Development and Psychopathology (2024), **36**, 1426–1441
doi:10.1017/S0954579423000639

Regular Article

Theta and alpha activity are differentially associated with physiological and rating scale measures of affective processing in adolescents with but not without ADHD

Mária Takács[1,2], Brigitta Tóth[3], Orsolya Szalárdy[3,4] and Nóra Bunford[1]

[1]Clinical and Developmental Neuropsychology Research Group, Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Budapest, Hungary, [2]Department of Cognitive Science, Faculty of Natural Sciences, Budapest University of Technology and Economics, Budapest, Hungary, [3]Sound and Speech Perception Research Group, Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Budapest, Hungary and [4]Institute of Behavioural Sciences, Faculty of Medicine, Semmelweis University, Budapest, Hungary

Abstract

Although atypical theta and alpha activity may be biomarkers of attention-deficit/hyperactivity disorder (ADHD) outcomes such as atypical affective processing and attention, the exact nature of the relations of these characteristics is unknown. We examined in age- and sex-matched adolescents ($N = 132$; $M_{age} = 14.944$, years, $SD = .802$) with and without ADHD, whether resting state (RS) theta and alpha power or theta and alpha event-related synchronization (ERS) during affect regulation (1) differ between adolescents with and without ADHD; (2) are differentially associated with event-related potential (ERP) and parent- and self-report measures of affective processing and inattention, given ADHD status and sex, and (3) are differentially lateralized, given ADHD status and sex. Adolescents with ADHD exhibited lower RS frontal-midline alpha power than adolescents without ADHD. In adolescents with ADHD, right parietal theta ERS was positively associated with the ERP measure of elaborate affective/motivational processing and right parietal RS alpha power was negatively associated with self-reported positive affectivity. In adolescents without ADHD, associations were nonsignificant. There was no disassociation of theta and alpha activity with affective processing and inattention. Consistent with clinical impressions, the between-group difference in frontal-midline theta ERS was more marked in boys than girls.

Keywords: ADHD; affect; attention; EEG power spectrum; EEG synchronization

(Received 2 September 2022; revised 23 May 2023; accepted 23 May 2023; first published online 26 June 2023)

Attention-deficit/hyperactivity disorder (ADHD) is characterized by developmentally inappropriate levels of inattention and hyperactivity/impulsivity (American Psychiatric Association, 2013). ADHD is an early-onset, chronic, and prevalent disorder that is associated with a host of negative outcomes including behavior problems and risk-taking as well as functional impairment in virtually all major life domains such as the academic, occupational, and the social domains (Bunford, Brandt, et al., 2015; Bunford, Evans, et al., 2018; Bunford et al., 2021; Faraone et al., 2006; Kieling et al., 2010; Le et al., 2014). Accordingly, identification of predictors of prognosis and response to treatment is key. Evidence indicates that although clinical and demographic indices are weak predictors (Ball et al., 2014), electrophysiological measures are promising (Bunford, Kujawa, Fitzgerald, et al., 2017; Hámori et al., 2023; Kujawa et al., 2016).

In terms of resting electroencephalogram (EEG), data show ADHD is most consistently and reliably associated with atypical theta activity (Arns et al., 2013; Barry et al., 2003); a large body of work indicates enhanced absolute (Arns et al., 2013; Bresnahan et al., 1999; Chabot & Serfontein, 1996, Clarke et al., 1998, 2001c; Defrance et al., 1996) and relative (Boutros et al., 2005) theta power in individuals with ADHD, and findings also show enhanced event-related frontal-midline theta synchronization (Guo et al., 2020) as well as adult-like posterior theta lateralization (Guo et al., 2020). Results also suggest elevated theta/alpha (TAR) (Clarke et al., 2001c, 2002) and elevated theta/beta (TBR) (Arns et al., 2013; Monastra et al., 1999, 2001) ratios, though findings with proportion variables are less well-replicated (Koehler et al., 2009).

Elevated theta in ADHD has been central to theories of cortical hypoarousal, developmental deviation, and a maturational lag (Barry et al., 2003). On one hand, the frontal focus of elevated theta indicates that cortical hypoarousal may disrupt anterior attentional network functioning. On the other hand, while theta activity decreases with age in neurotypical individuals, it is elevated in ADHD. This suggests the complementary interpretation that elevated theta reflects a maturational delay, especially of frontal, executive, and inhibitory networks (Barry et al., 2003). Of import, theta power decrease from pre- to post-treatment correspond to cognitive improvement in youth with ADHD (Lubar et al., 1995), suggesting that theta activity is an index of processes that are potential mechanisms of response to treatment.

Corresponding author: Nóra Bunford; Email: bunford.nora@ttk.hu

Orsolya Szalárdy and Nóra Bunford contributed equally.

Cite this article: Takács, M., Tóth, B., Szalárdy, O., & Bunford, N. (2024). Theta and alpha activity are differentially associated with physiological and rating scale measures of affective processing in adolescents with but not without ADHD. *Development and Psychopathology* **36**: 1426–1441, https://doi.org/10.1017/S0954579423000639

Theta oscillations (measured, typically, at 4–8 Hz) are generated across many brain structures, including the prefrontal-midline region of the cortex and the anatomically defined limbic system (Knyazev, 2007). Across species, theta activity is associated with voluntary motor movement, learning, and memory (Knyazev, 2007). In humans, theta activity has been linked primarily to affective processing, including affect regulation and discrimination of emotional stimuli (Nishitani, 2003) and to attention (Mann et al., 1992), including affectively motivated attention (Knyazev, 2007; W. Zhang et al., 2013). Although whether theta activity is an index of affect regulation or attention was unclear (Knyazev, 2007) – and in some regards, arguably, remains to be (Loo et al., 2018) – conceptually, frontal-midline theta corresponds to affect regulation (i.e., cognitive control; Cavanagh & Frank, 2014) whereas parietal theta corresponds to attention (i.e., affectively motivated attention; Aftanas et al., 2008).

Alpha oscillations (measured, typically, at 7–13 Hz) are hypothesized to be generated by the thalamus and layer V pyramidal cells of the occipital cortex and have been observed to propagate from anterosuperior to posteroinferior cortex (Halgren et al., 2019). Alpha oscillations have also been implicated in ADHD (Barry et al., 2003) and have also been linked to both inhibition and attention (Knyazev, 2007; Saalmann et al., 2012). Findings across a number of studies indicate attenuated relative alpha power in individuals with ADHD (Clarke et al., 2001b, 2002), including in posterior (Callaway et al., 1983) as well as frontal and central (Clarke et al., 1998) sites. Observations of a task-related decrease in alpha power have been interpreted as alpha being a mechanism of inhibiting functions and input that are conflicting with or unnecessary to a given task (Knyazev, 2007) and the involvement of the lower alpha band in attentional processes has been confirmed in neuroimaging (Laufs et al., 2003) and electrophysiological (Babiloni et al., 2004; Dockree et al., 2004; Sauseng et al., 2005) research.

ADHD is associated with deficits in both affect regulation and attention; atypicalities in affective processing, such as enhanced negative and positive dispositional affectivity (Bunford et al., 2021; Lahey, 2009; Martel & Nigg, 2006), enhanced aggression (including physical, relational, and verbal (Bunford, Evans, & Wymbs, 2015)), and deficits in regulating negative and positive affect (Bunford, Evans, & Wymbs, 2015) are consistently documented features of the disorder. Indirectly, in boys, ADHD has also been linked to atypical connectivity of functional neuronal networks in frontal and occipital lobes (Nasab et al., 2022) and altered phase synchronization stability (Ansarinasab et al., 2022) during facial affect processing as well as atypical resting-state functional connectivity involving the affective network (Gao et al., 2019) and regions (Yu et al., 2020). Difficulties in directing and sustaining attention are among the most marked ADHD symptoms (American Psychiatric Association, 2013).

Taken together, atypicalities in both theta and alpha activity have been linked to ADHD and both theta and alpha have been implicated in inhibitory, regulatory processes (in case of theta, in affect regulation, specifically) and in attention. Further, both affective dysregulation and inattention are key correlates of the ADHD phenotype. Yet, the complex interrelations across these variables, i.e., whether there are dissociable relations of theta and alpha with affect regulation and attention and how these associations are related to ADHD, is unknown.

For EEG markers to be truly valuable as biomarkers, their precise meaning (or affective-cognitive correlates) needs to be clearly understood. Relative to a host of research on the association between theta activity and attention in ADHD (Barry et al., 2003; Guo et al., 2020), to our knowledge, no data are available on the association between theta activity and affective processing in ADHD and no studies have attempted to decipher the interrelations of theta and alpha activity with affective processing and attention in ADHD. Specifically, whether (1) frontal-midline and parietal theta and/ or alpha activity are differentially associated with affective processing and attention remains to be empirically examined.

Although empirical focus has historically been on assessment of between-group differences, e.g., comparing youth with ADHD to controls on a hypothesized correlate, such as theta power or synchronization, more recent data show that even in the absence of between-group differences in such correlates, the correlate or variable of interest may differentially relate to outcomes in youth with relative to youth without ADHD; the same characteristic may confer risk for a negative outcome in those with ADHD but not in those without. For example, in one research, emotional lability was positively associated with behavioral difficulties in children with ADHD but not in children without ADHD (Rosen et al., 2015). In another research, although TBR did not differ between youth with and without ADHD, it was positively associated with inattention in youth with ADHD (D. W. Zhang et al., 2019). As a further example, across multiple studies, no differences in theta power during sleep were observed between children with and without ADHD (Scarpelli et al., 2019). However, theta power during sleep is negatively associated with memory performance in youth with ADHD but positively associated with such performance in children and adults without ADHD (Scarpelli et al., 2019). These data underscore the importance of moving beyond simple between-group comparisons to assessing differences between groups in the *relations* between hypothesized predictors and outcomes. As such, whether (1) frontal-midline and parietal theta and/ or alpha activity and affective processing and attention differ between adolescents with and without ADHD is a pertinent yet to-date unaddressed question.

Age and sex are both key third variables to consider in the context of the associations between theta and alpha activity with affective processing, attention, and ADHD; Regarding electrophysiological variables, EEG patterns are characterized by age-related differences (Segalowitz et al., 2010), including, as noted, a decrease in theta activity (Barry et al., 2003) and an increase in theta synchronization during adolescence (Uhlhaas & Singer, 2011). In research where differences in the EEG across sexes in typically developing children were examined, findings were mixed, indicating no sex differences (Gasser et al., 1988), differences suggestive of a maturational lag in girls (Harmony et al., 1990), and differences showing males exhibit less absolute and relative theta and more relative alpha power (Clarke et al., 2001a). Also, age- and sex-related differences are also evident in affective processing (Bunford, Evans, et al., 2018) and in attention/ inattention (Langberg et al., 2008). Boys are considerably more – up to three times as frequently in community samples and nine times as frequently in clinical samples – often diagnosed with ADHD than girls (Skogli et al., 2013). Differences in diagnostic rates may be a function, in part, of differences in disorder expression across boys and girls (Biederman et al., 2002; Gaub & Carlson, 1997; Quinn, 2008). Findings on the differences in prevalence and/ or manifestation of ADHD are coupled with results showing that certain biological (i.e., genetic) characteristics differentially confer risk for outcomes and symptoms in boys relative to girls with ADHD (Nymberg et al., 2013) and, with regard to electrophysiological variables specifically, EEG absolute and relative power differences have been observed to be greater between males with and without ADHD than between females with and without ADHD, where total power, absolute alpha and beta, and relative delta and alpha were sensitive to differences between males but only TAR and TBR were sensitive to differences between females (Clarke et al., 2001b).

Multi-method and –informant measurement, especially of complex and heterogeneous characteristics such as affective processing and regulation, have long been recommended for research on child and adolescent psychopathology (De Reyes & Kazdin, 2005; Dirks et al., 2012; Mash & Hunsley, 2005). In case of affective processing, self-report is key, given the largely internal and subjective nature of emotions (Bunford, Evans, & Wymbs, 2015). However, as children and adolescents with ADHD are often unreliable reporters of their behavior and functioning, augmenting self-report with observer-report (e.g., parent-report) as well as a physiological index is advantageous for capturing the different, multi-faceted aspects of the phenomenon. A physiological, event-related potential (ERP) measure of affective processing is the late positive potential (LPP), a sustained positivity in the ERP following presentation of affectively or motivationally relevant stimuli (Cuthbert et al., 2000). The LPP reflects sustained attention toward or elaborative processing of affectively salient information as well as activation of the brain's motivational systems (Cuthbert et al., 2000; Hajcak et al., 2011; Schupp et al., 2006). Evincing its reliability and validity, the LPP is reliable across development (middle childhood through adolescence) (Kujawa, Klein, et al., 2013), is sensitive to differences between pleasant/unpleasant and neutral pictures and words as well as between more and less intense stimuli (Hajcak et al., 2010), and is associated with self-report measures of both anxiety (Wessing et al., 2015) and affect regulation (Hajcak et al., 2011). Further, attending to increasingly arousing or emotional aspects of stimuli is associated with an enhancement in the LPP, whereas application of emotion regulation strategies is associated with an attenuation in the LPP (Hajcak & Nieuwenhuis, 2006).

