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Dysfunction of right-hemisphere attentional networks in attention deficit hyperactivity disorder

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Although differential right-hemisphere dysfunction has been implicated in attention deficit hyperactivity disorder (ADHD) for more than 15 years, this relation remains controversial. Neuroimaging studies suggest asymmetric dysfunction, but neuropsychological evidence in support of this is rather inconsistent. This study examined attentional asymmetry in ADHD adults with a psychophysical extinction task. The interference from right- or left-hemifield distractors with contralateral orientation sensitivity was determined. In a previous study using this paradigm, right brain-damaged patients with left neglect displayed asymmetric distractor interference, meaning a significant interference from a right distractor with left-hemifield orientation sensitivity but no interference from a left distractor with right-hemifield orientation sensitivity. A similar but less pronounced asymmetry was observed in a group of ADHD adults (n = 16). These results indicate dysfunction of right-hemisphere attentional circuits in ADHD.

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is a prevalent developmental disorder that, according to the Diagnostic and Statistical Manual of Mental Disorders (4th edition; DSM-IV; American Psychiatric Association, 1994) criteria, is characterized by a persisting pattern of behavioral symptoms of inattention, hyperactivity, and impulsivity. Because ADHD is conceptualized as a developmental disorder, research has focused primarily on children and adolescent populations, although many of the core symptoms seem to persist into adulthood. Follow-up studies have revealed that between 30% and 50% of children diagnosed with ADHD continue to have problems related to their disorder well into adulthood (Barkley, Fischer, Edelbrock, & Smallisch, 1990; Weiss & Hechtman, 1993). Some of this research suggests that for adults with ADHD the most prominent symptoms relate to the inattention and distractibility domains, with some attenuation of the hyperactivity/impulsivity symptoms (Spencer et al., 1995; Wender, 1997).

Although the behavioral and cognitive difficulties in ADHD have long been ascribed to abnormal brain function, there still is no consensus about the specific brain structures that are involved in the deficit. A substantial body of evidence suggests an important role for prefrontal structures and their connections with the striatum in ADHD pathology. Structural magnetic resonance imaging (MRI) studies found anomalies (smaller than normal size) in the corpus callosum, basal ganglia, and frontal lobes in ADHD children (Castellanos et al., 1996; Hynd et al., 1991b). Functional imaging studies observed hypoperfusion in the frontal lobes and caudate-striatal regions of ADHD children (Lou, Hendrickson, & Bruhn, 1984, 1990; Lou, Hendrickson, Bruhn, Borner, & Nielsen,
ADHD AND RIGHT-HEMISPHERE DYSFUNCTION 43

1989) and adults (Zametkin et al., 1993; Zametkin et al., 1990). Neuropsychological data seem to corroborate these observations. ADHD children present with behavioral symptoms that are similar to those of patients with frontal lesions (impulsivity, inability to organize behavior) and show deficits on neuropsychological tasks measuring executive function (Wisconsin Card Sorting task, Stroop test, Tower of Hanoi), which are assumed to represent frontal dysfunction (Boucugnani & Jones, 1989; Grodzinsky & Diamond, 1992; Pennington, Groisser, & Welsh, 1993). Moreover, involvement of frontostriatal pathways, rich in dopaminergic innervation, is compatible with the dopaminergic action of medications successful in the treatment of ADHD (Sagvolden & Sergeant, 1998).

Other evidence, although less agreed upon, points to a differential involvement of the right hemisphere in ADHD pathology. Hynd, Semrud-Clikeman, Lorys, Novey, and Eliopulos (1990) and Filipek et al. (1997) reported smaller than average right frontal lobes, due to a lack of normal (larger right than left frontal lobes) asymmetry. Reversed asymmetry of caudate nucleus volume has also been reported (Castellanos et al., 1996; Hynd et al., 1993; Mataro, Garcia-Sanchez, Junque, Estevez-Gonzalez, & Pujol, 1997), although the studies differ as to whether this asymmetry normally favors the right or the left caudate.

