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Sustained and Focused Attention Deficits in Adult ADHD

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Objective: To examine the specificity of deficits in focused attention and sustained attention in adults with ADHD and to evaluate the effect of comorbidity. Method: Twenty-eight adults with ADHD without comorbidity were compared with 28 ADHD outpatients with comorbidity. Two control groups were used: 68 adults referred for ADHD but with another psychopathology rather than ADHD (non-ADHD) and 28 healthy controls. All participants completed attention tests of the Amsterdam Neuropsychological Tasks program. Results: Both ADHD groups demonstrated a sustained attention deficit relative to the control groups, as indicated by a disproportionate deterioration of speed fluctuation with time-on-task reflecting temporal lapses in attention. Only the ADHD + group showed focused attention deficits in that they were less able to ignore irrelevant information. Conclusion: These findings show that adults with ADHD have specific deficits in sustained attention. Additional deficits in focused attention are confined to outpatients with ADHD and comorbidity. (J. of Att. Dis. 2008; 11(6) 664-676)

Keywords: ADHD; adults; attention; comorbidity; ANT

Longitudinal and follow-up studies of children with ADHD suggest that its core features persist into adulthood in at least 30% to 60% of cases (Biederman et al., 1998; Manuzza & Klein, 2000; Weiss & Trokemberg-Hechtman, 1993). Whereas some evidence suggests that ADHD involves deficits in attention processes (Tannock, 2003; Van der Meere, Wekking, & Sergeant, 1991), much of the research on adult ADHD has focused on other domains of cognitive functioning. There has been emphasis on the study of executive function, notably, inhibitory processes (see Hervey, Epstein, & Curry, 2004). Thus, far less is known about the deficits in attention processes associated with adult ADHD. As inattention is a core feature of the disorder (American Psychiatric Association [APA], 1994), especially in adults (Biederman, Mick, & Faraone, 2000), it is imperative to establish the nature of attention deficits in adults with ADHD. This is the major aim of this article.

Over the years, attention has been regarded as a multifactorial construct that encompasses three major conceptualizations: (a) focusing attention, (b) sustaining attention, and (c) shifting attention (Mirskey, Pascualvaca, Duncan, & French, 1999; Parasuraman, 1998). Focused attention refers to the ability to attend to relevant information while ignoring irrelevant stimuli (Mirskey et al., 1999; Parasuraman, 1998). The most commonly used measures of focused attention involve traditional neuropsychological tests, such as the Stroop-Color-Word Test. It is unfortunate that studies comparing ADHD...
adults with healthy controls using these traditional measures revealed inconsistent results (Hervey et al., 2004; Woods, Lovejoy, & Ball, 2002). This can be due to several pitfalls. First, these traditional tests typically do not measure unitary cognitive functions (Sergeant, Geurts, & Oosterlaan, 2002). Second, to examine the hypothesis of an inhibitory deficit in ADHD, as suggested by some models, most of these studies focused primarily on inhibitory control rather than attention processes (Barkley, 1998; Nigg, 2001). Furthermore, experimental approaches using methods derived from information processing theories were not conducted in recent studies investigating selective attention in adults with ADHD. Such information processing paradigms include precise measures of response latency, variability, and accuracy and are less subject to administration and scoring errors (Tannock, 2003). Some studies examined focused attention in children with ADHD. Several studies used a focused attention task of the Amsterdam Neuropsychological Tasks program by De Sonnevile (1999, 2005; De Sonnevile, Njokiktjen, & Bos, 1994; Hanisch, Konrad, Günther, & Herpertz-Dahlmann, 2004; Kalff et al., 2005; Konrad, Günther, Hanisch, & Herpertz-Dahlmann, 2004). These studies generally found focused attention deficits in children with ADHD relative to controls. Three of these studies documented positive methylphenidate effects in these children with ADHD (De Sonnevile et al., 1994; Hanisch et al., 2004; Konrad et al., 2004). Research on focused attention skills in adults with ADHD therefore seems justified.

With respect to sustained attention, a similar picture emerges. Sustained attention refers to the ability to maintain a stable performance level over time (Mirsksy et al., 1999; Parasuraman, 1998). Performance is usually measured in tasks that measure response speed and is expressed by mean reaction time (RT), RT variability (SD of RT), time-on-task (TOT), and errors (Börger et al., 1999). In attention research, the errors of omission (failure to detect the target stimulus) usually reflect inattention symptoms, whereas the commission errors (false alarms) are assumed to reflect a lack of inhibition or impulsivity (Corkum & Siegel, 1993). Children with ADHD were reported to be impaired in a continuous performance task (CPT) compared with healthy controls. They showed increased variability, more TOT effects, and decreased accuracy (both on omission and commission errors) in their task performance (Börger et al., 1999; De Sonnevile et al., 1994; Kalff et al., 2005; Swaab-Barneveld et al., 2000). However, these deficits in attention processes do not appear to be highly specific to children with ADHD because various other clinical groups, such as children with pervasive developmental disorder, conduct disorder, and mood and anxiety disorders, show similar deficits (Althaus, De Sonnevile, Minderaa, Hensen, & Til, 1996a, 1996b; Pennington & Ozonoff, 1996; Swaab-Barneveld et al., 2000). It is therefore of interest to evaluate whether a similar picture emerges in adults with ADHD.

