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Robin Gustafsson

Aalto University

School of Electrical Engineering

Bioinformation Technology

ROBIN GUSTAFSSON

Review of studies on neural mechanisms of emotional attention in ADHD

Bachelor's Thesis

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Instructor: M.Sc. (Tech.) Sofia Tauriainen

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PL 13000	
00076 AALTO	

Tekijä: Robin Gustafsson	
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Vastuuopettaja: D.Sc. (Tech.) Markus Turunen	
Ohjaaja: M.Sc. (Tech.) Sofia Tauriainen	
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Tiivistelmä – Abstract in Finnish:

Tarkkaavuus- ja ylivilkkaushäiriöön (ADHD) liittyvä tunnepitoisen tarkkaavaisuuden poikkeavuus vaikuttaa suoraan oppimiseen, käyttäytymisen säätelyyn ja arjen toimintakykyyn, minkä vuoksi sen aivomekanismien ymmärtäminen on kliinisesti ja yhteiskunnallisesti merkittävää. Tässä kandidaatintyössä tarkastellaan aivojen tunnepitoisen tarkkaavaisuuden mekanismeja ADHD:ssa. Työn tavoitteena on koota ja analysoida aivokuvantamistutkimuksia, joissa on tutkittu, miten emotionaalinen informaatio vaikuttaa tarkkaavaisuuden suuntaamiseen ja säätelyyn ADHD:ssa. Tulevaisuudessa koottua tietoa voidaan hyödyntää kliinisten hoitojen ja koulutusohjelmien räätälöimiseen henkilöille, joilla on ADHD.

Kirjallisuustutkimus perustui yhteentoista neurokuvantamistutkimukseen, joissa on käytetty toiminnallista magneettikuvausta (tMK) ja elektroenkefalografiaa (EEG). Tutkimukset, jotka käsittelivät vain tunteiden tunnistamista, tunnesäätelyä tai ei-emotionaalisia kognitiivisia tehtäviä, rajattiin pois. Tutkimusten perusteella havaittiin, että ihmisillä, joilla on ADHD esiintyy poikkeavaa aivotoimintaa esimerkiksi etuotsalohkon, pihtipoimun, mantelitumakkeen ja ohimolohkon alueilla. Stroop-tehtävissä ilmeni, että emotionaaliset ärsykkeet hidastavat reaktioita ja aiheuttavat poikkeavaa mediaalisen otsalohkon aktivaatiota. Affective Stroop- ja kuvapohjaisissa tehtävissä havaittiin heikentynyttä etuotsalohkon verkostojen yhteistoimintaa, mutta samalla voimistunutta visuaalisten ja limbisten alueiden reaktiivisuutta. Tehtävissä havaittiin kompensatorinen mekanismi: ADHD-ryhmät ylläpitivät tai yrittivät ylläpitää normaalia suoritustasoa, mutta tämä vaati korostunutta kontrollialueiden aktivaatiota. Lisäksi tulokset viittaavat kehitykselliseen muutokseen, jossa lapsilla korostuu aivojen yliaktivaatio ja aikuisilla vastaavasti aliaktivaatio haastavissa tilanteissa.

Tulokset osoittavat, että ADHD:ssa emotionaalinen informaatio saa tavanomaista suuremman painoarvon tarkkaavaisuuden säätelyssä. Tämä ilmenee sekä limbisen järjestelmän yliherkkyytenä että etuotsalohkon ohjausverkkojen heikompana koordinaationa. Havainto tukee käsitystä ADHD:sta laaja-alaisena itsesäätelyn häiriönä, jossa tunnepitoisen tarkkaavaisuuden mekanismit poikkeavat neurotyypillisestä mallista. Tulosten perusteella suositellaan tutkimuksia, joissa tarkastellaan ADHD:n alatyyppejä erikseen yhteneväisempien tulosten saavuttamiseksi. Myös luonnollisempia tehtävätyyppejä tulisi käyttää, jotta tulokset vastaisivat mahdollisimman hyvin arkielämää.

Avainsanat: ADHD, aivomekanismit, aivokuvantaminen, tunteellinen tarkkaavaisuus

AALTO UNIVERSITY	BACHELOR'S THESIS
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Author: Robin Gustafsson	
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Supervisor: D.Sc. (Tech.) Markus Turunen	
Instructor: M.Sc. (Tech.) Sofia Tauriainen	
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Abstract:

Abnormalities in emotional attention associated with Attention-Deficit/Hyperactivity Disorder (ADHD) directly affect learning, behavioral regulation, and daily functioning, making the understanding of their underlying brain mechanisms clinically and socially significant. This Bachelor's thesis examines the neural mechanisms of emotional attention in ADHD. The aim of the study is to compile and analyze neuroimaging studies that investigate how emotional information influences attention in ADHD. In the future, the gathered information can be utilized to tailor clinical treatments and educational programs for individuals with ADHD.

The literature review was based on eleven neuroimaging studies utilizing fMRI and EEG methods. Studies focusing solely on emotion recognition, emotion regulation, or non-emotional cognitive tasks were excluded. The findings indicate that individuals with ADHD exhibit abnormal brain activity, for example in the prefrontal cortex, cingulate cortex, amygdala, and temporal lobe. Stroop tasks revealed that emotional stimuli slow down reactions and cause aberrant activation in the medial prefrontal cortex. Affective Stroop and image-based tasks showed weakened connectivity in prefrontal networks, accompanied by heightened reactivity in visual and limbic regions. A compensatory mechanism was observed: ADHD groups could or would try to maintain normal behavioral performance, but this required enhanced activation of the control regions. Additionally, the results suggest a developmental shift, characterized by neural hyper-responsivity in children and hypo-function in adults during demanding tasks.