Behaviorally, ADHD patients may show symptoms similar to those of patients with acquired right-hemisphere lesions. Garcia-Sanchez, Estevez-Gonzales, Suarez-Romero, and Junque (1997) reported that ADHD adolescents performed worse than controls on measures of visuospatial, visuoperceptual, and visuoconstructive functions, which are assumed to be mediated by the right hemisphere.

Poor performances on vigilance measures in ADHD subjects are indicative of sustained attention deficits (Sergeant, 1989). Vigilance or sustained attention functions have been related to right-hemisphere fronto-parietal networks (Posner & Petersen, 1990). Right-hemisphere lesions are also associated with spatial attention deficits such as hemispatial neglect and extinction (Heilman, Watson, & Valenstein, 1993; Milner & McIntosh, 2005). Patients with hemispatial neglect or extinction tend to ignore their left side due to right-hemispheric brain damage. Some studies suggest that ADHD subjects may have subtle spatial-attentional deficits. Voeller and Heilman (1988) observed that children with ADHD demonstrated more left-sided errors of omission on a letter cancellation task than did control subjects. Sheppard, Bradshaw, Mattingley, and Lee (1999) reported significant rightward deviations on a line bisection task in ADHD children. As unilateral neglect is often associated with right parietal lesions, the occurrence of neglect-like symptoms in ADHD has led some authors to suggest that not only frontal but also right parietal dysfunctions are critically involved in ADHD. BenArtsy, Glicksohn, Soroker, Margalit, and Myslobodsky (1996), however, were not able to replicate the previous results in either cancellation or line bisection tasks.

Hemispheric asymmetry of attentional dysfunction in ADHD has often been assessed using the “covert visual spatial orienting” paradigm (Posner, Walker, Friedrich, & Rafal, 1984). This procedure presents the subjects with a left- or right-hemifield target stimulus that is preceded either by a valid (same location) or by an invalid (opposite location) warning cue. Patients with right parietal lesions show an asymmetrical performance deficit characterized by increased costs (reaction times) for invalidly cued left-visual-field targets (Posner et al., 1984). A similar extinction-like response pattern in ADHD subjects would strengthen the right-parietal-lobe theories. However, this paradigm yielded very inconsistent results.

A first study by Swanson et al. (1991) observed decreased instead of increased costs for invalidly cued left targets, which was interpreted as a left-hemisphere deficit in sustained attention. Carter, Krener, Chaderjian, Northcutt, and Wolfe (1995) interpreted the same result as indicating a right-hemisphere deficit. Epstein, Conners, Erhardt, March, and Swanson (1997), on the other hand, obtained the opposite result (increased costs for invalidly cued left targets), which again was interpreted as evidence for a right-hemisphere deficit. That the latter result was only obtained at 800-ms cue–target intervals and not at shorter (100-ms) intervals was taken as evidence for an endogenous deficit resulting from right anterior but not posterior attention mechanisms. Other authors were not able to replicate asymmetric cuing effects (Aman, Roberts, & Pennington, 1998; Epstein, Johnson, Varia, & Conners, 2001), although some did observe asymmetry (slower detection of left targets) for targets that were not cued (McDonald, Bennett, Chambers, & Castiello, 1999; Nigg, Swanson, & Hinshaw, 1997).

In the present study, an extinction paradigm was used to study attentional asymmetry in ADHD participants. By using an extinction task with threshold measurements we tried to increase the sensitivity of the paradigm. More specifically, thresholds for orientation discrimination were measured psychophysically. Orientation sensitivity...
was determined for left- and right-hemifield gratings presented with or without a contralateral distractor grating. Extinction was assessed by measuring the influence of the contralateral distractor grating. We chose adult ADHD participants because until now relatively little research is performed in adults and because attentional dysfunctions seem to be more persistent in adults while impulsivity/hyperactivity symptoms become less obvious (Walker, Shores, Trollor, Lee, & Sachdev, 2000; Wender, 1997). Moreover, since we measured eye movements during the experiments, participants had to be able to sit still.