Despite the fact that most previous research on ADHD has focused on children, there is growing interest in investigating attention deficits in ADHD adults. To date, a number of studies as well as meta-analytic reviews examined sustained attention. These are usually measured by CPTs in controlled designs in which adults with ADHD are compared with healthy controls (Barkley, Murphy, & Kwasnik, 1996; Epstein, Conners, Sitarenios, & Erhardt, 1998; Epstein, Johnson, Varia, & Conners, 2001; Murphy, Barkley, & Bush, 2001; Ossman & Mulligan, 2003). These studies reported impaired performance in terms of RT, variability of RT, and response accuracy as measured by errors of commission and omission. RT variability is considered an important parameter in evaluating sustained attention deficits because it is a measure of performance stability. The evaluation of performance with TOT effect is also important. The TOT effect is a crucial marker of sustained attention (Van der Meere & Sergeant, 1988), yet it was usually not measured or neglected in earlier studies. Research on the various aspects of attention in adults with ADHD is therefore warranted. Measures relating to both focused and sustained attention should be taken.

Comorbidity is an additional factor that studies into adult ADHD should encompass in view of its importance in children. There is an extremely high rate of comorbidity in adults with ADHD. For instance, in 50% to 80% of cases, ADHD occurs simultaneously with other psychiatric problems and/or diagnoses, such as antisocial and other personality disorders, substance abuse, anxiety, and mood disorders (Biederman, Newcorn, & Sprich, 1991; Marks, Newcorn, & Halperin, 2001). Some studies on children with ADHD found that the neuropsychological deficits of children with concurrent ADHD and a comorbid disorder (i.e., conduct disorder, anxiety disorder, oppositional defiant disorder, reading disorder) are worse than those of children with ADHD only (Swaab-Barneveld et al., 2000; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). In adults with both ADHD and a comorbid disorder, it is important to determine whether cognitive deficits, such as attention deficits, are the result of co-occurring symptomatology or ADHD itself.

In summary, the aims of this study were threefold. First, focused and sustained attention processes were examined by computerized attention tasks in adults with
ADHD only. Second, TOT performance on a sustained attention task was examined. Third, the specificity of the focused and sustained attention profile and the effect of comorbidity were investigated by including three control groups, namely, an ADHD with comorbidity group, a non-ADHD group, and a healthy control group. Based on the previous studies, we first hypothesized that the ADHD adults would show impairments on the focused and sustained attention tasks and that the impairments would be more pronounced in the ADHD with comorbidity group. We also hypothesized that if the performance of the ADHD groups with and without comorbidity was significantly different from the performance of the other two groups, the impairments would be attributable to ADHD. If the performance of the ADHD with comorbidity group and the non-ADHD group were significantly different from the performance of the ADHD without comorbidity group, the impairments would be attributable to the comorbidity.

**Method**

**Participants**

The patients in this study were referred to a specialized outpatient health care setting in a general psychiatric hospital (Psychomedical Center Vijverdal Maastricht, in the southern Netherlands). At the time of referral, these individuals had complaints and/or a medical history suggestive of adult ADHD. Referral was always by general practitioners or medical specialists. There were three outpatient groups, namely, individuals with ADHD without comorbidity (ADHD; n = 28), ADHD individuals with comorbidity (ADHD; n = 28), and outpatients with complaints in the domain of ADHD but with another psychiatric diagnosis (non-ADHD; n = 68), and can be regarded as consecutive referrals assessed from 1998 to 2003.

A multidisciplinary workup was used, as detailed in other studies (e.g., Barkley, Murphy, & Bush, 2001). Briefly, the clinical assessment included a standard diagnostic and research protocol, including a semistructured diagnostic interview and a clinical interview with both the patient and a cross-informant (usually a parent or spouse). In these interviews, the following topics were collected: (a) demographic, academic, and work history, (b) the developmental course, (c) the ADHD symptoms and criteria according to the DSM-IV, but also other cognitive complaints, and (d) the comorbidity psychopathology. The interviewer then rated if a symptom was present or not. In addition, self-report rating scales, including a Dutch version of the Wender Utah Rating Scale (WURS; Ward, Wender, & Reimherr, 1993) and a Dutch version of the ADHD Rating Scale based on the DSM-IV criteria, including recall of current symptoms and retrospective report during childhood (APA, 1994), were moreover completed and used as additive experimental diagnostic tools. A neuropsychological examination (e.g., intelligence, attention) and a review of school reports, if available, were also part of the assessment. Diagnosis and classification of ADHD were made by a multidisciplinary health care team, including psychiatrists and licensed health care psychologists, and were based on a clinical consensus in which all the data mentioned above were judged. It is worth noting that the clinical neuropsychological evaluation was always part of the assessment, but the information it contained can be regarded as a supplementary tool in the diagnostic process. All individuals in the ADHD group met the diagnostic criteria for ADHD according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV; APA, 1994), including current symptoms and a retrospective diagnosis of childhood ADHD. All individuals in the ADHD group met criteria for ADHD and also DSM-IV criteria for mood disorders (n = 9), anxiety disorders (n = 1), mood and anxiety disorders (n = 1), substance-related disorders (n = 6), personality disorders (n = 10), and a combination of mental disorders (mood disorders, PTSD, psychosis NOS) with a borderline personality disorder (n = 1). The individuals in the non-ADHD group presented with complaints possibly reminiscent of manifestations of ADHD but did not meet the criteria for ADHD. Individuals in this group were diagnosed with personality disorders (n = 20), a combination of DSM-IV mental disorders (mood, anxiety disorder, or substance-related) with personality disorders (n = 11), mood disorders (n = 5), anxiety disorders (n = 4), mood and anxiety disorders (n = 1), oppositional disorder (n = 1), schizophrenia (n = 1), borderline ADHD (some symptoms of ADHD but less than six) with a personality disorder or a substance-related disorder (n = 6), mental retardation (Axis-2) (n = 1), burn-out (n = 1), and no DSM-IV diagnosis (n = 17). Participants using short-acting stimulant medication (e.g., methylphenidate) for ADHD were not excluded from this study. They were asked to cease, in general, their medication 24 hours before the testing.

