulsive players (Chan & Rabinowitz, 2006). They are also as good at playing videogames as matched participants without ADHD despite the usual difficulties on the CPT-II (Shaw, Grayson, & Lewis, 2005). It is still unclear which aspect of the videogame setting is motivating for people with ADHD. Factors could include diversity of cognitive operations solicited, a brisk pace of change, brief response-to-stimulus intervals, playfulness of the setting, a sense of competition, intensive discriminative feedback concerning ongoing performance, or diversity of that feedback.

Striatal dopamine networks are heavily engaged in reward in humans (Schott et al., 2008). Methylphenidate is thought effective in ADHD because it is thought to normalize the hypodopaminergic-driven motivational fragility of people with ADHD, specifically in the striatum (Krause, Dresel, Krause, Kung, & Tatsch, 2000; Volkow, Wang, Fowler, & Ding, 2005; Wilkinson, Kircher, McMahon, & Sloane, 1995).

Altogether, these findings indicate that people with ADHD have low tolerance for unmotivating tasks. Little is known however about how this translates to performance at work. In a study on adults with ADHD, Biederman and colleagues (2005) measured a series of performances in a simulated workplace. Curiously, they found several significant impairments of the ADHD group compared with the comparison group, but not in the attentional domain. It thus seems important to start modeling the work environment in the laboratory to determine which components of occupational settings would be disadvantageous or favorable to people with ADHD in the domain of their core symptoms. It appeared relevant to us to attempt to establish that it is possible to simulate a global work environment optimized for good performance of adult ADHD.
Method

Participants

Adults with ADHD (combined type only) were sought among parents of juveniles being treated for ADHD in a psychiatric hospital, in self-help groups of parents of ADHD children, and physicians and clinical neuropsychologists specialized in the diagnosis and/or treatment of adult ADHD. Adults without ADHD (of any kind) were targeted for recruitment among the same network and spouses of the ADHD candidates, as well as public advertisements. All participants received $10.00 CAN and signed a consent form authorized by the Rivieres-des-Prairies Psychiatric Hospital (Montreal).

Inclusion criteria into the study were (1) being 18 years old or more, (2) not meeting any of the DSM-IV exclusion criteria for ADHD, namely a pervasive developmental disorder, a psychotic disorder, and a personality disorder, (3) normal reading ability (an ability required to complete the experimental task) on the Griffin dyslexia test (Griffin, Walton, & Ward, 1998), (4) absence of a neurological condition (e.g., tumor, epilepsy, head injury, etc.), (5) an IQ of 85 or more on the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), this level being judged necessary for validly completing the experimental task, (6) absence of an alcohol or drug abuse problem, and (7) absence of a learning disability (based on questions to that effect concerning such a diagnosis by the school system or a practitioner, normal performance on the reading test, and normal performance on the “numerical operations” subscale of the Wechsler Individual Achievement Test-II).

Recruitment of the ADHD participants required that they (1) answer to the inclusion criteria based on a biographical questionnaire followed up by questioning during and after psychometric testing, (2) answer to DSM-IV criteria of ADHD (combined type) based on the semi-structured interview, (3) obtain a score of 1.5 SD or more on at least one of the following scales of the Conners’ Adult ADHD Rating Scales (CAARS), self-completed or completed by a knowledgeable respondent: Impulsivity, Hyperactivity, or Total hyperactivity index. The semi-structured interview, designed by us to maximally enable and validate the DSM-IV diagnosis of ADHD, lasted approximately 30 min. Following the recommendations of Johnston (2002) and Weiss and Weiss (2004) for semi-structured interviewing for adult ADHD, it extensively probed repositories of schooling, social life, and professional life in youth and adulthood (see Delisle, 2011, for more details). The semi-structured interview, all testing of participants, and the diagnosis of ADHD were carried out by a certified licensed practicing clinical neuropsychologist.

