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ERP responses of adolescents diagnosed with ADHD in the presence of emotional distractors and the potential effects of treatment on these responses

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Abstract

Attention-deficit/hyperactivity disorder (ADHD) is associated not only with difficulties in attention and impulse control, but also with altered neural processing of emotional facial expressions. This study examined how emotional-face distractors influence behavioral performance and event-related potentials (ERPs) in adolescents with ADHD compared with healthy controls. Twenty adolescents with ADHD and 22 age matched healthy controls, aged 12–16 years, completed an arrow-direction task in which arrows were superimposed on facial images depicting five emotional expressions: neutral, fearful, happy, sad, and angry. Fourteen participants with ADHD were reassessed after psychostimulant treatment. Drug-naïve adolescents with ADHD showed enhanced right-lateralization of P100 amplitude, accompanied by reduced N170 and P300 amplitudes and a broader anterior–posterior distribution of late LPP activity. Psychostimulant treatment led to reduced post-P300 centro-parietal positivity in the simple 2-choice task. These findings suggest that adolescents with ADHD may allocate neural resources differently when processing task-irrelevant facial expressions, with alterations emerging from early perceptual stages and extending through later, sustained attentional processing. Overall, the results point to altered spatiotemporal organization of neural responses to emotional distraction in adolescent ADHD.

1. Introduction

Attention-deficit hyperactivity disorder (ADHD) is a childhood-onset neurodevelopmental disorder characterized by inattention, impulsivity, and hyperactivity [1]. Although these symptoms define the core clinical picture, ADHD is also associated with difficulties in executive functioning, social interaction, emotional awareness, and emotion regulation [2], and frequently co-occurs with oppositional defiant disorder, anxiety, depression, tic disorders, and learning disabilities [3]. These broader socio-emotional difficulties may be particularly relevant during adolescence, a period marked by increasingly complex social relationships and greater sensitivity to emotional cues; therefore, examining socio-emotional processing in adolescent ADHD is clinically and developmentally important [4,5] .

Social-emotional functioning involves inferring others' emotional states from facial expressions, eye gaze, and body language [6]. In ADHD, lower emotional intelligence and higher alexithymia have been reported [7,8], whereas findings on social cognition remain mixed. Given the developmental sensitivity of social-cognitive processes, narrow age ranges are important [9], and inconsistent findings may reflect individual differences in age, attention, executive functions, verbal abilities, and emotional evaluation [2,9,10]. Emotional distractors may also affect task performance in ADHD [11], possibly because early dominance of emotional stimuli in sensory cortices can propagate to higher-order cognitive circuits [12]. Moreover, methylphenidate has been associated with improvements in emotion regulation and emotion recognition in ADHD [13,14].

Emotional facial expressions are among the most fundamental cues from the social environment and can shape attentional orienting, environmental evaluation, and behavioral response selection [15,16]. Even

when irrelevant to the ongoing task, emotional faces may capture attentional resources and influence performance in a disruptive or facilitative manner, depending on the context [17]. The direction of this effect may vary according to stimulus emotion, threat salience, task load [18]. In particular, anger and fear expressions may be prioritized by the attentional system because they signal potential threat or social conflict. However, under relatively 2-choice task conditions, threat-related faces may transiently enhance attention or arousal and thereby facilitate goal-directed performance. Consistent with this, O'Toole and colleagues (2011) showed that angry and fearful faces facilitated attentional orienting relative to happy faces in a simple attention task, whereas this effect disappeared as task demands increased. Thus, the impact of task-irrelevant emotional facial expressions should be considered not only in relation to stimulus emotion, but also in relation to the cognitive load and contextual demands of the task[19].

While electrophysiological studies in ADHD have yielded important insights into emotional processing, alongside executive functions such as attentional control, sustained attention, and response selection, studies examining the interaction between these domains remain limited [20,21]. In particular in adolescents with ADHD, studies examining the effects of emotional distractors on both behavioral performance and Event Related Potentials (ERP) responses are limited [22,23].

In research on emotion–attention interactions, investigating (ERPs), addition to behavioral performance, facilitates a more comprehensive evaluation by providing high temporal resolution to the assessment of cognitive processes across multiple stages, from lower-order to higher-order processing [16]. During the processing of emotional facial expressions, the P100 component is thought to reflect early visual processing and attentional sensitivity [24] whereas the N170 is associated with the early structural encoding of facial stimuli [25,26]. The P300 has been linked to attentional resource allocation, stimulus evaluation, and context updating [27], while the late positive potential (LPP) is considered to reflect the later and sustained processing of emotionally and motivationally significant stimuli [28,29].

Previous studies on the processing of emotional facial expressions in adolescents with ADHD has indicated potential differences in ERP components related to early face perception, attentional orienting, and later emotional evaluation processes [21,30]. However, findings are not entirely consistent at either the behavioral or electrophysiological level; it has been reported that behavioral performance does not always differentiate between groups, whereas ERP measures can more sensitively reveal differences in the temporal dynamics of emotional face processing [22,23]. Furthermore, a substantial proportion of existing studies have utilized task-relevant paradigms that require participants to directly identify, evaluate, or respond to emotional facial expressions. Consequently, it remains unclear how task-irrelevant emotional facial expressions interact with goal-directed attention and response selection processes in adolescents with ADHD. Building on this gap, the present study aims to investigate the effects of task-irrelevant emotional facial expressions on behavioral performance and ERP time-course measures during a simple goal-directed attention task between adolescents with ADHD and typically developing controls. Differences in ERP responses between the two groups are hypothesized. Further, it

is hypothesized that ERP responses in adolescents with ADHD receiving treatment for the first time would become more similar to those of the control group following psychostimulant treatment.

2. Results

2.1 Socio-Demographic Results

A Mann–Whitney U test was conducted to examine whether age differed between the ADHD and control groups. The analysis showed no statistically significant difference in age between the groups, $U = 148$, $z = -1.87$, $p = .062$.

A chi-square test was used to compare gender distribution between the ADHD and control groups. The results indicated that gender distribution did not differ significantly between the groups, $\chi^2(1, N = 42) = 2.30$, $p = .129$. These findings suggest that the groups were comparable in terms of age and gender distribution.

2.2 Behavioral Results

Bar-On Emotional Intelligence Scale for Children and Adolescents:

The independent samples t-test revealed a statistically significant group difference, $t(40) = -4.84$, $p < .001$, indicating that the control group had significantly higher total EQ scores than the ADHD group.

The Wilcoxon signed-rank test showed that total EQ scores increased significantly after medication, $Z = -2.07$, $p = .038$, $r = .55$.

Alexithymia Scale for Children:

An independent samples t-test revealed a significant difference in total alexithymia scores between the ADHD and control groups, $t(40) = 3.21$, $p = .003$. The ADHD group had significantly higher total alexithymia scores (Mean: 17.25 ± 6.97) than the control group (10.86 ± 5.94). Within the ADHD group, no significant difference was observed between pre- and post-medication total alexithymia scores.

Continuous Performance Test (CPT): CPT test accuracy differed significantly between groups, with the control group demonstrating higher accuracy than the ADHD group $U = 153$, $z = -2.08$, $p = .038$, $r = .32$). Although the ADHD group exhibited higher false alarm rates and longer reaction times (RT) compared to controls, these differences did not reach statistical significance (False alarm rate: $U = 161.50$, $z = -1.56$, $p = .120$; Reaction Times: $U = 162$, $z = -1.46$, $p = .144$).

Wilcoxon signed-rank tests showed that hit rate increased significantly from pre-test to post-test ($Z = 2.08$, $p = .037$, 2-sided, $N = 14$) No significant changes were observed for false alarm rate ($p = .160$) or RT ($p = .277$).

RMET (Reading Mind from Eye Test): RT did not differ between ADHD (Mean: 6.46 ± 1.36) and control participants (Mean: 6.32 ± 1.07; t (40) = 0.38, p = .705). Similarly, no significant group differences were found for accuracy (U = 184, p = .361), total duration (U = 169, p = .199), and inverse efficiency score (U = 180, p = .314).

No significant pre–post differences were observed for RMET performance, including RT, accuracy, total duration, and inverse efficiency score (all p > .05).

Correlations among scales

Associations among the scale scores were examined using Spearman's rank-order correlation analysis. A strong negative correlation was found between total alexithymia scores and total EQ scores, ρ = −.804, p < .001, indicating that higher alexithymia levels were associated with lower EQ.