The healthy control group included 28 individuals who responded to advertisements in a local newspaper and notices in Maastricht University Hospital and Maastricht University. Control participants took part in a telephone screening and completed a self-report rating on ADHD. Exclusion criteria for this sample were as follows: (a) current regular use of medication and/or..
drugs, (b) IQ below 85, (c) self-reported history of a psychiatric disorder (including ADHD), (d) active medical or neurological diseases, such as a serious head trauma, seizures, and diabetes mellitus, and (e) learning disabilities.

Participant characteristics of the ADHD and comparison groups are represented in Table 1.

Measures

To measure attention, all participants performed a baseline speed task, a focused attention task, and a sustained attention task of the well-validated Amsterdam Neuropsychological Tasks (ANT) program (De Sonneville, 1999, 2005). The ANT is a computer-aided assessment battery of RT tasks that allows for the systematic evaluation of information processing capacities. Ample studies have proven the ANT to be a sensitive and valid tool in nonreferred samples (e.g., Brunnekreef, 2007), as well as in referred samples, such as attention deficit disorders (e.g., Konrad et al., 2004; Slaats-Willemse, Swaab-Barneveld, De Sonneville, & Buitelaar, 2005). Test-retest reliabilities for the ANT have also been found to be satisfactory (De Sonneville, 2005; Günther, Herpertz-Dahlmann, & Konrad, 2005). All participants provided written informed consent. The three attention tasks used for this article were selected to directly address the study topics and were administered in the order listed.

**Task 1: Baseline speed task.** A cross is displayed in the center of the computer screen as a fixation point, which may change into a white square (Figure 1a, top left). When this change occurs, participants should press the mouse button as fast as possible, after which the cross returns and this sequence repeats itself. The postresponse interval (PRI; period between response and next stimulus onset) varied randomly between 500 and 2500 ms to prevent anticipation strategies. This task includes 10 practice trials and 32 real trials for each hand, starting with the nondominant hand followed by the dominant hand. This task is known to measure simple speed, which requires minimal cognitive demands and can therefore be used as a measure for simple automated motor reaction. The following two main outcome measures were chosen:

1. **Speed.** Median RTs for baseline speed (in ms; averaged over both hands) were calculated as an index of speed of information processing.
2. **Speed variability.** Within-subject standard deviations of RTs of baseline speed (averaged over both hands) were calculated as a measure of speed variability.

**Task 2: Focused attention task** (Figure 1c, bottom). During this task, two diagonally placed letters are presented on the screen. Although the two letters can appear on either one of the two diagonals, the participant is asked to press the “yes” button only in response to the letter 1 (target letter) on the relevant axis (upper-left or lower-right positions) and to press the “no” button in all other cases. The “yes” and “no” buttons correspond to the right and left mouse buttons, respectively, for right-handers, and vice versa for left-handers. The fixed PRI was 1200 ms and the stimulus duration was 300 ms. In this task, 60 relevant targets (letter 1 on relevant axis), 20 relevant nontargets (nontarget letters on relevant axis), 20 irrelevant targets (letter 1 presented on irrelevant axis), and 20 irrelevant nontargets (nontarget letters on irrelevant axis) are presented in a random order. This task was chosen to evaluate the ability to discriminate relevant from irrelevant information (i.e., the ability to focus attention). The following three main outcome parameters were included:

1. **Speed.** Median RTs determined for relevant targets, relevant nontargets, irrelevant targets, and irrelevant nontargets (all in ms) were used as measures of speed of information processing.
2. **Speed variability.** The average of the within-subject standard deviations of RTs for all four possible correct responses was calculated as a measure of speed variability.
3. **Accuracy.** The percentages of false alarms (to irrelevant targets, relevant nontargets, irrelevant nontargets) and misses (of relevant targets) were calculated separately to obtain the error percentages as an index of accuracy.
Task 3: Sustained attention task. This task is a variant of a widely used CPT. During this task, a square with three, four, or five dots is continuously depicted on the screen. The participant is required to press “yes” if four dots (target) are presented and to press “no” whenever three or five dots (nontargets) are presented (Figure 1b, top right). In this task, 50 series of 12 items, a total of 600 items, are presented according to a balanced presentation of four signals of each type (three-, four-, and five-dot patterns) in random order in each series. It was a self-paced task, with a PRI of 250 ms, and it takes about 15 minutes to complete. The main parameters were:

1. Speed (tempo). Mean completion time per series (MST) was calculated as an index for tempo of sustained attention performance. Mean tempo per block of 10 series (five periods) was computed.

