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Electrophysiological evidence of an attentional bias towards appetitive and aversive words in adults with attention-deficit/hyperactivity disorder

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HIGHLIGHTS

- ADHD patients show an attentional bias to emotional words as reflected by the N2pc ERP component.
- The N2pc amplitude is associated with symptom severity and poor emotion regulation in patients.
- Patients perform worse on negative vs. positive and emotionally vs. neutrally cued trials.

ABSTRACT

Objective: Emotional dysregulation has emerged as a core symptom domain in adults with Attention-Deficit/Hyperactivity Disorder (ADHD). However, the pathophysiological underpinnings remain poorly understood. This study investigated attentional biases to positive and negative emotional words as possible contributing mechanisms.
Methods: Event-related potentials (ERPSs) and behavioral attention bias indices were recorded from 39 adult patients with ADHD and 41 healthy controls during a verbal dot-probe task with positive-neutral, negative-neutral, and neutral-neutral word pairs.
Results: Cue-locked N2pc amplitudes indicated a significant attentional bias towards emotional words in patients with ADHD and healthy controls. In healthy controls, the bias was only significant in positive trials. In patients, the bias was associated with ADHD severity and self-reported poor emotion regulation skills. ADHD patients also exhibited reduced target-locked P1 amplitudes and inferior behavioral performance compared with healthy controls.
Conclusions: Our findings provide evidence of an attention bias to positive and negative emotional stimuli in adult patients with ADHD and adverse effects of emotional stimuli on task performance.
Significance: An attentional bias to emotional stimuli might contribute to emotional reactivity and dysregulation in adult patients with ADHD.

1. Introduction

The emotional symptom domain of Attention-Deficit/Hyperactivity Disorder (ADHD) has received increasing attention in the past decade (see Shaw et al., 2014; Retz et al., 2012 for reviews). Moving beyond the traditionally studied symptom domains of hyperactivity, impulsivity, and inattention is particularly important, considering the findings of significant and independent impairments associated with emotion dysregulation (ED) in patients with ADHD (Barkley and Murphy, 2010; Bunford et al., 2014). Importantly, a recent meta-analysis of the efficacy of pharmacological ADHD treatments revealed only small to moderate effect sizes for symptoms of ED in adults with ADHD (Lenzi et al., 2018). Thus, a more thorough understanding of the pathophysiological mechanism of ED in ADHD is needed as a prerequisite for an advancement of treatment.

Currently, ED in ADHD is discussed in terms of an underlying executive control deficit (Barkley, 2010; Petrovic and Castellanos, 2016) as well as in terms of heightened emotional reactivity (Nigg and Casey, 2005; Posner et al., 2014; Sonuga-Barke, 2002).

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Many ED-related correlates in ADHD patients have been derived from behavioral and imaging studies. These findings include impaired behavioral performance (i.e., slower reaction times, higher error rates) on various executive functioning tasks with emotional distractors (Marx et al., 2014, 2011; Villemonteix et al., 2017) as well as volumetric, functional, and connectivity abnormities in regions and circuits involved in emotion processing and emotion regulation (Brotman et al., 2010; Gallo and Posner, 2016; Hoogman et al., 2017; Hulvershorn et al., 2014; Posner et al., 2011; Tajima-Pozo et al., 2016). These studies support the hypothesis of ED as a core feature of ADHD psychopathology (Barkley, 2010) rather than an associated feature, as conceptualized by the DSM 5 (American Psychiatric Association, 2013). However, to disentangle the impaired sub-processes of emotion processing and regulation in ADHD patients, techniques with a higher temporal resolution, such as the event-related potential (ERP) technique, are crucial (Barry et al., 2003; Banaschewski and Brandeis, 2007; Johnstone et al., 2013).

In this study, we investigated an attentional bias to emotional stimuli (positive and negative words) as a potential mechanism of heightened emotional reactivity in adult ADHD patients. Attentional biases are considered important variables in the etiology and maintenance of mood and anxiety psychopathology (Gibb et al., 2016) and have been linked to ED in healthy subjects (Bardeen et al., 2017). The most extensively studied paradigm in the context of attentional biases is the dot-probe task (MacLeod et al., 1986). A neutral and an emotional stimulus (i.e., words, faces, or images) are presented simultaneously, followed by a target stimulus (dot) presented in the location of either the emotional or the neutral stimulus. Participants are required to respond to the target as quickly and accurately as possible. Beyond the traditionally studied behavioral attention bias indices, more recent approaches emphasize the advantages of electrophysiological correlates of attention biases (Gibb et al., 2016). Specifically, the cue-locked N2pc has been suggested as a more reliable measure of attention shifts in the dot-probe paradigm compared with reaction times (Kappenman et al., 2015, 2014; Reutter et al., 2017). The N2pc is a negative-going ERP component, associated with neural generators within the ventral visual processing pathway, which is maximal at posterior electrode sites contralateral to the location of an attended stimulus (Luck, 2012). Additionally, the target-locked P1, an exogenous visual component associated with neural generators in the extrastriate visual cortex, has been found to be higher for probes with emotional vs. neutral cues (Brosch et al., 2008; Pourtois et al., 2004).