In order to equalize the visibility of stimuli in left and right hemifields, we first measured luminance thresholds for left- and right-hemifield positions in a horizontal–vertical grating discrimination task. Gratings with luminances of 20 times these thresholds were then used in the orientation discrimination task. Orientation sensitivity was determined for left- and right-hemifield gratings either with or without the simultaneous presentation of a contralateral irrelevant distractor grating. An important difference with typical extinction paradigms was the use of an irrelevant distractor. Attention was always cued towards the target stimulus position and away from the distractor position. In typical extinction paradigms, attention needs to be divided over left and right stimulus positions.

The same paradigm was previously used in right brain-damaged (RBD) patients with or without neglect (Geeraerts, Lafosse, Vandenbussche, & Verfaillie, 2005a; Geeraerts, Michiels, Lafosse, Vandenbussche, & Verfaillie, 2005b). When contraipsilesional differences in stimulus visibility were eliminated by adapting the luminances of the stimuli, neglect patients, but not RBD patients without neglect, displayed a significant extinction effect (i.e., significant interference from a right distractor with left-hemifield orientation sensitivity; no interference from a left distractor with right-hemifield orientation sensitivity).

We hypothesized that ADHD patients would show a similar, although less pronounced, asymmetry. This would indicate a dysfunction of right-hemisphere attentional circuitry in ADHD.

**METHOD**

**Participants**

A total of 16 ADHD patients and 16 control participants without ADHD were tested. Patients were recruited from a local support group for ADHD patients. To be included in the study, ADHD had to be diagnosed by a specialized neuropsychiatrist. Moreover, on a behavior rating scale based on DSM-IV criteria, participants had to fulfil at least five criteria from both the inattention and the hyperactivity/impulsivity subscales (Buitelaar & Kooij, 2000). Thus, all participants would have been diagnosed as displaying the combined subtype of ADHD. This was confirmed by the Attention-Deficit Scale for Adults (ADSA; Triolo & Murphy, 1996), a useful instrument to identify adults with ADHD on the basis of 54 items that address symptoms to be sensitive to problems associated with ADHD. The raw scores of the content scales (except the total score) corresponded to a transformed T-score above 70 on the scales (I) Attention-Focus/Concentration and (III) Behavior-Disorganized Activity, indicating the presence of the combined (attention-hyperactivity) subtype of ADHD. For all ADHD participants, the scores on the content scales were beyond one or two standard deviations from the normal mean suggesting rather serious problems with respect to ADHD symptomatology. There was an absence of any comorbid psychiatric or neurologic diagnosis. (See Table 1.)

Finally, patients had to be off medication for at least 24 hours before the start of the experiments. Normal control participants were volunteers without any neurological or psychiatric history. The mean age of the control participants was 38.1 years (range 28–52). The mean age of the ADHD participants was 38.6 years (range 27–50).

We assessed whether there were signs of visual neglect in the ADHD group with a standard line bisection test (Schenkenberg, Bradford, & Ajax, 1980). Rightward deviation of bisections is indicative of neglect.

**Luminance thresholds**

Participants were seated in front of the computer screen at a distance of 114 cm with the head restrained by a forehead and chin rest. A central red fixation point (diameter 0.2°) was presented throughout the experiment, together with a peripheral cue, indicating the position of the next stimulus. The cue was a white circle (diameter 4.5°), the center of which was presented at 5° eccentricity from the fixation point on the 45° diagonal in either the left or the right upper visual field quadrant (Figure 1).

Stimuli were circular patches of square-wave gratings (diameter 4.5°, spatial frequency 1c/deg) with either horizontally or vertically oriented bars. The gratings were luminance modulated with dark
bars of a constant background luminance (0.001 cd/m²) and bright bars of luminances that varied according to the participants’ performance. Bright bars were constructed from random noise patterns. The stimuli only appeared at the cued position (left or right upper quadrants). Luminance thresholds were determined with an adaptive staircase procedure (MUEST; Snoeren & Puts, 1997) converging around a performance level of 70% correct. The threshold is the luminance for which the participant reaches a 70% correct discrimination between horizontal and vertical gratings.