Current study

Our goals were to address the identified gaps in knowledge and, in a carefully phenotyped sample of middle-late adolescents with and without ADHD matched for age and sex, assess whether resting state (RS) theta and alpha power or event-related theta and alpha synchronization during affect regulation (measured at frontal-midline, centroparietal and bilateral parietal regions) (1) differ between adolescents with and without ADHD; (2) are differentially associated with an ERP measure of affective processing, the LPP, and parent- and self-reported measures of affective processing and attention, given ADHD status and sex, and (3) are differentially lateralized, given ADHD status and sex. We expected that

(1) adolescents with ADHD would exhibit enhanced RS theta power, enhanced theta ERS during affect regulation, and attenuated RS alpha power, relative to adolescents without ADHD;

(2) in adolescents without ADHD, (i) greater (frontal-midline) RS theta power and greater theta ERS during affect regulation will be associated with *greater* LPP (Lapomarda et al., 2022) and with *lower* parent- and self-reported affective dysregulation and self-reported affectivity (Lapomarda et al., 2022) and (ii) greater RS alpha power will be associated with better attention and thus *lower* IA and with greater LPP and with *lower* parent- and self-reported affective dysregulation and self-reported affectivity (Wang et al., 2022) but in adolescents without ADHD, associations described in (i) and (ii) would be either in an opposite direction or weaker (Rosen et al., 2015; Scarpelli et al., 2019; D. W. Zhang et al., 2019); and

(3) adolescents with ADHD would exhibit "adult-like" theta lateralization but adolescents without ADHD would exhibit less or no lateralization (Guo et al., 2020).

Method

Procedures

Data were collected in the context of a larger longitudinal project, the Budapest Longitudinal Study of ADHD and Externalizing Disorders (BLADS) study, aimed at identifying behavioral and biological protective and risk factors of behavior problems and functional impairments in adolescents exhibiting a range of ADHD symptoms but oversampled for ADHD. Data analyzed in the current study were obtained during the first (cognitive and clinical) and second (EEG) assessment sessions during baseline measurements.

Adolescents between the ages of 14–17 years were recruited mainly from public middle-, technical and vocational-, and high schools as well as two child and adolescent psychiatry clinics in Budapest, Hungary. In case of schools, research staff visited classrooms and presented on the opportunity to participate in a research program. In case of clinics, research staff distributed an e-mail and fliers with information on the research program. Exclusionary criteria were cognitive ability at or below the percentile rank corresponding to an FSIQ of 80 across administered indices; autism spectrum disorder (severity ≥ 2); neurological illness; and having visual impairment as defined by impaired vision < 50 cm, unless corrected by glasses or contact lenses.

Parents and participants provided written informed consent (and assent) and then participants underwent a series of tests, including assessment of cognitive ability and a structured clinical interview (to assess and establish all but ADHD and externalizing diagnoses), an EEG measurement, and completion of questionnaires across two sessions. Parents also completed a series of questionnaires using the Psytoolkit platform (Stoet, 2010, 2017) and the Qualtrics software, Version June 2020–March 2021 (Qualtrics, Provo, UT). This research was approved by the National Institute of Pharmacy and Nutrition (OGYÉI/17089-8/2019) and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

ADHD diagnoses were determined using parent report on the ADHD Rating Scale-5 (ARS-5) (DuPaul et al., 2016). For an ADHD diagnosis, adolescents had to meet a total of five (in case of youth ≥ 17 years old) or six (in case of youth < 17 years old) (or more) of the Diagnostic and Statistical Manual of Mental Disorders (5th ed; DSM-5) (American Psychiatric Association, 2013) inattention or hyperactivity/impulsivity symptoms and exhibit impairment (i.e., rating of $2 =$ moderate impairment or $3 =$ severe impairment) in at least three areas of functioning (G. DuPaul, personal communication, July 19, 2021).

Participants

Participants included in the current study were 132 age- and gender-matched adolescents between the ages of 14–17 years

($M_{\text{age}} = 14.944$ years; $SD = .802$), $n = 66$ met criteria for ADHD. The majority (95.46%) identified as White and 4.54% identified as part of an ethnic minority group in Hungary. Average cognitive ability was in the 63rd percentile ($SD = 22.253$), with estimated VCI percentile rank: $M = 66.074$, $SD = 25.380$, estimated PRI percentile rank $M = 59.853$, $SD = 26.248$. Participants were from an above-average socioeconomic background based on parental income (average family net income fell in the 5 001-700 000 HUF/month range, with average net income in Hungary being 289 000 HUF/month) (Központi Statisztikai Hivatal, 2021).

Of 66 adolescents with ADHD, $n = 33$ (50%) were medication-naïve at the time of assessments. Of those who currently used ADHD medication ($n_{\text{simulants}} = 12$ (66%) and $n_{\text{nonstimulants}} = 6$ (33%)), 9 took a ≥ 24-hr medication hiatus prior to (EEG) testing, 2 did not, and 6 did not indicate whether they took a hiatus.

Measures

Clinician administered measures

Wechsler Intelligence Scales. To estimate cognitive ability, abbreviated versions of the Wechsler Intelligence Scales were used. The Wechsler Intelligence Scale for Children, Fourth Edition (Wechsler, 2003) for youth under the age of 17 and the Wechsler Adult Intelligence Scale – Fourth Edition (Wechsler, 2008) for youth 17 and above. Two subtests were administered of the Perceptual Reasoning subscales (PR), Matrix Reasoning and Picture Concepts (WISC), and Matrix Reasoning and Visual Puzzles (WAIS). Two subtests were administered of the Verbal Comprehension subscales (VC), Similarities and Vocabulary (both WISC and WAIS). These subtests allow for calculation of a Perceptual Reasoning Index (PRI) and Verbal Comprehension Index (VCI) estimate and percentile ranks corresponding to these estimates were used as indices of cognitive ability.

Adolescent self-report measures

Positive and Negative Affect Schedule (PANAS; Watson, Clark, Tellegen, et al., 1988**).** The PANAS is a 20-item self-report measure of state and/or trait positive and negative affect, comprised of two subscales, the positive affect (PA) subscale, reflecting the extent to which a person feels enthusiastic, active and alert, and a negative affect (NA) subscale, reflecting a general dimension of subjective distress and a variety of aversive mood states such as anger, contempt, disgust, fear, guilt, and nervousness. Respondents rate the extent to which they are experiencing each mood state "right now" (i.e., state version) or "during the past two weeks" (i.e., trait version) on a five-point Likert-type response format scale (1 – 'very slightly or not at all' to 5 – 'very much'). Higher scores on the PA and NA subscales indicate greater positive and negative affect, respectively. Prior findings indicate that PANAS scales have good internal consistency (αs ranging from .86 to .90 for PA and from .84 to .87 for NA) and good convergent and discriminant associations with distress and psychopathology measures of the underlying affectivity factors (e.g., Beck Depression Inventory [BDI], Hopkins Symptom Checklist [HSCL], STAI) (Watson, Clark, & Tellegen, 1988). The Hungarian translation also demonstrated acceptable psychometric properties, including good internal consistency (PA $\alpha = .82$, NA $\alpha = .83$ [alpha values are provided only to the second decimal in the source article]) (Gyollai et al., 2011).

In the current sample, the PANAS-trait was administered internal consistency of the subscales was ≥acceptable, with Cronbach's alpha values as follows: NA = .788; PA = .804. In the current study, data from the PA and NA subscales were analyzed.

Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004**).** The DERS is a 36 item self-report measure of ED, comprised of six subscales, Nonacceptance of Emotional Responses (Nonacceptance, e.g., *When I'm upset, I become angry with myself for feeling that way*), Difficulties Engaging in Goal-Directed Behavior (Goals, e.g., *When I'm upset, I have difficulty concentrating*), Impulse Control Difficulties (Impulse, e.g., *When I'm upset, I become out of control*), Lack of Emotional Awareness (Awareness, e.g., *When I'm upset, I acknowledge my emotions*), Limited Access to Emotion Regulation Strategies (Strategies, e.g., *When I'm upset, I believe that wallowing in it is all I can do*), and Lack of Emotional Clarity (Clarity, e.g., *I have difficulty making sense out of my feelings*). Items are rated on a five-point Likert-type response format scale (1 – 'Almost Never' to 5 – 'Almost Always'), with higher scores indicating greater difficulty with emotion regulation. Prior findings indicate the DERS has acceptable psychometric properties, including good internal consistency, good test–retest reliability, and adequate construct and predictive validity in multiple adolescent samples (Adrian et al., 2009; Bunford, Evans, Becker, et al., 2015; Bunford, Evans, et al., 2018; Vasilev et al., 2009; Weinberg & Klonsky, 2009). In addition, the DERS exhibited robust correlations with psychological problems reflecting ED (Weinberg & Klonsky, 2009) and physiological measures of ED (Vasilev et al., 2009). The Hungarian translation also demonstrated acceptable psychometric properties, including good internal consistency (all αs > .70) as well as construct and convergent validity with the Zung Self-rated Depression Scale (Kökönyei et al., 2014).

In the current sample, internal consistency of the subscales was ≥acceptable, with Cronbach's alpha values as follows: Awareness = .806; Clarity = .816; Goals = .879; Impulse = .871; Non-Acceptance = .842; Strategies = .874; Total DERS: .928. In the current study, data from the Total score were analyzed.

Parent-report measures

ADHD Rating Scale-5 (ARS 5; DuPaul et al., 2016**).** The ARS-5 is a 30-item parent- and teacher-report measure of the past 6-month presence and severity of DSM-5 ADHD symptoms (nine inattentive symptom items and nine hyperactivity/impulsivity symptom items) and functional impairment across six domains: relationship with significant others (family members for the home version), relationship with peers, academic functioning, behavioral functioning, homework performance and self-esteem (2 × 6 impairment items, with one set corresponding to inattention and one to hyperactivity/impulsivity). Parents and teachers rate items on a four-point scale ranging in case of symptoms from 0 (never or rarely) to 4 (very often) and in case of impairment from 0 ("no problem") to 3 ("severe problem"), with higher scores indicating more severe symptoms and impairment. The ARS-5 is comprised of two symptoms scales, Inattention and Hyperactivity-Impulsivity, and a Total Scale. The ARS-5 is suitable for ages 5-17 years, with separate forms for children (5–10 years) and adolescents (11–17 years) and age-appropriate and DSM-5 compatible descriptions of symptoms. In the current study, the adolescent home (i.e., parent-report) version was used. The ARS-5 has well-established reliability of the adolescent, home version (e.g., internal consistency and 6-week test-retest reliability) and validity (i.e., factor structure; concurrent validity and predictive validity and clinical utility) (DuPaul et al., 2016).

For purposes of the current study, the English version of the ARS-5 was translated into Hungarian following evidence-based guidelines: (1) the English version was translated into Hungarian by three independent translators; (2) these three translations were combined into a single "summary translated" measure by a fourth independent translator, reconciling all discrepancies across the three translations/ors; (3) the "summary" was back-translated into English by two additional independent translators and (4) the two back-translations were combined into a single "summary back-translated" measure by members of the research team, reconciling all discrepancies in a manner that the "summary back-translation" measure best matches the Hungarian "summary translated" measure. This "summary back-translated" questionnaire was sent to the original author(s) who provided the research team with feedback and ultimately approved the translated measure (G. DuPaul, personal communication, June 5, 2020). In the current sample, internal consistency of the ARS-5 was ≥acceptable, with a Cronbach's alpha value of .916 for the Inattention (IA) subscale and .806 for the Hyperactivity/impulsivity (H/I) subscale. In the current study, data from both subscales and the Total score were used for diagnostic purposes and, to index attention/inattention in statistical analyses, data from the IA subscale were analyzed.

Difficulties in Emotion Regulation Scale Parent-Report (DERS-P; Bunford et al., 2020**).** The DERS-P is a 29 item parent-report measure of ED, comprised of four subscales, Attuned (e.g., "*My child pays attention to how he/she feels*"), Catastrophize (e.g., "*When my child is upset, he/she believes that he/she will end up feeling very depressed*"), Distracted (e.g., "*When my child is upset, he/she has difficulty concentrating*"), and Negative Secondary ("*When my child is upset, he/she feels ashamed with him/herself for feeling that way*"). Items are rated on a five-point Likert-type response format scale (1 – 'Almost Never' to 5 – 'Almost Always'), with higher scores indicating greater difficulty with emotion regulation. Prior findings indicate the DERS-P has acceptable psychometric properties, including acceptable internal consistency, convergent, concurrent, and incremental validity in adolescents with and without ADHD (Bunford et al., 2020). As items are re-worded versions (from e.g., "When I am upset" to "When my child is upset"), a Hungarian translation of the DERS-P was created by taking items of the Hungarian translation of the DERS (Kökönyei et al., 2014) and applying the same re-wording as was done for the English version.

In the current sample, internal consistency of the subscales was ≥acceptable, with Cronbach's alpha values as follows: Attuned = .914; Catastrophize = .939; Distracted = .907; Negative Secondary = .901; Total DERS-P: .948. In the current study, data from the Total score were analyzed.

Experimental paradigm

Resting-state EEG measurement

A six-minute interval was used to record eyes-open RS theta and alpha power at the end of the EEG assessment session. Adolescents were instructed to look at a fixation cross for 2 × 3 min while their head was placed on a chin rest.

ERP measurement

In the larger study, the Doors task (Dunning & Hajcak, 2007; Foti & Hajcak, 2009; Kujawa, Smith, et al., 2013; Kujawa et al., 2014, 2018) was used to probe initial responsiveness to reward attainment and here, a portion of the task was conceptualized as probing affect regulation. The task consisted of 120 trials in total, presented in two blocks of 30 trials/condition. Participants were told that on each trial, they could either gain 100 or lose 50 (HUF). At the beginning of each trial, a fixation mark (+) appeared for 900 ms. Then, participants were presented with an image of two doors for 3000 ms and asked to choose one door by pressing the number 7 or 8 on the keypad (for the left and the right door, respectively). Finally, after a short delay (1100 ms with a jitter of ±50 ms), feedback was presented for 1500 ms on the screen. Gain was indicated by a green "↑" and loss was indicated by a red "↓". The duration of the intertrial interval was 2000 ms with a jitter of ± 250 ms. In a single block, 30 gain and 30 loss trials were presented in random order.