The results suggest that in ADHD, emotional information is given greater weight in attentional regulation than is typical. This manifests as both hypersensitivity of the limbic system and weaker coordination of prefrontal control networks. This observation supports the view of ADHD as a broad disorder of self-regulation, where mechanisms of emotional attention deviate from the neurotypical model. Based on the results, future research should examine ADHD subtypes separately to obtain more consistent results. Furthermore, more naturalistic task types should be employed to ensure results correspond as closely as possible to daily life. Avainsanat:

ADHD, neural mechanism, neuroimaging, emotional attention

Table of Contents

Abbreviations

ACC	Anterior Cingulate Cortex
ADHD	Attention-Deficit/Hyperactivity Disorder
AST	Affective Stroop Task
BOLD	Blood-Oxygen-Level Dependent
DAN	Dorsal Attention Network
DLPFC	Dorsolateral Prefrontal Cortex
dMFC	Dorsomedial Frontal Cortex
DMN	Default Mode Network
DSM-5	The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
ECPT	Emotional Continuous Performance Test
EEG	Electroencephalography
EFNBACK	Emotional Face N-Back Task
ERP	Event-Related Potential
EST	Emotional Stroop Task
fMRI	Functional Magnetic Resonance Imaging
ICD-11	International Classification of Diseases, 11th Revision
mPFC	Medial Prefrontal Cortex
OFC	Orbitofrontal Cortex
VACP	Visual Continuous Performance Test
VAN	Ventral Attention Network
VLPFC	Ventrolateral Prefrontal Cortex

1 Introduction

Attention-deficit/hyperactivity disorder (ADHD) is characterized by developmentally inappropriate symptoms of inattention, impulsivity, and motor restlessness (hyperactivity). Among the most commonly diagnosed neurodevelopmental disorders in childhood, ADHD affects more than 5 % of children globally and frequently persists into adolescence and adulthood (Drechsler *et al.*, 2020). Given the established increased morbidity associated with ADHD, including impaired academic, occupational, and social functioning, determining the underlying neural substrate of the disorder is of great importance.

Despite extensive research, the neurobiological underpinnings of ADHD have not been fully elucidated. According to Konrad and Eickhoff (2010), ADHD is recognized as a highly heterogeneous disorder. They emphasized a shift from focusing on regional brain abnormalities to characterizing dysfunction in distributed network organization. This perspective aligns with a systems approach to understanding pathophysiology, where function emerges from the interaction of regionally specialized elements.

Clinical definitions require dysfunction and significant problems in daily life, but emerging evidence suggests ADHD may involve atypical patterns of network dynamics rather than simple deficits (Konrad and Eickhoff, 2010). This opens the door to understanding how both impairments and context-dependent differences in emotional attention could emerge from the same systems. According to Vuilleumier (2005), emotional attention is referred to as the mechanism that selects and prioritizes emotionally significant stimuli within the brain. This thesis is motivated by the practical aim of clarifying the neural mechanisms of emotional attention in ADHD so that educational and clinical approaches can be better tailored to the needs of individuals with ADHD.

This thesis reviews recent literature on emotional attention in ADHD as studied with brain imaging, with particular interest in what these findings imply for tailoring educational and clinical supports. The second Chapter offers a theoretical background with sections for defining attention and ADHD, and to review the relevant neuroimaging methods used to research brain mechanisms. After this theoretical background, the thesis continues in Chapter 3 by synthesizing recent imaging research on emotional attention in ADHD, highlighting functional differences in brain regions related to emotional prioritization.

The objective is to provide a comprehensive overview of emotional attention mechanisms in ADHD, highlight gaps in current evidence, and suggest future research directions, particularly to assess if emotional stimulus should be used in education or therapy.

2 Theoretical background

This theoretical background aims to establish a conceptual and neural definition of attention, providing a foundation for interpreting the imaging studies discussed in Chapter 3. This chapter will also examine attention and emotional attention as subsection of general attention, ensuring conceptual clarity in the subsequent analysis. Finally, this chapter will define ADHD and present an overview of the neuroimaging methodologies employed in the studies that will later be reviewed.

2.1 Defining attention in the brain

While complete consensus on the precise neural mechanisms and boundaries that constitute attention remains elusive, there is a strong and widely accepted foundational framework for understanding it. Attention can be defined simply as the mechanism the brain uses to selectively prioritize or enhance the information most relevant to one's current behaviour or goals (Buschman and Kastner, 2015). This prioritization is necessary because the brain is a system with limited capacity for processing information (Buschman and Kastner, 2015).

Buschman and Kastner (2015) describe attention acting by increasing the strength of selected neural representations and preferentially routing them through the brain. This is viewed as resolving competition for limited processing resources in favour of information that is currently task relevant. This idea is formalized in the "biased competition" theory, which proposes that competing stimuli vie for representation, and attention biases this process (Vuilleumier, 2005; Daitch *et al.*, 2013; Katsuki and Constantinidis, 2014; Buschman and Kastner, 2015; Moore and Zirnsak, 2017). There can thus be many simultaneously presented stimuli, that compete for neuronal representation.

Katsuki and Constantinidis (2014) write that attention has been broadly categorized into two based on the origin of the signal that's causing it. They explain how endogenous (top-down) attention is goal-driven and originates from internal cognitive control processes, such as consciously deciding to focus on a particular object or location. In contrast, exogenous (bottom-up) attention is stimulus-driven and is captured automatically by salient external events, such as a sudden flash of light or hearing your own name in another conversation. According to Katsuki and Constantinidis (2014), these two systems interact continuously to determine the focus of perception and action. Their review reveals how neurophysiologically, top-down attention is associated with activity in the fronto-parietal control networks that send biasing signals to sensory cortices, while bottom-up attention relies more heavily on temporo-parietal and subcortical regions that detect and respond to salient stimuli in the environment. Together, these mechanisms enable flexible, adaptive behaviour by dynamically allocating limited neural resources toward the most relevant aspects of the sensory world.

Reviews by both Katsuki and Constantinidis (2014) and Saghravanian (2025) show that in the recent decades our understanding of attention has improved, and it is guided by a combination of both top-down factors (relevance) and bottom-up factors (saliency). They refer to this unified signal as stimulus priority or an attentional priority map. According to them the concept of the priority map arose because neural correlates of both bottom-up and top-down attention show the coactivation of the same network of parietal and prefrontal cortical areas. They explain how the mechanism that prioritizes information (attention) must interface with goal representations and is modulated by task demands, meaning purely bottom-up effects are often difficult to measure in isolation.