A moderate negative correlation was observed between RMET accuracy scores and total alexithymia scores, ρ = −.423, p = .005. This finding suggests that higher alexithymia levels were associated with lower accuracy in recognizing mental states.

In addition, RMET accuracy scores were moderately and positively correlated with total EQ scores, ρ = .415, p = .006, indicating that higher EQ was associated with better RMET performance.

Face distracted 2-choice task:

Accuracy performance analysis revealed a significant main effect of GROUP, (F(1, 40) = 23.87, p < .001, ηp^2 = .374) indicating overall differences between groups (ADHD vs Control), and a significant main effect of EMOTION, indicating variation across levels (F(3.275, 131.013) = 5.34, p = .001, ηp^2 =.118). GROUP × EMOTION interaction was also significant, indicating that the emotion-related accuracy profile differed between groups (F(4, 160) = 2,74, p = 0.041, ηp^2 = .064). Bonferroni-adjusted simple-effects pairwise comparisons of EMOTION within ADHD group revealed that accuracy in angry face condition was significantly higher than happy face condition (p = 0.011).

In RT, there was a significant main effect of EMOTION (F(3.019, 120.755) = 3.50, p = .017, ηp^2 =.081) without a group effect. Bonferroni-adjusted pairwise level comparisons of EMOTION factor indicated that RT in sad-face condition were significantly longer than neutral (p = 0.031) and happy face conditions (p = 0.002).

Pre–Post medication comparison in the face distracted 2-choice task:

In the face-distractor task, mean accuracy increased from .837 at pre-test to .893 at post-test. Repeated-measures ANOVA revealed a significant main effect of drug, F(1, 13) = 16.69, p = .001, ηp^2 = .562, indicating higher accuracy after medication. For RT, the main effect of drug was not significant. Neither the main effect of condition, nor the drug × condition interaction, reached statistical significance.

Simple 2-Choice Task Results:

A Mann–Whitney U test revealed a significant difference in mean accuracy between the ADHD and control groups. The control group showed significantly higher accuracy than the ADHD group, $U = 108$, $z = -2.83$, $p = .005$, r = .44. In contrast, mean RT did not differ significantly between the groups. Within the ADHD group, pre- and post-test performance was compared using paired samples t-tests. Mean accuracy did not differ significantly between the pre-test (Mean: 0.885 ± 0.084) and post-test (Mean: 0.880 ± 0.161), $t(13) = 0.091$, $p = .929$, 95% CI [− 0.099, 0.108]. Similarly, mean RT did not change significantly from pre-test (Mean: 0.472 ± 0.093) to post-test (Mean: 0.460 ± 0.096).

2.3 ERP Results

ERP mean-amplitude evaluation time windows were defined as follows: 90–150 ms for P100, 150–200 ms for N170, 250–400 ms for P300, 400–600 ms for early LPP, 600–800 ms for middle LPP, and 800–1000 ms for late LPP.

Face distracted 2-choice task: Comparison Between the ADHD and Control Groups

Early-latency visual ERP components (P100 and N170) were evaluated over the parieto-occipital region. In the ADHD group, the P100 component exhibited right-lateralization, as indicated by a significant GROUP × LAT interaction, $F(2, 80) = 5.42$, $p = .006$, $\eta p^2 = .119$. This interaction indicated a stronger right-hemispheric lateralization in the ADHD group relative to the control group. In the 150–200 ms time window, corresponding to the N170 component, a significant main effect of group was observed over the parieto-occipital region, $F(1, 40) = 4.46$, $p = .041$, $\eta p^2 = .10$. The control group showed more negative mean amplitudes than the ADHD group.

P300 amplitude, evaluated at centro-parietal electrodes (C3, Cz, C4, CP3, CPz, CP4, P3, Pz, P4), was significantly higher in the control group than in the ADHD group, which appeared as a main effect, $F(1, 40) = 4.52$, $p = .040$, $\eta p^2 = .102$. This finding indicates that mean amplitudes were higher in the control group than in the ADHD group.

LPP amplitude, evaluated in the 800–1000 ms time window across frontocentral, central, centroparietal, and parietal regions, showed a significant Region × Group interaction, $F(1.278, 51.136) = 7.52$, $p = .005$, $\eta p^2 = .158$, indicating that the scalp distribution of LPP amplitudes differed between the ADHD and control groups. This interaction indicates that the scalp distribution of LPP amplitudes differed between the ADHD and control groups. No significant main effects of emotion or Emotion × Group interactions were observed for any of the examined ERP components, including P100, N170, P300, and LPP. In the simple 2-choice task, no significant differences were found between the ADHD and control groups in any of the examined ERP time windows (Fig. 1.).

Pre–Post Medication ERP Comparisons

In the face-distractor task, no significant pre- to post-medication differences were observed in any of the examined ERP time windows.

For the simple 2-choice task, post-P300 activity was examined in the 400–600 ms and 600–800 ms time windows. In the 600–800 ms time window, a significant main effect of DRUG was observed, $F(1, 13) = 10.60$, $p = .012$, $\eta p^2 = .449$, indicating reduced mean amplitudes after medication across the included electrodes (Fig. 2). A significant DRUG × AP interaction was also observed in the 400–600 ms time window, p = .008. This interaction indicated that the fronto-parietal increase in amplitude observed before medication was attenuated after medication. Overall, mean amplitudes were reduced after medication in both post-P300 time windows.

3. Discussion

3.1 Behavioral Measurement

In the present study, adolescents with ADHD showed lower EQ and higher alexithymia scores than controls, consistent with previous literature [7,8]. The negative correlation between EQ and alexithymia across whole sample further supports the view that difficulties in recognizing, labeling, and expressing emotions are central to the emotional profile associated with ADHD [31,32].

The absence of significant group differences in RMET performance should be interpreted cautiously, given the task's sensitivity to age, verbal comprehension, semantic knowledge, general cognitive functioning, and attentional performance[33,34]. Social-cognitive findings in ADHD are heterogeneous and may vary according to developmental stage, cognitive level, task characteristics, and symptom profile[9,10]. Although meta-analytic evidence suggests reduced theory of mind performance in ADHD[10], RMET findings remain mixed, with some adolescent studies reporting no clear group differences[35] and some child samples showing poorer performance, possibly related to attentional processes[36]. In the present study, RMET accuracy was associated with higher EQ and lower alexithymia, suggesting that social-affective cue decoding may be more closely related to emotional self-awareness and emotional competence than to diagnostic status alone [37,38].

Adolescents with ADHD showed lower accuracy than controls in both the CPT and the simple 2-choice task, consistent with our hypothesis and prior evidence on attentional difficulties in ADHD [39,40]. In contrast, mean RT did not differ between groups, suggesting that behavioral differences in ADHD may be more evident in accuracy, error rates, and performance stability than in mean response speed. This interpretation is supported by meta-analytic evidence showing impairments in sustained attention and error-related CPT indices in ADHD, while also indicating that CPT measures alone have limited diagnostic discriminative value [39,40].

Findings from the face-distracted 2-choice task suggest that attentional performance may be modulated by emotional context. Task-irrelevant emotional faces may engage attentional resources and compete with ongoing task demands [41]. In the ADHD group, higher accuracy in the angry-face condition than in the happy-face condition suggests that emotional distractors may influence performance differently

depending on their emotional content and threat salience. Thus, systematic reviews examining emotion recognition accuracy in ADHD have shown that while some studies report broad impairments across emotions, others describe deficits that are specific to particular emotional expressions [42]. From the perspective of Pessoa's (2009) dual competition model, emotionally and motivationally salient stimuli may influence both perceptual processing and executive control, leading to either performance impairment or facilitation depending on task context and cognitive control demands. Accordingly, in the present study the higher accuracy observed for angry faces may indicate that the social-threat salience of anger transiently enhanced attentional or arousal engagement during this relatively 2-choice task. This interpretation is also consistent with O'Toole et al. (2011)[19], who showed that angry and fearful faces facilitated attentional orienting relative to happy faces in task contexts, whereas this effect disappeared as task difficulty increased.