The trial sequence was the following. When central fixation was maintained for 500 ms, the cue circle was replaced by the grating stimulus for a period of 300 ms. The participant had to respond to the orientation of the grating by pressing a left response key for horizontal and a right response key for vertical orientations. Participants were urged to guess when they were unsure about the grating’s orientation. Response time was unlimited. Feedback was given in the form of an auditory signal for incorrect responses. Only after a response was made and after a 2,000-ms intertrial interval was the next trial initiated.

Eye movements were monitored with the ASL 210 eye tracker. Trials with eye movements out of a 2-deg fixation window were discarded and repeated. Stimuli were presented in four blocks of 20 trials (not counting trials with eye movements). Within a block, the stimulus was always presented in the same position. Blocks with left- and right-hemifield stimulus positions were alternated. Thus, each condition or each threshold estimation consisted of 40 trials.

**Orientation thresholds**

Unless stated otherwise, the stimuli and procedures were the same as for the luminance threshold measurements. Stimuli could be either target gratings or distractor gratings, both of them having the same size and spatial frequency as the luminance gratings (Figure 2). Target gratings were always presented at the cued (left or right hemifield) position; distractor gratings were always presented in the opposite hemifield, at the homologue position. The luminance of both target and distractor gratings was set at 20 times the luminance threshold that was obtained for their respective positions.

Orientation thresholds were determined for target gratings in left and right visual fields, with and without the simultaneous presentation of a distractor grating. We used a constant stimuli paradigm
to measure orientation sensitivity independently of the point of subjective visual verticality. Five equally spaced and informative orientations (−8°, −4°, 0°, 4°, 8°) spanning the vertical were used as target stimulus orientations. Distractor orientations were chosen randomly in each trial and could be any orientation between 0 and 360°.

Blocks of 20 trials with a left-hemifield target stimulus were alternated with 20-trial blocks with a right-hemifield target. Within a block, the five target stimulus orientations were randomly presented. In half of the trials of each block (random) a distractor grating was presented simultaneously, for the same duration, and in the opposite hemifield to that of the target. Participants were instructed to ignore the distractor as much as possible. The cue always indicated the position of the target to be presented. If the target orientation deviated clockwise from vertical, participants had to press the right response key; for an anticlockwise deviation, the left response key had to be pressed. All experiments were carried out in a completely darkened room, so that there was no reference frame for comparison with the grating orientations.

Trials with eye movements out of a 2-deg window were discarded and repeated. A total of 100 trials per condition (20 trials per orientation level, not counting trials with eye movements) had to be completed.

RESULTS

Standard neglect test

Rightward line bisection deviation averaged 0.2% (SD = 3.4) for the control group and 1.5% (SD = 3.7) for the ADHD group. Although the deviation was slightly more rightwards in ADHD participants than in controls, this difference was not significant, $F(1, 30) = 0.98; p > .30$.

Luminance thresholds

The luminance thresholds in the horizontal–vertical discrimination task were log-transformed to homogenize variance. The mean left- and right-hemifield log-transformed luminance thresholds for the two participant groups are shown in Figure 3. A two-way repeated measures analysis of variance (ANOVA) on these data revealed no significant main effects, $F(1, 30) = 0.02; p > .80$, and $F(1, 30) = 0.1; p > .75$, nor a significant interaction, $F(1, 30) = 0.002; p < .97$. Control and ADHD participants obtained similar thresholds in their left and right hemifields.

Orientation thresholds

For each individual participant, and for the different conditions, the normalized percentages of “clockwise deviation from vertical” responses were plotted against the presented orientations (ordered from the largest anticlockwise to the largest clockwise deviation). Just noticeable differences (JNDs) in orientation were estimated via least squares linear regression analyses. The JND is an inverse measure of the slope of the regression line. A significant correlation between grating orientation and normalized percentage clockwise responses was observed in each participant in all the conditions ($r > .80; p < .05$; Pearson product moment correlation), meaning reliable thresholds were obtained.