Keitel, Thut and Gross (2020) state how early models likened attention to a single, unique 'spotlight' that highlights a selected item, which was thought to shift continuously from location to location at a rate of approximately 20 Hz. However, their work reframes attention as a highly dynamic and flexible resource. This dynamicity includes intrinsic rhythmicity, leading to the conceptualization of attention as a "blinking spotlight" that periodically samples the attended location rather than maintaining a continuous beam.

In summary, attention is a flexible and interactive process that helps the brain decide what to focus on at any given moment. It is not a single mechanism but the combined activity of several interconnected systems that balance internal goals with external sensory input. This balance allows limited processing resources to be directed toward the most relevant or meaningful information. Understanding attention in this broad sense provides a foundation for interpreting how it appears in brain imaging studies.

2.2 Defining emotional attention

In addition to more traditional forms of attention, such as spatial attention (focusing on a location) and object-based attention (grouping features of an object), which have been a focus for research for many decades, Vuilleumier (2005) stated that attention is also influenced by emotional and motivational factors. They refer to emotional attention as the prioritization of emotionally significant stimuli, such as those linked to threat or reward. According to them this process is supported by the amygdala, which acts as a relevance detector and sends feedback to sensory areas like the visual cortex, enhancing the representation of emotional events. Emotional attention operates in parallel with the voluntary, top-down control of the fronto-parietal network and can act additively to boost sensory processing. To conclude, modulation of emotional attention is both automatic and flexible (Vuilleumier, 2005; Xue and Pourtois, 2025).

2.3 Defining ADHD

The diagnosis of ADHD has been defined by the International Classification of Diseases, 11th Revision (ICD-11). It is the global diagnostic standard developed and maintained by the World Health Organization. It provides a common framework for classifying diseases and health conditions across countries and healthcare systems, ensuring consistency in diagnosis, research, and health statistics (*ICD-11*, no date). In some regions, the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) is used instead of the ICD-11.

ADHD is diagnosed through a clinical evaluation. According to ICD-11, the disorder is characterised by a persistent pattern (at least six months) of inattention and/or hyperactivity-impulsivity that has a direct negative impact on academic, occupational or social functioning. Manifestations must be evident across multiple settings (for example, home and school or work) and not better accounted for by another mental, behavioural or neurodevelopmental condition. Three presentations are recognised: predominantly inattentive, predominantly hyperactive-impulsive, and combined, which differ in symptom profile, comorbidity and treatment response. Treatment generally involves behavioural interventions and pharmacotherapy, most commonly stimulants such as methylphenidate or amphetamines, with non-stimulants such as atomoxetine and guanfacine as alternatives (*ICD-11 for Mortality and Morbidity Statistics*, no date).

In recent years interest has grown towards finding objective biomarkers for clinically reliable diagnosis. Brain imaging has been central in clarifying the neural mechanisms of ADHD. Studies reveal ADHD as a more complex condition compared to the clinical definition (Chen *et al.*, 2025). They point to alterations in networks involved in attention, executive control, and reward processing, including prefrontal regions, striatal circuits, and the DMN. Results, however, are often inconsistent due to the heterogeneity of ADHD symptoms and subtypes (Albajara Sáenz, Villemonteix and Massat, 2019; Chen *et al.*, 2025).

Despite the words "attention-deficit" implying dysfunction in attention as the core problem, some researchers argue that ADHD may be better understood as a disorder of executive function rather than attention (Barkley, 2012). Attention, as defined earlier in this theoretical section, is often regarded as a fundamental component of the cognitive system known as cognitive control or executive control. Cognitive control refers to the brain's ability to guide thoughts and actions in alignment with internal goals. It encompasses higher-order processes such as decision-making, goal-setting, and behavioural regulation. Within this system, attention functions as the selective mechanism that determines which sensory or internal information is most relevant at a given moment. In this sense, attention can be seen as the brain's filtering or spotlighting mechanism, while cognitive control serves as the overarching management system that decides how to use that information to achieve goals (Buschman and Kastner, 2015). Despite the name attention-deficit/hyperactivity disorder, most neural findings emphasize executive networks. This raises the question: what do imaging studies reveal about attention itself in ADHD?

In summary there is a tension between research and the ICD-11 definition. While the ICD-11 describes ADHD mainly through words like inattention and hyperactivity, more recent research describes it as a broader disorder of executive function, affecting self-regulation, planning, and goal-directed behaviour (Drechsler *et al.*, 2020). Both "inattention" and "hyperactivity," as used in the ICD-11 and DSM-5 frameworks, are behavioural descriptions rather than precise cognitive or neural constructs (*DSM*, no date; *ICD-11*, no date), and they can thus be misleading in neuroscience research, where "attention" is a quite clearly defined as seen in section 2.1 of this thesis. This has led some to argue that the older wording "attention-deficit" is misleading, and that terms such as executive function disorder reflect the underlying cognitive nature of the condition more accurately (Barkley, no date). This thesis will continue investigating current knowledge on the neural mechanisms of emotional attention in ADHD. The studies researching emotional attention (as a prioritization mechanism) in ADHD are very limited compared to studies that use the word "attention" to describe a broader set of neural and cognitive mechanisms including for example executive function.

2.4 Introducing the relevant neuroimaging methods

To understand the empirical studies reviewed in Chapter 3, it is necessary to understand the methodologies used to acquire neural data. Each of the studies included in this review utilize Functional Magnetic Resonance Imaging (fMRI) or Electroencephalography (EEG). These two techniques offer complementary views of brain function: while fMRI is generally characterized by high spatial resolution, EEG offers superior temporal precision. The following sections outline the basic principles of these methods.

2.4.1 Functional Magnetic Resonance Imaging (fMRI)

fMRI is an advanced neuroimaging technique used to map brain activity by detecting related changes in blood flow. The fundamental concept relies on measuring the Blood-Oxygen-Level Dependent (BOLD) signal (Mulert and Lemieux, 2010).

Hainc, Reinhardt and Stippich, (2020) write how the BOLD signal principle is based on the different magnetic properties of hemoglobin molecules when they are bound to oxygen versus when they are not. Specifically, they explain how oxygenated hemoglobin is diamagnetic, while deoxygenated hemoglobin is paramagnetic, causing localized distortions in the magnetic field. According to them, when a brain region is highly active, local cerebral blood flow (CBF) increases dramatically to deliver oxygen and glucose; however, this increase typically exceeds the tissue's actual oxygen consumption. This disproportionate increase leads to a temporary decrease in the concentration of deoxygenated blood, which is what the fMRI scanner detects as a BOLD signal. This signal is then interpreted as heightened neural activity.

