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Altered event-related potentials in adults with ADHD during emotional faces processing

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HIGHLIGHTS

- Behavioral and neural correlates of emotional processing in adults with ADHD were examined using scalp-recorded event-related potentials (ERPs).
- ERP results provide indication of modulation of emotion processing in ADHD adults, reflected in altered P1, N170 and P3 to emotional faces.
- Brain function measures of emotion processing may provide valuable additional tools for the study and clinical assessment of ADHD in adulthood.

ABSTRACT

Objective: This study investigated behavioral and neural correlates of emotional processing in adults with ADHD using scalp-recorded event-related potentials (ERPs).
Methods: We used a visual-emotional oddball paradigm, in which subjects were confronted with neutral and emotional faces (happy and angry). Responses to target and non-target stimuli were compared across groups of 17 adults with ADHD and 20 control subjects.
Results: Participants with ADHD had slower RTs than controls in response to happy but not to angry faces. ADHD participants, but not controls, responded faster to angry than to happy faces. ERP results indicated that group significantly interacted with the type of facial expression. P1 was significantly increased for the ADHD group compared with controls, but only to emotional (and not to neutral) faces. In the ADHD group, but not in controls, P1 was greater in response to emotional compared with neutral faces. N170 was more pronounced to angry than to happy faces in the ADHD group, while in the control group N170 was more pronounced to happy than to angry faces. Participants with ADHD showed a pronounced reduction in P3 to both emotional and neutral faces.
Conclusions: The current results provide indication of altered behavioral responses as well as altered P1, N170 and P3 to emotional faces in adults with ADHD compared with healthy controls.
Significance: Behavioral and brain function measures of emotion processing may provide valuable additional tools for clinical assessment of ADHD in adulthood.

1. Introduction

A growing body of research has been focused on the possible differences in social, interpersonal and emotional functions of children and adults with Attention-Deficit/Hyperactivity Disorder (ADHD) compared with individuals without ADHD. Indeed, convergent evidence from several lines of investigation suggests that children and adults with ADHD may have deficits in emotion processing and emotion regulation in addition to cognitive impairments (for review see Wehmeier et al., 2010). More specifically, individuals with ADHD show deficits in appraisal of the emotional state of others, recognition and labeling of facial expressions of emotion, recognition of emotions on the basis of contextual

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information and emotion dysregulation (Children: Faraone et al., 1998; Singh et al., 1998; Cadesky et al., 2000; Corbett and Glidden, 2000; Pelc et al., 2006; Boakes et al., 2007; Yuill and Lyon, 2007; Sinzig et al., 2008; Williams et al., 2008; Da Fonseca et al., 2009. Adults: Rapport et al., 2002; Friedman et al., 2003; Reimherr et al., 2005; Conzelmann et al., 2009; Miller et al., 2010).

Over the past decade many studies have been conducted in an effort to gain better understanding of the neurobiological basis and pathophysiology of ADHD (Curatolo et al., 2009; Dickstein and Castellanos, 2012). Data from neuroimaging, neuropsychological and neurochemical studies have indicated substantial structural and functional abnormalities in several brain areas and neural circuits in children, adolescents and adults with ADHD (Barry et al., 2003a; Bush et al., 2005; Krain and Castellanos, 2006; Konrad and Eickhoff, 2010; Cubillo et al., 2012). In this line of research, some evidence for alterations and abnormalities in brain function of individuals with ADHD has emerged from studies using the event-related potentials (ERPs) technique.

Most ERP studies in ADHD examined cognitive processes such as selective attention and inhibitory control, using non-emotional stimuli in continuous performance tests (CPTs), oddball, stop-signal, Go/NoGo, and distraction tasks. The research to date has identified a substantial number of ERP correlates of ADHD, including ERP deficits in early components such as N1, N2, P2 and Mismatch negativity (MMN), as well as in late components such as P3 and slow wave (Barry et al., 2003b; Johnstone et al., 2013). It appears that the most robust and consistent finding in relation to ADHD is the reduced posterior-parietal P3 amplitude to target stimuli in ADHD individuals compared with healthy controls (Jonkman et al., 2000; Wiersema et al., 2006; Barry et al., 2009; Itagaki et al., 2011; Senderecka et al., 2012).