Longer RT for the sad-face condition in both groups suggest that sad facial cues imposed a general processing cost independent of diagnostic status. This slowing may reflect prolonged attentional engagement or greater difficulty in disambiguating sad expressions, consistent with evidence that sad faces can elicit longer response times than other expressions [43]. Similarly, Liu et al. (2013)[44], using a facial expression flanker paradigm, found that sad faces were associated with longer RT and lower accuracy than neutral faces.

Following psychostimulant treatment, the ADHD group showed increased accuracy in the face-distracted 2-choice task, whereas no comparable improvement was observed in the 2-choice task without emotional distractors. This finding suggests that treatment-related gains may reflect improved task performance under relatively greater cognitive demand requiring emotional distractors.

3.2. ERP Discussion

P100

The right-lateralized P100 response in the ADHD group suggests altered early visual processing in the presence of task-irrelevant emotional faces. Although P100 lateralization findings remain inconsistent [30,45], this variability may reflect differences in stimulus types and experimental protocols across studies [46]. The present finding may indicate that task-irrelevant faces more readily engage early attentional processing in adolescents with ADHD, consistent with evidence linking P100 to early emotion detection and right-hemisphere involvement in emotional stimulus processing [12,47].

N170

In the present study, task-irrelevant emotional faces elicited more negative N170 responses in controls than in adolescents with ADHD. This reduced N170 negativity may indicate less efficient early structural encoding of background facial expressions in ADHD under simultaneous attentional demands, suggesting that ADHD-related alterations in emotional distractor processing are not limited to later cognitive processes of facial expression [48]. Although participants were instructed to respond only to

arrow direction, the robust N170 response in controls suggests that task-irrelevant faces were not fully suppressed at the stage of structural face encoding. This is consistent with evidence that face processing is not entirely automatic or independent of attention, and that task-irrelevant faces may still be processed implicitly under certain conditions [26,49,50]. From this perspective, the reduced N170 negativity in ADHD may reflect greater vulnerability of early face-encoding processes when facial information competes with task-relevant attentional demands.

The emotional sensitivity of the N170 remains debated. Some studies suggest that N170 is relatively independent of emotional expression [51], whereas others report selective sensitivity, particularly to fearful faces [52] or a more general sensitivity to emotional content without specificity for a particular emotion category [53]. Consistent with some of the studies, the present study showed a group difference in N170 but no emotion-specific modulation, suggesting that the effect may be more closely related to early structural encoding of task-irrelevant emotional faces than to a specific emotion category[26]. This finding may also be considered developmentally, given evidence for delayed cortical maturation in ADHD [54,55] and age-related changes in N170 across childhood and adolescence [56].

P300

P300 amplitude is sensitive to the attentional resources allocated to task-relevant stimuli and tends to decrease when resources are limited or task demands increase [27,57]. Emotional facial content can also modulate P300 responses, reflecting later evaluative processing of emotional faces[48].

In the present study, the lower P300 amplitude in the ADHD group during the face-distracted 2-choice task suggests less efficient late attentional control and stimulus evaluation under social-emotional distraction. Although participants responded only to arrow direction, background facial expressions may have increased processing demands as salient social-emotional distractors. The absence of group differences in the 2-choice task without faces further suggests that this effect was not only driven by basic task demands alone, but also by the distractor context introduced with facial stimuli. This interpretation is consistent with previous ERP findings showing attenuated late cognitive components in ADHD. Münger et al. (2021)[58] reported lower P300 amplitudes in ADHD, Kaiser et al. (2020)[59] linked reduced P300 responses to difficulties in attentional resource allocation and response control, and Tan et al. (2025)[60] reported lower P300 amplitudes and longer latencies in children with ADHD during a visual oddball task. Although these studies did not directly examine emotional face distractors, together with the present findings it can be suggested that adolescents with ADHD may have reduced capacity to allocate and maintain attentional resources for task-relevant information in existence of social-emotional distractor.

LPP

Although no significant group differences were observed during the early and middle LPP time windows, the significant Region × Group interaction in the late LPP interval (800–1000 ms) indicates that

emotional face distractors led to different topographical distribution between groups during sustained processing (Fig. 2). The centro-parietal/posterior distribution of LPP has been linked to motivational attention and the allocation of processing resources to emotional stimuli [29]. In the present study, controls had the expected anterior-to-posterior increase in LPP amplitude, whereas adolescents with ADHD showed a broader positivity along the anterior–posterior axis. This scalp distribution suggests altered topographic organization of attentional resources during late processing of emotional distractor in ADHD. Furthermore increase in positivity from frontal to parietal regions observed in healthy individuals may represent a successful and relatively low-cost filtering mechanism. By contrast, the widespread elevation of positivity across electrodes in the ADHD group may reflect both increased engagement of frontal region and persistent sensitivity to emotional distractors at posterior region. This pattern provides electrophysiological evidence that adolescents with ADHD may process emotional distraction in a more effortful and less efficient manner, requiring greater neural recruitment without achieving comparable regulatory efficiency.

Following Zhang et al. (2023)[61], frontal LPP activity can be interpreted as an index of cognitive effort or control cost. In the present study, the enhanced frontocentral positivity observed in the ADHD group may therefore suggest that adolescents with ADHD required greater cognitive resources to ignore task-irrelevant emotional faces. Because the task did not involve explicit emotion regulation, these distractors would be expected to be filtered implicitly and with relatively low cost. The elevated frontal LPP in ADHD may thus reflect a less efficient automatic filtering process and the recruitment of a more effortful, explicit-like control mechanism. Current findings are also in accordance with emotion regulation difficulty highly reported in subjects with ADHD and suggested role of LPP in emotion regulation[62].

Together with P100, N170, and P300 findings, the late LPP effect suggests that social-emotional distractor processing in ADHD differ not only during early perceptual and attentional stages, but also during later sustained emotional processing [28]. This finding is also consistent with the view proposed by Hajcak and Foti (2020)[63], who conceptualize the LPP and P300 not as entirely distinct components, but rather as different manifestations of the response to the meaning conveyed by a stimulus. From this perspective, both components may reflect the activity of a common neural system involved in detecting meaningful environmental stimuli and allocating motivational and attentional resources accordingly [64].

Effect of Psychostimulant on ERP Findings in the ADHD Group

In the simple 2-choice task, adolescents with ADHD showed reduced centro-parietal positivity after pharmacological treatment, most prominently in the 600–800 ms window. Given the absence of emotional content and mean RT of approximately 440–450 ms, this late activity is more likely to reflect a post-response centro-parietal slow wave or sustained processing activity than a classical P300 response [65].

The absence of a clear ERP difference between controls and medication-free adolescents with ADHD limits interpretation of the post-treatment reduction as a straightforward normalization effect. Previous

studies about psychostimulant effect on P300 in in children and adolescents with ADHD have yielded inconsistent findings, including increase in auditory P300 amplitude [66,67], and no significant change in visual P300 reported by Taylor et al. (1993)[68]. In this context, the present finding may indicate that psychostimulant treatment was associated with reduced post-response sustained cognitive activity in the ADHD group, possibly reflecting a shorter or less resource-demanding processing.

ERP responses in the face-distracted 2-choice task remained largely unchanged following subchronic psychostimulant treatment, suggesting that measurable treatment-related changes in the underlying neural circuitry may require longer treatment durations.

4. Strengths and Limitations

One strength of the present study is the relatively narrow age range of the sample (12–16 years), which may have reduced developmental variability in behavioral and electrophysiological measures and facilitated interpretation within a specific adolescent period [69]. Nevertheless, the relatively small sample size limits the generalizability of the findings and reduces the interpretability of subgroup analyses, particularly for post-treatment effects. Because the post-treatment assessment was conducted one month after treatment initiation, longer-term behavioral and electrophysiological effects of psychostimulant treatment could not be evaluated. Variability in dose adjustment and clinical treatment response may also have influenced the post-treatment findings.

5. Conclusion

In conclusion, adolescents with ADHD showed differences in both behavioral performance and ERP responses during emotional distractor processing compared with healthy adolescents. These differences were evident across multiple stages of processing, including early visual sensitivity, structural face encoding, attentional resource allocation, and late sustained processing, as reflected by the P100, N170, P300, and LPP findings. No significant differences related to emotional expression were observed for any of the ERP components examined in either group. ADHD may be associated with atypical timing and organization of social-emotional information processing, particularly when goal-directed attention must be maintained in the presence of emotional distractors. Future studies with larger samples, tasks varying in cognitive load, and later LPP windows extending beyond 1000 ms are needed to clarify how social-emotional distractors influence sustained processing mechanisms in ADHD.