Matching of the two groups, ADHD and normals, required that their full-scale IQ, education, revenue, and gender not differ. Seventeen participants who had met initial inclusion criteria for ADHD had to be excluded after completion of testing because they did not meet all the inclusion criteria or because they distorted matching criteria. This report bears on the remaining 14 women and 16 men in each group. All participants using stimulant medication for ADHD (N = 7) accepted to abstain from that medication for at least 24 h prior to testing (Table 1).

Anxiety or mood disorder were not exclusion criteria, but were estimated with the Beck anxiety (BAI) and the Beck depression inventories (BDI) (Freestone, Ladouceur, Thibodeau, Gagnon, & Rheaume, 1994) in view of statistical processing (Table 2).

The CAARS is an abridged self-report or respondent-report scale of ADHD which has been found valid for clinical characterization of ADHD in adults (Riccio & Reynolds, 2001). All the participants of the present study completed this test, and the spouse or a close friend completed the respondent version (Fig. 1, Table 3).

Table 1. Student’s t-tests of the inference of a difference between the control and the ADHD groups on matching variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADHD (combined type) (N = 30; mean [SD])</th>
<th>Control group (N = 30; mean [SD])</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>39.03 (10.70)</td>
<td>40.00 (9.84)</td>
<td>−0.36</td>
<td>.72</td>
</tr>
<tr>
<td>Years of education</td>
<td>13.83 (2.88)</td>
<td>13.73 (2.28)</td>
<td>0.15</td>
<td>.88</td>
</tr>
<tr>
<td>Full-scale IQ</td>
<td>114.20 (12.67)</td>
<td>117.00 (9.74)</td>
<td>−0.96</td>
<td>.42</td>
</tr>
<tr>
<td>Annual income</td>
<td>$54,071 (36,221)</td>
<td>$47,321 (24,445)</td>
<td>0.82</td>
<td>.64</td>
</tr>
<tr>
<td>Reading speed</td>
<td>22.37 (6.30)</td>
<td>21.40 (6.08)</td>
<td>0.61</td>
<td>.55</td>
</tr>
<tr>
<td>Numerical (WIAT-II)</td>
<td>29.67 (2.09)</td>
<td>30.34 (1.37)</td>
<td>−1.47</td>
<td>.15</td>
</tr>
</tbody>
</table>

Notes: ADHD = attention deficit/hyperactivity disorder. The measure of reading speed is from the “Test de dyslexie” Griffin and colleagues (1998). The WIAT-II is the Wechsler Individual Achievement Test (2nd revision), specifically the “Numerical operations” subscale (Wechsler, 2001).
The inter-stimulus intervals (ISIs) are 1, 2, and 4 s with a display time of 250 ms. The test structure consists of 6 blocks and 3 sub-blocks, each containing 20 trials (letter presentations). The presentation order of the different ISIs varies between blocks. There is no error feedback, nor are there any prompts.

All participants also completed a computerized task comprising several measurements of executive function formatted as a single multitask realistically simulating an occupational environment and also comprising an incidental memory task at the end of the procedure (Guimond, Braun, Godbout, & Rouleau, 2006; Guimond, Braun, Rouleau, & Godbout, 2008). The program is termed simulation of occupational activities (SOA). It is a game-like environment implemented on the Visual Basic software inherent to Windows for PC simulating 4 days in the life of a diabetic home-based working accountant who has to self-inject insulin at four precise times of the day.