2. Speed variability. Within-subject standard deviations of mean series time (SMST) (across 50 series) were calculated as a measure of fluctuation in tempo.

3. Accuracy. The percentage of misses (pressing “no” for four dots) and the percentage of false alarms (pressing “yes” for three or five dots) were calculated as an index of accuracy of task performance. The balanced presentation (equal number of three, four, and five dots) paradigm will invoke a response bias in the participants, as they should press “no” twice as often as “yes.” That is, the less participants are capable of inhibiting biased response tendencies, the more misses they will produce relative to false alarms with TOT (De Sonneville et al., 1994). Thus, in this task, the number of misses makes up an index of response disinhibition, and false alarms reflect inadequate stimulus evaluation.

4. Time-on-task. Changes in performance with TOT were computed by dividing the 600 responses in blocks of 10 series (five periods). Speed (RT) and fluctuation in speed (SD of RT) were calculated for the mean of the first two periods (block 1) and the last two periods (block 2). Finally, to study accuracy over time, the percentages of misses and false alarms for the first 40% of responses (mean of first two periods) and last 40% of the responses (mean of last two periods) were calculated. A disproportionate number of misses with TOT was taken as an indication of a failure to sustain inhibition of prepotent responses.

Estimated intellectual functioning. Estimated IQ was assessed for all participants with the age-related shortened form of a widely used Dutch intelligence test, the Groningen Intelligence Test (GIT; Luteijn & van der Ploeg, 1983). There is general agreement that the use of the three subtests (Arithmetic, Mental Rotation, Analogies) yields a good approximation of a full-scale IQ ($M = 100; SD = 15$) (Luteijn & van der Ploeg, 1983).

Data Analysis

Prior to all analyses, the three tasks were examined separately for extreme values in median RTs and within-subject standard deviations (> 3 SD from within-group median value) and for error percentages ≥ 50%. Several participants had to be excluded because of this. In addition, some participants had to be excluded for particular tasks because they did not complete the task. The number of participants excluded per variable ranged from 2 (for the four groups together, $N = 148$) to 17. The number of degrees of freedom in the statistical tests consequently varied somewhat for the various groups. All participants with missing data or extreme values were pairwise excluded from the ANOVA analyses for the outcome measures and they were listwise excluded for the repeated measures analyses.

Overall task performance of the four groups in terms of the main outcome measures of speed and speed variability was analyzed with General Linear Model (GLM) univariate ANOVA analyses per task. Accuracy on the focused and sustained attention tasks and TOT effects was analyzed by GLM repeated measures analyses. Greenhouse-Geisser correction probabilities were used to deal with unequal sample sizes and for violation of Mauchly’s Test of Sphericity. In addition, bivariate correlation analyses between the outcome measures and demographic variables (see Table 1) were made to investigate the possible effect of these confounding variables. In case of a significant correlation, these confounding demographic variables were included in a second step as covariates in the analyses.

Statistical significance was set at $p \leq .05$, two-tailed, for all comparisons. Significant group differences were analyzed post hoc using Fischer’s Least Significant Difference with $\alpha = .05$. Simple contrasts were used to test our planned comparisons (ADHD vs. NC, ADHD+ vs. non-ADHD, ADHD+ vs. ADHD*, ADHD+ vs. NC, ADHD+ vs. non-ADHD). In an effort to better identify the strength of the associations, we used partial eta squared ($\eta^2$) values as an estimate of effect size as reported by the SPSS output files (Pierce, Block, & Aguinis, 2004). Values for $\eta^2$ approximately correspond to the following effect size conventions: small (0.01), medium (0.06), and large (0.14) (Cohen, 1988). All statistical analyses were performed using SPSS for Windows 11.0.
Results

Demographic Characteristics

As can be seen in Table 1, significant group differences were found with respect to medication, IQ, and education. A significantly higher percentage of non-ADHD adults were (recently) taking medication, including antidepressants and anxiolytics. Also, the non-ADHD group had a lower IQ than the healthy controls and ADHD adults (p < .05), and educational level was significantly lower in the non-ADHD adults than in the healthy controls and the ADHD* adults (p < .05). The groups were equivalent in gender and age.

Baseline Speed Task

GLM univariate analysis of the median RTs revealed a significant main effect of group, F(3, 139) = 5.34, p = .002, \eta_p^2 = .103 (see Figure 2). Simple contrasts indicated that the ADHD adults reacted faster than the healthy controls (p = .001) and ADHD* adults (p = .007), but no differences were found between the ADHD* adults and non-ADHD adults. The ADHD* adults were also slower than the non-ADHD adults (p = .027), but not in comparison with healthy controls. There was a significant negative correlation between medication and speed (r = -.178, p = .024). Univariate analyses with medication as a covariate yielded comparable results.