The mean log-transformed JNDs in orientation for the ADHD and control groups are plotted in Figure 4. For comparison, results of the RBD neglect and nonneglect patients of the study of Geeraerts, Lafosse, Vandenbussche, and Verfaillie

![Figure 2. Schematic depiction of stimuli and trial sequences for the orientation discrimination task.](image)

![Figure 3. Mean log-transformed left- and right-hemifield 70% correct luminance thresholds (and standard deviations) for the two participant groups.](image)
For the conditions without distractors, a two-way repeated measures ANOVA on the data of the ADHD and normal control groups resulted in significant main effects from the group, $F(1, 30) = 12.02; p < .002$, and hemifield, $F(1, 30) = 5.64; p < .02$, factors. The interaction between group and hemifield was not significant, $F(1, 30) = 0.26; p > .60$. ADHD patients obtained higher thresholds than control participants in both hemifields. ADHD and control participants obtained higher left- than right-hemifield thresholds.

To examine the effect of distractors on the orientation thresholds, distractor conditions were incorporated in the analysis. A three-way repeated measures ANOVA on the data of the present study resulted in a significant three-way interaction between group, hemifield, and distractor condition, $F(1, 30) = 16.12; p < .0004$. Compared to the control group, the ADHD group showed a tendency towards an increased right-distractor interference with left-hemifield JNDs and a decreased left-distractor interference with right-hemifield JNDs. For the control group, the interference from left and right distractors seemed to be of about the same magnitude, with slightly larger left-distractor interference. Two-way ANOVAs were performed for each group separately. For the ADHD group this resulted in a significant interaction between hemifield and distractor condition, $F(1, 15) = 17.57; p < .0008$, while this interaction was not significant in the control group, $F(1, 15) = 2.61; p > .10$. In the control group, however, a main effect of distractor condition was observed, $F(1, 15) = 20.65; p < .0004$. Thus, ADHD patients displayed
asymmetric distractor interference, and control participants symmetric distractor interference.

When the results are compared with those of the study of Geeraerts et al. (2005a), ADHD patients display results very similar to, but less pronounced than, those of the neglect group. Both RBD neglect patients and ADHD patients show asymmetric distractor interference; the RBD control group (without neglect), however, shows symmetric distractor interference.

To represent results from individual participants, asymmetry indexes were determined. The asymmetry index (AI) equals the difference between left- and right-hemifield distractor effects divided by the sum of left- and right-hemifield distractor effects. The distractor effects were determined for each participant by dividing the JNDS from the distractor conditions by the JNDS from the nondistractor conditions. A left-hemifield distractor effect denotes the interference of a right distractor with left-hemifield orientation sensitivity, a right-hemifield distractor effect denotes the interference of a left distractor with right-hemifield orientation sensitivity. The individual asymmetry indexes are displayed in Figure 5 for the ADHD ($n = 16$) and control ($n = 16$) participants from the present study and for the RBD neglect ($n = 10$) and nonneglect ($n = 10$) participants from the Geeraerts et al. (2005a) study. Positive indexes indicate larger right- than left-distractor interference with contralateral orientation sensitivity; negative indexes indicate larger left- than right-distractor interference. Asymmetry indexes of ADHD and neglect participants are more positive than those of normal and RBD control participants. A total of 12 out of 16 ADHD participants obtained an AI of more than one standard deviation above the average of the normal control group.

Eye fixation data

Trials with eye movements outside the 2-deg fixation window were not incorporated in the threshold measurements. Table 2 presents the number of eye movements made in the different conditions of the luminance and orientation discrimination tasks. An ANOVA was performed on the logarithms of these numbers. For the luminance task, no significant main or interaction effects were obtained. For the orientation task, significant group, $F(1, 30) = 5.58; p < .02$, and hemifield, $F(1, 30) = 7.47; p < .01$, main effects were observed. No significant main effect of distractor condition and no significant interaction effects were observed. More eye movements were made by ADHD patients than by control participants; more eye movements were made in right- than in left-hemifield target stimulus conditions. Although the effects were not significant in the luminance task, ADHD patients made more eye movements as well.