To date, no study has investigated an attentional bias to emotional stimuli in ADHD patients using the dot-probe paradigm. The evidence from behavioral and fMRI studies employing emotional Stroop tasks is mixed, with findings pointing to a specific attentional bias towards only positive stimuli (Passarotti et al., 2010a; Hwang et al., 2015), positive and negative stimuli (Posner et al., 2011; Yarmolovsky et al., 2017) or no difference in attentional bias in ADHD patients compared with healthy controls (Ma et al., 2018). Critically, all of these studies were conducted in pediatric or adolescent patients. Although there are no ERP studies investigating attentional biases in ADHD patients, there is evidence of enhanced initial processing of positive and negative facial expressions (Raz and Dan, 2015), reflected in an enhanced N170, which is consistent with an attentional bias. The results on mid-latency components are ambiguous: while López-Martín et al. (2013) report findings of enhanced N2 amplitudes to emotional images in boys with ADHD, another study (Herrmann et al., 2009) found attenuated early posterior negativity (EPN) amplitudes to positive images in adults with ADHD. The late-latency components such as the P300, the late positive potential (LPP), and the N400 have been found to be attenuated during the processing of affective facial expressions and in tasks employing emotional stimuli as distractors (Köchel et al., 2013, 2012; Tye et al., 2014; Williams et al., 2008). However, in a recent study of emotion regulation in an adult ADHD sample, we found abnormally elevated LPP amplitudes to negative IAPS images (Shushakova et al., 2018).

To shed more light on the mechanisms of ED in ADHD, we tested the hypothesis of an underlying attentional bias. More specifically, we hypothesized that the allocation of attention to positive and negative emotional stimuli would be enhanced in patients with ADHD compared with healthy controls. We expected the attentional bias to be reflected in higher cue-locked N2pc amplitudes as well as in elevated target-locked P1 amplitudes elicited by emotionally vs. neutrally cued probes. Behaviorally, an attentional bias towards emotional stimuli could be reflected in positive attention bias, facilitation or disengagement indices, as well as in higher accuracy rates in trials with emotionally vs. neutrally cued probes.

2. Methods

The current study is part of a larger project investigating the electrophysiological and neural correlates of emotional reactivity and regulation in adult ADHD patients. Thus, recruitment, diagnostic assessment, EEG recording, and processing methods in this study are similar to our previously published paper on emotion regulation in adult ADHD (Shushakova et al., 2018).

2.1. Participants

Forty-five adults with diagnoses of ADHD according to the DSM-5 (American Psychiatric Association, 2013) and 44 healthy controls (HC) were included in the study. "We recruited the patients from the Outpatient Clinic of the Department of Psychiatry and the Outpatient Clinic of the Department of Psychology at the University of Münster. The controls were recruited through advertisements in local newspapers" (Shushakova et al., 2018), and matched for age, gender, and years of education.

The diagnostic assessment was conducted by a trained clinical psychologist and consisted of a pre-screening with the Adult ADHD Self-Report Scale (ASRS; Kessler et al., 2005), the structured Diagnostic Interview for ADHD in adults (DIVA 2.0; Kooij, 2012), self-report questionnaires to determine current (ADHD self-report (ADHD-SR): Rösler et al., 2008) and lifetime ADHD symptoms (Wender Utah Rating Scale German short version (WURS-K): Retz-Junginger et al., 2002), and tests of the general intellectual ability (Vocabulary and Matrix Reasoning subtests from the German version of the Wechsler Adult Intelligence Scale WAIS-IV; Wechsler, 2008) and attention (Frankfurt Attention Inventory, FAIR-2; Moosbrugger and Oehlschlägel, 2011). The Structured Clinical Interview for DSM-IV (Wittchen et al., 1997) was conducted to identify clinical diagnoses in all participants. We further assessed the severity of depressive symptoms with the Beck Depression Inventory-II (BDI-II; Beck et al., 1996) and trait anxiety with the STAI (Laux et al., 1981). Additionally, self-reported emotion regulation skills (SEK-27; Berking and Znoj, 2008), were assessed in all participants.

"Exclusion criteria for both groups included bipolar disorder, psychotic disorder, obsessive-compulsive disorder, a severe major depressive episode within the last five years, substance abuse or dependence, borderline personality disorder (screened with the Borderline Symptom List BSL-23; Bohus et al., 2009), neurological disorders, brain damage or a serious head injury. In the ADHD group, one subject was excluded due to cannabis abuse, and another was excluded due to intellectual disability. In the control