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Conflict control processing in adults with developmental dyslexia: An event related potentials study

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HIGHLIGHTS

- Conflict monitoring (i.e., N2) and conflict resolution (i.e., P3b and Nogo P3) were investigated with ERPs in dyslexic adults.
- Behavioral data revealed differences between incongruent and congruent trials for reaction times in both groups but for error rate only in dyslexics.
- Dyslexics showed impaired conflict monitoring and allocation of attentional resources but preserved inhibition process.

ABSTRACT

Objective: The present study investigated the time course for processing conflict in dyslexic adults using a flanker task.
Methods: Sixteen dyslexic and 15 control adults performed a flanker task comprising congruent and incongruent trials in which participants had to indicate the direction of targets surrounded by flankers. Early negative potentials associated with orienting of attention (i.e., N1) and conflict monitoring (i.e., N2) and two positive potentials associated with conflict resolution (i.e., P3b and Nogo P3) were recorded.
Results: The behavioral data showed differences between incongruent and congruent trials for reaction times in both groups but for error rate only in dyslexics. As in previous studies, controls displayed greater N1, N2 and NoGo P3 as well as a smaller P3b in incongruent trials. Dyslexics lacked N1, N2 and P3b modulation whereas NoGo P3 effect was preserved.
Conclusion: Dyslexics showed impairments in conflict monitoring and in some aspects of conflict resolution (i.e., the allocation of attentional resources) whereas other aspects of conflict resolution (i.e., the inhibition) were preserved.
Significance: This is the first study to investigate conflict control processing in dyslexic adults using ERPs. Results provide evidence for deficits in orienting of attention, conflict monitoring and allocation of attentional resources in dyslexics.

1. Introduction

Conflict control is an important cognitive ability in human behavioral regulation. Many conflicts may occur between perceptual inputs or between required responses and the individuals' preferred responses. In these situations, conflict control allows appropriate adjustments in information processing based on goals and instructions (Botvinick et al., 2001). Two complimentary cognitive operations are involved in processing conflict: monitoring and resolution of conflict (Botvinick et al., 2001; Fan et al., 2003; Rueda et al., 2004). The conflict monitoring process is considered as the evaluative side of conflict control. It enables the evaluation of both the occurrence and the current levels of conflict (Botvinick et al., 2001; Kerns et al., 2004; Liu et al., 2011). The conflict resolution process is considered as the operative side of conflict control. It is involved once a conflict has been detected and enables the selection of task-relevant information and the inhibition of task-irrelevant information.

One of the most common tasks reported in the literature to measure conflict control is the flanker task (Eriksen and Eriksen,

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1974). In this paradigm, participants are required to respond to a central target arrow while ignoring surrounded flankers, which can be congruent (e.g. arrows pointing in the same direction), or incongruent (e.g. arrows pointing in the opposite direction) with respect to the target. Conflict is induced by flankers in incongruent trials, which produce longer reaction times (RTs) and higher error rates than congruent trials. This difference in performance between incongruent and congruent trials is referred to as the interference flanker effect. An effect of conflict has also been reported in electrophysiological studies. Some experiments have reported an effect of conflict on N1 amplitude, indicating a modulation of the orienting of attention towards stimuli according to flankers' congruency (Johnstone et al., 2009; Näätänen and Picton, 1987). Importantly, monitoring and resolution of conflict have both been associated with distinct event related potential (ERP) components. Firstly, conflict monitoring has been linked to the fronto-central N2, an ERP component originating from the anterior cingulate cortex (ACC) and observed between 300 and 500 ms post-stimulus (Johnstone et al., 2009; Van Veen and Carter, 2002; Yeung et al., 2004). Flanker task studies showed increased N2 amplitude in incongruent trials compared to congruent trials (Forster et al., 2011; Johnstone et al., 2009; Van Veen and Carter, 2002; Yeung et al., 2004). Some flanker task studies have even reported the occurrence of N2 only in incongruent trials (Hsieh et al., 2012; Van't Ent, 2002). These findings have been linked to conflict detection in incongruent trials. N2 has also been reported to be sensitive to the degree of conflict, with amplitude increasing with an increase in the proximity of distracting information (Danielmeier et al., 2009). Secondly, the conflict resolution process has been associated with two later ERP components originating from prefrontal and posterior parietal regions (Bledowski et al., 2004) and occurring between 300 and 750 ms post-stimulus: the frontal P3 and the parietal P3 (Neuhaus et al., 2007, 2010). Experimental data suggest that conflict exerts different modulating effects on P3 amplitude depending on scalp topography: an increased frontal P3 amplitude (Neuhaus et al., 2010) but a decreased parietal P3 amplitude (Neuhaus et al., 2007, 2010) in incongruent trials compared to congruent trials. Similar findings have also been consistently reported in Go-NoGo tasks: an enhanced frontal P3 and a reduced parietal P3 in NoGo trials compared to Go trials (Jonkman et al., 2003; Roberts et al., 1994). Therefore the frontal P3 is currently labeled the NoGo P3 (Jonkman et al., 2003; Neuhaus et al., 2010; Roberts et al., 1994). The frontal NoGo P3 has been linked to an inhibition process (Neuhaus et al., 2010), whereas the parietal P3, termed the P3b, may represent the allocation of attentional resources (Hillman et al., 2009) and the amount of information transmitted to working memory (Polich and Kok, 1995). P3b amplitude has been reported to be sensitive to task difficulty (Wickens et al., 1983).