**DISCUSSION**

A psychophysical extinction paradigm was used to study distractor interference in ADHD patients and normal controls. ADHD patients were expected to show asymmetric distractor interference, indicating right-hemisphere involvement in the deficit. In an attempt to equalize the visibility of left- and right-hemisphere gratings, luminance thresholds for the discrimination of horizontal from vertical gratings were first determined. No differences were observed between groups or between hemifields, both groups having comparable left- and right-hemifield luminance thresholds. In other words, no hemispheric asymmetry was observed when validly cued unilateral stimuli were used. These results indicate that, without the presence
of distracting information, ADHD patients are able to direct attention to both hemisfields equally well. Moreover, ADHD does not seem to be associated with asymmetric dysfunction in primary visual input regions. The orientation discrimination thresholds in conditions without distractors confirm this conclusion. Although unilateral left-hemifield orientation thresholds were higher than unilateral right-hemifield thresholds, this difference was the same in the ADHD and control groups. Thus, ADHD patients do not show a larger than normal asymmetry in orientation sensitivity for validly cued unilateral stimuli.

In conditions without distractors, higher orientation thresholds were observed in both hemisfields of ADHD patients than in control participants. Orientation discrimination has been shown to be mediated by the right hemisphere (Kerkhoff, 1999; Taira, Kawashima, Inoue, & Fukuda, 1998; Vandenberghe et al., 1996). Right-hemisphere dysfunction is thus a possible explanation for orientation discrimination deficits in both hemisfields. Not only ADHD patients, but also RBD patients with neglect obtained higher orientation thresholds in both hemisfields. RBD patients without neglect, on the other hand, obtained higher thresholds only in the contralesional hemisfield. Thus, the observed deficit might be related to specific brain regions that are involved in both neglect and ADHD.

Gratings were presented either in isolation or simultaneously with a contralateral distractor grating to study the effects of the distractors on orientation sensitivity. As hypothesized, asymmetric distractor interference was observed in the ADHD group. Control participants displayed symmetric distractor interference. Compared to the control group, ADHD patients not only demonstrated an increased interference from a right-hemifield distractor when the orientation of a left-hemifield stimulus had to be reported, but there was even a tendency for a decreased interference from a left-hemifield distractor when they had to attend to and evaluate the orientation of a right-hemifield stimulus. These results suggest involvement of right-hemisphere attentional networks in ADHD. ADHD patients seem to have problems with directing their attention to the left hemisfield when a right hemisfield stimulus is presented simultaneously. The results are not in agreement with models that explain ADHD primarily as a response inhibition deficit (Barkley, 1997; Quay, 1997). According to these models, the capacity to inhibit or filter out competing information is disturbed in any position of the visual field. However, ADHD patients show even less than normal interference from left-hemifield distractors, clearly indicating a lateralized deficit.2

The observed results of ADHD patients were very similar to those of neglect patients, using the same task paradigm. Although the effects were less pronounced in ADHD patients, asymmetric distractor interference was observed in both ADHD and neglect groups. In the RBD patients without neglect, however, an equally large (symmetric) interference was observed from left- and right-hemifield distractors, as was the case in normal control participants. Lesion or dysfunction in the right hemisphere is not always associated with asymmetric distractor interference but probably only when spatial attentional networks are involved.

Neglect and extinction are most common and most severe after right parietal lesions (Heilman et al., 1993). Consequently, the similarities in the results of ADHD and neglect patients might suggest right parietal involvement in ADHD pathology.