6. Methods and materials

6.1 Participants

The study group comprised 20 adolescents (aged 12–16) who had been diagnosed with ADHD and 22 age and gender matched healthy controls. ADHD patients were recruited from the Child and Adolescent Psychiatry Outpatient Unit at Acibadem Altunizade Hospital. Written informed consents was obtained

from both the participants and their parents. Twenty drug-naive participants diagnosed with ADHD underwent behavioral and neurophysiological assessments. Of the twenty drug-naive participants with ADHD assessed at baseline, fourteen completed the one-month follow-up assessment after sustained-release methylphenidate treatment (6 were lost to follow-up). Exclusion criteria for both groups included a history of head trauma and medication use. In the ADHD group, participants with comorbid neuropsychiatric disorders were also excluded from the study. The study was approved by Acibadem University and Acibadem Health Care Institutions Medical Research Ethics Comitee (2022-20/19). All methods were performed in accordance with the Declaration of Helsinki and the relevant guidelines and regulations. Written informed consent was obtained from the parents or legal guardians of all participants, and assent was obtained from the adolescents prior to participation.

6.2 Behavioral Evaluation

Alexithymia Scale for Children: This 20-item self-report scale was developed by Rieffe, et al. (2006)[70], and adapted into Turkish by Koçak R. (2015)[71]. Items are rated on a 3-point Likert scale and grouped into three subscales: Difficulty Identifying Emotions (7 items); Difficulty Describing Emotions (5 items); and Externally Oriented Thinking (8 items).

Bar-On Emotional Intelligence Scale for Children and Adolescents: Originally developed by Bar-On and Parker (2000)[72], this scale was adapted to Turkish by Köksal A. (2007)[73] and includes 60 items suitable for individuals aged 7–18. The scale assesses the following domains: Intrapersonal (emotional awareness and expressing needs); Interpersonal (understanding others' emotions); Adaptability (problem solving and flexibility); Stress Management (coping with stress); General Mood (optimism); Positive Impression (tendency to present oneself positively); and Inconsistency (careless or random responding).

Continuous Performance Test (CPT)

Participants were presented with a randomized sequence of letters (B, C, D, E, F, G, H, J, L, T, A, and Z) on a computer screen and were instructed to press the spacebar only when the letter "Z" was preceded by "A" (target condition). The participants were requested to emphasize both speed and accuracy. Omission errors (failure to respond to targets) indicated attentional deficits, while commission errors (incorrect response to non-targets) were considered indicative of impulsivity.

Reading the Mind in the Eyes Test (Child Version)

This task, developed by Baron-Cohen et al. (1997a)[74] and adapted into Turkish by Girli A. (2014)[75], consists of 28 black-and-white photographs displaying only the eye region of human faces. For each image, participants were instructed to choose the most appropriate word from a provided list of four choices to describe the mental or emotional state expressed within up to 20 seconds. Higher accuracy scores reflected better theory of mind and social cognition abilities. In the present study, we also evaluated, mean RT, total duration and inverse efficiency score (mean RT/accuracy).

6.3 EEG data acquisition

EEG data was recorded at the Child and Adolescent Psychiatry Outpatient Unit of Acibadem Altunizade Hospital. Recordings were obtained using a 30-channel EEG system with electrodes placed according to the international 10–20 system. Electro-oculogram (EOG) was recorded bipolarly from outer canthus of the right eye and nasion. All EEG activity was referenced to linked earlobes. Electrode impedances were kept below 10 kΩ. Electrical activity were amplified by BrainAmp, DC (Brain Products GmbH) with a band pass filter of 0.015–70 Hz and digitized with a sampling rate of 500 Hz. EEG was recorded while participants performed simple and face-distracted versions of 2-choice task.

The EEG data were initially high-pass filtered at 0.1 Hz and visually inspected to identify and exclude segments contaminated by head movements, muscle activity, or excessive sweating artifacts. Independent component analysis (ICA) was applied to identify and remove ocular artifact components.

Simple 2-choice Task: Participants were presented with 60 visual stimuli comprising elliptical shapes filled with a light tan hue (Hex: #FFE5CC), each superimposed with either leftward (<<<<) or rightward (>>>>) directional arrows. Those arrows were displayed in black at 30% opacity and arrow direction was randomized with equal probability across trials. Participants were instructed to press the corresponding arrow key (left or right) on the keyboard as quickly and accurately as possible. Each image was presented for 300 ms with an inter-stimulus interval randomly selected from 1.5, 1.7 or 1.9 seconds. (Fig. 3).

Face-distracted 2-choice Task: The stimuli were selected from the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al., 1998)[76] database and included the following five categories of emotional expression: neutral, fear, happiness, sadness and anger. Each category contained 60 images, with an equal number depicting males and females. Leftward (<<<<) or rightward (>>>>) arrow symbols were superimposed on each face image and displayed in black at 30% opacity. Arrow direction, emotional expression, and gender of the face stimuli were randomized across trials with equal probability. Participants were instructed to press the corresponding arrow key (left or right) on the keyboard as quickly and accurately as possible. Each image was presented for 300 ms, with an inter-stimulus interval randomly selected from 1.5, 1.7 or 1.9 seconds (Fig. 4).

EEG data from correctly responded trials were segmented into epochs from − 200 to 1000 ms relative to stimulus onset. All segments were averaged separately according to task condition and baseline-corrected to a 200 ms prestimulus interval. ERP time-windows and relevant electrode sites were determined on the basis of the literature and adapted according to the grand-averaged waveforms. In both the simple 2-choice task and the face-distracted 2-choice task, the early ERP components P100 (90–150 ms) and N170 (150–200 ms) were quantified at parieto-occipital electrode sites (P7, Pz, P8, O1, Oz, O2). Full width at half maximum (FWHM) method was adopted for P100 and N170 components which exhibited a clear peak with approximately symmetric rise and fall. N170 measurements were

conducted on EEG data with an optimized high-pass filter of 0.9 Hz, in accordance with Zhang et al. (2024)[77].

P300 amplitude was quantified over a centro-parietal region of interest (C3, Cz, C4, CP3, CPz, CP4, P3, Pz, and P4) in both tasks. In the simple 2-choice task, the P300 peak and subsequent sustained positivity were measured within consecutive 200–400, 400–600, and 600–800 ms time windows. In the face-distracted task, P300 amplitude was quantified within the 250–400 ms interval. In the same task, LPP amplitude was additionally measured over a broader centro-parietal region (FC3, FCz, FC4, C3, Cz, C4, CP3, CPz, CP4, P3, Pz, and P4) across early (400–600 ms), middle (600–800 ms), and late (800–1000 ms) time windows.

6.4 Statistical Analyses

6.4.1 Behavioral tests

Univariate statistical analyses were performed on EQ and alexithymia scores, as well as accuracy and mean RTs from the CPT, simple 2-choice task, face-distracted 2-choice task, and RMET. Total completion time and inverse efficiency scores were additionally analyzed for the RMET. Normality was assessed using the Shapiro–Wilk test, and homogeneity of variances was assessed using Levene's test. Independent-samples t-tests were used for group comparisons, and paired-samples t-tests were used to evaluate drug treatment effects. When the assumption of normality was violated, group comparisons were conducted using the Mann–Whitney U test, whereas within-subject treatment effects were assessed using the Wilcoxon signed-rank test. The relationships between RMET accuracy scores, Alexithymia, and EQ, three bivariate Spearman rank-order correlations were computed, as Shapiro-Wilk testing confirmed violations of normality across variables. To control for family-wise Type I error, Bonferroni corrected results are reported.

6.4.2 Event Related Potential

We conducted a series of repeated-measures ANOVAs on the mean amplitude intervals corresponding to the P100, N170, P300, and late positive potential (LPP) components. The model included GROUP (ADHD vs. Control) as the between-subjects factor, and the within-subject's factors as anteroposterior distribution (AP) and lateral distribution (LAT). The ANOVA design for the face-distracted 2-choice task also included EMOTION as a within-subject factor with five levels (5 facial expression emotion categories). Topographic distribution factors were defined as follows: the laterality factor (LAT) consisted of three levels (left, midline, right), and the antero–posterior factor (AP) comprised two to four levels depending on the regions of interest for the respective waveforms. We applied Greenhouse–Geisser corrections to the degrees of freedom whenever the assumption of sphericity was violated.