Univariate GLM analyses with the standard deviations of median RTs of baseline speed resulted in no significant effect of group, F(3, 138) = 1.89, p = .134, \eta_p^2 = .04. As simple speed variability correlated significantly with education (r = -.25, p = .001), univariate GLM analysis with education as a covariate was performed. The results were comparable after correcting for education, thus indicating no group differences in simple speed variability.

Focused Attention Task

A 2 × 2 × 4 (group) GLM repeated measures analysis with location (relevant vs. irrelevant axis) and type of stimulus (target letter vs. nontarget letter) as within-subject factors and group as the between-subject factor revealed significant within-subject main effects of location, F(1, 126) = 11.07, p = .001, \eta_p^2 = .081, type of stimulus, F(1, 126) = 29.44, p < .001, \eta_p^2 = .189, and a location × type of stimulus interaction, F(1, 126) = 218.08, p < .001, \eta_p^2 = .634. This indicated that the four groups identified target letters faster than nontarget letters when these were presented on the relevant axis, whereas the reverse was found when target letters were presented on the irrelevant axis. This result confirms the focused attention model paradigm with the appropriate exhaustive search on the relevant axis and time-consuming distraction by presentation of irrelevant target letters. There were no significant interactions between the four groups and the within-subject factors. Also, there was no main effect of group on speed, F(3, 126) = 0.36, p = .779, \eta_p^2 = .009.

A significant main effect of group, F(3, 134) = 4.06, p = .009, \eta_p^2 = .086, resulted for variability in RT. The ADHD* adults and non-ADHD adults had a significantly higher variability in speed than ADHD adults and healthy controls (see Figure 3). Because speed variability correlated significantly with IQ (r = -.396, p < .001), a GLM univariate analysis with IQ as a covariate was performed. Results revealed a main effect of IQ (p < .001) in combination with an attenuation of the group effect (p = .112, \eta_p^2 = .045).

The 2 × 2 × 4 (group) GLM repeated measures analysis with location and stimulus type as within-subject factors and group as the between-subject factor for accuracy revealed a significant effect of location, F(1, 129) = 29.21, p < .001, \eta_p^2 = .185, and a location × stimulus type

### Table 1: Participant Characteristics of the Four Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>ADHD (n = 28)</th>
<th>ADHD* (n = 28)</th>
<th>Non-ADHD (n = 68)</th>
<th>NC (n = 28)</th>
<th>F</th>
<th>\chi^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (% women)</td>
<td>39.3</td>
<td>25</td>
<td>33.8</td>
<td>50</td>
<td>4.11</td>
<td></td>
</tr>
<tr>
<td>Medication (% yes)</td>
<td>25</td>
<td>32.1</td>
<td>52.9</td>
<td>0</td>
<td>26.26**</td>
<td></td>
</tr>
<tr>
<td>Age (M, SD)^a</td>
<td>33.80 (9.64)</td>
<td>32.36 (8.23)</td>
<td>32.22 (10.49)</td>
<td>28.87 (6.51)</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td>IQ (M, SD)</td>
<td>108.43 (10.81)</td>
<td>103.46 (13.95)</td>
<td>101.93 (15.17)</td>
<td>109.93 (13.43)</td>
<td>2.94*</td>
<td></td>
</tr>
<tr>
<td>Education (M, SD)^b</td>
<td>4.00 (1.63)</td>
<td>4.11 (1.64)</td>
<td>3.38 (1.52)</td>
<td>5.11 (1.44)</td>
<td>8.30**</td>
<td></td>
</tr>
</tbody>
</table>

Note: ADHD = individuals with ADHD without comorbidity; ADHD* = ADHD individuals with comorbidity; non-ADHD = individuals referred for ADHD but with another psychopathology; NC = healthy controls.

a. The age range was 19 to 62 years.
b. Measured on an 8-point scale ranging from primary school (1) to university degree (8) (De Bie, 1987).

*p < .05. **p < .001.
After adjusting for IQ (ADHD adults (MST), as IQ correlated significantly with MST, indicating that the ADHD factor revealed no significant TOT effect and no group within-subject factor and group as the between-subject GLM repeated measures analysis of mean completion time with TOT interaction. This indicated that the ADHD and ADHD adults did not differ from healthy controls and non-ADHD adults concerning changes in tempo with TOT. A close inspection of the data revealed that the ADHD adults, non-ADHD adults, and healthy controls became faster in the second block of the task, but this did not reach significance (see Figure 5a, left panel).

Univariate GLM analysis of mean fluctuation in tempo (SMST) revealed significant group differences, F(3, 142) = 4.019, p = .009, η² = .078. The ADHD adults demonstrated a larger fluctuation than the healthy controls (p = .026), and the ADHD adults had a larger fluctuation in tempo than the healthy controls (p = .003) and non-ADHD adults (p = .011). GLM repeated measures analysis of fluctuation in tempo with TOT (block 1 vs. block 2) as the within-subject factor and group as the between-subject factor revealed a significant TOT effect, F(1, 142) = 21.076, p < .001, η² = .129, and a significant TOT × group interaction, F(3, 142) = 2.73, p = .046, η² = .055 (see Figure 5b, right panel). Inspection of Figure 5b reveals that, on average, fluctuation in tempo increases with TOT, but this applies in particular to both ADHD groups. As IQ correlated significantly with SMST (r = -.312, p < .001), an ANCOVA with IQ as a covariate was performed. The same results were found for the TOT × group interaction and main effect of group, but the TOT effect (p = .397) was attenuated.