To maximize effectiveness of the experimental paradigm, participants were told that the virtual money they accumulated can be exchanged for snacks (candy, chips, etc.), with more virtual money exchangeable for more desirable snack options (as ranked by the participant prior to the tasks).

We conceptualized that an emotion regulation process occurs after feedback stimuli are presented on the screen; whether an adolescent wins or loses, he/she has to regulate his/her affective response to such feedback as the next trial is upcoming.

EEG data acquisition and processing

EEG data were recorded and processed as described previously (Bunford et al., 2023; Hámori et al., 2022, 2023). Briefly, continuous EEG was acquired with a 64-channel BrainAmp DC system equipped with actiCAP active electrodes (Brain Products GmbH, Gilching, Germany) and digitized at a sampling rate of 1000 Hz and 16-bit resolution. Impedances were kept under 10 kΩ, and the FCz electrode was used as online reference. One electrooculogram electrode was placed below the left eye and another lateral to the outer canthus of the right eye.

The FieldTrip MATLAB toolbox was used for offline processing of the EEG data (Oostenveld et al., 2011). Hamming-windowed sinc finite impulse response filters were used to filter the EEG (for details on filter parameters, see Supplement). Bad channels were removed (*M*±*SD*: 1.84 ± 1.57 channels, range: 0–8), then interpolated at a later stage of the preprocessing. The infomax independent component analysis (ICA) algorithm (Bell & Sejnowski, 1995) was applied, then components related to blinks, eye movements and transient or persistent noise artifacts (*M* ± *SD*: 3.45 ± .98 components, range: 1–8) were removed. The ICA-cleaned data was then high-pass filtered at 0.1 Hz and re-referenced to the average of TP9 and TP10 electrodes located at the left and right mastoids, respectively. The FCz electrode was included in the group of active electrodes. The continuous EEG was then epoched from −200 ms to 1000 ms around the stimuli (cue or target). Epochs containing high muscle activity or meeting the following criteria were automatically rejected: a voltage step of more than 50 μV between data points, a voltage difference of 300 μV within a trial, and a voltage difference of <.50 μV within 100 ms intervals (Bunford, Kujawa, Fitzgerald, et al., 2017; Bunford, Kujawa, Swain, et al., 2017; Kujawa et al., 2015, 2016). Next, a final visual inspection was applied to remove remaining epochs with artifacts. Following, trials were baseline corrected to the first 200 ms of the epochs.

Resting-state spectral analyses. The EEGLAB Matlab toolbox was used for spectral analyses. Four regions of interest (ROI) were defined as follows: Frontal-midline theta (4–7 Hz) and alpha (8–12 Hz) were scored at Fz FC1, FC2, C1, Cz, and C2; parietal theta and alpha at CP4, CP6, P4, and P6 (right) and CP5, CP3, P5, and P3 (left); and a centroparietal, event-related region (i.e., using the same electrodes as for the LPP) theta and alpha at CP1, CPz, CP2, P1, Pz, P2, and POz.

Resting state EEG data were concatenated and 120 triggers were randomly placed into the recording. The recording was cut after each trigger into 1000–3000 ms-long epochs (same time window as for the LPP) and data in each epoch were convolved with a set of Morlet wavelets using 2–7 cycles increased linearly from 1–30 Hz in .5 Hz frequency steps, and then the mean of all epochs was used for decibel normalization. Time frequency/power spectrum values for channels of interest were obtained as results. Next, the mean of channels for each ROI was calculated, followed by calculation of the means of frequency bands, theta (4–7 Hz) and alpha (8–12 Hz) at a time window of 1600–2000 ms, for statistical analyses.

Event-related spectral analysis. Analyses for data obtained during the Doors task were comparable to those applied to data obtained during rest, except that each participant's raw RS data were used for normalization purposes. Recording obtained during the Doors task was cut to 1000–3000 ms-long, post-feedback (i.e., after the chosen door either "wins" or "loses" as indicated by a green "↑" or a red "↓") windows and the same spectral analyses as to the RS data, were applied. Using this method, desynchronization/synchronization could be defined as an average decrease/increase of power spectrum values from rest to during affect regulation. Obtained desynchronization and synchronization values are in dB.

ERP analyses. ERPs were averaged for each participant and for each condition, from the pre-processed EEG (i.e., final output of the pre-processing workflow) as follows. (1) The EEG was epoched from −200 ms to 3000 ms around feedback stimuli. (2) To ensure proper operation of our automatic artifact rejection algorithm, trials were low-pass filtered at 45 Hz (order: 294; transition width: 11.3 Hz). (3) Epochs containing high muscle activity (detected during step (3) of pre-processing) were removed. (4) An automatic artifact rejection method implemented in Matlab was used to reject additional trials containing artifacts. Artifact removal was based on the following criteria: (i) a voltage step of more than 50 μV between data points, (ii) a voltage difference of 300 μV within a trial, and (iii) a voltage difference of less than .50 μV within 100 ms intervals (Bunford, Kujawa, Fitzgerald, et al., 2017; Bunford, Kujawa, Swain et al., 2017; Kujawa et al., 2015, 2016). (5) We performed a final visual evaluation to detect and remove remaining epochs with artifacts (6) Next, trials were baseline corrected using the 200 ms time interval prior to the stimulus onset. (7) After that, for each participant and for each condition, we computed the ERP averages, then these averages were low-pass filtered at 30 Hz (order: 442; transition width: 7.5 Hz). (8) As a final step, for each component, grand average ERP waveforms were calculated from individual ERP averages. As such, based on chosen electrodes and time windows, one ERP value per condition was calculated for each participant.

Given prior data with youth with anxiety disorders and other psychiatric symptoms indicating that the effects of psychopathology on the LPP were most apparent 1000–3000 ms after stimulus onset (Bunford, Kujawa, Swain, et al., 2017; Leutgeb et al., 2010), we used the 1000–3000 ms post-feedback time window to index the LPP. Consistent with earlier adult (Stange et al., 2017) and child studies (Bunford, Kujawa, et al., 2018, ; Bunford, Kujawa, Swain, et al., 2017), where the LPP was scored at CP1, CP2, Cz, and Pz and at O1, O2, Oz, PO3, PO4, P3, P4, and Pz, electrodes for LPP scoring were: CP1, CPz, CP2, P1, Pz, P2, and POz. Analyses were conducted on the gain minus loss difference score.

Variables included in analyses were RS frontal-midline, centroperietal, and left and right parietal theta; RS frontal-midline, centroperietal, and left and right parietal alpha; event-related frontal-midline, centroperietal, and left and right parietal theta synchronization; and event-related frontal-midline, centroperietal, and left and right parietal alpha synchronization; and the LPP.

Analytic plan

Data were analyzed using IBM SPSS Statistics (version 28.0.1.0), through a two-step process involving analysis of variance (ANOVA) and bivariate correlations.

Normality was assessed using the Kolmogorov–Smirnov (with Lilliefors correction) test and visual inspection of diagnostic plots (density and Q–Q plots, histograms). Normality was violated in case of RS: centroparietal, left and right parietal theta; centroparietal, and left and right parietal theta synchronization; RS left parietal alpha; left and right parietal alpha synchronization; negative affectivity, self-report DERS, and IA.

For Aim 1, youth with and without ADHD were compared on key predictor variables, i.e., RS theta and alpha power and event-related theta and alpha synchronization (and also on outcome variables: affectivity and affect regulation as indexed by the PANAS NA, PANAS PA and the self- and parent-report DERS, and the LPP), using a one-way ANOVA in case of normally distributed and a Kruskal–Wallis test in case of non-normally distributed variables.

For Aim 2, bivariate correlations (Pearson's r where both variables were normally distributed and Spearman's rho where at least one was non-normally distributed) were computed for RS theta and alpha power and event-related theta and alpha synchronization variables and affectivity, affect regulation, and the LPP separately for groups with and without ADHD (with 95% confidence intervals [CIs] around the r values obtained with 1000 bootstrap resamples). Correlations with $p < .05$ in either group were chosen for further analysis, where selected r value-pairs (in the with and without ADHD groups) were transformed into z scores (Fisher's r to z transformation) which were compared for statistical significance. Obtained p values were Benjamini–Hochberg corrected for false discovery rate (FDR).

For Aim 3, to compare left and right RS theta and alpha power and left and right event-related theta and alpha synchronization and thus estimate lateralization, the probability of superiority measure (Delaney & Vargha, 2002; Ruscio, 2008), denoted by Aw, was calculated (given non-normal distribution of three of four compared variables) for boys and girls with and without ADHD, using the following formula for Aw: $Aw = [\#(p > q) + .5\#(p = q)/npnq]$ and for converting Aw to d-metric: $dA = \sqrt{}2\Phi - 1(Aw)$, where Φ is the normal cumulative distribution function.

Data analyzed in this study are available at [https://github.com/Bunfordlab/Takacs-et-al-Theta-and-alpha-activity-article].

Results

Event-related spectral perturbation of EEG power across boys and girls with and without ADHD at frontal-midline, centroparietal, and left and right parietal sites are depicted in Figures 1, 2, and 3.

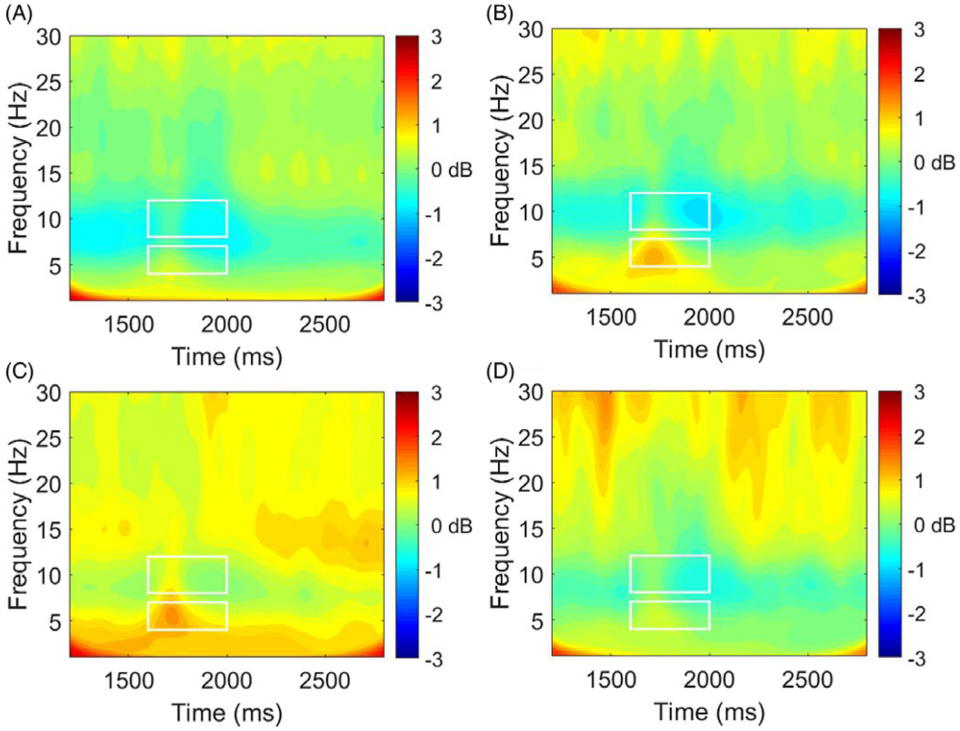

Figure 1. Event-related spectral perturbation of frontal-midline EEG power across boys and girls with and without ADHD. Figure depicts event-related synchronization of frontal-midline EEG power (scored in the 1000–3000 ms post-feedback time window, at Fz Fc1, Fc2, C1, Cz, and C2, with the average of theta band calculated in the 4–7 Hz frequency range (bottom rectangle) and the average of alpha calculated in the 8–12 Hz frequency range (top rectangle) both in the 1600–2000 ms time window) for (A) boys and (B) girls with ADHD as well as (C) boys and (D) girls without ADHD. Visual inspection indicates that in adolescents with ADHD, relative to boys (A), girls (B) exhibit a greater increase in theta and a greater decrease in alpha power in the time window of interest whereas in adolescents without ADHD, the opposite pattern is observable such that relative to girls (D), boys exhibit a greater increase in theta power in the time window of interest. Across groups, boys with ADHD exhibit the smallest increase in theta power in the time window of interest. *Note.* $n = 66$ adolescents with and 66 without ADHD, with $n = 48$ boys and 18 girls in each group.