Declarations

Conflict of interests

The authors declare no conflict of interests.

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Author Contribution

Author contributionsMerve Akyıldız contributed to the study conception, hypothesis formulation, and experimental design; performed the experiments; conducted the EEG and behavioral assessments; collected the data; and contributed to the statistical analyses.Betül Mazlum contributed to the study conception, hypothesis formulation, and statistical analyses, and was involved in writing and revising the manuscript.Mehmet Ergen contributed to the experimental design, statistical analyses, manuscript writing, and final approval of the version to be published.

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Part of this work, based on preliminary data collected during the ongoing study, was presented as a poster and published as an abstract entitled “Investigation of EEG responses to emotional distractors in adolescents diagnosed with attention-deficit/hyperactivity disorder” at the 50th National Physiology Congress in 2025.

Data Availability

The datasets generated and analysed during the current study are not publicly available due to ethical and privacy restrictions related to data from adolescent participants, but data with all personal identifiers removed data may be made available from the corresponding author upon reasonable request and subject to institutional approval.

References

1. Edition, F. Diagnostic and statistical manual of mental disorders. *Am. Psychiatric Assoc.* **21**, 591–643 (2013).
2. Haza, B., Gosling, C. J., Ciminaghi, F., Conty, L. & Pinabiaux, C. Research Review: Social cognition and everyday social skills in children and adolescents with attention-deficit/hyperactivity disorder: a meta-analysis of case-control studies. *J. Child. Psychol. Psychiatry*. **65**, 1245–1254. https://doi.org:10.1111/jcpp.14006 (2024).

3. Gnanavel, S., Sharma, P., Kaushal, P. & Hussain, S. Attention deficit hyperactivity disorder and comorbidity: A review of literature. *World J. Clin. Cases*. **7**, 2420–2426. https://doi.org:10.12998/wjcc.v7.i17.2420 (2019).
4. Blakemore, S. J. & Mills, K. L. Is adolescence a sensitive period for sociocultural processing? *Annu. Rev. Psychol.* **65**, 187–207. https://doi.org:10.1146/annurev-psych-010213-115202 (2014).
5. Bunford, N., Evans, S. W. & Langberg, J. M. Emotion Dysregulation Is Associated With Social Impairment Among Young Adolescents With ADHD. *J. Atten. Disord*. **22**, 66–82. https://doi.org:10.1177/1087054714527793 (2018).
6. Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y. & Plumb, I. The Reading the Mind in the Eyes test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *J. Child Psychol. Psychiatry*. **42**, 241–251 (2001).
7. Climie, E. A., Saklofske, D. H., Mastoras, S. M. & Schwean, V. L. Trait and Ability Emotional Intelligence in Children With ADHD. *J. Atten. Disord*. **23**, 1667–1674. https://doi.org:10.1177/1087054717702216 (2019).
8. Ben Turkia, I., Brahim, T. & Sahli, L. Emotional Intelligence and Attention-deficit/hyperactivity disorder (ADHD). *Eur. Psychiatry*. **66**, 512–S512. https://doi.org:10.1192/j.eurpsy.2023.1087 (2023).
9. Bora, E. & Pantelis, C. Meta-analysis of social cognition in attention-deficit/hyperactivity disorder (ADHD): comparison with healthy controls and autistic spectrum disorder. *Psychol. Med.* **46**, 699–716. https://doi.org:10.1017/S0033291715002573 (2016).
10. Nejati, V. Reading mind from the eyes in individuals with attention deficit-hyperactivity disorder (ADHD): A meta-analysis. *Expert Rev. Neurother.* **22**, 889–896 (2022).
11. Villemonteix, T. et al. Attentional control of emotional interference in children with ADHD and typically developing children: An emotional N-back study. *Psychiatry Res.* **254**, 1–7 (2017).
12. Hartikainen, K. M. Emotion-Attention Interaction in the Right Hemisphere. *Brain Sci.* **11** https://doi.org:10.3390/brainsci11081006 (2021).
13. Suzer Gamli, I. & Tahiroglu, A. Y. Six months methylphenidate treatment improves emotion dysregulation in adolescents with attention deficit/hyperactivity disorder: A prospective study. *Neuropsychiatric Disease Treatment*, 1329–1337 (2018).
14. Demirci, E. & Erdogan, A. Is emotion recognition the only problem in ADHD? effects of pharmacotherapy on face and emotion recognition in children with ADHD. *ADHD Atten. Deficit Hyperactivity Disorders*. **8**, 197–204 (2016).
15. Krumhuber, E. G., Skora, L. I., Hill, H. C. & Lander, K. The role of facial movements in emotion recognition. *Nat. Reviews Psychol.* **2**, 283–296 (2023).
16. Schindler, S. & Bublatzky, F. Attention and emotion: An integrative review of emotional face processing as a function of attention. *Cortex* **130**, 362–386 (2020).
17. Gupta, S. & Wentura, D. What is in a name when there is an emotional face: Interference from emotional face distractors at high perceptual load. *Journal Experimental Psychology: Hum. Percept. Performance* (2025).

18. Pessoa, L. How do emotion and motivation direct executive control? *Trends Cogn. Sci.* **13**, 160–166. https://doi.org:10.1016/j.tics.2009.01.006 (2009).
19. O'Toole, L. J., DeCicco, J. M., Hong, M. & Dennis, T. A. The impact of task-irrelevant emotional stimuli on attention in three domains. *Emotion* **11**, 1322–1330. https://doi.org:10.1037/a0024369 (2011).
20. Chronaki, G. Event-related potentials and emotion processing in child psychopathology. *Front. Psychol.* **7**, 564 (2016).
21. Karalunas, S. L., Weigard, A. & Alperin, B. Emotion–cognition interactions in Attention-Deficit/Hyperactivity Disorder: Increased early attention capture and weakened attentional control in emotional contexts. *Biol. Psychiatry: Cogn. Neurosci. Neuroimaging*. **5**, 520–529 (2020).
22. Dan, O. Recognition of emotional facial expressions in adolescents with attention deficit/hyperactivity disorder. *J. Adolesc.* **82**, 1–10 (2020).
23. Roberts, B. R. & Trossman, R. Face processing in ADHD: A review of the N170 event-related potential. *Can. J. Experimental Psychology/Revue canadienne de psychologie expérimentale*. **78**, 36 (2024).
24. Di Russo, F., Martínez, A., Sereno, M. I., Pitzalis, S. & Hillyard, S. A. Cortical sources of the early components of the visual evoked potential. *Hum. Brain. Mapp.* **15**, 95–111 (2002).
25. Eimer, M. The face-specific N170 component reflects late stages in the structural encoding of faces. *Neuroreport* **11**, 2319–2324 (2000).
26. Olivares, E. I., Iglesias, J., Saavedra, C., Trujillo-Barreto, N. J. & Valdes-Sosa, M. Brain Signals of Face Processing as Revealed by Event-Related Potentials. *Behav Neurol* 514361 (2015). (2015). https://doi.org:10.1155/2015/514361
27. Kok, A. On the utility of P3 amplitude as a measure of processing capacity. *Psychophysiology* **38**, 557–577. https://doi.org:10.1017/s0048577201990559 (2001).
28. Hajcak, G., MacNamara, A. & Olvet, D. M. Event-related potentials, emotion, and emotion regulation: an integrative review. *Dev. Neuropsychol.* **35**, 129–155. https://doi.org:10.1080/87565640903526504 (2010).
29. Matsuda, I. & Nittono, H. Motivational significance and cognitive effort elicit different late positive potentials. *Clin. Neurophysiol.* **126**, 304–313 (2015).
30. Alperin, B. R., Gustafsson, H., Smith, C. & Karalunas, S. L. The relationship between early and late event-related potentials and temperament in adolescents with and without ADHD. *PLoS One*. **12**, e0180627. https://doi.org:10.1371/journal.pone.0180627 (2017).
31. Parker, J. D., Taylor, G. J. & Bagby, R. M. The relationship between emotional intelligence and alexithymia. *Pers. Indiv. Differ.* **30**, 107–115 (2001).
32. Farina, E., Pepe, A., Ornaghi, V. & Cavioni, V. Trait Emotional Intelligence and School Burnout Discriminate Between High and Low Alexithymic Profiles: A Study With Female Adolescents. *Front. Psychol.* **12**, 645215. https://doi.org:10.3389/fpsyg.2021.645215 (2021).