### Table 2. Student’s t-tests and χ² test of the inference of a difference between control and ADHD groups on clinical variables

<table>
<thead>
<tr>
<th>Subscales</th>
<th>ADHD (combined type) ((N = 30; \text{mean } {SD}))</th>
<th>Control group ((N = 30; \text{mean } {SD}))</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anxiety (BAI)</td>
<td>15.33 (12.12)</td>
<td>4.87 (4.46)</td>
<td>4.26</td>
<td>.000</td>
</tr>
<tr>
<td>Depression (BDI)</td>
<td>13.13 (10.96)</td>
<td>4.67 (4.47)</td>
<td>3.82</td>
<td>.000</td>
</tr>
<tr>
<td>Psychotropic medication during the evaluation</td>
<td>23%</td>
<td>3%</td>
<td>χ²</td>
<td>.023</td>
</tr>
</tbody>
</table>

Notes: BAI = Beck Anxiety Inventory; BDI = Beck Depression Inventory; ADHD = attention deficit/hyperactivity disorder. All participants were required to stop using stimulants such as methylphenidate 24 h before testing. The medications described in this table are other than stimulants.

### Table 3. Student’s t-tests comparing the ADHD and the normal groups on the Conners’ Adult ADHD Rating Scales

<table>
<thead>
<tr>
<th>Subscales</th>
<th>ADHD (combined type) ((N = 30; \text{mean } {SD}))</th>
<th>Control group ((N = 30; \text{mean } {SD}))</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-administered questionnaire</td>
<td>Inattention (72.87 (9.42))</td>
<td>46.13 (7.39)</td>
<td>12.23</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Hyperactivity/agitation (63.10 (8.95))</td>
<td>44.10 (6.24)</td>
<td>9.54</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Impulsivity/emotional lability (66.6 (12.84))</td>
<td>47.70 (6.16)</td>
<td>7.23</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Poor self esteem (62.83 (9.95))</td>
<td>45.03 (6.28)</td>
<td>8.29</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Composite index of ADHD (73.83 (8.89))</td>
<td>47.53 (7.49)</td>
<td>12.39</td>
<td>.0005</td>
</tr>
<tr>
<td>Respondent completed questionnaire</td>
<td>Inattention (68.6 (9.75))</td>
<td>47.07 (7.34)</td>
<td>9.66</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Hyperactivity/agitation (58.13 (11.81))</td>
<td>45.77 (6.38)</td>
<td>5.05</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Impulsivity/emotional lability (62 (10.35))</td>
<td>45.87 (6.98)</td>
<td>7.07</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Poor self esteem (57.4 (8.78))</td>
<td>46.20 (5.42)</td>
<td>5.95</td>
<td>.0005</td>
</tr>
<tr>
<td></td>
<td>Composite index of ADHD (66.77 (9.87))</td>
<td>47.50 (6.54)</td>
<td>8.91</td>
<td>.0005</td>
</tr>
</tbody>
</table>

Fig. 1. Mean T score, of each participant, on the ensemble of the subscales of the CAARS, self-completed or completed by a knowledgeable respondent.
day, has to answer the phone and go to bed at midnight, has to do accounting-like activities, and has to organize a retirement party for a colleague. At several points in the initial presentation, the participant is instructed to complete the simulation as quickly as possible. The main display frame of the simulation consists of a grid of 30 actions, randomly displayed, all relevant to organizing the retirement party, which have to be selected by the participant in a logical order (script task). This is the script generation task. It occupies the participant throughout most of the simulation (Fig. 2).

