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Stimulus context and motor preparation in attention-deficit/hyperactivity disorder

T. Banaschewski [a,e,*], J. Yordanova [b], V. Kolev [b], H. Heinrich [c,d], B. Albrecht [a], A. Rothenberger [a]

[a] Child and Adolescent Psychiatry, University of Göttingen, von-Siebold-Str. 5, 37075 Göttingen, Germany
[b] Institute of Neurobiology, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., building 23, 1113 Sofia, Bulgaria
[c] Heckscher-Klinik, Deisenhofener Str. 28, 81539 München, Germany
[d] Child and Adolescent Psychiatry, University Clinics Erlangen, Schwabachanlage 6-10, 91054 Erlangen, Germany
[e] Department of Child and Adolescent Psychiatry and Psychotherapy, Central Institute of Mental Health, Postbox 12 21 20, D-68072 Mannheim, Germany

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Abstract

Aim: To investigate (1) whether and how local stimulus context variation may modify behavioural and preparatory motor processes in children, and (2) if these effects differ between healthy children and children with attention-deficit/hyperactivity disorder (ADHD) aged 9–12 years.
Methods: Behavioural parameters and contingent negative variation (CNV) at cortical motor electrodes were recorded during a cued continuous performance task (AX-CPT) in three stimulus context conditions (Go, NoGo, neutral). Stimulus context was varied on the basis of stimulus types preceding the cue letter A.
Results: In all children, responses were slowed in both the NoGo- and Go-conditions relative to the neutral condition. Stimulus context affected preparatory motor processes in both groups but differentially. ADHD children showed smaller CNV potentials and a functionally irrelevant over-activation of the ipsilateral motor area.
Conclusions: Local stimulus context may modify behavioural and preparatory motor processes in children. In ADHD, local context variations may disrupt behaviour due to inefficient regulation of supervisory higher control systems.

Keywords: ADHD; Slow negative potentials; CNV; Motor preparation; Executive control; Cued CPT; Stimulus context

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is characterized by inattentiveness, hyperactivity and impulsiveness (e.g., Castellanos and Tannock, 2002; Sagvolden et al., 2005; Taylor et al., 2004). In various neuropsychological tasks, the performance of individuals with ADHD has not only been found to be more inaccurate and slower but also more variable than that of healthy controls (Leth-Steensen et al., 2000; for a review see Castellanos and Tannock, 2002).

The temporal and contextual variability in symptom expression in ADHD has been associated with deficits in working memory, intention, attention and temporal processing (Barkley, 1997; Castellanos and Tannock, 2002). Recent neuropsychological and neuroimaging research has provided converging evidence for impaired executive control in ADHD (for reviews see Bush et al., 2005; Sergeant et al., 2002; Willcutt et al., 2005). Executive control refers to the ability to promote and facilitate task-relevant behaviour, and to inhibit task-irrelevant behaviour. This is achieved by a higher-order regulation of transient dynamic activation of cortical regions responsible for task-specific performance, while suppressing regions engaged with task-irrelevant information processing (Rabbitt, 1997). Since executive functions subserve a fast continuous re-adjustment of behaviour to dynamic changes in external and internal environment, they may largely contribute to performance inconsistency in ADHD (Willcutt et al., 2005).

Typically, the behaviour of children with ADHD is assessed in experimental situations where task-relevant and task-

* Corresponding author at: Department of Child and Adolescent Psychiatry and Psychotherapy, Central Institute of Mental Health, P.O. Box 12 21 20, D-68072 Mannheim, Germany. Tel.: +49 621 1703 4502; fax: +49 621 1703 4505.
E-mail address: tobias.banaschewski@zi-mannheim.de (T. Banaschewski).

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irrelevant stimuli are delivered. Overall task structure and instructions for responding to predefined stimuli create a global task context, which guides prepotent behaviour to response activation or suppression. In most of these tasks, however, the sequences of ongoing stimuli vary over time. At the psychological level, this can be described as a varying stimulus context (or local context). At the neurophysiological level, short-lasting changes in regional activation patterns occur and modify reaction time (RT) and RT variability (e.g., Jentzsch and Sommer, 2002; Los and van den Heuvel, 2001).

Previous studies have examined the effects of local stimulus context on *response inhibition* in Go/NoGo tasks (Durston et al., 2002a,b). In these studies, local prepotency to response activation was varied by increasing the number of Go trials preceding a NoGo trial. It was shown that in children, as compared to adults, there was an elevated susceptibility to interference with a salient preceding Go information, which deteriorated the efficiency of response inhibition (Durston et al., 2002a). In both adults and children, the effects of stimulus context were to a large extent determined by brain systems of cognitive control (Durston et al., 2002a,b).

