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Affective inhibitory control in adults with attention deficit hyperactivity disorder: Abnormalities in electrocortical late positivity

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HIGHLIGHTS

- ► Reduced late positivity in inhibition due to negative facial expressions in ADHD.
- ► Electrocortical but no behavioral deficits in affective inhibitory control in adults with ADHD.
- ► Positive correlation between emotional intelligence and ERP to negative expressions.

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ABSTRACT

Boys afflicted with ADHD (Attention-deficit/hyperactivity disorder) are characterized by deficient response inhibition and reduced electrocortical late positivity when presented with facial expressions of anger. This deficit might contribute to their problems in social interactions. We conducted the present event-related potential study with 15 men suffering from ADHD and 15 healthy controls in order to investigate whether similar dysfunctions are present in adult ADHD. The participants underwent an emotional version of a Go/NoGo task while event-related potentials (ERPs) were recorded. They were instructed to inhibit a motor response to one of four facial emotional expressions: anger, fear, sadness, or happiness. There were no behavioral differences in inhibitory control between the ADHD and the control group. However, the patients showed a reduced right parietal late positivity when instructed to inhibit a response to negative emotions. Obviously, the patients have learned to compensate for their deficit on a behavioral level, while it is still visible on the electrocortical level in this relatively simple task. Interestingly, the reduced positivity correlated with lowered self-reported emotional intelligence in the ADHD group.

1. Introduction

Attention-deficit/hyperactivity disorder (ADHD) is not just one of the most common mental disorders in school-aged children [1], but also frequently persists into adulthood as a clinical or subclinical syndrome [25]. Barkley et al. [3] reported a persistency rate of approximately 66% for the disorder. In adults, symptoms often look quite different than in children and are partially compensated [25]. Nevertheless, the symptoms hinder relationships and careers of adult ADHD patients.

One prominent theory of ADHD suggests a core deficit in inhibitory control [2] that leads to impairments in motor control and impulsive behavior. Behavioral data from children support this theory [indicated by commission errors; e.g., 4], but are inconsistent for adults afflicted with ADHD [7,16]. Changes in electrocortical reactivity [indicated by changes in event-related potentials; e.g. 4] are present in both children and adults with ADHD [e.g. 7, 16]. Compared to healthy controls, they showed decreased P300 to NoGo stimuli most likely reflecting reduced behavioral inhibition.

Inhibitory control has mainly been studied with cognitive, achievement tasks. However, inhibitory control is also important in an affective context. For social functioning, inhibitory control of inappropriate responses based on emotional signals is essential [5]. A facial display of anger for example is an important signal for social correction, and should therefore lead to response inhibition. In boys with ADHD the response inhibition to anger cues seems to be impaired [9]. In a former investigation by our group [9] we used an ‘emotional Go/NoGo’ task. Emotional facial expressions of anger, happiness, and sadness were presented in serial order, and the participants were required to either exhibit or inhibit a motor response to a specific emotional cue. Relative to a control group, children with ADHD had more problems to stop a prepotent response (key press) when the stop signal was an angry face which was not true

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for happy and sad faces. Moreover, the anger inhibition deficit in ADHD patients was accompanied by diminished right parietal late positivity in a time window between 500 and 600 ms. While in the control group the amplitudes differed between all emotional conditions, right parietal late positivity for anger cues did not differ from sad and happy cues in the ADHD group. The results were interpreted to reflect a reduced sensitivity accompanied by a reduced response inhibition to anger cues in boys suffering from ADHD. Their social behavior seems to be insufficiently guided by emotional feedback, which may be causal for the interpersonal problems that are typically described for this patient group [12,13]. Williams et al. [26] already reported impaired anger identification in children suffering from ADHD that had been accompanied by reductions in right parieto-temporal positivity.

To the best of our knowledge, there are no data on affective response inhibition in adult ADHD. The present ERP study aimed to determine whether deficient behavioral inhibition to anger cues can be identified in adult ADHD. The participants underwent an emotional Go/NoGo task including angry, sad, happy, and fearful faces. We attempted to replicate findings obtained for children with ADHD [9] and expected behavioral deficits in response inhibition towards anger signals together with diminished late positivity at right partial sites for an adult ADHD sample.

2. Methods

2.1. Participants

Fifteen men suffering from ADHD and 15 healthy men (control group, CG) aged from 19 to 33 years participated in the study. Participants of the patient group had a diagnosis of ADHD based on the Wender Utah Diagnosis Criteria for ADHD in adulthood [25]. Diagnoses were confirmed by a board-certified clinical psychologist.

Exclusion criteria for both groups were an intelligence quotient (IQ) below 80 [assessed by CFT 20-R, 24]. An interview was given to participants to rule out the presence of any somatic or mental disorder (besides ADHD). Additionally, psychopharmacological medication led to exclusion from the study.

The participants were recruited by newspaper advertisement, the outpatient clinic of the department of clinical psychology, and a local outpatient clinic for ADHD. The study was approved by the local ethics committee of the University of Graz. All participants gave written informed consent.