The key strength of fMRI is its excellent spatial resolution, which allows researchers to precisely pinpoint the location of brain activity, typically on the scale of millimeters (Mulert and Lemieux, 2010). This precision is vital for accurately identifying the involvement of small, deep brain structures, such as the amygdala, or cortical regions like the prefrontal cortex, which are involved in emotional regulation.

However, fMRI's primary drawback is its poor temporal resolution. The BOLD signal is an indirect measure of electrical neural activity, reflecting a slow hemodynamic response that lags behind the actual firing of neurons by several seconds (Hainc, Reinhardt and Stippich, 2020). Therefore, while fMRI is excellent for determining where activity occurs, it is less precise for determining exactly when a cognitive event takes place.

2.4.2 Electroencephalography (EEG) and Event-Related Potentials (ERPs)

EEG measures electrical activity in the brain directly from the scalp using electrodes. This technique captures the synchronous firing of large populations of cortical neurons (post-synaptic potentials). This electrical activity is thought to be a result of the ionic flows in cortical neurons (Brilla, 2019).

In modern research settings, EEG data is typically collected using an electrode cap. These setups normally use between 32 and 256 channels (electrodes) for spatial sampling of the electrical fields across the scalp (Brilla, 2019; Mulert and Lemieux, 2010). Due to the limited resolution of these electrodes, and the smearing of electrical potentials as they pass through the skull and scalp, the spatial accuracy of EEG is generally limited to the centimetre scale or less (Mulert and Lemieux, 2010). EEG compensates for the low spatial resolution with high temporal resolution in the millisecond range (Rojas *et al.*, 2018).

EEG analysis can be broadly divided into frequency analysis and ERPs. Frequency analysis examines the continuous EEG signal to determine the power of specific frequency bands, such as theta (4–8 Hz), alpha (8–13 Hz), and beta (13–30 Hz) (Brilla, 2019). The following studies in chapter 3 of this thesis are researching time- and event-dependent neural activity instead of resting state activity, making ERPs the more relevant analysis method in this context. ERP analysis isolates the neural response to a specific sensory or cognitive event. By averaging the EEG signal across many trials time-locked to a stimulus (e.g., an emotional face), background noise is cancelled out, revealing voltage deflections (referred to as N2 or P3 etc.) (Mulert and Lemieux, 2010). This is valuable in the following emotional attention studies to determine the exact time course of processing a distraction. Specifically, the N2 component is linked to processes like conflict monitoring or conflict detection while the P3 component has been linked to inhibition in the context of the studies in the review (López-Martín *et al.*, 2015).

Since EEG electrodes measure on the scalp. To know where the signals are form requires solving the "inverse problem," a mathematically ill-posed challenge where a specific distribution of surface potentials could theoretically arise from an infinite number of intracranial source configurations (Mulert and Lemieux, 2010). This estimation of the intracranial neuronal sources responsible for the electrical potentials is called source localization.

In summary, researchers utilize both fMRI and EEG/ERPs as complementary methods. fMRI provides the spatial information, answering the question of "where" the hyperactivity or structural alteration lies. EEG/ERPs provide more of the temporal information, answering the question of "when" the cognitive priority decision or inhibitory failure occurs. Mulert and Lemieux (2010) review using these methods together, though that is out of the scope of this thesis, as all the neuroimaging studies in chapter 3 use either fMRI or EEG separately.

3 Studies on Emotional Attention in ADHD

This review focused specifically on neuroimaging studies that examine emotional attention in ADHD, defined as how the brain prioritizes emotional information during task performance. Relevant papers were located through targeted searches in PubMed, Google Scholar, and ScienceDirect using combinations of terms such as ADHD, attention, emotional attention, Stroop, go/no-go, fMRI, and EEG.

To keep the scope precise, only studies from the past 15 years that (1) included participants with a clinical ADHD diagnosis, (2) used fMRI or EEG/ERP, and (3) used tasks where emotional material directly interfered with or biased attention (e.g., emotional stroop, emotional go/no-go) were included. Studies focusing only on emotion recognition, emotion regulation, or non-emotional cognitive tasks were excluded, as were behavioural-only studies without neural data. Following these criteria, the search yielded a limited set of 11 studies examining how emotional distractors, emotional conflict, or affective task components influence neural processing in ADHD. The studies are grouped into three different groups below, based on the task they measured.