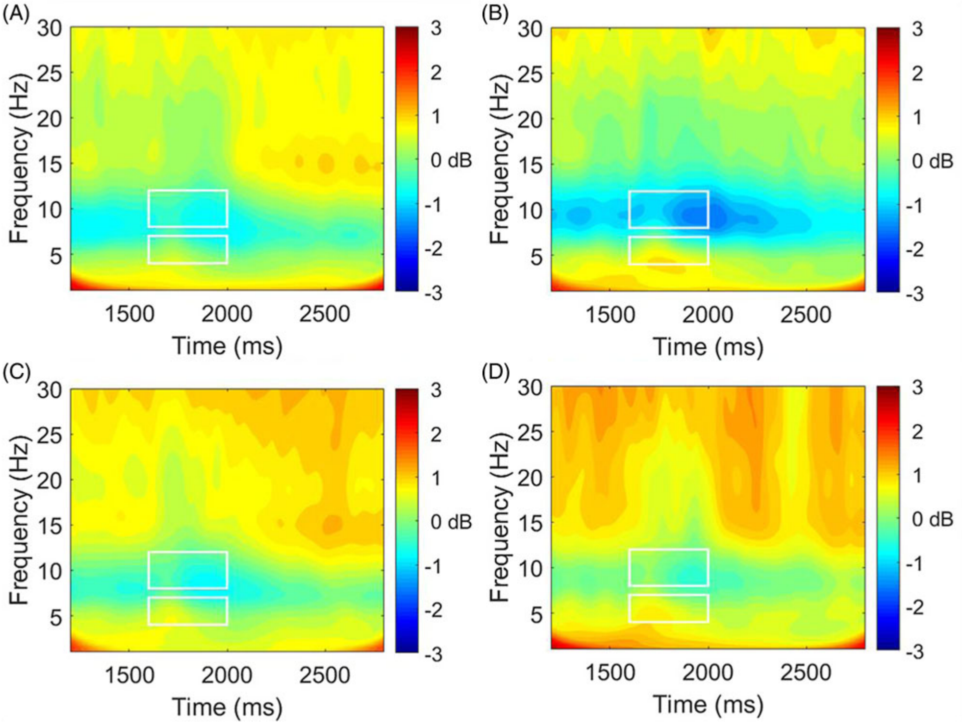

Figure 2. Event-related spectral perturbation of centroparietal EEG power across boys and girls with and without ADHD. Figure depicts event-related synchronization of centroparietal EEG power (scored in the 1000–3000 ms post-feedback time window, at CP1, Cpz, Cp2, P1, Pz, P2, and Poz, with the average of theta band calculated in the 4–7 Hz frequency range (bottom rectangle) and the average of alpha calculated in the 8–12 Hz frequency range (top rectangle), both in the 1600–2000 ms time window) for (A) boys and (B) girls with ADHD as well as (C) boys and (D) girls without ADHD. Visual inspection indicates in adolescents with ADHD, relative to boys (A), girls (B) exhibit a greater increase in theta and a greater decrease in alpha power whereas in adolescents without ADHD, in both boys (C) and girls (D), there appears only a slight increase in theta power (that is nevertheless greater than that apparent in boys with ADHD) in the time window of interest. *Note.* $n = 66$ adolescents with and 66 without ADHD, with $n = 48$ boys and 18 girls in each group.

LPP scalp distributions and grand average waveforms are shown in Figure 4.

Clinical, demographic, and behavioral performance descriptives across groups are reported in Table 1.

In the current sample, the LPP was marginally significantly associated with self-reported affective dysregulation total score (rho = .153, $p = .081$) but was not associated with the remaining affectivity or affect regulation variables: NA, PA, or parent-reported affective dysregulation total score ($ps > .164$). The LPP was not associated with inattention ($p = .356$).

Examination of the association between the LPP and affective dysregulation subscale scores revealed the LPP was associated with

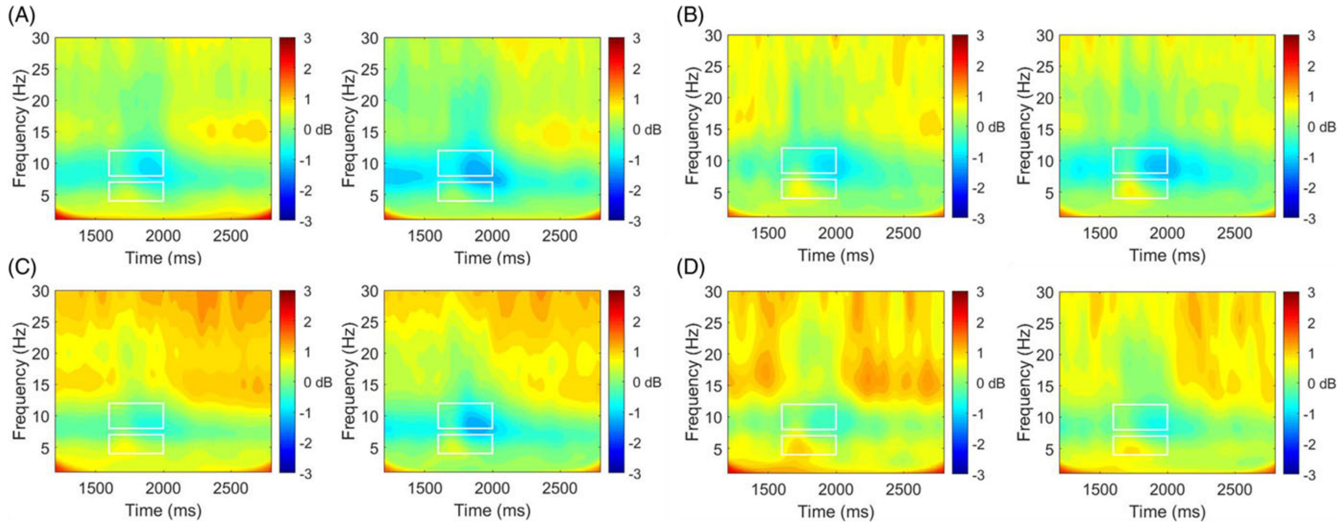

Figure 3. Event-related left and right parietal EEG power across boys and girls with and without ADHD. Figure depicts event-related left (left, across figures) and right (right, across figures) parietal EEG power synchronization (scored in the 1000–3000 ms post-feedback time window, at CP4, Cp6, P4, P6 (right) and CP5, CP3, P5, P3 (left), with the average of theta band calculated in the 4–7 Hz frequency range (bottom rectangle) and the average of alpha calculated in the 8–12 Hz frequency range (top rectangle), both in the 1600–2000 ms time window) for (A) boys and (B) girls with ADHD as well as (C) boys and (D) girls without ADHD. Visual inspection indicates, in the time window of interest, both boys (A) and girls (B) with ADHD exhibit a decrease in alpha power, with a greater decrease in the right hemisphere and boys with ADHD showing greatest decrease in the right hemisphere. Girls but not boys with ADHD also exhibit an increase in theta power. In adolescents without ADHD, boys (C) exhibit a comparable pattern as adolescents with ADHD with regard to a right parietal decrease in alpha power. They also exhibit, unlike boys with ADHD, a slight increase in theta power. Girls (D) do not show differences in parietal alpha power but do show such differences in parietal theta, driven more by the left side. *Note.* $n = 66$ adolescents with and 66 without ADHD, with $n = 48$ boys and 18 girls in each group.

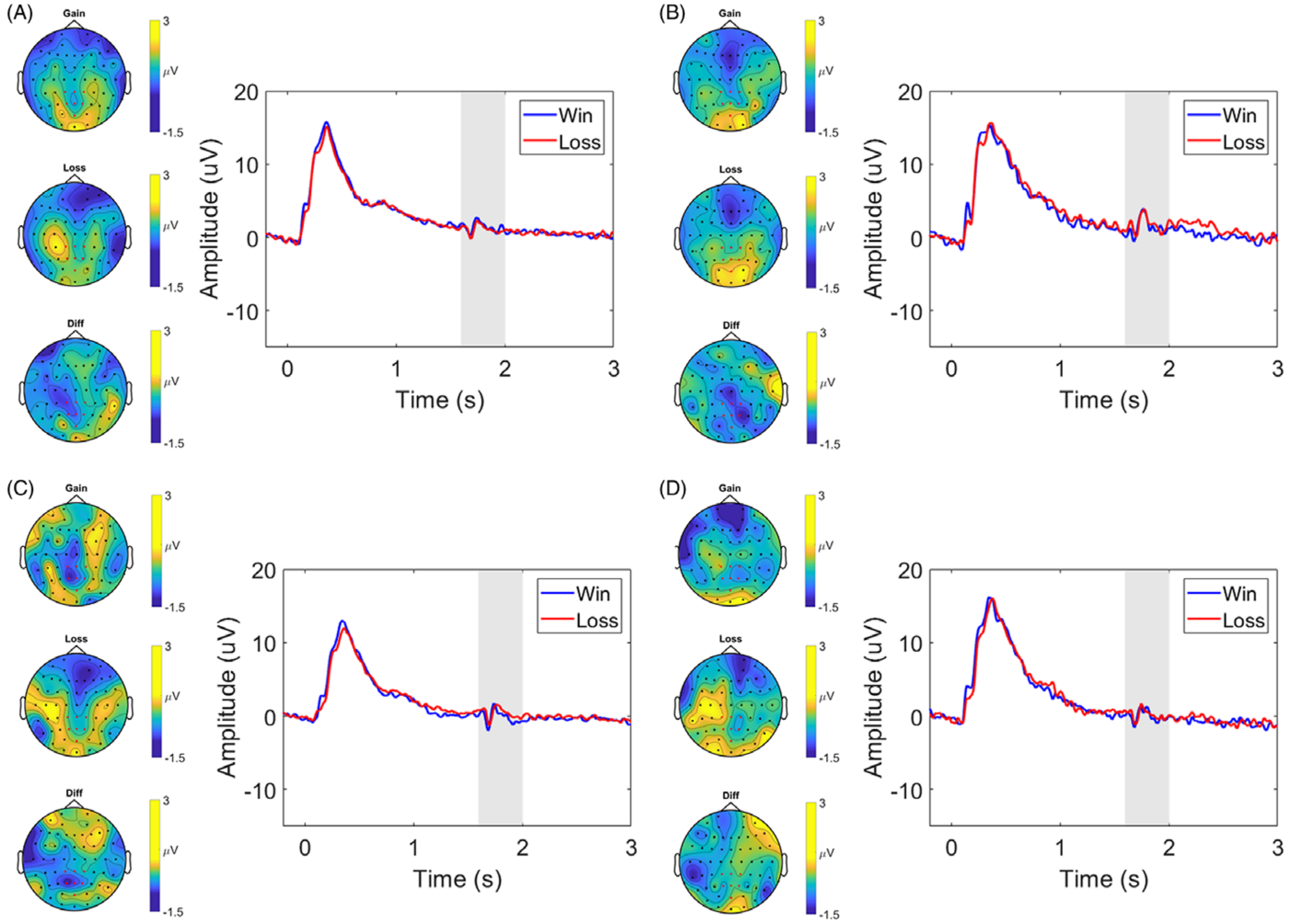

Figure 4. Late positive potential (LPP) scalp distributions and grand average waveforms across boys and girls with and without ADHD. Figure depicts scalp distributions to gain, loss, and the gain minus loss difference in the 1000–3000 ms time window as well as ERPs (scored at CP1, Cpz, Cp2, P1, Pz, P2, and Poz) for (A) boys and (B) girls with ADHD as well as (C) boys and (D) girls without ADHD. *Note.* $n = 66$ adolescents with and 66 without ADHD, with $n = 48$ boys and 18 girls in each group.

Table 1. Clinical, demographic, and behavioral performance descriptives across groups

	with ADHD				without ADHD				
	Girls ($n = 18$)		Boys ($n = 48$)		Girls ($n = 18$)		Boys ($n = 48$)		
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Diff (*p*)
Age	14.944	.802	15.208	1.202	14.944	.802	15.229	1.171	.870
SES	7.188	1.471	6.907	1.444	8.412	1.839	6.878	1.749	.031
PRI	61.833	25.334	51.521	28.522	65.667	18.398	65.263	25.238	.062
VCI	77.833	2.359	55.833	28.079	77.889	17.750	7.098	23.605	.009
IA	7.278	1.742	7.188	1.439	1.500	1.855	2.146	2.441	<.001
H/I	4.333	2.679	4.125	2.647	.778	1.166	1.042	1.543	<.001
ODD	4.056	2.313	3.729	2.322	1.111	1.605	1.043	1.920	<.001
CD	.278	.575	.438	.920	.111	.323	.152	.556	.106
Anxiety	56.647	8.306	53.933	5.941	52.500	5.113	53.083	4.667	.205
Depression	60.000	11.264	54.444	6.394	53.778	6.924	53.750	5.369	.083
NA	24.056	8.033	19.583	6.681	19.611	6.436	17.125	5.039	.010
PA	32.667	9.210	34.167	7.206	35.444	5.360	35.313	5.714	.486
DERS	95.222	27.699	81.333	18.537	84.833	23.073	70.875	18.188	.002
DERS-Parent	92.222	12.202	84.407	18.713	69.722	21.323	64.058	21.434	<.001
Behavioral performance	.883	.332	.814	.228	.865	.280	.845	.231	.943

Note. SES = socioeconomic status based on net family income/month coded as 1 = <50,000HUF, 2 = 50,001–99,000HUF, 3 = 100,000–150,000HUF, 4 = 150,001–200,000HUF, 5 = 200,001–300,000HUF, 6 = 300,001–500,000HUF, 7 = 700,001–800,000HUF, 8 = 800,001–1,000,000HUF, 9 = 1,000,000–1,200,000HUF, 10 = >1,200,000; PRI = perceptual reasoning index; VCI = verbal comprehension index; IA = parent-rated inattention symptoms on the ADHD Rating Scale–5; H/I = parent-rated hyperactivity/impulsivity symptoms on the ADHD Rating Scale–5; ODD = parent-rated oppositional defiant disorder symptoms on the Disruptive Behavior Disorders Rating Scale adapted to align with DSM-5; CD = parent-rated conduct disorder symptoms on the Disruptive Behavior Disorders Rating Scale adapted to align with DSM-5; Anxiety = Anxiety problems T score on the Youth Self Report; Depression = Depressive problems T score on the Youth Self Report; NA = negative affectivity on the Positive and Negative Affect Schedule; PA = positive affectivity on the Positive and Negative Affect Schedule; DERS = Difficulties in Emotion Regulation Scale scores; DERS-Parent = parent-rated Difficulties in Emotion Regulation Scale scores; behavioral performance = latency of response during the Doors task in ms.
Diff=between-groups comparisons using one-way ANOVAs for PA and DERS-Parent and Kruskal–Wallis tests for the remaining variables. In case of SES, families of girls without ADHD exhibited greater SES than boys with and boys without ADHD ($ps_{\text{Bonferroni-adjusted}} \leq .043$). In case of VCI, girls without ADHD exhibited higher VCI than boys with ADHD ($p_{\text{Bonferroni-adjusted}} = .020$). In case of IA, H/I, and ODD symptoms, girls and boys with ADHD exhibited greater IA ($ps_{\text{Bonferroni-adjusted}} < .001$), H/I ($ps_{\text{Bonferroni-adjusted}} < .001$), and ODD ($ps_{\text{Bonferroni-adjusted}} \leq .002$) scores than girls and boys without ADHD. In case of NA and DERS, girls with ADHD exhibited greater NA ($p_{\text{Bonferroni-adjusted}} = .006$) and DERS ($p_{\text{Bonferroni-adjusted}} = .003$) than boys without ADHD. In case of DERS-Parent, girls and boys with ADHD exhibited greater scores ($ps_{\text{Tukey HSD}} < .035$) than girls and boys without ADHD. None of the remaining between-groups comparisons were significant.