The virtual duration of each action varies and is displayed (1 min to 3 h). The participant is invited to consult a clock, at will, by clicking a clock-face icon (3 cm²), at which point the simulated time of day is displayed. That display has to be removed by the participant (with a mouse click) for him or her to proceed with the task. Another icon (syringe), 3 cm², has to be clicked to simulate an injection at virtual 800, 1000, 1200, and 1600 h (the target times are displayed under the icon at all times). Another icon (bed), 3 cm², has to be clicked on at virtual midnight (for 8 h of virtual sleep). Together, these two tasks are the measure of prospective time-based memory. Another icon (telephone), 3 cm², has to click on whenever it blinks (0.5 Hz, ongoing). An omission error is scored after 10 blinks, and the participant informed of this. This task is the measure of prospective event-based memory. When the 8th and the 24th retirement party action is correctly selected, the script grid display disappears and an attentional task is proposed to the participant and termed a “professional activity” (for the sake of plausibility): the first simulates Baddeley’s way of soliciting the central executive system, the phonological loop, and the visuospatial scratchpad (Baddeley, Della Sala, Papagno, & Spinnler, 1997); the second simulates Brickenkamp’s D2 test (1962). Both these attention tasks solicit effortful attention, that is, immediate working memory and are known to be sensitive to frontal lobe lesions (Bates & Lemay, 2004; Richer et al., 1993). Together, the two tasks correspond to the construct working memory. When each of these tasks is completed, the participant is returned to the script grid at the point where he/she had left off (plus one virtual hour, of which he or she is informed). When the script is completed, an unannounced memory task is imposed: 30 words are displayed and the participant is instructed to select those he/she had seen during the entire previous simulation. Ten are correct targets, 10 are semantically plausible distracters, and 10 are semantically unrelated. The target words are drawn from the instructions presented to the participant before he or she actually started the task. This is the only subtask where errors are not signaled to the participant. This subtask consists of an incidental episodic retrospective memory task. On all the other subtasks, errors of omission, of commission, and of decision and excessive time-on-task (beyond the normative mean) are immediately signaled to the participant by brief text displays embedded in a flashing red panel, to keep the participant on the task, and
to dissipate confusion. The participant is required to click on the error feedback panel to continue, thus helping the participant understand the nature of the error. In the particular case of excessive slowness, feedback included a re-presentation of instructions for whatever subtask was at hand.

In short, the participant has to quickly execute over a thousand constrained key presses, answering to multiple simultaneous high-order executive demands, while remaining constantly aware of ongoing virtual time, so as to complete each assignment at the right time (time-based prospective memory: injections and going to sleep) or at the right moment (event-based prospective memory: answering the phone). The participant has to plan a complex script (organize the retirement party) which requires reading the entire grid first and keeping most of it in working memory, has to engage in effort demanding working memory on two attention tasks which distract him or her from the script task, and at the end, has to recognize, without forewarning, words that had been displayed on screen during the instructions to the various tasks and discriminate them from words that had not been displayed.

Shared constructs on the two tasks. The CPT-II and the SOA both generated errors of omission and of commission in all participants. They also both comprise a measure of overall speed of processing on the task: global reaction time on the CPT-II and total time-on-task on the SOA. The same three constructs, inattentiveness, impulsivity, and speed, respectively, are thus measured on both tasks. However, these shared constructs are measured in very different task contexts. The CPT-II is optimized as a boring vigilance task, while the SOA is optimized as a motivating complex executive multitask. These shared constructs in such distinct contexts allow for differential tests of the three theoretical models outlined in the introduction.

Hypotheses

1. If impairments on the tasks of high-order executive function (planning, working memory, and prospective memory) were to be outstanding in the ADHD group on the SOA task, without any other effects involving the group factor, then that would support the “executive impairment model” of ADHD;
2. if the rate of errors of commission on both tasks, the CPT-II and the SOA, were to be outstanding in the ADHD group, without any other effects involving the group factor, then that would support the “inhibition impairment model” of ADHD;
3. if performance on the CPT-II were to be outstandingly impaired in the ADHD group, and not at all on the SOA, that being the only interaction involving the group factor, then that would support the “motivational impairment model” of ADHD.

Results

Age, salary, full-scale IQ, and gender did not correlate significantly with the independent variable, so these potentially contaminating variables were given no further consideration.

The Continuous Performance Test-II

Despite statistical control for depression and anxiety, the ADHD group made more errors of commission on the CPT-II. In addition, the D-prime index was also significantly biased, an effect we ascribe to the commissive bias since the correlation was $R = .91$ (Table 4).