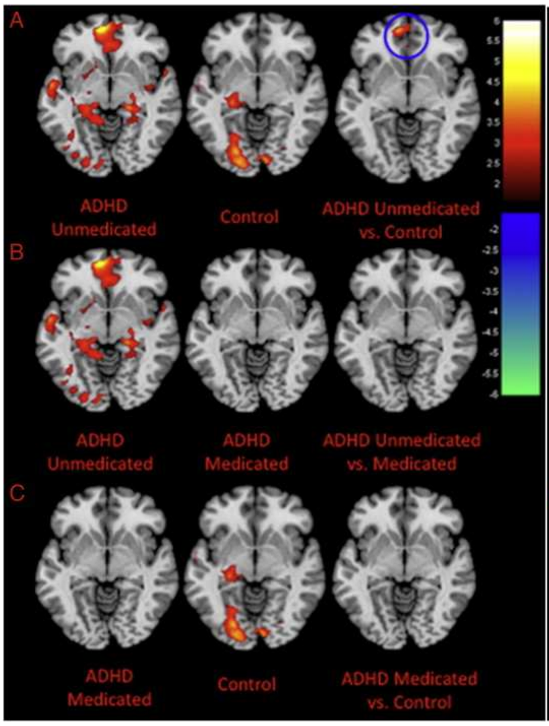
3.1 Stroop tasks

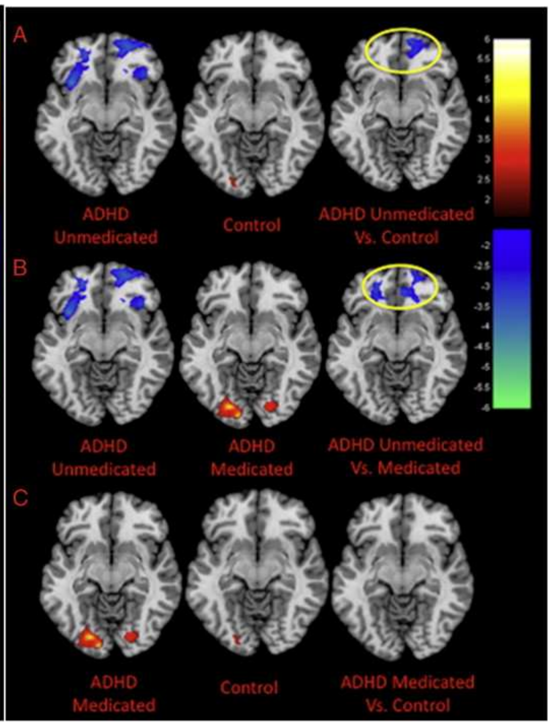
Four studies in this review used Stroop-type paradigms to examine how emotional information interferes with goal-directed attention in ADHD. All these tasks test how well participants can maintain focus on a neutral target when emotional material competes for attention.

3.1.1 Posner et al. (2011)

In this study, 15 adolescents with ADHD performed both an Emotional Stroop Task (EST) and a cognitive control version of the same task while being scanned with fMRI. Each word (neutral, positive, or negative) was shown several times, and participants indicated how many times the word appeared. All groups—unmedicated ADHD, medicated ADHD, and controls—showed slower reaction times when emotional or conflicting information was present. However, only the unmedicated ADHD group made more errors when negative or cognitively distracting words were shown.

In brain activity, unmedicated ADHD participants showed stronger activation in the left medial prefrontal cortex (mPFC) for positive words and stronger deactivation in the right mPFC for negative words compared with controls, as seen in figures 1 and 2. This valence-dependent "flip" in activation (up for positive, down for negative) was interpreted as increased neural reactivity in emotion-related control regions. When participants were scanned on stimulant medication, these abnormal mPFC responses normalized to control levels.





Figures 1 and 2 (left and right): Unmedicated ADHD patients showed altered medial prefrontal cortex activation for emotional words compared to controls (Posner *et al.*, 2011). Red and white colours mean increased activation. Blue and green on the contrary mean reduced activation.

3.1.2 Hwang et al. (2015)

Hwang and colleagues used an Affective Stroop Task (AST) where positive, negative, or neutral images briefly appeared before a simple number-comparison task for a group of 26 children adolescents with ADHD. This design tested how emotional distraction interacted with cognitive control demands (congruent vs incongruent trials). Children and adolescents with ADHD had slower average reaction times (964.78 ms) compared to healthy controls (816.12 ms) (P=0.006), but accuracy differences were small.

FMRI results showed that the ADHD group recruited the right dorsomedial frontal cortex (dMFC) less strongly during high-conflict trials, a pattern of hypo-recruitment of executive attention regions. Connectivity analyses revealed reduced coupling between this dMFC seed and the right lateral prefrontal cortex, suggesting weaker coordination within frontal control circuits. Despite this under-recruitment, emotional effects persisted: ADHD participants showed stronger responses to positive images in temporal visual regions (middle temporal and fusiform gyri) and weaker amygdala–striatal connectivity for positive versus neutral trials.

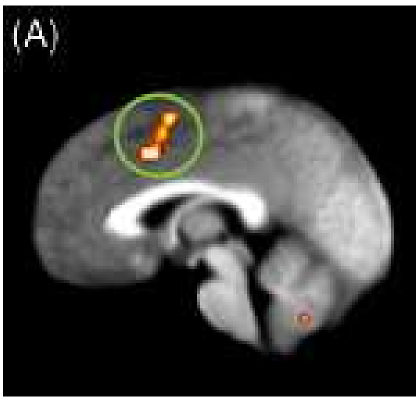


Figure 3: Frontal activation during the Affective Stroop Task (Hwang et al., 2015).

3.1.3 Vetter et al. (2018)

Vetter and colleagues examined 25 boys with ADHD and 25 typically developing peers during a perceptual discrimination task that included emotional distractors (negative, positive, or neutral images). Reaction times did not differ overall between groups, but all participants were slower when attending to negative versus neutral or positive pictures. The ADHD group, however, completed fewer valid trials (15.72 for ADHD group vs 17.8 for control group), reflecting more errors regardless of emotional valence.

Based on the fMRI data, boys with ADHD showed greater activation for negative stimuli in key salience-processing regions: the bilateral anterior insula, bordering the inferior frontal gyrus, as well as the right medial superior frontal gyrus and supplementary motor area. Region-of-interest analyses also found left amygdala hyperactivation to negative stimuli, and this amygdala response correlated with poorer task accuracy.

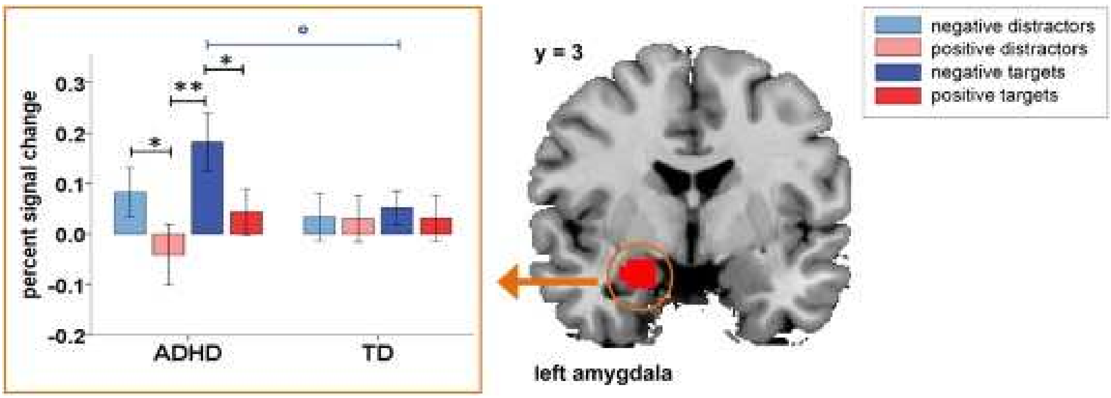


Figure 4: Adolescents with ADHD showed heightened activation in the amygdala when processing negative emotional distractors compared with controls (Vetter et al., 2018).

