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Covert orienting and focusing of attention in children with attention deficit hyperactivity disorder

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Abstract

Performance on the covert visuo–spatial attentional functions of orienting and focusing by a group of ADHD children ($n = 20$) was compared to that of age and sex-matched control children. In Experiment 1, responses were given to cued targets at valid and invalid locations. In Experiment 2, responses were given to targets presented in small, medium-sized or large visual field locations. For both experiments, the hypotheses that reaction times of ADHD children would be greater than those of control children and that performance would be asymmetrical, were supported. For Experiment 1, ADHD children showed bilaterally greater 'benefits' from having directed attention to the cued location and greater 'costs' in having to relocate the attentional focus than controls. In Experiment 2, the hypothesis that the function of focusing attention by ADHD children may show breakdown in the usual pattern of an increase in reaction time with focus area was partly supported by the finding of similar reaction times to targets presented in medium-sized and large regions of the left visual hemifield. These results have been interpreted as reflecting a stronger anchorage of attention by ADHD children upon a cued location and an inability to shift covert attention easily to an alternative location. The breakdown of the focusing function suggests adoption of similar time response sets across focus area size by the more compromised right hemisphere.

Keywords: ADHD; Asymmetry; Covert visuo–spatial attention; Frontostriatal pathways; Attentional focus

1. Introduction

It is estimated that attention deficit hyperactivity disorder (ADHD) affects between 3–7 children in every 100 [2]. It typically manifests prior to the age of seven years, with most diagnosed cases being male (3 : 1 male : female ratio [3]; however, see [16]). The main behavioural assessment techniques used to determine diagnosis of this disorder include parent and teacher rating scales and interviews, psychometric tests and continuous performance tasks (see [28] for review). It is only recently that experimental psychology paradigms have been employed to study the cognitive operations of these children and that inferences have been made from the results in determining the sites/pathways of neuropathology.

One such stream of cognitive research has been directed to the assessment of the covert attentional system. Essentially this system is said to allow attention to be directed to, and manipulated within, certain regions of visual space in the absence of eye movements. Allocation of attention in a covert manner ensures that the processing of stimuli in the attended area is more efficient than the processing of stimuli in non-attended areas. The well-known Posner paradigm [33] assesses this function by presenting the subject with cues that direct covert attention to regions of the visual space within which an imperative stimulus may subsequently appear. If the stimulus appears within the location indicated by the cue (e.g. cue points to the left and stimulus appears in the left visual hemispace) the trial is said to be 'valid'. If the stimulus appears in a location which was not indicated by the cue (e.g. cue points to the left but stimulus appears in the right visual hemispace) the trial is said to be 'invalid'. Relative to a neutral condition, in which the cue gives no directional information about the potential location of the stimulus, quicker reaction times ('benefits') to the stimulus are usually found for validly cued trials while slower reaction times ('costs') are usually found for invalidly cued trials. A comparison of benefits and costs gives an indication of the viability of the covert orienting system. This paradigm allows assessment of the dissociable functions of orienting attention to either the left or right, of engaging and disengaging attention, and of

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redirecting attention [35] and has been applied widely in the testing of non-brain-damaged subjects and various neurological populations [5, 26, 34, 35, 37, 43].

Relating the anatomy of pathology to the aforementioned elements tested by the Posner paradigm has promoted the formulation of hypotheses as to the neural substrates of covert attentional functions [6]. Conversely, in cases where the neuroanatomical bases of dysfunction are ill-defined, as is often the case for children with attention deficit hyperactivity disorder, theories of the cognitive anatomy of attention can assist in speculating about underlying neuropathology [40].

Few studies have assessed the viability and efficiency of the covert visuo–spatial attentional system in children with ADHD. As argued by Swanson et al. [40], such research is of obvious importance given that the designation of this syndrome suggests an attentional disorder but the 'presumed attentional deficits have not been linked either to specific cognitive operations or to specific neural systems' (p. S119). Further, the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* [1] includes 'inattention' as one of the two major impairments, yet as supposed by Barkley [4] ''research has not identified a deficit in attention in these children''.