The Simulation of Occupational Activities

The SOA measures three high-order executive functions: planning, working memory, and prospective memory. In addition, it measures another cognitive function, which is about as far removed from executive function as can be, incidental episodic retrospective memory. On this latter task, the participant is not forewarned that he or she will be tested for tangential details of the words comprising the instructions. To get normally distributed measures of these constructs as well as conceptually clear implementations, we $z$-transformed error scores and we $z$-transformed times on task. We then created a composite of speed and accuracy, equally balanced, for each of the four measures. We then compared the groups using these composites while statistically controlling for depression and anxiety (Table 5).
There are three measures on the CPT-II (Table 4) that have an analog on the SOA: errors of omission (which we designate as inattentiveness), errors of commission (which we designate as impulsiveness), and mean reaction time (which we designate as the opposite of speed, i.e., slowness). Results of comparison of the two groups on the analogs of these drawn from the SOA are displayed in Table 6.
In order to complete the tests of the hypotheses outlined at the end of the methods section, specifically hypothesis 3, we z-transformed those constructs (measures) which were “common” to both computerized tasks, or at least analogous, namely inattentiveness (errors of omission), impulsiveness (errors of commission), and speed [global reaction time (CPT-II)/total time-on-task (SOA)]. We then ran a 2 × 2 split plot repeated-measures ANCOVA (group × task, with BAI and BDI scores as covariables) on each of these three measures. The only effect of interest in these analyses was the interaction. This interaction effect fell short of significance for inattentiveness—\(F(1, 58) = 0.24, p = .629\)—and speed—\(F(1, 58) = 1.16, p = .286\), but not impulsiveness—\(F(1, 58) = 5.63, p = .021\). Specifically, the ADHD group was significantly more commissive than the control group on the CPT-II than on the SOA. (Absence of impairment on a measure is always of concern because it could be due to psychometric properties of the measure such as non-normality, high variability, a flooring or ceiling effect, too many ties, etc. However, with regard to the distributions of errors of commission, the SOA was more symmetric than the CPT-II, less platykurtic, had fewer ties, and had a smaller coefficient of variation.)

Discussion

Unmitigated Support for the “Motivational Impairment Model” of ADHD

The general profile of results is most compatible with the third hypothesis to the effect that the main problem in adult ADHD (combined type) is motivational, consisting of poor resistance to boredom. On the boring task (CPT-II), there was a severe propensity of the ADHD group to commit errors of commission. The far more “engaging” SOA multitask comprised the face validity of a workplace setting, constant and refined (diverse) error feedback, and an incessantly rapid pace. The ADHD group performed as well as the control group despite the fact that the mental operations solicited by the task are considered by many to be impaired in ADHD.

On the SOA, the ADHD participants were significantly more active than the control group in soliciting discriminative feedback (they checked the time) further indicating a motivational dimension to the situation. The fact that there was no evidence of a cost for this normalization, whether a speed/accuracy trade-off or an omissiveness/commissiveness trade-off, is further reason to believe in a substantial reduction in boredom on the SOA task for the ADHD group, leading to normalization of their performances on the SOA. The fact that the two groups of the present study were not only IQ matched but even matched for education and salary leads to believe that the very limited deficit zone observed here may be highly specific to ADHD (combined type) rather than to cognitive impairments. The absence of a group difference on errors of commission does not appear to be due to poor psychometric properties of the SOA, on the contrary. The distribution of errors of commission was more symmetric on the SOA than on the CPT-II, less platykurtic, was globally more normal according to the Sapiro–Wilks test of normality, and had a lower coefficient of variation. The SOA also had more uniform within-group variance for errors of commission than the CPT-II according to Levene’s test of equality of within group variances. “Commissiveness” was normalized on the SOA despite correction for measures of anxiety and of depression suggesting that this normalization is not an artifact of the main known comorbidities of ADHD. This part of the results is compatible with a finding of Shaw, Grayson, and Lewis (2005) in children. In that study, it sufficed to replace the CPT-II stimuli with well-known cartoon figurines of same size for the ADHD group to significantly improve its performance. It remains possible that the test–retest reliability of the SOA may be lower than that of the CPT-II, making the latter less sensitive to ADHD, an eventuality which will be resolved only when an actual determination of the SOA’s test-retest reliability will have been accomplished.