33. Baker, C. A., Peterson, E., Pulos, S., Kirkland, R. A. & Eyes A meta-analysis of the relationship between intelligence and Reading the Mind in the Eyes. *Intelligence* **44**, 78–92. https://doi.org:10.1016/j.intell.2014.03.001 (2014).
34. Mary, A. et al. Executive and attentional contributions to Theory of Mind deficit in attention deficit/hyperactivity disorder (ADHD). *Child. Neuropsychol.* **22**, 345–365. https://doi.org:10.1080/09297049.2015.1012491 (2016).
35. Razjouan, K. et al. Theory of mind in adolescents with Attention-Deficit Hyperactivity Disorder: A cross-sectional study. *Iran. J. Child. Neurol.* **17**, 81–90. https://doi.org:10.22037/ijcn.v17i1.39094 (2023).
36. Soyal, S. & Metin, B. The Association Between Attention Performance and Empathy in Children Diagnosed with ADHD. *J. Atten. Disord*. **10870547261419885** https://doi.org:10.1177/10870547261419885 (2026).
37. Demers, L. A. & Koven, N. S. The relation of alexithymic traits to affective theory of mind. *Am. J. Psychol.* **128**, 31–42 (2015).
38. Morellini, L. et al. Social Cognition in Adult ADHD: A Systematic Review. *Front. Psychol.* **13**, 940445. https://doi.org:10.3389/fpsyg.2022.940445 (2022).
39. Huang-Pollock, C. L., Karalunas, S. L., Tam, H. & Moore, A. N. Evaluating vigilance deficits in ADHD: a meta-analysis of CPT performance. *J. Abnorm. Psychol.* **121**, 360–371. https://doi.org:10.1037/a0027205 (2012).
40. Arrondo, G. et al. Systematic review and meta-analysis: clinical utility of continuous performance tests for the identification of attention-deficit/hyperactivity disorder. *J. Am. Acad. Child. Adolesc. Psychiatry*. **63**, 154–171 (2024).
41. Hodsoll, S., Viding, E. & Lavie, N. Attentional capture by irrelevant emotional distractor faces. *Emotion* **11**, 346 (2011).
42. Shepard, E. C., Ruben, M. & Weyandt, L. L. Emotion Recognition Accuracy Among Individuals With ADHD: A Systematic Review. *J. Atten. Disord*. **29**, 174–194. https://doi.org:10.1177/10870547241297005 (2025).
43. Choi, D. et al. Effect of empathy trait on attention to various facial expressions: evidence from N170 and late positive potential (LPP). *J. Physiol. Anthropol.* **33**, 18 (2014).
44. Liu, T., Xiao, T. & Shi, J. N. Neural correlates of conflict control on facial expressions with a flanker paradigm. *PLoS One*. **8**, e69683. https://doi.org:10.1371/journal.pone.0069683 (2013).
45. Schindler, S., Bruchmann, M., Steinweg, A. L., Moeck, R. & Straube, T. Attentional conditions differentially affect early, intermediate and late neural responses to fearful and neutral faces. *Soc. Cogn. Affect. Neurosci.* **15**, 765–774. https://doi.org:10.1093/scan/nsaa098 (2020).
46. Reinke, P., Deneke, L. & Ocklenburg, S. Asymmetries in event-related potentials part 1: A systematic review of face processing studies. *Int. J. Psychophysiol.* **202**, 112386. https://doi.org:10.1016/j.ijpsycho.2024.112386 (2024).

47. Utama, N. P., Takemoto, A., Koike, Y. & Nakamura, K. Phased processing of facial emotion: an ERP study. *Neurosci. Res.* **64**, 30–40. https://doi.org:10.1016/j.neures.2009.01.009 (2009).
48. Luo, W., Feng, W., He, W., Wang, N. Y. & Luo, Y. J. Three stages of facial expression processing: ERP study with rapid serial visual presentation. *Neuroimage* **49**, 1857–1867. https://doi.org:10.1016/j.neuroimage.2009.09.018 (2010).
49. Eimer, M. & Holmes, A. Event-related brain potential correlates of emotional face processing. *Neuropsychologia* **45**, 15–31. https://doi.org:10.1016/j.neuropsychologia.2006.04.022 (2007).
50. Maffei, A. et al. Spatiotemporal dynamics of covert versus overt processing of happy, fearful and sad facial expressions. *Brain Sci.* **11**, 942 (2021).
51. Eimer, M., Holmes, A. & McGlone, F. P. The role of spatial attention in the processing of facial expression: an ERP study of rapid brain responses to six basic emotions. *Cogn. Affect. Behav. Neurosci.* **3**, 97–110 (2003).
52. Batty, M. & Taylor, M. J. Early processing of the six basic facial emotional expressions. *Brain Res. Cogn. Brain Res.* **17**, 613–620. https://doi.org:10.1016/s0926-6410(03)00174-5 (2003).
53. Boucsein, W., Schaefer, F., Sokolov, E. N., Schröder, C. & Furedy, J. J. The color-vision approach to emotional space: cortical evoked potential data. *Integr. Physiological Behav. Sci.* **36**, 137–153 (2001).
54. Shaw, P. et al. Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation. *Proceedings of the national academy of sciences* 104, 19649–19654 (2007).
55. Berger, I., Slobodin, O., Aboud, M., Melamed, J. & Cassuto, H. Maturational delay in ADHD: evidence from CPT. *Front. Hum. Neurosci.* **7**, 691. https://doi.org:10.3389/fnhum.2013.00691 (2013).
56. Taylor, M., Batty, M. & Itier, R. The faces of development: a review of early face processing over childhood. *J. Cogn. Neurosci.* **16**, 1426–1442 (2004).
57. Vogel, E. K., Luck, S. J. & Shapiro, K. L. Electrophysiological evidence for a postperceptual locus of suppression during the attentional blink. *J. Exp. Psychol. Hum. Percept. Perform.* **24**, 1656 (1998).
58. Munger, M. et al. Behavioral and Neurophysiological Markers of ADHD in Children, Adolescents, and Adults: A Large-Scale Clinical Study. *Clin. EEG Neurosci.* **52**, 311–320. https://doi.org:10.1177/1550059421993340 (2021).
59. Kaiser, A. et al. Earlier versus later cognitive event-related potentials (ERPs) in attention-deficit/hyperactivity disorder (ADHD): A meta-analysis. *Neurosci. Biobehav Rev.* **112**, 117–134. https://doi.org:10.1016/j.neubiorev.2020.01.019 (2020).
60. Tan, C. et al. P300 event-related potentials as diagnostic biomarkers for attention deficit hyperactivity disorder in children. *Front. Psychiatry*. **16**, 1590850. https://doi.org:10.3389/fpsyt.2025.1590850 (2025).
61. Zhang, Y. et al. Implicit, but not explicit, emotion regulation relieves unpleasant neural responses evoked by high-intensity negative images. *Neurosci. Bull.* **39**, 1278–1288 (2023).