Swanson et al. [40] used one version of the Posner paradigm to test children who had been diagnosed with ADHD by use of parent interviews and teacher ratings of inattention/overactivity on the Iowa Conners scale [21]. They reported that the ADHD children showed reaction times to targets, presented 800 ms following an invalid cue, that were much greater for those targets presented on the right than for those presented on the left. There was no such laterality difference for validly cued targets or for any targets presented 100 ms following the cue. These results were explained as reflecting a dysfunction in the ability to sustain the engagement of attention upon a cued right visual field location, with the result that targets in alternative locations recaptured the attentional focus more readily.

Swanson et al. [40] supposed that the difference according to cue/stimulus interval could reflect the use of overt orienting responses in the 800 ms interval, and recommended further research to define such possible dysfunction. Further, the paradigm they used involved the use of peripheral cues (highlighting of a left or right box) which appeared at the probable location of the stimulus. Such cues are said to elicit exogenous, more automatic, mechanisms for the shift in covert attention to the cued location [15, 17, 29, 41, 45]. As noted by Carter et al. [6], the use of these peripheral cues plus the weighting towards valid trials could mean that both exogenous and endogenous mechanisms are recruited, making interpretation of the Swanson et al. [40] results difficult both in terms of the underlying cognitive deficit and the neural systems involved.

In an attempt to dissociate these two cueing mechanisms, Carter et al. [6] utilised both exogenous and endogenous cues to test 20 controls and 20 ADHD children, as diagnosed by DSM-III-R criteria [1] using parent and children interviews and psychiatric evaluation. Endogenous cues were presented centrally, and gave a symbolic indication of the true (valid) or false (invalid) position of subsequent targets in laterally positioned boxes. The results for this type of cueing mirrored those of Swanson et al. [40] with a reduction of costs for targets appearing in the left visual field after having being cued in the right visual hemispace 800 ms earlier. Because only the target was lateral, Carter et al. [6] argued that this reflected a dysfunction in the ability to orient to the left visual field (and thus of right hemispheric attentional control) rather than in the ability to maintain attention to a right cued location (and thus of left hemispheric control). The exogenous task was similar to that of Swanson et al. [40], with cues being presented peripherally at the site of the potential stimulus, but the ability of subjects to adopt probabilistic strategies was reduced by giving equal trial number allocation to valid and invalid conditions. In contrast to the Swanson et al. [40] results, the ADHD subjects showed asymmetry only at the 150 ms cue/stimulus interval with greater costs for left than for right visual field targets. At the 800 ms interval the results for both groups were indicative of a classic inhibition of return, with validly cued trials showing greater reaction times than invalidly cued trials. The ADHD subjects did not show an asymmetrical performance at this latter interval.

The finding of slower overall reaction times and asymmetry in the attentional dysfunction was confirmed by Nigg et al. [30] in a study of a group of ADHD boys who were slower to respond to targets in the left than in the right visual field. In contrast to previous studies however, this lateralised slowness was for trials that had not been cued, rather than showing any clear relation to invalid trials or to cue/stimulus interval. Such a result was counter to the proposed hypotheses that the boys would show dysfunction with maintaining attention in the left visual field [14], or that the left hemisphere would show problems maintaining attention [24]. The researchers concluded that the results suggested hypoarousal dysfunction to the noradrenergic system of the right hemisphere with the consequence of a rightward biasing of covert orienting [35].

It is clear from the foregoing summaries that the description of deficits to the covert attentional system in children with attention deficit hyperactivity disorder is not yet clearly defined. A primary aim of the current study was thus to assist in this definition. The function of orienting covert attention was assessed using an endogenous cueing paradigm whereby the cue is presented centrally and gives information about the probable location of targets to be presented in either the left or right visual field. The use of this paradigm was to