A Trend Toward Support for the “Executive Impairment Model” of ADHD?

The pattern of results of the present investigation does not completely discredit the two other theoretical models of ADHD. It can be noticed from Table 5 that all the measures of high-order executive function on the SOA non-significantly tended to favor the control group. This might not be simply due to chance. In distinction to this, it can be noticed that the only cognitive construct on SOA that showed a non-significant trend toward better performance of the ADHD group was a task that required no mental effort whatsoever, the incidental episodic memory task. Accordingly, Ceci and Trishman (1984) and Shaw and Brown (1991) have found that incidental episodic retrospective memory may even be significantly better in ADHD than in controls. We z-transformed the three non-overlapping measures of high-order executive function (planning, working memory, prospective memory) and created a composite. We also z-transformed the measure of incidental episodic retrospective memory. We ran a split plot repeated measures ANOVA (group × task). The interaction did not reach significance. Thus, the present results provide only a trend in support of the “executive function deficit” model of adult ADHD (combined type).

Could it be that the SOA is insensitive to dorsolateral frontal lobe dysfunction, or less so then the CPT-II? This seems unlikely to us for several reasons. The SOA is highly sensitive to the effect of normal aging in the young adult to middle age range.
(Guimond et al., 2006). Even in the young adult age range of the present investigation, most measures of the SOA manifested an association with, that is, a cost of, increasing age. This was the case for the script task composite \( R = .37, p = .004, N = 60 \), the working memory composite \( R = .34, p = .008, N = 60 \), the prospective memory composite \( R = .41, p = .001, N = 60 \), omission errors \( R = .33, p = .01, N = 60 \), and even the retrospective memory composite \( R = .26, p = .047, N = 60 \). Errors of commission failed to relate to age on the SOA. On the CPT-II only errors of commission \( R = -.27, p = .048, N = 60 \) and reaction time \( R = .32, p = .013, N = 60 \) correlated with age, and it should be noted that errors of commission on the CPT-II actually diminished with age, reflecting an increasing bias toward omission over commissivity known to occur with advancing age (Aylward, Brager, & Harper, 2002; Guimond et al., 2006). Thus, on the CPT-II, there is evidence of a mass action effect of brain atrophy associated with age, indexed by reaction time (Salthouse, Fristoe, & Rhee, 1996), and of strategic compensatory allocation of mental resources toward “prudence”, indexed by decrease in errors of commission, but contrarily to the SOA, the CPT-II does not seem suited to provide evidence of specific dorsolateral frontal atrophy associated with normal aging. The ensemble of correlates of age of the present study also suggests that adults with ADHD (combined type) seem to resemble young more than elderly normal adults: ADHD adults (combined type) are more easily bored and then cannot help being commissive.

**A Trend Toward Support for the “Inhibition Impairment Model” of ADHD?**

As for the disinhibition model of ADHD, the pattern of results obtained here qualifies it and constrains it, but certainly does not completely discredit it. After all, the only single performance measure that highly significantly distinguished the two groups was errors of commission on the CPT-II, a pure measure of disinhibition. Thus impulsivity was outstanding in this cohort of adult ADHD (combined type), but it appears that this problem of impulsivity can be overcome by means of a task context which is not boring for people with ADHD. We created an index of balance between commissivity and omissivity on the SOA (errors of commission/errors of omission). This index did not significantly separate the two groups. Thus, this study provides only a non-specific trend in support of the “impulsivity” or “disinhibition” model of adult ADHD (combined type).