DERS Nonacceptance ($r = .201$, $p = .021$) and marginally significantly with DERS Clarity ($r = .147$, $p = .092$) and Strategies ($r = .159$, $p = .068$) (but not the remaining DERS subscales ($ps > .154$)).

Aim 1: Theta and alpha activity differences between youth with and without ADHD

Adolescents with and without ADHD did not differ on any power spectrum or ERP variables ($ps > .086$), except for RS frontal-midline alpha power, $F(1, 126) = 6.514$, $p = .012$; youth with ADHD exhibited lower alpha power ($M = .256$ [95%CI = −.071; .611], $SD = 1.440$ [95%CI = 1.152; 1.660]) than youth without ADHD ($M = .943$ [95%CI = .535; 1.351], $SD = 1.603$ [95%CI = 1.248; 1.928]), with a medium effect size (Cohen's $D = -.451$).

Groups also differed on NA: $H(1) = 5.382$, $p = .020$, DERS: $H(1) = 8.160$, $p = .004$, and DERS-P: $F(1, 126) = 35.669$, $p < .001$) scores, such that youth with ADHD exhibited greater NA ($M = 20.877$ [95%CI = 18.986; 22.656], $SD = 7.324$ [95% CI = 6.042; 8.470]), and greater affect dysregulation (DERS: $M = 85.569$ [95%CI = 80.473; 90.771], $SD = 21.958$ [95% CI = 18.048; 25.446]; DERS-P: ($M = 86.538$ [95%CI = 82.165; 90.614], $SD = 17.583$ [95%CI = 13.952; 20.316])) than youth without ADHD (NA: ($M = 17.841$ [95%CI = 16.457; 19.226], $SD = 5.626$ [95%CI = 4.478; 6.630]); DERS: ($M = 74.936$ [95% CI = 70.107; 80.192], $SD = 20.803$ [95%CI = 15.355; 25.083]); DERS-P: ($M = 65.603$ [95%CI = 60.263; 70.877], $SD = 21.902$ [95%CI = 17.996; 25.156]). These differences corresponded to a medium effect size for NA (Cohen's $d = .464$) and self-report DERS (Cohen's $d = .497$) and a large effect size for parent-report DERS (Cohen's $d = 1.054$).

Aim 2: Associations between indices of theta and alpha activity and measures of affective processing and attention in youth with and without ADHD

For correlations between alpha and theta RS and synchronization variables with affective processing, age, and sex in the entire sample, see Tables S1 and S2.

Correlations of event-related right parietal theta synchronization and PA differed between adolescents with and without ADHD ($p = .018$) (Table 2). In youth with ADHD, event-related right parietal theta synchronization was positively associated with PA whereas in youth without ADHD, it was negatively associated with PA (at a trend level) (Table 2).

Figure 1 indicated boys with ADHD exhibit different event-related frontal-midline theta synchronization during affect regulation than girls with and youth without ADHD. To quantify visual inspection, a two-way ANOVA was conducted and indicated no main effect by ADHD or sex ($ps > .301$) but a marginally significant ADHD*sex interaction effect ($F(1, 128) = 2.923$, $p = .090$) on event-related frontal-midline theta

Table 2. Differences across groups in relations between EEG variables and rating scale measures of affective and motivational processing

	r (p) with ADHD	r (p) without ADHD	diff. z (p*)
		Theta activity	
		PA	
Right parietal theta synchronization†	.253 (.041)	−.226 (.068)	2.74 (.018)
Right parietal theta synchronization† ctrl sex	.250 (.045)	−.228 (.067)	2.74 (.036)
		Alpha activity	
		LPP	
RS right parietal alpha ctrl med	−.327 (.008)	.096 (.445)	−2.45 (.049)
RS right parietal alpha ctrl sex	−.290 (.020)	.115 (.375)	−2.29 (.049)

Note. ADHD = attention-deficit/hyperactivity disorder; diff = r values were transformed into z scores (i.e., Fisher's r to z transformation), which were compared for statistical significance. All correlations calculated using Pearson's r, unless otherwise indicated. ctrl = controlling for. med = current ADHD medication status. †Correlations calculated using Spearman's rho. *p values are Benjamini–Hochberg corrected for FDR within frequency band (i.e., alpha [7 comparisons] and theta [9 comparisons] variables).

synchronization. Given small sample sizes especially for subsamples involving girls ($ns = 18$) follow-up calculations of effect size were conducted. Boys with ($M = .715$; $SD = 1.445$) and without ($M = 1.418$; $SD = 1.635$) ADHD differed from each other to a moderate extent ($d_{\text{corrected for small samples}} = .449$). Girls with ($M = .9982$; $SD = 1.898$) and without ($M = .578$; $SD = 1.278$) ADHD differed to a small extent ($d_{\text{corrected for small samples}} = .247$). The difference between boys and girls without ADHD was also moderate ($d_{\text{corrected for small samples}} = .564$) but that between boys and girls with ADHD was negligible ($d_{\text{corrected for small samples}} = .156$). (All other pairwise comparisons were small or negligible).

Given these findings, comparison of correlations across groups were repeated by controlling for sex.

Partial correlations of right parietal theta synchronization with PA differed between adolescents with and without ADHD ($p = .036$) (Table 2). In youth with ADHD, right parietal theta synchronization was positively associated with PA whereas in youth without ADHD, it was negatively associated with PA (at a trend level).

Partial correlations of RS right parietal alpha power differed between adolescents with and without ADHD ($p = .049$) (Table 2). In youth with ADHD, RS right parietal alpha power was negatively, whereas in youth without ADHD, it was not associated with the LPP (Table 2).

Aim 3: Theta and alpha lateralization across boys and girls with and without ADHD

Lateralization was apparent in RS parietal theta and alpha power in girls with ADHD, in RS parietal theta power in boys with ADHD, and in event-related parietal theta synchronization in girls without ADHD (Table 3). In girls with ADHD, power was greater in the right hemisphere, in boys with ADHD, power was greater in the left hemisphere, and in girls without ADHD, synchronization was greater in the left hemisphere (Table 3).

As current ADHD medication status was associated with RS right parietal alpha power ($r = .183$, $p = .036$), the effect of medication status on Aim 1 and 2 findings involving RS right parietal alpha power was evaluated. Controlling for medication status, adolescents with and without ADHD did not differ on RS right parietal alpha power ($p = .737$) but adolescents with and without ADHD did differ in terms of the association between RS right parietal alpha power and the LPP (Table 2). In youth with ADHD, RS right parietal alpha power was negatively, whereas in youth without ADHD, it was not associated with the LPP.

Discussion

Our main research questions were whether RS or event-related synchronization (ERS) of theta and alpha activity are differentially associated with an ERP index and parent- and self-report measures of affective processing and a parent-report measure of inattention and whether observed associations differ between adolescents with and without ADHD. We also examined between-group differences in- and in lateralization of these EEG measures.

Findings indicated no between-group differences in RS or ERS of theta and alpha activity across frontal-midline, centroparietal, and parietal sites, with the exception of RS frontal-midline alpha power, which, consistent with earlier results (Ter Huurne et al., 2013; Vollebregt et al., 2016) was lower in youth with relative to without ADHD. The absence of group differences in RS theta activity is inconsistent with a body of work indicating atypical RS theta activity in ADHD and may reflect a developmental effect where youth with ADHD may have either developed a compensatory mechanism to counter a deficit or, as we measured middle-late adolescents, the maturational lag between youth with and without ADHD may have decreased to an extent where simple between-group differences are not detectable. Regarding ERS of theta, earlier findings indicate during a visual spatial attention task, 8–13-year-old children with ADHD exhibit elevated frontal-midline theta synchronization relative to children without ADHD (Guo et al., 2020) whereas we found no differences in RS theta activity or, during affect regulation, in theta synchronization, between adolescents with and without ADHD. Differences across studies may be explainable, at least in part, by differences in experimental paradigms; Guo et al. applied a cognitively demanding visual spatial attention task and the elevated frontal-midline theta synchronization they observed may reflect a compensatory mechanism that counters attenuated attention arousal to achieve behavioral performance that is comparable to children without ADHD (Guo et al., 2020). Here, we applied a simple guessing task that may have not elicited such compensatory cognitive mechanisms.

When examining associations in adolescents with and without ADHD separately, first, because visual inspection indicated boys with ADHD may exhibit different event-related frontal-midline

Table 3. Parietal theta and alpha lateralization across boys and girls with and without ADHD

		Left *M* (*SD*)	Right *M* (*SD*)	*Aw*	*dm*
Girls with ADHD (*n* = 18)					
Parietal theta	RS power	.234 (.863)	.402 (.465)	.602	**.365**
	Synchronization	.816 (1.267)	.731 (1.314)	.497	−.011
Parietal alpha	RS power	−.008 (.697)	.190 (.388)	.620	**.433**
	Synchronization	.457 (1.057)	.271 (1.896)	.522	.077
Boys with ADHD (*n* = 48)					
Parietal theta	RS power	.154 (.301)	.196 (.234)	.548	.171
	Synchronization	1.038 (1.602)	.665 (1.887)	.454	−.163
Parietal alpha	RS power	.003 (.335)	−.035 (.260)	.437	**−.226**
	Synchronization	.469 (1.967)	.386 (2.088)	.450	−.005
Girls without ADHD (*n* = 18)					
Parietal theta	RS power	.268 (.243)	.289 (.172)	.543	.153
	Synchronization	1.291 (1.834)	1.083 (1.674)	.429	**−.253**
Parietal alpha	RS power	.038 (.353)	.047 (.249)	.481	−.066
	Synchronization	.700 (2.596)	.641 (2.097)	.494	−.022
Boys without ADHD (*n* = 48)					
Parietal theta	RS power	.203 (.452)	.235 (.356)	.530	.105
	Synchronization	1.124 (1.603)	.750 (2.086)	.461	−.142
Parietal alpha	RS power	.015 (.313)	.005 (.225)	.475	−.089
	Synchronization	.724(.683)	.498 (2.365)	.490	−.037

Note. *dm* = d-metric, interpretable along the same cutpoints as Cohen's *d*: $.2 < d < .5$ = a small effect, $d \geq .5$ a medium effect, and $d \geq .8$ a large effect. Differences that are at least small are in bold.

theta synchronization during affect regulation than girls with and youth without ADHD, we conducted follow-up analyses and found that both boys with ADHD and girls with ADHD differed (exhibited lower synchronization) from their age- and sex-matched counterparts without ADHD but the difference between boys with and without ADHD was much larger than that between girls with and without ADHD. As noted, there continues to be debate about whether ADHD is less frequently diagnosed in girls because it is actually less prevalent in girls or it is less frequently diagnosed because girls with ADHD exhibit behavioral manifestations that are considerably less disruptive and, as a result, are less often referred for ADHD assessment. Relative to boys, girls with ADHD exhibit fewer hyperactive/impulsive but more inattentive symptoms (Biederman et al., 2005; Gaub & Carlson, 1997; Gershon, 2002) and more commonly meet criteria for the inattentive presentation (Hinshaw et al., 2006). It may be for these reasons that teachers more often refer boys than girls for treatment for ADHD, even when showing equal levels of impairment (Sciutto et al., 2004). An alternative and related explanation is that because of these differences in manifestation, boys with ADHD may differ more from boys without ADHD than the degree to which girls with ADHD differ from girls without ADHD. The pattern of findings obtained here is consistent with this hypothesis, at least with regard to frontal-midline theta synchronization during affect regulation. Certainly, there is also indication in the broader literature that childhood disorders are, although more prevalent in males, are more severe in females (Eme, 1992) and this counters the above interpretation.

Second, when comparing correlations across groups, controlling for sex, there were no differential associations of ERS and RS theta and alpha power with affective processing and attention. Lack of differential association and especially absence of an association between theta and alpha activity measures with inattention may be due to differences in methods. In prior studies (where such differentiation and association were observed) (Cavanagh & Frank, 2014; Diao et al., 2017; Kawasaki & Yamaguchi, 2012), attention was experimentally manipulated and measured in the laboratory. Here, attention was measured employing parent-report on a rating scale. Whereas the former method likely captures considerably more basic, homogeneous aspects and manifestations of differences in attention, the latter method captures more heterogeneous, observable aspects, and manifestations of attention.

There was, however, a double disassociation between ERS theta and RS alpha power with affectivity and elaborate affective/motivational processing. Controlling for sex, in adolescents with ADHD, event-related right parietal theta synchronization was positively associated with positive affectivity and RS right parietal alpha power was negatively associated with elaborate affective/motivational processing. These associations were in the opposite direction (at a trend level) in case of the theta-affective processing relation and were nonsignificant in case of the alpha-affective processing relation.