A 2 × 4 (group) GLM repeated measures analysis of accuracy with error type (misses vs. false alarms) as the within-subject factor and group as the between-subject factor revealed a significant effect of error type, F(1, 146) = 106.11, p < .001, η² = .423, but no
error type \times \text{group interaction}, F(3, 146) = 1.24, \ p = .297, \ \eta^2_p = .025. \ This \ indicated \ that \ participants \ made \ more \ misses (7.5\%) \ than \ false \ alarms (3\%) \ and \ confirms \ the \ development \ of \ a \ response \ bias \ within \ the \ four \ groups. \ No \ significant \ effect \ of \ group \ was \ found, F(3, 146) = 2.18, \ p = .093, \ \eta^2_p = .043. \ A \ 2 \times 2 \times 4 \ \text{GLM \ repeated \ measures \ analysis \ with \ error \ type \ and \ TOT (block \ 1 \ vs. \ block \ 2) as \ the \ within-subject \ factor \ and \ group \ as \ the \ between-subject \ factor \ revealed \ a \ significant \ TOT \ effect, F(1, 146) = 40.90, \ p < .001, \ \eta^2_p = .219, \ a \ significant \ effect \ of \ error \ type, F(1, 146) = 93.63, \ p < .001, \ \eta^2_p = .391, \ and \ a \ TOT \ error \ type \ interaction, F(1, 146) = 23, \ p < .001, \ \eta^2_p = .136. \ This \ indicated \ that \ the \ percentage \ of \ errors \ increased \ with \ TOT \ within \ the \ four \ groups \ and \ this \ was \ mainly \ true \ for \ the \ percentage \ of \ misses \ (see \ Figure \ 6). \ Simple \ contrasts \ revealed \ that \ the \ ADHD^* \ adults (p = .022) \ and \ ADHD^\# \ adults (p = .056) \ were \ less \ accurate \ than \ the \ healthy \ controls, \ but \ this \ has \ to \ be \ interpreted \ with \ caution \ as \ no \ interaction \ of \ error \ type \ or \ TOT \ with \ group \ was \ found.

**Discussion**

In general, with respect to our hypotheses, we found that the ADHD outpatients with and without comorbidity were slower and more variable in their tempo over time on a sustained attention task. This indicates that sustained attention deficits were specific to ADHD regardless of comorbidity. In addition, the ADHD outpatients with comorbidity were only impaired with respect to focusing attention. More specifically, they were less accurate than the other three groups on a focused attention task, indicating that the combination of ADHD with comorbidity is more confined to problems with focusing attention. These findings also indicate that adults with ADHD and comorbidity are characterized by different attention problems. When adjusted for IQ and medication usage, the findings remained essentially the same. These results warrant a more detailed discussion per task.

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**Figure 4**

Percentage of Errors (and standard error) for the Four Groups (ADHD\^, ADHD\^\#, non-ADHD, NC) as a Measure for Accuracy on the Focused Attention Task

**Figure 5a and 5b**

Mean Tempo (and standard error) (Figure 5a) and Speed Variability (standard deviation of mean tempo and standard error) of the First Two Periods (block 1) and Last Two Periods (block 2) (Figure 5b) for the Four Groups (ADHD\^, ADHD\^\#, non-ADHD, NC) on the Sustained Attention Task

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Note: ADHD = individuals with ADHD without comorbidity; ADHD\^ = ADHD individuals with comorbidity; non-ADHD = individuals referred for ADHD but with another psychopathology; NC = healthy controls.

Note: ADHD = individuals with ADHD without comorbidity; ADHD\^ = ADHD individuals with comorbidity; non-ADHD = individuals referred for ADHD but with another psychopathology; NC = healthy controls.
Baseline Speed

The hypothesis that no group differences would be found on this task was supported with respect to simple speed variability but not with respect to speed. The ADHD− adults were significantly faster than the ADHD+ adults and healthy controls, also when medication usage was taken into account. This suggests that there is a small but distinct difference in simple information processing between adults with ADHD with and without comorbid disorders. Because ADHD+ adults could not be differentiated from healthy controls, this finding cannot be seen as clinically significant. This finding is consistent with earlier research on adult ADHD as reviewed by Hervey et al. (2004), who reported small effect sizes and no performance differences between ADHD adults and healthy controls in terms of processing and speed outcome measures that require minimal processing demands.

Focused Attention

The hypothesis concerning focused attention deficits in adults with ADHD was partially confirmed. The ADHD adults did not differ from the healthy controls in speed (processing time), speed variability, and accuracy, indicating that there is no deficit in focused attention in these ADHD adults. It is interesting that this result shows that attention processes and performance are different in adults as compared with children with ADHD. Previous studies with children with ADHD revealed other findings, although the same focused attention paradigm was used (De Sonneville et al., 1994; Hanisch et al., 2004; Kalf et al., 2005). Other studies on adult ADHD reported inconsistent findings with regard to focused attention (Hervey et al., 2004; Woods et al., 2002). This is likely due to the fact that these studies generally used traditional tests, such as the Stroop-Color-Word Test. These tests are known to measure not only focused attention but also other processes, such as inhibition and interference control. Therefore, results generated by these tests must be interpreted with caution (Sergeant et al., 2002).