62. Schonfelder, S., Kanske, P., Heissler, J. & Wessa, M. Time course of emotion-related responding during distraction and reappraisal. *Soc. Cogn. Affect. Neurosci.* **9**, 1310–1319. https://doi.org:10.1093/scan/nst116 (2014).
63. Hajcak, G. & Foti, D. Significance?& Significance! Empirical, methodological, and theoretical connections between the late positive potential and P300 as neural responses to stimulus significance: An integrative review. *Psychophysiology* **57**, e13570. https://doi.org:10.1111/psyp.13570 (2020).
64. Schupp, H. et al. Brain processes in emotional perception: Motivated attention. *Cognition Emot.* **18**, 593–611. https://doi.org:10.1080/02699930341000239 (2004).
65. Teixeira-Santos, A. C. et al. Probing the relationship between late endogenous ERP components with fluid intelligence in healthy older adults. *Sci. Rep.* **10**, 11167. https://doi.org:10.1038/s41598-020-67924-4 (2020).
66. Hermens, D. F. et al. Predicting stimulant medication response in ADHD: evidence from an integrated profile of neuropsychological, psychophysiological and clinical factors. *J. Integr. Neurosci.* **4**, 107–121 (2005).
67. Ozdag, M. F., Yorbik, O., Ulas, U. H., Hamamcioglu, K. & Vural, O. Effect of methylphenidate on auditory event related potential in boys with attention deficit hyperactivity disorder. *Int. J. Pediatr. Otorhinolaryngol.* **68**, 1267–1272. https://doi.org:10.1016/j.ijporl.2004.04.023 (2004).
68. Taylor, M., Voros, J., Logan, W. & Malone, M. Changes in event-related potentials with stimulant medication in children with attention deficit hyperactivity disorder. *Biol. Psychol.* **36**, 139–156 (1993).
69. Barriga-Paulino, C. I., Rodriguez-Martinez, E. I., Arjona, A., Morales, M. & Gomez, C. M. Developmental trajectories of event related potentials related to working memory. *Neuropsychologia* **95**, 215–226. https://doi.org:10.1016/j.neuropsychologia.2016.12.026 (2017).
70. Rieffe, C., Oosterveld, P. & Terwogt, M. M. An alexithymia questionnaire for children: Factorial and concurrent validation results. *Pers. Indiv. Differ.* **40**, 123–133 (2006).
71. KOÇAK, R. Çocuklar İçin Aleksitimi Ölçeği Türkçeye Uyarlanması: Güvenirlik Ve Geçerlik Çalışması. *Journal Turkish Studies* **10** (2015).
72. Bar-On, R. & Parker, J. D. Emotional quotient inventory: Youth version. (2000).
73. Köksal, A. Bar-On Duygusal Zekâ Ölçeği Çocuk ve Ergen Formu geçerlik ve güvenirlik çalışması. *Uluslararası Duygusal Zeka ve İletişim Sempozyumu* (2007).
74. Baron-Cohen, S., Jolliffe, T., Mortimore, C. & Robertson, M. Another advanced test of theory of mind: evidence from very high functioning adults with autism or asperger syndrome. *J. Child. Psychol. Psychiatry*. **38**, 813–822. https://doi.org:10.1111/j.1469-7610.1997.tb01599.x (1997).
75. Girli, A. Psychometric properties of the Turkish child and adult form of Reading the Mind in the Eyes Test. *Psychology* **5**, 1321–1337 (2014).
76. Lundqvist, D., Flykt, A. & Öhman, A. Karolinska directed emotional faces. *Cognition Emotion* (1998).

77. Zhang, G., Garrett, D. R. & Luck, S. J. Optimal filters for ERP research II: Recommended settings for seven common ERP components. *Psychophysiology* **61**, e14530. https://doi.org:10.1111/psyp.14530 (2024).

Figures

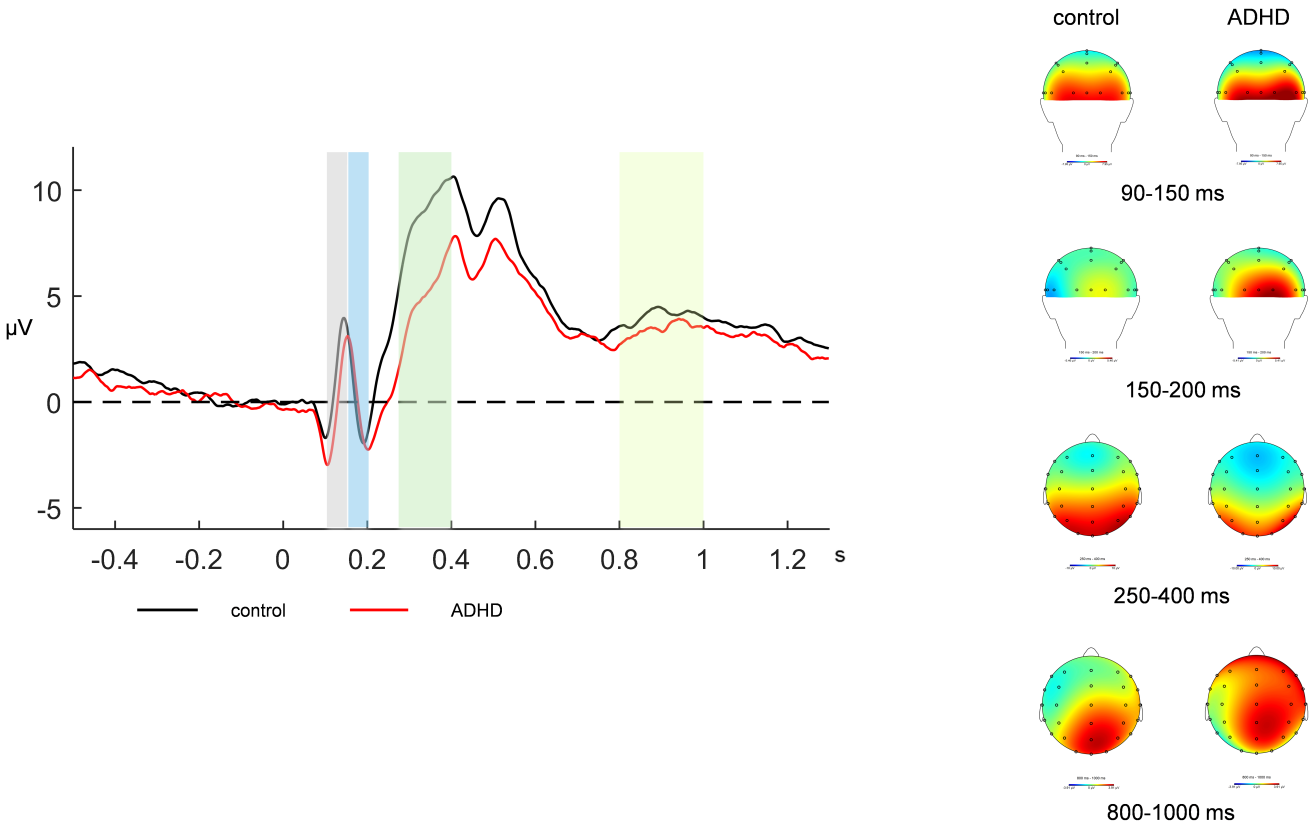


Figure 1

Grand-average ERP waveforms and scalp topographies for the ADHD (red) and control (black) groups. Shaded regions indicate the ERP analysis windows. Topographic maps are displayed from a posterior view for the P100 (90–150 ms) and N170 (150–200 ms) components, and from a superior view for the P300 (250–400 ms) and LPP (800–1000 ms) components.

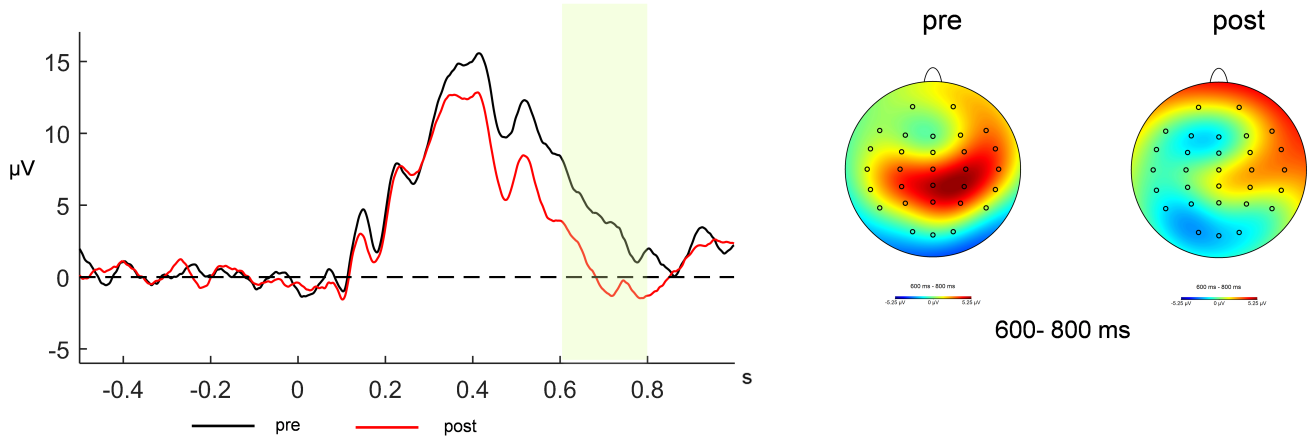


Figure 2

Grand-average ERP waveforms and corresponding scalp topographies before and after medication in adolescents with ADHD during the simple two-choice task. The shaded region indicates the post-P300 time window (600–800 ms), for which scalp topographies are displayed.