These results have both general and specific conceptual implications. *Regarding general implications,* our findings highlight the importance of moving beyond assessing simple between-group comparisons (e.g., comparing youth with to youth without ADHD) to – as has been done in an emerging body of work (Rosen et al., 2015; Scarpelli et al., 2019; D. W. Zhang et al., 2019) – the assessment of between-group differences in the *relations* across the characteristics of interest. The first approach (simple between-group comparisons) assumes that characteristics operate in isolation and thus that if groups differ on a relevant variable (e.g., ADHD diagnosis), they will also differ on the characteristics of interest (e.g., RS or event-related theta synchronization). Yet, developmental psychopathology research consistently shows that characteristics do not operate in isolation and that there is a complex interplay between various protective and risk factors (Cicchetti & Rogosch, 1996). The second approach (comparison of between-group differences in the relations across characteristics) appreciates this complexity; although groups may not differ on a relevant correlate or susceptibility trait, they may differ in how those conditions or traits interact and operate. *Regarding specific implications,* these data show that in adolescents with ADHD, event-related right parietal theta synchronization and RS right parietal alpha power may be employed as electrophysiological indices of behaviorally different ADHD-related affective characteristics that have been previously shown to be prognostically relevant, i.e., affectivity (Bunford et al., 2021). Event-related theta synchronization during affect regulation following monetary gain or loss may be a biological marker of individual differences in dispositional affectivity whereas RS alpha power is a marker of elaborate affective/motivational processing.

Of note, the LPP has been conceptualized as reflecting not only elaborate affective/motivational processing but also sustained attention towards information that is affectively and motivationally salient (Bunford, Kujawa, et al., 2018; Kujawa, Klein, et al., 2013). In this framework, in adolescents with ADHD, there was arguably a disassociation between ERS and RS theta and alpha power with affective processing and attention. As with any ERP, the cognitive function behind the LPP, the meaning of the LPP is largely determined by the experimental task during which it is elicited and measured. the Doors task by nature is appropriate for manipulating motivational processes; as such, even if emphasis is on the sustained attention interpretation of the LPP, the sustained attention it reflects is motivationally dependent or modulated. Further, in the current sample, the LPP was more closely related to rating scale measures of affective processing than of attention, underscoring an elaborate affective/motivational processing interpretation.

Finally, we found lateralization predominantly in adolescents with ADHD; in girls, RS parietal theta and alpha power was greater in the right hemisphere and in boys, RS parietal alpha power was greater in the left hemisphere. One exception was that in girls without ADHD, event-related parietal theta synchronization was greater in the left hemisphere. Prior results show that during a visual spatial attention task, 8–13-year-old children with ADHD exhibited adult-like posterior theta lateralization, such that in children with ADHD, the theta modulation index (i.e., changes in power to different stimuli) was greater in the right relative to the left hemisphere, whereas there was no right–left difference in children without ADHD (Guo et al., 2020). In another study employing the same paradigm, in children with ADHD, alpha modulation was not attenuated in the right but was attenuated in the left hemisphere (Guo et al., 2019). In combination with the current findings, data show an abnormal unilateral advantage in the parieto-occipital area in children with ADHD but the exact manifestation of such advantage – hyper- vs. hypoactivity and specificity to the left vs. the right hemisphere across theta and alpha – is unclear. Nevertheless, Guo et al., attributed such "adult-like" theta lateralization in children with ADHD to atypical neurodevelopment in the disorder where the premature development of lateralized theta modulation compensates for attention deficits and thereby promotes (close to typical) behavioral performance.

Directions for future research

It will be key to evaluate whether our findings generalize across development, i.e., they apply to children and adults with ADHD, especially given that at least in terms of the manifestation of ADHD symptoms, those become more differentiable, more dissimilar from each other from childhood through adolescents and into adulthood (Martel et al., 2016). This increased differentiation may also characterize the differential relations between alpha and theta activity and inattention and affective processing in this population.

It will also be key to examine whether these findings replicate in independent samples, especially results obtained on differences across sexes, as the boy and girl subsamples were moderate in size.

Assessment of attention/ inattention via self-report, especially in children and adolescents with ADHD is not recommended (Pelham et al., 2005). However, in studies aiming to address research questions similar to the ones evaluated here, augmenting parent-report with a biological, e.g., ERP, measure of attention – as we did for affective processing – will be an important extension and replication of our results.

As there is indication that EEG activity may differ across ADHD presentations (2001b; Barry et al., 2003, Clarke et al., 2001c), it will be important to determine whether such presentations – the inattentive vs. the hyperactive/impulsive or the combined presentations – have any bearing on the findings observed here.

ADHD pharmacotherapy is associated with differences in cognitive performance and neural processing even when such therapy has been discontinued (Schlochtermeier et al., 2011), the association between ADHD medication status and the relation between the herein examined EEG indices and affective processing and attention will need to be evaluated.

Conclusion

We examined, for the first time, whether – and at which sites – theta and alpha activity are differentially associated with affective processing and attention and whether these differential relations are modulated by ADHD status.

When ADHD status and sex are accounted for, in adolescents with ADHD, there is a double disassociation between ERS theta and RS alpha power with affectivity and elaborate affective/motivational processing. In either adolescents with or in adolescents without ADHD, there is no disassociation of ERS and RS theta and alpha power with affective processing and attention.

Findings also showed that as behaviorally, boys with ADHD differ from their age and sex matched peers without ADHD in event-related frontal-midline theta synchronization more than girls do.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0954579423000639

Data availability statement. Datasets and codes generated and/or analyzed for the current study are available from the corresponding author on reasonable request.

Funding statement. This research was funded by a Hungarian Academy of Sciences Momentum ("MTA Lendület") Grant awarded to NB (#LP2018-3/

2018). During the preparation of this article, TM was supported by a Hungarian Academy of Sciences Hungarian Brain Research Program ("NAP 3.0") Grant awarded to NB (HAS-ELRN NAP2022-I-2/2022) and TB was supported by a Hungarian Academy of Sciences János Bolyai Grant (BO/00237/19/2).

Competing interests. None.

Ethical standard. This research was approved by the National Institute of Pharmacy and Nutrition (OGYÉI/17089-8/2019) and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

References

Adrian, M., Zeman, J., Erdley, C., Lisa, L., Homan, K., & Sim, L. (2009). Social contextual links to emotion regulation in an adolescent psychiatric inpatient population: Do gender and symptomatology matter? *Journal of Child Psychology and Psychiatry*, *50*(11), 1428–1436. https://doi.org/10.1111/j.1469-7610.2009.02162.x

Aftanas, L. I., Reva, N. V., & Makhnev, V. P. (2008). Individual variability of brain oscillatory and autonomous concomitants of motivated attention. *International Journal of Psychophysiology*, *69*(3), 197. https://doi.org/10.1016/j.ijpsycho.2008.05.533

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5). Diagnostic and Statistical Manual of Mental Disorders 4th Edition TR* (Vol. *280*). American Psychiatric Association. https://doi.org/10.1176/appi.books.9780890425596.744053

Ansarinasab, S., Panahi, S., Ghassemi, F., Ghosh, D., & Jafari, S. (2022). Synchronization stability analysis of functional brain networks in boys with ADHD during facial emotions processing. *Physica A: Statistical Mechanics and Its Applications*, *603*, 127848. https://doi.org/10.1016/j.physa.2022.127848

Arns, M., Conners, C. K., & Kraemer, H. C. (2013). A decade of EEG theta/beta ratio research in ADHD: A meta-analysis. *Journal of Attention Disorders*, *17*(5), 374–383. https://doi.org/10.1177/1087054712460087

Babiloni, C., Miniussi, C., Babiloni, F., Carducci, F., Cincotti, F., Del Percio, C., Sirello, G., Fracassi, C., Nobre, A. C., & Rossini, P. M. (2004). Sub-second, temporal attention, modulates alpha rhythms. A high-resolution EEG study. *Cognitive Brain Research*, *19*(3), 259–268. https://doi.org/10.1016/j.cogbrainres.2003.12.010

Ball, T. M. M., Stein, M. B. B., & Paulus, M. P. P. (2014). Toward the application of functional neuroimaging to individualized treatment for anxiety and depression. *Depression and Anxiety*, *31*(11), 920–933. https://doi.org/10.1002/da.22299

Barry, R. J., Clarke, A. R., & Johnstone, S. J. (2003). A review of electrophysiology in attention-deficit/hyperactivity disorder: I. Qualitative and quantitative electroencephalography. *Clinical Neurophysiology*, *114*(2), 171–183. https://doi.org/10.1016/S1388-2457(02)00362-0

Bell, A. J., & Sejnowski, T. J. (1995). An information-maximization approach to blind separation and blind deconvolution. *Neural Computation*, *7*(6), 1129–1159. https://doi.org/10.1162/neco.1995.7.6.1129

Biederman, J., Kwon, A., Aleardi, M., Chouinard, V. A., Marino, T., Cole, H., Mick, E., & Faraone, S. V. (2005). Absence of gender effects on attention deficit hyperactivity disorder: Findings in nonreferred subjects. *American Journal of Psychiatry*, *162*(6), 1083–1089. https://doi.org/10.1176/appi.ajp.162.6.1083

Biederman, J., Mick, E., Faraone, S. V., Braaten, E., Doyle, A., Spencer, T., Wilens, T. E., Frazier, E., & Johnson, M. A. (2002). Influence of gender on attention deficit hyperactivity disorder in children referred to a psychiatric clinic. *American Journal of Psychiatry*, *159*(1), 36–42. https://doi.org/10.1176/appi.ajp.159.1.36

Boutros, N., Fraenkel, L., & Feingold, A. (2005). A four-step approach for developing diagnostic tests in psychiatry: EEG in ADHD as a test case. *Journal of Neuropsychiatry and Clinical Neurosciences*, *17*(4), 455–464. https://doi.org/10.1176/jnp.17.4.455

Bresnahan, S. M., Anderson, J. W., & Barry, R. J. (1999). Age-related changes in quantitative EEG in attention- deficit/hyperactivity disorder. *Biological Psychiatry*, *46*(12), 1690–1697. https://doi.org/10.1016/S0006-3223(99)00042-6

Bunford, N., Brandt, N. E., Golden, C., Dykstra, J. B., Suhr, J. A., & Owens, J. S. (2015). Attention-deficit/hyperactivity disorder symptoms mediate the association between deficits in executive functioning and social impairment in children. *Journal of Abnormal Child Psychology*, *43*(1), 133–147. https://doi.org/10.1007/s10802-014-9902-9

Bunford, N., Dawson, A. E., Evans, S. W., Ray, A. R., Langberg, J. M., Owens, J. S., DuPaul, G. J., & Allan, D. M. (2020). The difficulties in emotion regulation scale-parent report: A psychometric investigation examining adolescents with and without ADHD. *Assessment*, *27*(5), 921–940. https://doi.org/10.1177/1073191118792307

Bunford, N., Evans, S. W., Becker, S. P., & Langberg, J. M. (2015). Attention-deficit/hyperactivity disorder and social skills in youth: A moderated mediation model of emotion dysregulation and depression. *Journal of Abnormal Child Psychology*, *43*(2), 283–296. https://doi.org/10.1007/s10802-014-9909-2

Bunford, N., Evans, S. W., & Langberg, J. M. (2018). Emotion dysregulation is associated with social impairment among young adolescents with ADHD. *Journal of Attention Disorders*, *22*(1), 66–82. https://doi.org/10.1177/1087054714527793

Bunford, N., Evans, S. W., & Wymbs, F. (2015). ADHD and emotion dysregulation among children and adolescents. *Clinical Child and Family Psychology Review*, *18*(3), 185–217. https://doi.org/10.1007/s10567-015-0187-5

Bunford, N., Hámori, G., Nemoda, Z., Angyal, N., Fiáth, R., Sebők-Welker, T.É., Pászthy, B., Ulbert, I., & Réthelyi, J. M. (2023). The domain-variant indirect association between electrophysiological response to reward and ADHD presentations is moderated by dopaminergic polymorphisms. *Comprehensive Psychiatry*, *124*, 152389. https://doi.org/10.1016/j.comppsych.2023.152389

Bunford, N., Kujawa, A., Dyson, M., Olino, T., & Klein, D. N. (2021). Developmental pathways from preschool temperament to early adolescent ADHD symptoms through initial responsiveness to reward. *Development and Psychopathology*, *16*(3), 1–13. https://doi.org/10.1017/S0954579420002199

Bunford, N., Kujawa, A., Fitzgerald, K. D., Swain, J. E., Hanna, G. L., Koschmann, E., Simpson, D., Connolly, S., Monk, C. S., & Phan, K. L. (2017). Neural reactivity to angry faces predicts treatment response in pediatric anxiety. *Journal of Abnormal Child Psychology*, *45*(2), 385–395. https://doi.org/10.1007/s10802-016-0168-2

Bunford, N., Kujawa, A., Fitzgerald, K. D. K. D., Monk, C. S. C. S., & Phan, K. L. L. (2018). Convergence of BOLD and ERP measures of neural reactivity to emotional faces in children and adolescents with and without anxiety disorders. *Biological Psychology*, *134*, 9–19. https://doi.org/10.1016/j.biopsycho.2018.02.006

Bunford, N., Kujawa, A., Swain, J. E., Fitzgerald, K. D., Monk, C. S., & Phan, K. L. L. (2017). Attenuated neural reactivity to happy faces is associated with rule breaking and social problems in anxious youth. *European Child & Adolescent Psychiatry*, *26*(2), 215–230. https://doi.org/10.1007/s00787-016-0883-9