When examining the specificity of the focused attention deficits, a pattern of clear group differences emerged. The ADHD+ adults were less accurate than the healthy controls but also less accurate than the ADHD− adults and non-ADHD adults. Post hoc comparisons of the three false alarm types and misses separately revealed a significant main effect of group on false alarms for irrelevant targets \(p < .01\). The ADHD+ adults made significantly more false alarms for irrelevant targets than the three other control groups. This finding indicates that ADHD adults with comorbidity have specific problems in inhibiting a response to irrelevant information on a focused attention task that involves high controlled processing demands. This is a relatively new finding, as the presentation of such a focused attention task to adults with ADHD has no precedent in the literature. In addition, we also found that the comorbid ADHD outpatients had a higher variability in speed than healthy controls and ADHD outpatients without, although checking for IQ attenuated this effect. This underscores the importance of the intermediating IQ factor in ADHD symptomatology. These findings suggest that the ADHD adults with comorbidity have specific problems in inhibiting a response to irrelevant information on a focused attention task that involves high controlled processing demands. This is a relatively new finding, as the presentation of such a focused attention task to adults with ADHD has no precedent in the literature. In addition, we also found that the comorbid ADHD outpatients had a higher variability in speed than healthy controls and ADHD outpatients without, although checking for IQ attenuated this effect. This underscores the importance of the intermediating IQ factor in ADHD symptomatology. These findings suggest that the ADHD adults with comorbidity have specific problems in inhibiting a response to irrelevant information on a focused attention task that involves high controlled processing demands.

Note: ADHD− = individuals with ADHD without comorbidity; ADHD+ = ADHD individuals with comorbidity; non-ADHD = individuals referred for ADHD but with another psychopathology; NC = healthy controls.

Figure 6
Percentage of Misses and False Alarms (and standard error) of the First Two Periods (block 1) and Last Two Periods (block 2) for the Four Groups (ADHD−, ADHD+, non-ADHD, NC) on the Sustained Attention Task

![Figure 6](http://jad.sagepub.com)
Sustained Attention

On the whole, compared with healthy controls and non-ADHD adults, the ADHD outpatients with and without comorbidity were somewhat slower and demonstrated larger fluctuations in speed. We found that the ADHD adults were not different in speed compared with healthy controls. This finding is consistent with previous studies that compared ADHD adults with healthy controls and revealed no group differences on the CPT hit RT measure (Epstein et al., 1998; Epstein et al., 2001; Murphy et al., 2001).

However, with respect to the specificity of speed of performance, our results revealed that the ADHD+ adults were generally slower from the very beginning of the task than the healthy controls and non-ADHD controls, but no TOT-related decrease in tempo was found in these ADHD+ adults. The ADHD+ adults, non-ADHD adults, and healthy controls even became faster with TOT, but this change was not significant. This finding is consistent with previous studies that compared children with ADHD with other clinical and healthy controls with regard to sustained attention tasks and found no TOT decrease in RT (Börger et al., 1999; Kalff et al., 2005; Swaab-Barneveld et al., 2000). This absence of TOT decrease in speed in ADHD adults can partly be explained as an effect of the task paradigm that invokes a response bias that induces faster response at the expense of accuracy. As the bias increases with TOT, speed may not decrease, at the cost of an increase in misses with TOT. In contrast to our expectation, the ADHD adults did not show a larger response bias and were not less accurate. This indicates that the ADHD and ADHD+ adults were capable of inhibiting prepotent responses to the same extent as healthy controls and non-ADHD controls. This interesting finding is not consistent with results found in children with ADHD. These children were found to be more susceptible to the effect of a response bias (De Sonneville et al., 1994; Swaab-Barneveld et al., 2000) and were also characterized by higher numbers of misses (De Sonneville et al., 1994; Swaab-Barneveld et al., 2000). Likewise, there was some research in adults with ADHD that reported more commission errors (e.g., measure for inhibition; Epstein et al., 1998; Epstein et al., 2001; Murphy et al., 2001). In general, our finding does not confirm the inhibition hypothesis that Barkley (1998) stated for children. According to this notion, response inhibition is the core deficit in the wide pattern of cognitive impairments in children with ADHD. Some studies confirmed a deficit in response inhibition in adults with ADHD (Epstein et al., 2001; Rapport, Van Voorhis, Tzelepis, & Friedman, 2001), but this does not extend to our study. Therefore, further research on elaboration of these models is necessary.