Applying the same experimental design to children with ADHD has demonstrated that a preceding prepotency to activate responses compromised response inhibition in ADHD more than in healthy controls (Durston et al., 2003). Also, ADHD patients were less sensitive to graded variations in local stimulus context. These previous results strongly indicate that local stimulus context specifically alters response inhibition in ADHD. However, it remains unclear whether and how *response activation* in ADHD depends on preceding stimulus context.

The objective of the present study was to address this question. This was done by analyzing the effects of local context biasing response activation, response inhibition, or response-neutral prepotency on behavioural and preparatory motor processes in children with ADHD and healthy controls.

To model the local context of response prepotency, a cued version of the continuous performance task (CPT) was employed (Rosvold et al., 1956). CPTs require the detection of low probability targets such as a letter X or target sequences of letters such as A-X occurring randomly among other alphabetical letters. In the present study, the A-X version of CPT (cued CPT) was used for the following reasons. Firstly, preparatory processing elicited by the cueing signal A (warning stimulus) can be separated from the target processing elicited by the imperative target letter X. Secondly, it has been demonstrated that subject's performance in the A-X CPT largely depends on both the global and local stimulus context (Dias et al., 2003, 2006). In the study of Dias et al. (2003), the associations of the cue (A) with the following Go (X) or NoGo (nonX) stimulus were manipulated by increasing the probability of either the Go or the NoGo stimulus after the cue. Expectedly, this manipulation strongly affected the local (i.e., following A) prepotency of making a Go or a NoGo response. When the local prepotencies of Go and NoGo decisions were equal (i.e., when the probabilities of X and nonX stimuli after A were equal), brain activation was modulated by overall increasing the percentage of single X stimuli (i.e., X uncoupled with A, and therefore, requiring response inhibition). A higher rate of single Xs biased the global prepotency of responding toward a NoGo context because of the frequent response inhibition after single Xs.

In the present study, it was suggested that the preparatory motor activity of children in the A-X interval would depend not only on the instructed priming of the cue A but also on the uninstructed dynamic contextual priming induced by the stimuli *preceding* the cue A (Dias et al., 2003, 2006; Durston et al., 2002a, 2003). To distinguish primarily local context effects, the global probabilities of A-X, A-nonX, or single X trials were not varied and were kept equal, whereas the cue A trials were grouped according to the following context selection (see Fig. 1 and below):

(1) Cue A trials preceded by A-X trials (*Stimulus context Go*). Because A-X trials required response activation and execution, this selection was made to model an increased local prepotency to response activation after A induced by recent refreshment of sensory-motor programs.
(2) Cue A trials preceded by single X stimuli unpaired with A (*Stimulus context NoGo*). Single X stimuli were non-targets requiring active response inhibition and were therefore selected to model an increased prepotency to response suppression. Alternatively, the NoGo stimulus context could be modeled by selecting A-X trials preceded by A-nonX trials with the assumption that more inhibition would be needed to suppress a prepared rather than unprepared response. For the following reasons, however, single X stimuli unpaired with A were chosen to model inhibition prepotency in the present study. (a) A negative priming effect of preceding single Xs can be expected. It has been demonstrated that response speed or accuracy to a target stimulus may be hampered if this target has been preceded by an identical or related stimulus that had to be ignored as an irrelevant distracter. This effect, known as negative priming, is believed to reflect the efficiency to handle irrelevant distracting information, which is recognized as a major deficit in ADHD (e.g., Schacter and Buckner, 1998). (b) More importantly, the intensity of inhibition of an actively prepared movement would be strongly modulated by the degree of preparatory activation. Previous CPT

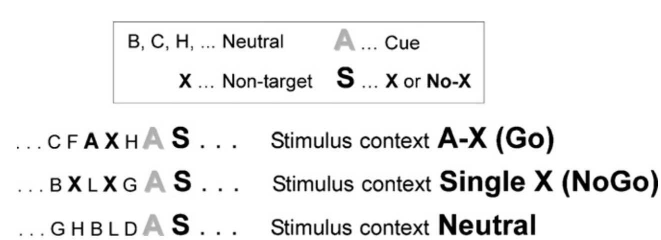

Fig. 1. Schematical presentation of the paradigm continuous performance task and differentiation of three stimulus context conditions: (a) stimulus context Go, in which the cue-stimulus (A-S) pair is preceded by other A-X sequences, (b) stimulus context NoGo, in which single X stimuli precede the A-S pair and (c) stimulus context neutral, in which neither A-X pairs nor single X stimuli, but motor-unrelated letters precede the A-S sequences. For analysis of performance data A-X pairs were used. For analysis of CNV data A-S (A-X and A-nonX) pairs were used.