3.1.4 Leon et al. (2025)

Leon and colleagues investigated emotional interference using EEG. The study employed a variation of the Stroop test called the Emotional Stroop Word-Face variant. In this task, participants must categorize a facial expression (e.g., neutral, angry) while simultaneously trying to ignore a distracting emotional word (e.g., 'Failure,' 'Success') superimposed on the face. This measures how effectively the brain can filter out irrelevant emotional content (the word) to focus on the goal (categorizing the face).

Behaviourally, the ADHD group of 43 children demonstrated significantly slower reaction times (RTs), with an overall delay of approximately 40 milliseconds (ms) compared to healthy controls. This in itself doesn't imply a heightened susceptibility to emotional distraction, as the authors didn't report the reactions times of emotionally distracting tests compared to neutral tests. Instead the focus of the study is on the neural differences.

The EEG source localization results showed that during the critical time window before a response, the ADHD group exhibited increased activity in frontal and temporal brain regions when compared to healthy controls. This abnormal brain response suggests that emotional information consumes more processing capacity in ADHD. Furthermore, the analysis identified a specific pattern of brain activity, an EEG microstate called Map 3 (a specific configuration of electrical brain activity), as a trait marker for the disorder. A trait marker (or endophenotype) is an internal, measurable characteristic that is strongly associated with the disorder but is simpler than the full range of symptoms. Identifying this stable trait marker may provide an objective tool for diagnosis that is less susceptible to individual variability in behaviour.

3.2 Go-No-Go tasks

The following four studies used emotionally modified Go/No-Go paradigms to examine how emotional contexts interact with inhibitory control in ADHD. Both tasks require participants to either execute or suppress motor responses depending on presented cues, allowing researchers to probe the neural mechanisms of response inhibition under emotional influence.

3.2.1 Schulz et al. (2014)

Schulz et al. (2014) examined how emotional facial expressions modulate cognitive control in adults with a childhood diagnosis of ADHD. 14 participants with ADHD performed a face-emotion Go/No-Go task while undergoing fMRI scanning. Gray-scaled images of happy, sad, and neutral faces were used as cues, alternating across runs to test how emotional valence influenced both response execution and inhibition.

Adults with childhood ADHD (probands) made fewer correct responses and correct inhibitions compared to controls, indicating reduced overall task performance. Both groups, however, showed similar emotional patterns: happy faces were hardest to inhibit (producing the fewest correct No-Go trials), while sad faces produced the most interference in response execution. No significant group x emotion interactions emerged, meaning that emotion influenced behavioural performance similarly in both groups.

The fMRI and connectivity results revealed neural differences: the Probands showed reduced functional connectivity between the right Dorsolateral Prefrontal Cortex (DLPFC) and limbic regions (such as the subgenual cingulate cortex) compared to controls. This indicates impaired integration between the executive control center (DLPFC) and the emotional processing system. Furthermore, while controls showed adaptive, valence-dependent activation in limbic areas, the ADHD Probands lacked this modulation in the amygdala.

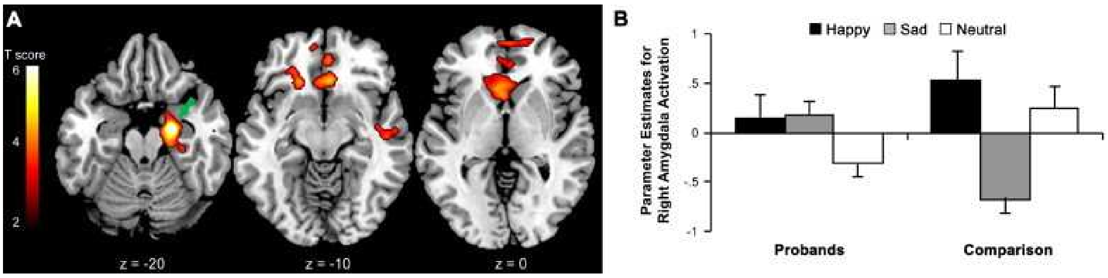


Figure 5: In a face-emotion Go/No-Go task, adults with a childhood ADHD diagnosis showed no modulation of right amygdala activity by emotional valence, whereas controls displayed reduced amygdala activation to sad compared with happy or neutral faces (Schulz et al., 2014).

3.2.2 López-Martín et al. (2015)

López-Martín and colleagues utilized event-related potentials with source localization to study emotional response inhibition in 24 children with ADHD. They employed a modified Go/No-Go which was performed under three emotional contexts, negative, neutral, and positive, created by pictorial backgrounds behind the actual cues. Behaviourally, the ADHD group successfully maintained a performance level comparable to controls (similar reaction times and error rates) across all emotional conditions.

Despite similar behavioural performance, the ERP data revealed key differences in the neural effort required to achieve this inhibition. As seen in figure 6, the ADHD group displayed a significantly enhanced amplitude of the No-Go P3 component (a known ERP marker for inhibition and resource allocation) compared to controls, especially when stimuli were emotionally arousing (both positive and negative). Source localization further attributed this heightened activity to the anterior cingulate cortex

(ACC) and the orbitofrontal cortex (OFC). This indicates that, in emotional contexts, the ADHD brain relies on over-recruiting frontal inhibitory mechanisms to compensate for potential distraction and maintain performance.