2As suggested by one of the reviewers, it is possible that ADHD patients show a lateralized deficit superimposed on a global, nonlateralized deficit. The latter is supported by the observation of reduced performance of ADHD patients in vigilance tasks with central stimulus presentation (possibly related to frontal-subcortical dysfunction).
In conditions without distractors, the increased orientation discrimination thresholds may be the result of orientation discrimination deficits. Orientation discrimination has been associated with the parietal lobes (Taira et al., 1998; Vandenberghe et al., 1996). In a study of Aman et al. (1998), ADHD patients were found to perform deficiently on several tasks assumed to measure “parietal” functions. Moreover, in ADHD adults, reduced cerebral glucose metabolism was observed in right posterior parietal regions by Zametkin and Liotta (1998). Although there seems to be evidence in favor of right parietal involvement in ADHD, it is possible that it is not primary parietal dysfunction that is responsible for this, but that frontal-subcortical dysfunction has an indirect influence on parietal activity (also see Footnote 1).

Studies using the covert visual spatial orienting paradigm (Posner et al., 1984) have tried to disentangle anterior (frontal) versus posterior (parietal) involvement in ADHD (Aman et al., 1998; Epstein et al., 1997, 2001; McDonald et al., 1999; Nigg et al., 1997; Schaughency & Hynd, 1989). Covert shifts of attention during short cue–target intervals (100 ms) have been linked to automatic attention mechanisms in posterior parietal brain regions. Attention shifts during longer (800 ms) cue–target intervals have been related to anterior volitional mechanisms (Posner & Petersen, 1990). None of the studies was able to demonstrate an extinction-like (parietal) response pattern in ADHD patients. Possibly this paradigm is only sensitive to severe parietal lobe damage, and dysfunction in ADHD is more subtle. Asymmetric effects were observed with 800-ms cue–target intervals, indicating a mainly anterior instead of posterior deficit in ADHD (Carter et al., 1995; Epstein et al., 1997). However, the results are very inconsistent (both left- and right-hemifield deficits being observed) and may have been confounded by eye movements. In our study, ADHD patients were found to make more eye movements than control participants. Previous studies never mentioned the use of eye movement control. Thus, unwanted eye movements may have altered the results, especially in the 800-ms cue–target interval conditions. In the present study, trials with eye movements were excluded.

Although extinction (asymmetric distractor interference) was observed in the ADHD patients, they did not show neglect on the line bisection task. This is in agreement with the negative result of BenArtsey et al. (1996). Sheppard et al. (1999), on the other hand, observed neglect in ADHD children using a computerized version of the line bisection task instead of a paper and pencil version. This version may have been more sensitive.

Asymmetry indexes of individual participants were calculated as well. A total of 12 out of 16 ADHD patients obtained an asymmetry index of more than one standard deviation above the average of the control group. Obviously, this task paradigm alone is not sufficient for diagnostic purposes, as no other single measure is. However, in combination with other diagnostic instruments, our task may have an important clinical value. A total of 4 ADHD participants obtained asymmetry indexes almost as large as the average of neglect patients. Such an attentional asymmetry may very well have serious debilitating effects in the patients’ daily lives. Dobler, Manly, Verity, Woolrych, and Robertson (2003) described the case of a 7-year-old ADHD child showing clear signs of neglect, which had gone undetected until specific testing was performed. These results demonstrate the importance of including attentional asymmetry assessments within routine neuropsychological ADHD test batteries.

In our study, only participants of the combined ADHD subtype were used. It is possible that different subtypes display different patterns of results. The inattentive and combined subtypes, for example, may show neglect-like symptoms because of a stronger involvement of posterior attentional brain regions. Hyperactive/impulsive subtypes may suffer mainly anterior involvement and consequently may lack such symptoms. However, studies that tried to relate posterior–anterior dysfunction to inattentive and hyperactive subtypes, respectively, did not yield unequivocal results (Hynd et al., 1991a; Landau, Lorch, & Milich, 1999). Since we only tested participants of the combined inattentive and hyperactive/impulsive subtype, we are not able to clarify this putative relation. As a group, however, ADHD adults do show asymmetric distractor interference, similar to neglect patients, clearly indicating dysfunction of right-hemisphere attentional circuitry.

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