2.2. Material and procedure

2.2.1. Diagnostic session

The selection of the participants was based on two ADHD questionnaires: the German version of the Wender Utah Rating Scale [WURS-k, 19] and the ADHD questionnaire for adults [ADHS-SB, 21]. The WURS-k is used to retrospectively establish the childhood diagnosis of ADHD. It consists of 21 items and 4 additional control items. Each item is judged on a 5-point scale and refers to the age between 8 and 10 years [Cronbach $\alpha = 0.91$, 18]. The ADHD-SB allows a judgment of ADHD-symptoms in adulthood and consists of 22 items that have to be rated on a 4-point scale (Cronbach's $\alpha = 0.90$). For the participation in the clinical group a cut-off score of 30 points in the WURS-k was required. This is suggested to provide a high sensitivity and specificity for ADHD [18]. Additionally to a WURS-k score of at least 30, an ADHD-SB score of 15 or above was required for the ADHD group. Participants of the control group were required to have scores below 25 (WURS-k) and below 15 (ADHD-SB).

In a diagnostic session, the Wender–Reimherr-Interview [WRI; 20] was used for a detailed diagnosis of ADHD. This structured interview (Cronbach's $\alpha = 0.60–0.72$) covers 28 symptoms from seven symptom domains: inattention, hyperactivity, hot temper, affective lability, emotional hyperreactivity (stress intolerance), disorganization, and impulsivity. Each symptom is judged on 4-/5-point scales. To ensure the absence of other mental disorders a standardized clinical interview was used for both groups [Mini-DIPS, 11]. Additionally, participants filled out the German version of the Trait Meta Mood Scale [TMMS; 14] that assesses three aspects of emotional intelligence and is suggested to be associated with accuracy of facial emotion perception (Cronbach's α: 0.81–0.88).

2.2.2. Experimental session

In a second session the 'emotional Go/NoGo task' with EEG recording was conducted. The stimuli comprised of faces from the Karolinska Directed Emotional Faces [KDEF; 10] and were presented serially in a pseudo-randomized order. The four blocks of emotional tasks required the execution or inhibition of a button press for a specific emotional face conveying anger, sadness, happiness, or fear (25% in each case). Each of the four emotions was used as a NoGo stimulus (inhibition of a button press) while the others served as Go stimuli. Additionally, one block of a non-emotional task (control condition) was a sex discrimination task that included male and female neutral faces. In one block (duration: approximately 5 min), 192 facial stimuli were presented for 1000 ms each with an interstimulus-interval of 500 ms. Presentation of emotional and neutral blocks was randomized for each subject. The ratio for Go:NoGo stimuli was 3:1.

2.3. Data recording and analysis

The EEG was recorded by a Brain Amp 32 AC (Brain Products, Gilching, Germany) using an EasyCap (EasyCap, Hersching, Germany) from 29 positions of the 10/20 electrode reference system [6] including the mastoids (TP9, TP10). The electrooculogram (EOG) was recorded with two electrodes from the outer epicanthus of each eye, vertical EOG was recorded by one electrode below the right eye. FCz served as reference and AFz as ground. The EEG was recorded with a sampling rate of 500 Hz (passband: 0.016–100 Hz). For further analysis (Brain Vision Analyzer 2.0), the data were down-sampled to 250 Hz (spline interpolation) and a high pass filter was set (0.1 Hz, 24 dB/Oct). Independent Component Analysis was used to correct for ocular artifacts (blinks, saccades), remaining artifacts (e.g. muscle activity, movement) were rejected by means of visual inspection. Afterwards, the EEG was re-referenced to linked mastoids, filtered (20 Hz, 24 dB/Oct), and segmented. Trials of each condition were averaged and baseline corrected (200 ms pre-stimulus interval). This included only trials in which subjects gave a correct response (inhibition in NoGo cues; motor response in Go cues). The selected time window and electrodes were based on our previously conducted study using the 'emotional Go/NoGo' paradigm in children with ADHD [9]. Mean amplitudes for the electrodes P7, PZ, P8 for the late positive potential (LPP: 500–600 ms) were computed and submitted to statistical analysis.

Behavioral data comprised of the percentage of wrong responses to NoGo-stimuli (commission errors).

Statistical analyses were conducted with SPSS (Statistical Package for Social Science, version 19). For all analyses, violation of sphericity was controlled by Greenhouse–Geisser adjusted degrees of freedom. Three-way ANOVA's with the between-subject factor *GROUP* (ADHD, CG), the within-subject factors *CONDITION* (Go, NoGo) and *EMOTION* (anger, sadness, happiness, fear, neutral) were conducted separately for mean amplitudes on right (P8), left (P7), and central parietal (Pz) sites. Additional correlation analyses should clarify relations between electro-cortical data and emotional intelligence [TMMS; 14] that is suggested to predict accuracy of affective face recognition. For behavioral data