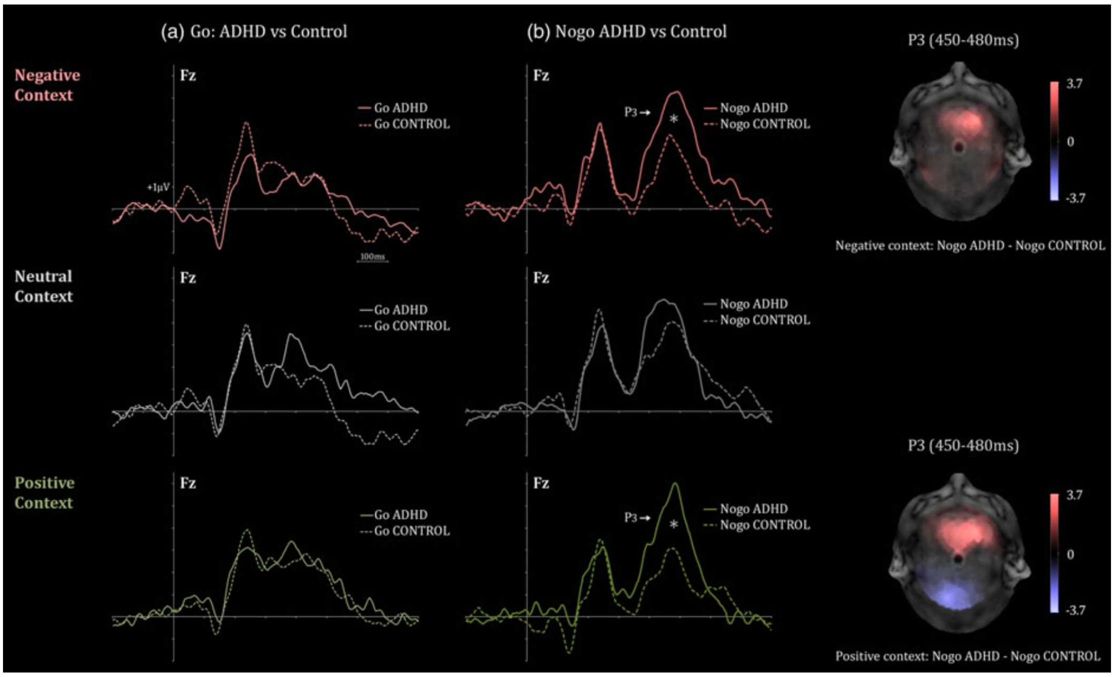


Figure 6: Children with ADHD showed larger P3 amplitudes than controls when inhibiting responses in positive and negative emotional contexts, but not in neutral ones. This suggests that emotional cues, regardless of valence, evoke stronger neural engagement during inhibition (López-Martín et al., 2015).

3.2.3 Karalunas, Weigard and Alperin (2020)

Karalunas and colleagues used ERPs to investigate how emotional stimuli affect inhibitory and attentional control in 61 adolescents with ADHD. They employed an Emotional Go/No-Go task, with task cues being neutral, positive, or negative faces. Behaviourally, the ADHD group was significantly slower overall and showed that emotional contexts further impaired performance. The most notable finding was that positive/happy cues specifically exacerbated impulsivity (leading to more commission errors and slower reactions) in the ADHD group compared to controls.

The ERP analysis revealed a two-part neural mechanism underlying this dysfunction. First, the ADHD brain showed increased early and automatic attention capture by positive stimuli. This was demonstrated by a larger amplitude of the P1 component, an early brainwave related to initial visual processing. Secondly, a modelling technique known as Drift Rate analysis indicated that the ADHD group initiated the decision-making process faster for these positive cues. Finally, they observed reduced amplitude of the N2 component during inhibitory trials.

3.2.4 Réthelyi et al. (2025)

Réthelyi and colleagues used fMRI to investigate brain function in 34 adults with ADHD while they performed an Emotional Go/No-Go task. The study aimed to compare the BOLD activation patterns between the ADHD group and healthy controls during this demanding task. This information is limited as the public abstract of the study only reports the general methods and findings.

The fMRI results revealed differential BOLD activation across large-scale functional networks in the ADHD group compared to controls. The ADHD subjects showed increased BOLD activation within both the Dorsal Attention Network (DAN) (involved in goal-directed attention) and the Ventral Attention Network (VAN) (involved in detecting salient external events). This suggests that the ADHD brain has to over-recruit these external-attention systems to perform the task. Conversely, the ADHD group showed higher deactivation of the Default Mode Network (DMN) (the network typically active during rest and internal focus) across all conditions.

3.3 Other emotional distraction tasks

The three following studies used other kind of emotional distraction tasks that don't fit under the Stroop task or Go-no-go paradigms. The studies are included, since they measure how emotional context distracts the attention of the participants in other ways.

3.3.1 López-Martín et al. (2013)

López-Martín and colleagues used ERPs to study how 20 boys with ADHD reacted to emotional distractions. The children were asked to do a simple task: categorize a digit shown on a screen. The challenge was that while they focused on the digit, an irrelevant emotional picture (either arousing negative, arousing positive, or neutral) was flashed in the background. The average reaction times of the ADHD group were faster than the RTs of the control group (means and standard errors: 689.72 ± 37.37 and 798.2 ± 37.37) Behaviourally, these emotional distractors successfully interfered with the ADHD groups performance: their reaction times were around 30 ms longer when emotional distraction was present, while the control group's performance remained unaffected.

The ERP analysis revealed the brain's reaction to this distraction. The ADHD group showed a larger anterior N2 brainwave when facing emotional distractors compared to neutral ones. The critical finding was that the amplitude of this N2 wave grew bigger the more emotionally arousing the picture was, but only in the ADHD group.

3.3.2 Ojha et al. (2024)

Ojha and colleagues investigated brain activity in adults with ADHD using fMRI. They divided participants into three groups: those with ADHD that persisted into adulthood (n=47), those whose symptoms desisted or faded in adulthood (n=93), and healthy controls (n=42). All groups performed an Emotional Face N-Back task, which is a demanding working memory test that forces participants to concentrate on remembering faces while ignoring irrelevant emotional expressions. Behaviourally, participants who had no lifetime ADHD history performed significantly better (faster and more accurately) than those with persisting or desisting ADHD, particularly on trials that combined the hardest memory step with emotional distraction.

The fMRI results focused on how the brain resists emotional interference. The key finding was a reduced level of brain activity in the prefrontal cortex, specifically in the Dorsolateral and Ventrolateral Prefrontal Cortex (DLPFC/VLPFC), in the group with persisting ADHD. This reduced activation occurred during the hardest task trials where the brain needed to actively block out emotional distractions. Crucially, this diminished DLPFC/VLPFC activity was directly associated with higher scores in affect lability (emotional instability) in the persisting ADHD group.