While cognitive deficits have been studied extensively, the neurofunctional deficits during emotion processing in ADHD have been given much less attention. In this context, very few ERP studies have tested emotional dysfunction among children (Williams et al., 2008; Köchel et al., 2013; López-Martín et al., 2013), and adults (Herrmann et al., 2009; Ibáñez et al., 2011; Köchel et al., 2012) with ADHD. Köchel et al. (2012) have reported reduced right parietal late positivity when adults with ADHD were instructed to inhibit a response to negative facial expressions. Herrmann et al. (2009) investigated the ERPs to positive, negative and neutral pictures among adults with ADHD compared with healthy controls. They found significantly reduced early posterior negativity (EPN) values for the ADHD patients compared to the healthy controls, but only in the positive stimuli condition, without any significant differences in the negative stimuli condition. They suggested that ADHD patients show less reactivity to positive visual stimuli. Ibáñez et al. (2011) used a dual valence task (DVT), in which faces and words were presented to test the effects of stimulus type (faces, words, or face-word stimuli) and valence (positive versus negative). Compared to controls, the adult ADHD group showed deficits in N170 emotion modulation for facial stimuli. These N170 impairments were observed in the absence of any deficit in facial structural processing. Authors concluded that these findings suggest a specific ADHD impairment in early facial emotion modulation.

The aim of the present study was to further investigate the potential neural correlates of emotional processing in adults with ADHD using scalp-recorded ERPs. Specifically, we sought to identify the ERP correlates of emotional face processing by using a visual-emotional oddball paradigm, in which subjects were confronted with one frequent standard stimulus (a neutral face) and two deviant stimuli (a happy and an angry face, which they had to detect as quickly as possible). ERPs and behavioral responses were then compared across groups of young adults with and without ADHD. Many studies have identified ERP correlates of emotional face processing in normative populations, including the P1, N170 and P3 components (e.g. Batty and Taylor, 2003; Eimer and Holmes, 2007; Hajcak and MacNamara, 2010; Schupp et al., 2004), but reports on ERP correlates of emotional face processing in ADHD are scarce. The oddball paradigm has been chosen considering that it is among the most reliable and frequently used paradigms for the elicitation of P3 (Duncan et al., 2009; Hajcak and MacNamara, 2010), and considering that the most consistent finding in relation to ADHD is the altered P3 to target stimuli (Barry et al., 2009). To our knowledge there are no oddball studies of ERPs to emotional stimuli in ADHD.

Regarding the emotional oddball task, at the behavioral level we expected poorer performance of ADHD participants which would be reflected in higher omission and commission error rates, slower RTs and poorer response time consistencies among adults with ADHD compared with controls. We also expected group differences in performance to interact with the type of facial expression.

At the electrophysiological level, we expected that individuals with ADHD would demonstrate differences in peak amplitudes of early ERP components (P1 and N170) associated with early perception and encoding of emotional faces compared to those without ADHD. Given the nature of the task (oddball) and given the convincing evidence for a P3 deficit in ADHD (Barry et al., 2003b; Williams et al., 2008; Johnstone et al., 2013), we expected ADHD to be reflected in reduced P3 amplitudes in response to target stimuli. Moreover, we expected group differences in ERPs to interact with the type of facial expression. Due to the novelty of this investigation, our analyses remain partly exploratory in nature.

2. Methods

2.1. Participants

Thirty-seven participants (mean age 24.32 ± 2.40 years) were selected from a pre-screening sample of 180 undergraduate students and divided into two groups: participants diagnosed with ADHD ($n = 17$; 14 females, mean age 24.07 ± 1.73),[1] and healthy controls without ADHD ($n = 20$; 14 females, mean age 24.52 ± 2.87). Of the 17 ADHD participants, 8 reported the sporadic use of medications (7 Ritalin, 1 Concerta), i.e. most of them were not using medications on a daily basis but only from time to time. Inclusion criteria for the ADHD group were (a) previous professional diagnosis (made by either neurologist or psychiatrist) of adult ADHD from an established clinic in the field of psychoeducational assessment, (b) at least six symptoms either of inattention or of hyperactivity-impulsivity on the ADHD Rating Scale-IV (DuPaul et al., 1998), (c) satisfaction of the diagnostic criteria of DSM-IV for adult ADHD using a modified adult version of the ADHD module in the Diagnostic Interview Schedule for Children (DISC) (Shaffer et al., 2000), and (d) low scores on an Online Continuous Performance Test (OCPT) (Raz et al., 2012), defined as more than two errors of omission and/or more than four errors of commission (based on the manufacturer's norms for adult OCPT performance).

Inclusion criteria for the control group were (a) no previous diagnosis of ADHD, (b) fewer than four symptoms either of inattention or of hyperactivity-impulsivity on the ADHD Rating Scale-IV, (c) failure to meet DSM-IV criteria for adult ADHD based on the clinical interview, and (d) scores on the OCPT task within the normal range, defined as no more than two errors of omission and/or no more than four errors of commission. The ADHD and control groups did not differ with respect to mean age, education or

[1] ADHD subtypes according to the structured clinical interview and according to the self-report rating scale: out of the 17 participants in the ADHD group, 14 were classified as the combined subtype (inattentive + hyperactive–impulsive), and 3 as the inattentive subtype (attention deficit disorder; ADD).