Callaway, E., Halliday, R., & Naylor, H. (1983). Hyperactive children's event-related potentials fail to support underarousal and maturational-lag theories. *Archives of General Psychiatry*, *40*(11), 1243. https://doi.org/10.1001/archpsyc.1983.01790100089012

Cavanagh, J. F., & Frank, M. J. (2014). Frontal theta as a mechanism for cognitive control. *Trends in Cognitive Sciences*, *18*(8), 414–421. https://doi.org/10.1016/j.tics.2014.04.012

Chabot, R. J., & Serfontein, G. (1996). Quantitative electroencephalographic profiles of children with attention deficit disorder. *Biological Psychiatry*, *40*(10), 951–953. https://doi.org/10.1016/0006-3223(95)00576-5

Cicchetti, D., & Rogosch, F. A. (1996). Equifinality and multifinality in developmental psychopathology. *Development and Psychopathology*, *8*(04), 597–600. https://doi.org/10.1017/S0954579400007318

Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (1998). EEG analysis in attention-deficit/hyperactivity disorder: A comparative study of two subtypes. *Psychiatry Research*, *81*(1), 19–29. https://doi.org/10.1016/S0165-1781(98)00072-9

Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (2001a). Age and sex effects in the EEG: Development of the normal child. *Clinical Neurophysiology*, *112*(5), 806–814. https://doi.org/10.1016/S1388-2457(01)00488-6

Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (2001b). Age and sex effects in the EEG: Differences in two subtypes of attention-deficit/hyperactivity disorder. *Clinical Neurophysiology*, *112*(5), 815–826. https://doi.org/10.1016/S1388-2457(01)00487-4

Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (2001c). EEG-defined subtypes of children with attention-deficit/hyperactivity disorder. *Clinical Neurophysiology*, *112*(11), 2098–2105. https://doi.org/10.1016/S1388-2457(01)00668-X

Clarke, A. R., Barry, R. J., McCarthy, R., & Selikowitz, M. (2002). EEG analysis of children with attention-deficit/hyperactivity disorder and comorbid reading disabilities. *Journal of Learning Disabilities*, *35*(3), 276–285. https://doi.org/10.1177/002221940203500309

Cuthbert, B. N., Schupp, H. T., Bradley, M. M., Birbaumer, N., & Lang, P.J. (2000). Brain potentials in affective picture processing: Covariation with autonomic arousal and affective report. *Biological Psychology*. *52*, 95–111.

De Reyes, A. L., & Kazdin, A. E. (2005). Informant discrepancies in the assessment of childhood psychopathology: A critical review, theoretical framework, and recommendations for further study. *Psychological Bulletin*, *131*(4), 483–509. https://doi.org/10.1037/0033-2909.131.4.483

Defrance, J. F., Smith, S., Schweitzer, F. C., Ginsberg, L., & Sands, S. (1996). Topographical analyses of attention disorders of childhood. *International Journal of Neuroscience*, *87*(1-2), 41–61. https://doi.org/10.3109/00207459608990752

Delaney, H. D., & Vargha, A. (2002). Comparing several robust tests of stochastic equality with ordinally scaled variables and small to moderate sized samples. *Psychological Methods*, *7*(4), 485–503. https://doi.org/10.1037/1082-989X.7.4.485

Diao, L., Qi, S., Xu, M., Fan, L., & Yang, D. (2017). Electroencephalographic theta oscillatory dynamics reveal attentional bias to angry faces. *Neuroscience Letters*, *656*, 31–36. https://doi.org/10.1016/j.neulet.2017.06.047

Dirks, M. A., De Los Reyes, A., Briggs-gowan, M., Cella, D., & Wakschlag, L. S. (2012). Embracing not erasing contextual variability in children's behaviour. *Journal of Child Psychology and Psychiatry*. https://doi.org/10.1111/j.1469-7610.2012.02537.x. Embracing

Dockree, P. M., Kelly, S. P., Roche, R. A. P., Hogan, M. J., Reilly, R. B., & Robertson, I. H. (2004). Behavioural and physiological impairments of sustained attention after traumatic brain injury. *Cognitive Brain Research*, *20*(3), 403–414. https://doi.org/10.1016/j.cogbrainres.2004.03.019

Dunning, J. P., & Hajcak, G. (2007). Error-related negativities elicited by monetary loss and cues that predict loss. *Neuroreport*, *18*(17), 1875–1878. https://doi.org/10.1097/WNR.0b013e3282f0d50b

DuPaul, G. J., Power, T. J., Anastopoulos, A. D., & Reid, R. (2016). *ADHD rating scale-5 for children and adolescents*. The Guilford Press.

Eme, R. F. (1992). Selective females affliction in the developmental disorders of childhood: A literature review. *Journal of Clinical Child Psychology*. https://doi.org/10.1207/s15374424jccp2104_5

Faraone, S. V., Biederman, J., & Mick, E. (2006). The age-dependent decline of attention deficit hyperactivity disorder: A meta-analysis of follow-up studies. *Psychological Medicine*, *36*(2), 159–165. https://doi.org/10.1017/s003329170500471x

Foti, D., & Hajcak, G. (2009). Depression and reduced sensitivity to non-rewards versus rewards: Evidence from event-related potentials. *Biological Psychology*, *81*(1), 1–8. https://doi.org/10.1016/j.biopsycho.2008.12.004

Gao, Y., Shuai, D., Bu, X., Hu, X., Tang, S., Zhang, L., Li, H., Hu, X., Lu, L., Gong, Q., Huang, X. (2019). Impairments of large-scale functional networks in attention-deficit/hyperactivity disorder: A meta-analysis of resting-state functional connectivity. *Psychological Medicine*, *49*(15), 2475–2485. https://doi.org/10.1017/S003329171900237X

Gasser, T., Verleger, R., Bächer, P., & Sroka, L. (1988). Development of the EEG of school-age children and adolescents. I. Analysis of band power. *Electroencephalography and Clinical Neurophysiology*. https://doi.org/10.1016/0013-4694(88)90204-0

Gaub, M., & Carlson, C. L. (1997). Gender differences in ADHD: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry*, *36*(8), 1036–1045. https://doi.org/10.1097/00004583-199708000-00011

Gershon, J. (2002). A meta-analytic review of gender differences in ADHD. *Journal of Attention Disorders*, *5*(3), 143–154. https://doi.org/10.1177/108705470200500302

Gratz, K. L., & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the Difficulties in Emotion Regulation Scale. *Journal of Psychopathology and Behavioral Assessment*, *26*, 41–54. https://doi.org/10.1023/B:JOBA.0000007455.08539.94

Guo, J., Luo, X., Li, B., Chang, Q., Sun, L., & Song, Y. (2020). Abnormal modulation of theta oscillations in children with attention-deficit/hyperactivity disorder. *NeuroImage. Clinical*, *27*, 102314. https://doi.org/10.1016/j.nicl.2020.102314

Guo, J., Luo, X., Wang, E., Li, B., Chang, Q., Sun, L., & Song, Y. (2019). Abnormal alpha modulation in response to human eye gaze predicts inattention severity in children with ADHD. *Developmental Cognitive Neuroscience*, *38*, 100671. https://doi.org/10.1016/j.dcn.2019.100671

Gyollai, Á., Simor, P. P. P., Köteles, F., Demetrovics, Z., Gyollai, A., Simor, P. P. P., Koteles, F., Demetrovics, Z., Gyollai, Á., Simor, P. P. P., Köteles, F., & Demetrovics, Z. (2011). Psychometric properties of the Hungarian version of the original and the short form of the Positive and Negative Affect Schedule (PANAS). *Neuropsychopharmacologia Hungarica: A Magyar Pszichofarmakologiai Egyesulet Lapja = Official Journal of the Hungarian Association of Psychopharmacology*, *13*(2), 73–79.

Hajcak, G., MacNamara, A, & Olvet, D. M. (2010). Event-Related potentials, emotion, and emotion regulation: an integrative review. *Developmental Neuropsychology*, *35*, 129–155.

Hajcak, G., & Nieuwenhuis, S. (2006). Reappraisal modulates the electrocortical response to unpleasant pictures. *Cognitive, Affective, & Behavioral Neuroscience*, *6*, 291–297.

Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2011). ERPs and the study of emotion. In S. J. Luck & E. Kappenman (Eds.), *Handbook of event-related potential components* (pp. 441–472). Oxford University Press.

Halgren, M., Ulbert, I., Bastuji, H., Fabó, D., Eross, L., Rey, M., Devinsky, O., Doyle, W. K., Mak-McCully, R., Halgren, E., Wittner, L., Chauvel, P., Heit, G., Eskandar, E., Mandell, A., & Cash, S. S. (2019). The generation and propagation of the human alpha rhythm. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(47), 23772–23782. https://doi.org/10.1073/pnas.1913092116

Hámori, G., File, B., Fiáth, R., Pászthy, B., Réthelyi, J. M., Ulbert, I., & Bunford, N. (2023). Adolescent ADHD and electrophysiological reward responsiveness: A machine learning approach to evaluate classification accuracy and prognosis. *Psychiatry Research*, *323*, 115139. https://doi.org/10.1016/j.psychres.2023.115139

Hámori, G., Rádosi, A., Pászthy, B., Réthelyi, J. M., Ulbert, I., Fiáth, R., & Bunford, N. (2022). Reliability of reward ERPs in middle-late adolescents using a custom and a standardized preprocessing pipeline. *Psychophysiology*, *59*(8), e14043.

Harmony, T., Marosi, E., Díaz de León, A. E., Becker, J., & Fernández, T. (1990). Effect of sex, psychosocial disadvantages and biological risk factors on EEG maturation. *Electroencephalography and Clinical Neurophysiology*, *75*(6), 482–491. https://doi.org/10.1016/0013-4694(90)90135-7

Hinshaw, S. P., Owens, E. B., Sami, N., & Fargeon, S. (2006). Prospective follow-up of girls with attention-deficit/hyperactivity disorder into adolescence: Evidence for continuing cross-domain impairment. *Journal of Consulting and Clinical Psychology*, *74*(3), 489–499. https://doi.org/10.1037/0022-006X.74.3.489

Kawasaki, M., & Yamaguchi, Y. (2012). Effects of subjective preference of colors on attention-related occipital theta oscillations. *NeuroImage*, *59*(1), 808–814. https://doi.org/10.1016/j.neuroimage.2011.07.042

Kieling, C., Kieling, R. R., Rohde, L. A., Frick, P. J., Moffitt, T., Nigg, J. T., Tannock, R., & Castellanos, F. X. (2010). The age at onset of attention deficit hyperactivity disorder. *American Journal of Psychiatry*, *167*(1), 14–16. https://doi.org/10.1176/appi.ajp.2009.09060796

Knyazev, G. G. (2007). Motivation, emotion, and their inhibitory control mirrored in brain oscillations. *Neuroscience and Biobehavioral Reviews*, *31*(3), 377–395. https://doi.org/10.1016/j.neubiorev.2006.10.004

Koehler, S., Lauer, P., Schreppel, T., Jacob, C., Heine, M., Boreatti-Hümmer, A., Fallgatter, A. J., & Herrmann, M. J. (2009). Increased EEG power density in alpha and theta bands in adult ADHD patients. *Journal of Neural Transmission*, *116*(1), 97–104. https://doi.org/10.1007/s00702-008-0157-x

Kökönyei, G., Urbán, R., Reinhardt, M., Józan, A., & Demetrovics, Z. (2014). The difficulties in emotion regulation scale: Factor structure in chronic pain patients. *Journal of Clinical Psychology*, *70*(6), 589–600. https://doi.org/10.1002/jclp.22036

Központi Statisztikai Hivatal (2021). *435 200 forint volt a bruttó átlagkereset*. GYORSTÁJÉKOZTATÓ. Keresetek, 2021. Március.

Kujawa, A., Carroll, A., Mumper, E., Mukherjee, D., Kessel, E. M., Olino, T., Hajcak, G., & Klein, D. N. (2018). A longitudinal examination of event-related potentials sensitive to monetary reward and loss feedback from late childhood to middle adolescence. *International Journal of Psychophysiology*, *132*, 323–330. https://doi.org/10.1016/j.ijpsycho.2017.11.001

Kujawa, A., Klein, D. N., & Proudfit, G. H. (2013). Two-year stability of the late positive potential across middle childhood and adolescence. *Biological Psychology*, *94*(2), 290–296. https://doi.org/10.1016/j.biopsycho.2013.07.002

Kujawa, A., Proudfit, G. H., & Klein, D. N. (2014). Neural reactivity to rewards and losses in offspring of mothers and fathers with histories of depressive and anxiety disorders. *Journal of Abnormal Psychology*, *123*(2), 287–297. https://doi.org/10.1037/a0036285

Kujawa, A., Proudfit, G. H. H., Kessel, E. M. M., Dyson, M., Olino, T., & Klein, D. N. N. (2015). Neural reactivity to monetary rewards and losses in childhood: Longitudinal and concurrent associations with observed and self-reported positive emotionality. *Biological Psychology*, *104*, 41–47. https://doi.org/10.1016/j.biopsycho.2014.11.008

Kujawa, A., Smith, E., Luhmann, C., & Hajcak, G. (2013). The feedback negativity reflects favorable compared to nonfavorable outcomes based on global, not local, alternatives. *Psychophysiology*, *50*(2), 134–138. https://doi.org/10.1111/psyp.12002

Kujawa, A., Weinberg, A., Bunford, N., Fitzgerald, K. D., Hanna, G. L., Monk, C. S. S., Kennedy, A. E., Klumpp, H., Hajcak, G., Phan, K. L. L., Swain, J. E., Monk, C. S., Hajcak, G., Phan, K. L. (2016). Error-related brain activity in youth and young adults with generalized or social anxiety disorder before and after treatment. *Progress in Neuro-Psychopharmacology & Biological Psychiatry*, *71*, 162–168. https://doi.org/10.1016/j.pnpbp.2016.07.010

Lahey, B. B. (2009). Public health significance of neuroticism. *American Psychologist*, *64*(4), 241–256. https://doi.org/10.1037/a0015309

Langberg, J. M., Epstein, J. N., Altaye, M., Molina, B. S. G., Arnold, L. E., & Vitiello, B. (2008). The transition to middle school is associated with changes in the developmental trajectory of ADHD symptomatology in young adolescents with ADHD. *Journal of Clinical Child and Adolescent Psychology: The Official Journal for the Society of Clinical Child and Adolescent Psychology, American Psychological Association, Division*, *37*(3), 651–663. https://doi.org/10.1080/15374410802148095

Lapomarda, G., Valer, S., Job, R., & Grecucci, A. (2022). Built to last: Theta and delta changes in resting-state EEG activity after regulating emotions. *Brain and Behavior*, *12*(6), e2597. https://doi.org/10.1002/brb3.2597

Laufs, H., Krakow, K., Sterzer, P., Eger, E., Beyerle, A., Salek-Haddadi, A., & Kleinschmidt, A. (2003). Electroencephalographic signatures of attentional and cognitive default modes in spontaneous brain activity fluctuations at rest. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(19), 11053–11058. https://doi.org/10.1073/pnas.1831638100

Le, H. H., Hodgkins, P., Postma, M. J., Kahle, J., Sikirica, V., Setyawan, J., & Doshi, J. A. (2014). Economic impact of childhood/adolescent ADHD in a european setting: The Netherlands as a reference case. *European Child & Adolescent Psychiatry*, *23*(7), 587–598.