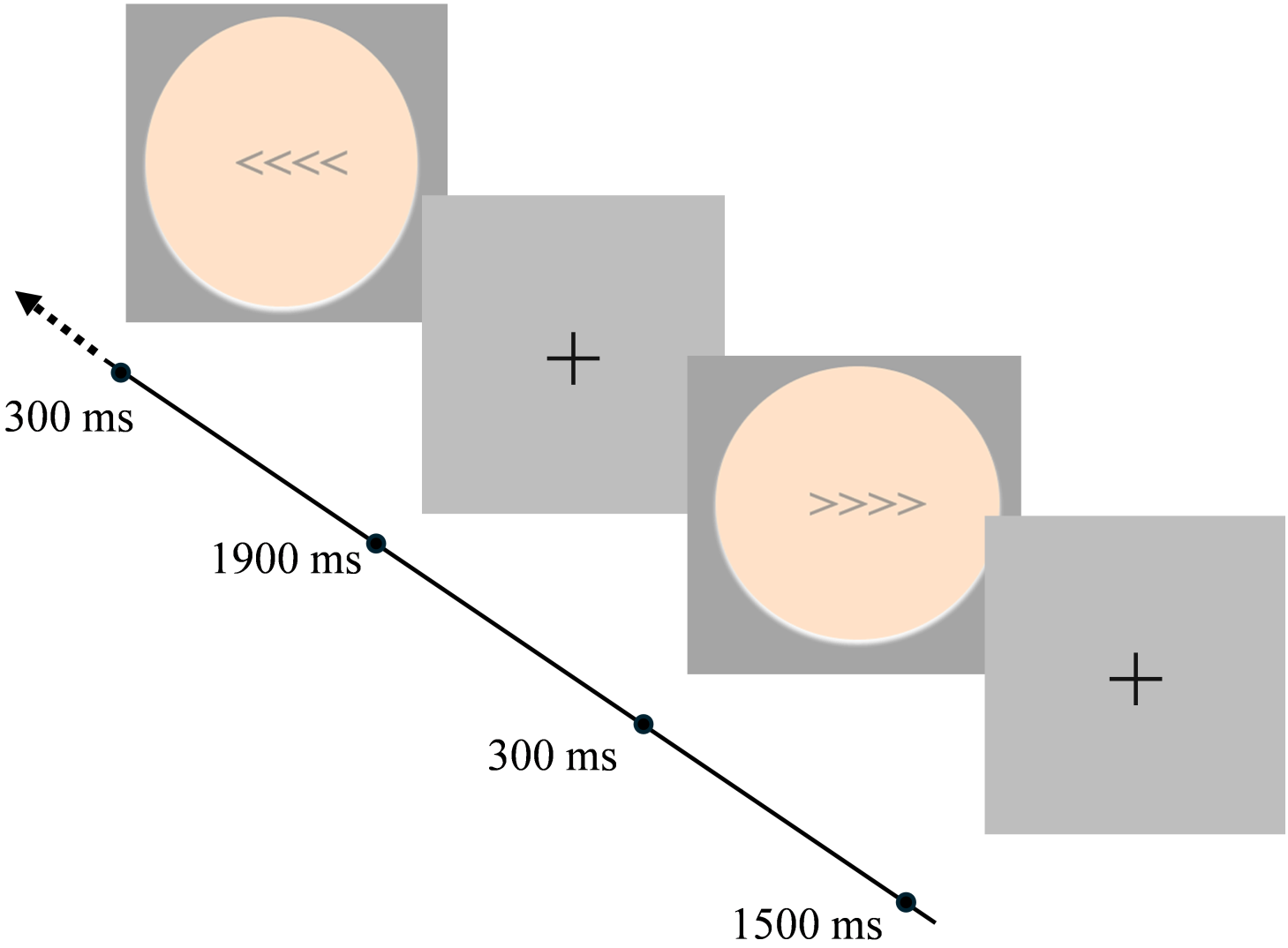


Figure 3

Schematic illustration of the simple two-choice task procedure (inter-stimulus interval varied randomly among 1.5, 1.7, and 1.9 s).

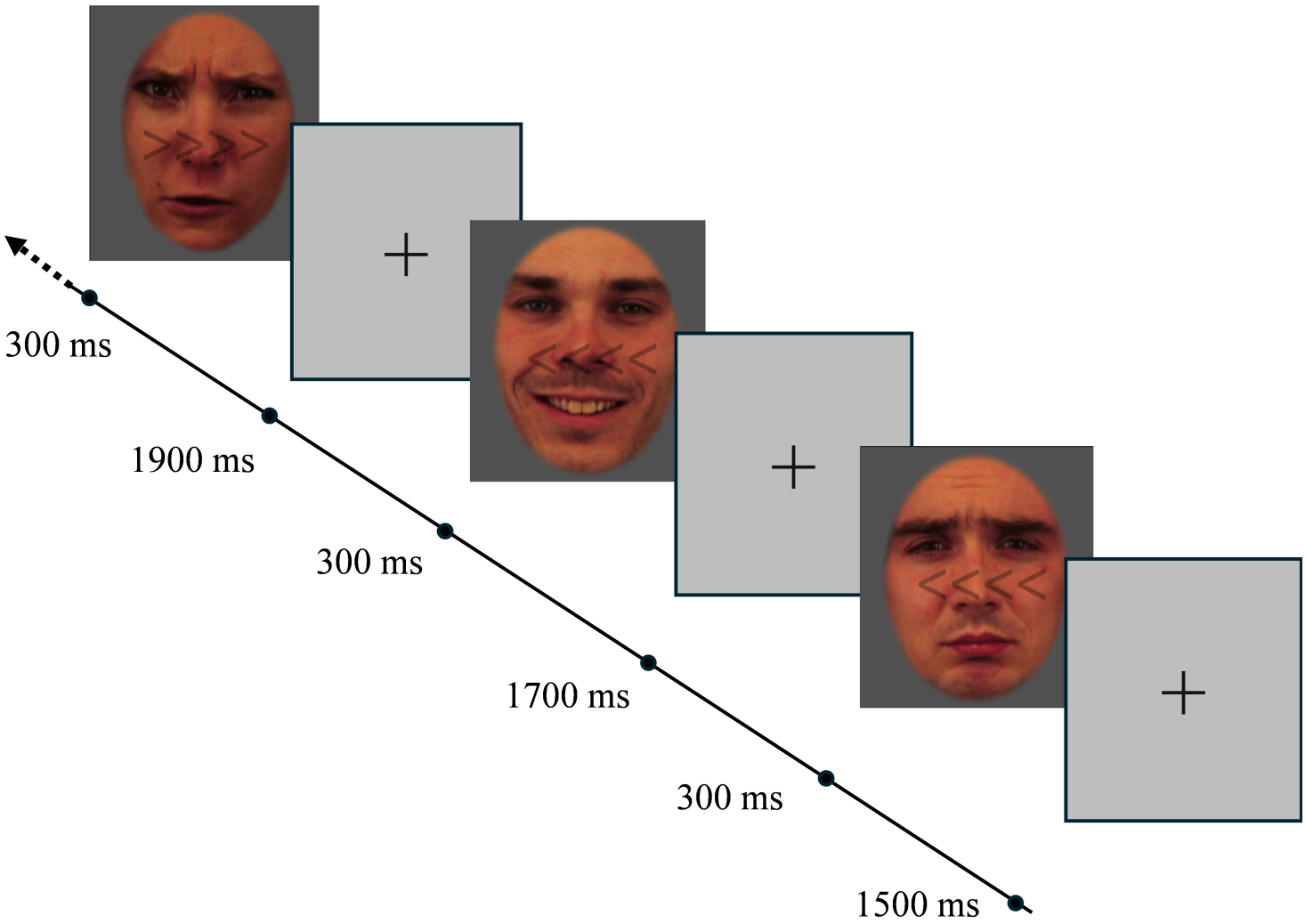


Figure 4

Schematic illustration of the face-distracted 2-choice task procedure (inter-stimulus interval varied randomly among 1.5, 1.7, and 1.9 s). The facial-expression stimuli were obtained from the Karolinska Directed Emotional Faces database (KDEF; Lundqvist et al., 1998)[76] and do not depict study participants.