**Vicissitudes of Checking the Time with the Clock Icon**

The SOA offers an opportunity for the participant to simplify the mental work required to self-inject on time and go to bed on time. It would be perfectly possible to avoid mistakes without checking the virtual time with the clock icon. However, to do so require mentally adding up virtual durations displayed on the left panel of the interface and parsing in an hour’s cost stated to have occurred on each of the professional activities (working memory tasks). It is obvious that clicking the clock icon for a display of the virtual time of day is a good way of freeing the mind for other very demanding and pressing aspects of the multi-task. Clicking the clock icon on the SOA simulates checking the time on one’s watch. It seems hard to imagine a busy executive or professional trying to earn his or her living without a watch or a clock at the workplace. When time-based prospective memory is part of the work demands, it would be foolhardy not to exploit a watch or clock. Getting the time is an active search for task-relevant discriminative feedback.

To our surprise however, clock checking was not significantly related to performance on the prospective memory task in the present study. It was significantly negatively related only to total errors of omission \( R = -.28, p = .028, N = 60 \) and to the composite of errors + time-on-task of incidental episodic retrospective memory \( R = -.26, p = .048, N = 60 \). In short, checking the time was linked to fewer errors of omission, overall, and to better performance on the incidental episodic retrospective memory task. It is noteworthy that these two correlations were significant for only the ADHD group, not the control group. The ADHD cohort consulted the clock significantly more frequently than the control group (ADHD: \( M = 21.2, SD = 11.8 \); controls: \( M = 15.2, SD = 10.4 \); \( t = 2.1, p = .042 \)). Thus, the ADHD group sought discriminative feedback more actively than the control group. However, the ADHD participants probably checked the time more than usefully. Perhaps they enjoyed doing so. This trait would then simply reflect diffuse attention, perhaps with an element of playfulness, the former of which pays off on the incidental episodic retrospective memory task.

**Conclusion**

Overall, this study suggests that the problem of impulsivity of adults with ADHD (combined type) is compensable in a work-like environment (see Biederman et al., 2005, for similar results). It remains to determine whether this is actually the case in real workplaces and exactly how this might be so. It would seem useful now to determine which type of work environment would best correspond to the intact capabilities of adults with ADHD demonstrated here. Telephone receptionist comes to mind, or restaurant manager, or other occupations with constant and intense action demands and much discriminative feedback.
In opposition to this, menial, slow, or repetitive or unsupervised work might not be conducive to employee satisfaction nor to employer satisfaction in adults with ADHD (combined type). It will also be useful to determine precisely which contingencies of the workplace are conducive to reducing boredom in people with ADHD. It will be interesting to determine whether simple and monotonous components of work are less boring for people with ADHD if they can be processed at a fast rate in which case they are carried out more effectively (Sagvolden, Aase, Zeiner, & Berger, 1998). Likewise, it will be interesting to determine whether in a complex executive environment, channels of employee-controlled access to discriminative feedback will be of specific help to people with ADHD (combined type) in improving their performance at work. We have shown that there is a spontaneous “interest” in such opportunities in adult ADHD (combined type) on a computer simulation. There are many other possibilities such as implementation of rewards, frequent and/or varying performance related feedback in real time from the employer, etc.

Though this study proposes a context for normalizing impulsivity in a work like environment, its methodology comprises several limitations. This study cannot disambiguate which aspect of SOA helped the ADHD participants to normalize their performance. It could have been the highly structured and complex multitask environment, constant discriminative feedback, the diversity of the feedback (concerning speed, errors of omission, errors of commission), the rapid pace of the task, the setting made to look like a competitive situation, strategic repetition of instructions, the monitor-keyboard environment, or a special combination of these. Selection of the participants into the two groups would have gained from a better separation of observations on the CAARS, that is, from selection only of more extreme cases in each group. The participants were not tested in a real work environment. There was no appetitive feedback (unambiguous reward) in the present study. Participants were not tested when on and off methylphenidate and were not functionally imaged for the dopaminergic circuit. In combination with experimental manipulation of task environments in real work environments, these would be very useful ways of further testing the validity of the frontostriatal dopaminergic/motivational model of ADHD.

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**Conflict of Interest**

None declared.

**References**