Furthermore, with regard to speed variability, the ADHD+ adults showed greater fluctuations in speed. The increase in speed fluctuation with TOT was also larger compared with healthy controls, who had a tendency to show a decrease or no change in fluctuation. This parameter has barely been investigated in adults with ADHD. Most other studies used CPTs in studying adult ADHD that reported overall higher speed variability (RT SD) in adults with ADHD relative to healthy controls (Barkley et al., 1996; Epstein et al., 2001; Murphy et al., 2001; Walker, Shores, Trollor, Lee, & Sachdev, 2000). These studies failed to report whether changes in performance with TOT discriminate between these groups. A change (deterioration) in fluctuation with TOT is considered an important marker of sustained attention deficit and reflecting temporal lapses in attention, which is even more appropriate than overall RT variability (Castellanos & Tannock, 2002; De Sonneville et al., 1994; Van der Meere & Sergeant, 1988). Support for this finding is also provided by previous studies that investigated the effects of nicotine treatment in adults with ADHD (Levin, Conners, Silva, Canu, & March, 2001). Their results indicated that acute and chronic nicotine treatment significantly reduced variability in RT over trial blocks on a CPT in adults with ADHD. Our results with respect to speed (RT) variability with TOT are also consistent with similar research conducted in previous pediatric populations (Epstein et al., 2003; Kalff et al., 2005; Swaab-Barneveld et al., 2000). These results, therefore, extend these findings to adults with ADHD. This increased variability in speed in adults with ADHD suggests that the underlying problem in these adults may be a difficulty in maintaining an optimal level of performance or lack of consistent effort, which has also been reported in children with ADHD (Börger et al., 1999; Kuntsi, Oosterlaan, & Stevenson, 2001).

With respect to the specificity of speed variability in adults with ADHD, it is noted that the ADHD+ adults also had an enlarged fluctuation in speed over time compared with healthy controls and non-ADHD adults, suggesting that this TOT-related deficit is specific for adult ADHD. In general, few studies have controlled for the effect of comorbid conditions. In addition, few studies have used an ADHD group with comorbidity and clinical non-ADHD controls as comparison groups to delineate specific ADHD-related neuropsychological deficits with computerized attention tasks (Hervey et al., 2004). However, Murphy et al. (2001) did address the effects of comorbidity on neuropsychological measures (including...
the CPT). On the basis of a cohort control approach, they found that the additional presence of comorbid symptomatology did not influence neuropsychological performance. This finding is consistent with our results concerning the sustained attention task. In contrast, Hervey et al. (2004) demonstrated, in their meta-analytic review, that ADHD patients with comorbid disorders usually demonstrated greater neuropsychological deficits than those with ADHD only. This finding is partially consistent with our focused attention findings that are specific for adults with comorbid ADHD. Further research in which these groups of ADHD subjects with and without comorbidity are compared is therefore necessary to provide further evidence on the specificity of speed variability in adults with ADHD. In summary, with respect to our second objective, we found that fluctuation in speed over time is an important and specific marker for sustained attention deficits in both ADHD-only adults and ADHD adults with comorbidity with regard to which they did not differ. Likewise, future studies assessing differences between ADHD subtypes in relation to attention deficits will shed more light on the potential differential mechanisms involved in adult ADHD that were beyond the scope of this article.

Limitations of the Study

Several possible limitations of the study merit consideration. Some concerns exist with respect to the approach taken to investigate the effect of comorbidity. The effect of comorbidity was analyzed by comparing a pure ADHD group with two heterogeneous clinical control groups. ADHD symptom severity as well as the range and heterogeneity of comorbidity were not controlled in all respects. Accordingly, the results do not enable inferences on the effect of the severity and nature of the various kinds of comorbidity. However, despite the fact that this could yield additional and relevant information, symptom severity and the range of comorbid disorders were not the primary focus of this study. Nonetheless, we recommend that future studies both control for ADHD symptom severity and include various but separate comorbid disorders together with ADHD and clinical controls. By doing this, it will be possible to delineate the extent to which attention test performance varies as a function of specific comorbid patterns.

A second limitation of this study relates to the treatment history of adult ADHD and non-ADHD outpatients. Although we used a 24-hour washout period before testing, it is possible that this period may not have been sufficiently adequate to control for the possible effects of stimulant medication. However, previous studies have also used a 24-hour washout procedure (Murphy et al., 2001), and the medication normally taken (notably Ritalin and Concerta) is known to have primarily short-term effects. Moreover, the focus of this study was placed on attention processes in adult ADHD. This study was clearly not a clinical trial on the effects of medication. In addition, we also controlled for this medication effect in all statistical analyses. Given that little is known about the long-term effects of medication on neuropsychological performance, future studies should explore this potential influence. To control for the effects of medication on attention, it may be advantageous to use a longer washout period, especially when longer acting psychoactive medication is taken.

A third issue pertains to the procedures taken during the diagnostic workup. More specifically, this concerns the psychometric properties of the diagnostic interviews and self-report rating scales. The procedures used in this study were identical to those described in the literature (e.g., Barkley et al., 2001). However, the psychometric properties of these instruments have not yet been investigated with a Dutch-speaking population. Nonetheless, they have been shown to be adequate in the United States (Epstein & Kollins, 2006).

Conclusion

In summary, the results of this study show that the adults with ADHD only and with comorbidity display a specific deficit in sustained attention compared with non-ADHD controls. It pertains to specific regulatory problems in maintaining a consistent level of performance, suggesting a less optimal effort allocation in adult ADHD. The ADHD adults with comorbidity show additional deficits on the focused attention task (i.e., lower accuracy), a finding that was specific to this group, suggesting higher vulnerability to (complex) controlled processing demands and difficulty in inhibiting foils. These findings provide evidence for a specific deficit in sustained attention control, irrespective of comorbidity, rather than a deficient response inhibition as has been noted by Castellanos and Tannock (2002) in adults with ADHD.

References


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