Conflict control processing has been investigated in some disorders including attention-deficit hyperactivity disorder (ADHD; Johnstone et al., 2009, 2010) and schizophrenia (Neuhaus et al., 2007) but only two studies have explored conflict control processing in developmental dyslexia, and both reported impaired conflict control in dyslexics (Bednarek et al., 2004; Facoetti and Turatto, 2000). It should be noted that both studies were carried out with children and only with behavioral measures. Bednarek et al. (2004) showed a specific impairment in conflict control, with a stronger interference effect in dyslexic children than in controls. This finding has been linked to the specific visuo-spatial attention deficits reported in developmental dyslexia: the inability to narrow the focus of attention (Facoetti et al., 2000; Geiger et al., 2008; Lorusso et al., 2004) and to inhibit the interference of distractors (Bucholz and McKone, 2004; Iles et al., 2000; Vidyasagar and Pammer, 1999). Facoetti and Turatto (2000) reported an asymmetric interference effect in dyslexics with the strongest interference by flankers in the right visual field (RVF) and less interference by flankers in the left visual field (LVF). This finding has been interpreted as (a) over-processing of the flanker in the RVF; and (b) reduced flanker processing in the LVF, in accordance with the hypothesis of a left-sided minineglect in developmental dyslexia (Facoetti and Molteni, 2001; Facoetti et al., 2001; Hari and Koivikko, 1999; Ruffino et al., 2010). Altogether, these behavioral data suggest impaired processing of conflict control in developmental dyslexia but do not indicate which of the two cognitive operations involved in conflict control is impaired.

The main aim of the present study was thus to determine whether both monitoring and resolution of conflict are impaired in dyslexics or if the deficit is limited to one of these two cognitive operations. The second aim was to determine if these potential impairments are influenced by the visual field or not. To answer these questions, we measured the ERP components associated with monitoring (i.e., N2) and resolution (i.e., NoGo P3 and P3b) of conflict for each visual field in a flanker task in adult dyslexics. We also analyzed the effect of conflict on the orienting of attention (i.e., N1). In line with previous data, in controls we expected to find an effect of conflict in components associated with conflict monitoring (i.e., increased N2 amplitude in incongruent trials in comparison with congruent trials) and conflict resolution (i.e., increased Nogo P3 and smaller P3b in incongruent than in congruent trials). In dyslexics, we expected impaired monitoring (smaller N2 in incongruent trials) and resolution (smaller NoGo P3 and larger P3b in incongruent trials) of conflict. In addition and in accordance with the results of Facoetti and Turatto (2000), we expected these two cognitive operations to be specifically impaired in the LVF.

2. Methods

2.1. Participants

Thirty-one right-handed native French speakers participated in the study, 16 adults with developmental dyslexia (9 women and 7 men; mean age 25.1 years ± 5.3 years) and 15 adult controls (10 women and 5 men, mean age, 24.5 years ± 2.9 years). All subjects reported normal or corrected to normal vision. None of the control participant reported any reading or spelling impairment. Dyslexics had all been diagnosed by a speech therapist during childhood but were free of other developmental learning diseases (e.g., dysorthographia, dysphasia) and ADHD. Each participant with dyslexia had completed several years of remediation training with a speech therapist (mean, 5.1 ± 2.4 years; range 2–10 years). All subjects gave their written informed consent, and the study protocol was approved by the local ethics committee (Besançon, CPP Est II).

Prior to the experiment, the reading and naming skills and nonverbal intelligence of all participants were evaluated. Oral reading skills were assessed using the French reading test 'L'Alouette' (Lefavrais, 1965). Raw data as well as the normative reading age provided by reading latency and the number of errors were analyzed. Rapid automatic naming was also investigated using picture, digit and color naming tasks adapted from the Phonological Assessment Battery (Frederickson et al., 1997). The sums of total naming times were calculated separately for picture, digit and color naming. Finally, nonverbal intelligence was assessed by Raven's Progressive Matrices (Raven et al., 1998) under time limited conditions (20 min).

2.1.1. Task design

Fig. 1 illustrates our task design. Participants performed a modified version of the Eriksen Flanker Task (Eriksen and Eriksen, 1974). Our task design is based on the Lateralized Attention