Leutgeb, V., Schäfer, A., Köchel, A., Scharmüller, W., & Schienle, A. (2010). Psychophysiology of spider phobia in 8- to 12-year-old girls. *Biological Psychology*, *85*(3), 424–431.

Loo, S. K., McGough, J. J., McCracken, J. T., & Smalley, S. L. (2018). Parsing heterogeneity in attention-deficit hyperactivity disorder using EEG-based subgroups. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *59*(3), 223–231. https://doi.org/10.1111/jcpp.12814

Lubar, J. F., Swartwood, M. O., Swartwood, J. N., & O'Donnell, P. H. (1995). Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in T.O.V.A. scores, behavioral ratings, and WISC-R performance. *Biofeedback and Self-Regulation*, *20*(1), 83–99. https://doi.org/10.1007/BF01712768

Mann, C. A., Lubar, J. F., Zimmerman, A. W., Miller, C. A., & Muenchen, R. A. (1992). Quantitative analysis of EEG in boys with attention-deficit-hyperactivity disorder: Controlled study with clinical implications. *Pediatric Neurology*, *8*(1), 30–36. https://doi.org/10.1016/0887-8994(92)90049-5

Martel, M. M., Levinson, C. A., Langer, J. K., & Nigg, J. T. (2016). A network analysis of developmental change in ADHD symptom structure from preschool to adulthood. *Clinical Psychological Science*, *4*(6), 988–1001. https://doi.org/10.1177/2167702615618664

Martel, M. M., & Nigg, J. T. (2006). Child ADHD and personality/temperament traits of reactive and effortful control, resiliency, and emotionality. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *47*(11), 1175–1183. https://doi.org/10.1111/j.1469-7610.2006.01629.x

Mash, E. J., & Hunsley, J. (2005). Evidence-based assesment of child and adolescent disorders: Issues and challenges. *Journal of Clinical Child and Adolescent Psychology*, *34*(3), 362–379.

Monastra, V. J., Lubar, J. F., & Linden, M. (2001). The development of a quantitative electroencephalographic scanning process for attention deficit-hyperactivity disorder: Reliability and validity studies. *Neuropsychology*, *15*(1), 136–144. https://doi.org/10.1037/0894-4105.15.1.136

Monastra, V. J., Lubar, J. F., Linden, M., VanDeusen, P., Green, G., Wing, W., Phillips, A., & Fenger, T. N. (1999). Assessing attention deficit hyperactivity disorder via quantitative electroencephalography: An initial validation study. *Neuropsychology*, *13*(3), 424–433. https://doi.org/10.1037//0894-4105.13.3.424

Nasab, S. A., Panahi, S., Ghassemi, F., Jafari, S., Rajagopal, K., Ghosh, D., & Perc, M. (2022). Functional neuronal networks reveal emotional processing differences in children with ADHD. *Cognitive Neurodynamics*, *16*(1), 91–100. https://link.springer.com/article/10.1007/s11571-021-09699-6

Nishitani, N. (2003). Dynamics of cognitive processing in the human hippocampus by neuromagnetic and neurochemical assessments. *NeuroImage*, *20*(1), 561–571. https://doi.org/10.1016/S1053-8119(03)00280-5

Nymberg, C., Jia, T., Lubbe, S., Ruggeri, B., Desrivieres, S., Barker, G., Büchel, C., Fauth-Buehler, M., Cattrell, A., Conrod, P., Flor, H., Gallinat, J., Garavan, H., Heinz, A., Ittermann, B., Lawrence, C., Mann, K., Nees, F., Salatino-Oliveira, A., . . . Schumann, G. (2013). Neural mechanisms of attention-deficit/hyperactivity disorder symptoms are stratified by MAOA genotype. *Biological Psychiatry*, *74*(8), 607–614. https://doi.org/10.1016/j.biopsych.2013.03.027

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J. M. (2011). FieldTrip: Open source software for advanced analysis of MEG, EEG, and invasive electrophysiological data. *Computational Intelligence and Neuroscience*, *2011*, 156869. https://doi.org/10.1155/2011/156869

Pelham, W., Fabiano, G. A., & Massetti, G. M. (2005). Evidence-based assessment of attention deficit hyperactivity disorder in children and adolescents. *Journal of Clinical Child and Adolescent Psychology*, *34*(3), 449–476. https://doi.org/10.1207/s15374424jccp3403_5

Quinn, P. O. (2008). Attention-deficit/hyperactivity disorder and its comorbidities in women and girls: An evolving picture. *Current Psychiatry Reports*, *10*(5), 419–423. https://doi.org/10.1007/s11920-008-0067-5

Rosen, P. J., Walerius, D. M., Fogleman, N. D., & Factor, P. I. (2015). The association of emotional lability and emotional and behavioral difficulties among children with and without ADHD. *ADHD Attention Deficit and Hyperactivity Disorders*, *7*(4), 281–294. https://doi.org/10.1007/s12402-015-0175-0

Ruscio, J. (2008). A probability-based measure of effect size: Robustness to base rates and other factors. *Psychological Methods*, *13*(1), 19–30. https://doi.org/10.1037/1082-989X.13.1.19

Saalmann, Y. B., Pinsk, M. A., Wang, L., Li, X., & Kastner, S. (2012). The pulvinar regulates information transmission between cortical areas based on attention demands. *Science*, *337*(6095), 753–766. https://doi.org/10.1126/science.1223082

Sauseng, P., Klimesch, W., Stadler, W., Schabus, M., Doppelmayr, M., Hanslmayr, S., Gruber, W. R., & Birbaumer, N. (2005). A shift of visual spatial attention is selectively associated with human EEG alpha activity. *European Journal of Neuroscience*, *22*(11), 2917–2926. https://doi.org/10.1111/j.1460-9568.2005.04482.x

Scarpelli, S., Gorgoni, M., D'atri, A., Reda, F., & De Gennaro, L. (2019). Advances in understanding the relationship between sleep and attention deficit-hyperactivity disorder (ADHD). *Journal of Clinical Medicine*, *8*(10). https://doi.org/10.3390/jcm8101737

Schlochtermeier, L., Stoy, M., Schlagenhauf, F., Wrase, J., Park, S. Q., Friedel, E., Huss, M., Lehmkuhl, U., Heinz, A., & Ströhle, A. (2011). Childhood methylphenidate treatment of ADHD and response to affective stimuli. *European Neuropsychopharmacology*, *21*(8), 646–654. https://doi.org/10.1016/j.euroneuro.2010.05.001

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: Event-Related brain potential studies. *Progress in Brain Research*, *156*, 31–51.

Sciutto, M. J., Nolfi, C. J., & Bluhm, C. (2004). Effects of child gender and symptom type on referrals for ADHD by elementary school teachers. *Journal of Emotional and Behavioral Disorders*. https://doi.org/10.1177/10634266040120040501

Segalowitz, S. J., Santesso, D. L., & Jetha, M. K. (2010). Electrophysiological changes during adolescence: A review. *Brain and Cognition*, *72*(1), 86–100. https://doi.org/10.1016/j.bandc.2009.10.003

Skogli, E. W., Teicher, M. H., Andersen, P. N., Hovik, K. T., & Øie, M. (2013). ADHD in girls and boys—Gender differences in co-existing symptoms and executive function measures. *BMC Psychiatry*. https://doi.org/10.1186/1471-244X-13-298

Stange, J. P., MacNamara, A., Barnas, O., Kennedy, A. E., Hajcak, G., Phan, K. L., & Klumpp, H. (2017). Neural markers of attention to aversive pictures predict response to cognitive behavioral therapy in anxiety and depression. *Biological Psychology*, *123*, 269–277. https://doi.org/10.1016/j.biopsycho.2016.10.009

Stoet, G. (2010). PsyToolkit: A software package for programming psychological experiments using Linux. *Behavior Research Methods*, *42*(4), 1096–1104. https://doi.org/10.3758/BRM.42.4.1096

Stoet, G. (2017). PsyToolkit: A novel web-based method for running online questionnaires and reaction-time experiments. *Teaching of Psychology*, *44*(1), 24–31. https://doi.org/10.1177/0098628316677643

Ter Huurne, N., Onnink, M., Kan, C., Franke, B., Buitelaar, J., & Jensen, O. (2013). Behavioral consequences of aberrant alpha lateralization in attention-deficit/hyperactivity disorder. *Biological Psychiatry*, *74*(3), 227–233. https://doi.org/10.1016/j.biopsych.2013.02.001

Uhlhaas, P. J., & Singer, W. (2011). The development of neural synchrony and large-scale cortical networks during adolescence: Relevance for the pathophysiology of schizophrenia and neurodevelopmental hypothesis. *Schizophrenia Bulletin*, *37*(3), 514–523. https://doi.org/10.1093/schbul/sbr034

Vasilev, C. A. A., Crowell, S. E. E., Beauchaine, T. P. P., Mead, H. K. K., & Gatzke-Kopp, L. M. M. (2009). Correspondence between physiological and self-report measures of emotion dysregulation: A longitudinal investigation of youth with and without psychopathology. *Journal of Child Psychology and Psychiatry*, *50*(11), 1357–1364. https://doi.org/10.1111/j.1469-7610.2009.02172.x

Vollebregt, M. A., Zumer, J. M., ter Huurne, N., Buitelaar, J. K., & Jensen, O. (2016). Posterior alpha oscillations reflect attentional problems in boys with Attention Deficit Hyperactivity Disorder. *Clinical Neurophysiology*, *127*(5), 2182–2191. https://doi.org/10.1016/j.clinph.2016.01.021

Wang, Z., Dong, F., Sun, Y., Wang, J., Zhang, M., Xue, T., Ren, Y., Lv, X., Yuan, K., & Yu, D. (2022). Increased resting-state alpha coherence and impaired inhibition control in young smokers. *Frontiers in Neuroscience*, *16*, 1026835.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1521/soco_2012_1006

Watson, D., Clark, L. A. L. A. L. A., Tellegen, A., Tellegan, A., Tellegen, A., & Tellegan, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Wechsler, D. (2003). *Wechsler intelligence scale for children-Fourth Edition (WISC-IV)*. The Psychological Corporation.

Wechsler, D. (2008). *Wechsler adult intelligence scale-Fourth Edition (WAIS-IV)*. APA PsycTests.

Weinberg, A., & Klonsky, E. D. D. (2009). Measurement of emotion dysregulation in adolescents. *Psychological Assessment*, *21*(4), 616–621. https://doi.org/10.1037/a0016669

Wessing, I., Rehbein, M. A., Romer, G., Achtergarde, S., Dobel, C., Zwitserlood, P., Fürniss, T., & Junghöfer, M. (2015). Cognitive emotion regulation in children: Reappraisal of emotional faces modulates neural source activity in a frontoparietal network. *Developmental Cognitive Neuroscience*, *13*, 1–10.

Yu, X., Liu, L., Chen, W., Cao, Q., Zepf, F. D., Ji, G., Wu, Z., An, L., Wang, P., Qian, Q., Zang, Y., Sun, L., & Wang, Y. (2020). Integrity of amygdala subregion-based functional networks and emotional lability in drug-naïve boys with ADHD. *Journal of Attention Disorders*, *24*(12). https://doi.org/10.1177/1087054716661419

Zhang, D. W., Li, H., Wu, Z., Zhao, Q., Song, Y., Liu, L., Qian, Q., Wang, Y., Roodenrys, S., Johnstone, S. J., De Blasio, F. M., & Sun, L. (2019). Electroencephalogram theta/beta ratio and spectral power correlates of executive functions in children and adolescents with AD/HD. *Journal of Attention Disorders*, *23*(7), 721–732. https://doi.org/10.1177/1087054717718263

Zhang, W., Li, X., Liu, X., Duan, X., Wang, D., & Shen, J. (2013). Distraction reduces theta synchronization in emotion regulation during adolescence. *Neuroscience Letters*, *550*, 81–86. https://doi.org/10.1016/j.neulet.2013.05.070