3.3.3 Vosough et al. (2025)

Vosough and colleagues conducted a large-scale study (involving 117 ADHD subjects and 183 controls) across a wide age range (children, adolescents, and adults) to investigate emotional processing and executive function. They measured ERPs and tested participants with two tasks: the classic Visual Continuous Performance Test (VCPT) (a standard executive function test) and the Emotional Continuous Performance Test (ECPT). The ECPT is an emotional variation that specifically requires the brain to encode and respond to facial emotional expressions. The results revealed a significant "interaction effect" specifically for reaction speed and attention lapses (omission errors), meaning the performance gap between the ADHD group and healthy controls widened significantly during the emotional task. This indicates that the presence of emotional stimuli imposes a disproportionate cognitive load on individuals with ADHD, causing them to slow down and miss targets more frequently than can be explained by the general attention deficit alone. However, this emotional impact was specific to attentional allocation; it did not exacerbate impulsivity (commission errors) or response inconsistency, as the ADHD group demonstrated significant, but stable, impairments in these areas regardless of the emotional context.

The neural findings in the Vosough et al. (2025) study primarily support a model of generalized neural hypofunction rather than a specific emotional over-prioritization. The ERP analysis revealed that the ADHD group exhibited significantly lower P3d amplitudes (a marker for inhibitory resource allocation) but found no significant group x task interaction for this component. Furthermore, the ADHD group showed reduced amplitudes in another EEG component, the N170, indicating less efficient or intense early neural encoding of facial information.

4 Discussion and limitations

The reviewed neuroimaging studies collectively indicate that emotional attention in ADHD is characterized by a dysfunction in the neural prioritization of stimuli. The general consensus across these studies suggests a dual impairment: a "bottom-up" hypersensitivity to emotional stimuli and a "top-down" deficit in the cognitive control systems required to regulate this response. Seven studies found that individuals with ADHD exhibit heightened neural reactivity in limbic or salience-processing regions when detecting emotional information (Posner *et al.*, 2011; Hwang *et al.*, 2015; López-Martín *et al.*, 2015; Vetter *et al.*, 2018; Karalunas, Weigard and Alperin, 2020; Leon *et al.*, 2025; Réthelyi *et al.*, 2025). Simultaneously, six studies found what appears to be insufficient recruitment or connectivity of prefrontal control networks, such as the dorsolateral prefrontal cortex (DLPFC) and medial prefrontal cortex (mPFC) (Posner *et al.*, 2011; Schulz *et al.*, 2014; Hwang *et al.*, 2015; Karalunas, Weigard and Alperin, 2020; Ojha *et al.*, 2024; Vosough *et al.*, 2025). These findings support the view that the "attention deficit" in ADHD is not merely a lack of attention, but an impairment in managing the competition between goal-relevant tasks and emotionally salient distractions.

While the majority of studies support a model of emotional hyper-responsivity and behavioural interference in ADHD, a few key findings challenge this generalization. Four of the eleven studies found either comparable behavioural performance between ADHD and control groups or neural patterns indicative of hypo-function rather than hyper-arousal. These divergences suggest that the impact of emotional stimuli on attention in ADHD is not uniform and may depend heavily on compensatory effort and specific task demands.

4.1 Neural compensation

One of the most significant deviations from the expected behavioural deficit is the finding of behavioural performance equivalence, or even superiority, in two ADHD groups. López-Martín et al. (2013) demonstrated that in a simple digit categorization task, the average reaction times of the boys with ADHD were, in fact, faster (689.72 ± 37.37 ms) than those of the control group 798.2 ± 37.37 ms). This wasn't found in any of the other 10 studies, but on its own suggests that processing in ADHD is characterized by a speed-accuracy trade-off, where impulsivity manifests as rapid but less accurate responses that can present as faster average reaction times. It should be noted that the ADHD group in this study consisted of 15 boys, making the study quite limited, and meaning the results might reflect the impulsivity of the boys heavily.

Two years later, López-Martín et al. (2015) found that in their emotional Go/No-Go task, children with ADHD successfully maintained behavioural performance, achieving reaction times and error rates statistically indistinguishable from healthy controls. This apparent absence of behavioural impairment, however, masked a neural cost. The study found that the ADHD group exhibited enhanced amplitudes of the No-Go P3 component and increased source activity in the ACC and OFC. Similar over-recruitment of control areas was found in four studies in total (Posner *et al.*, 2011; López-Martín *et al.*, 2015; Leon *et al.*, 2025; Réthelyi *et al.*, 2025). This finding demonstrates that behavioural performance in clinical settings may reflect successful or partly successful neural compensation. The result challenges the assumption that a lack of behavioural error signifies a lack of underlying neural dysfunction. The over-recruitment of control areas also challenges the prospect of insufficient recruitment and connectivity of control areas which was found as a general finding in the beginning of this chapter.

4.2 Hypo-function vs hyperfunction in the limbic system

Schulz et al. (2014) found that while adults with childhood ADHD performed worse overall on a Go/No-Go task, there was no significant group-by-emotion interaction, meaning that emotional stimuli did not disproportionately distract the ADHD group compared to the control group. This contradicts the view that individuals with ADHD are uniquely susceptible to emotional interference. Instead, Schulz et al. (2014)

observed a failure of neural modulation: unlike controls, who downregulated amygdala activity for sad faces, the ADHD group showed a static, non-adaptive amygdala response. This points to a deficit in flexibility rather than a simple excess of reactivity.

Furthermore, findings from Vosough et al. (2025) challenge the consensus of sensory hyper-arousal. While their behavioural results showed that emotional stimuli did slow down reaction times in the ADHD group, their neural data revealed reduced, rather than enhanced, activity. Specifically, they observed diminished amplitudes in the N170 component (associated with early facial encoding) and the P3d component (marker for inhibitory resource allocation) (Vosough et al., 2025). This "neural hypo-function" suggests that in certain contexts, particularly those involving facial affect recognition, the ADHD brain may fail to engage sufficient processing resources early in the perception stream, contrasting with the "early capture" or hyper-arousal mechanism described by Karalunas et al. (2020).

4.3 Limitations

The limitations of this review are best understood as occurring in multiple layers, beginning with the constraints of the primary research and compounding with the methodological decisions made during this review process. The studies included in this analysis were heterogeneous and utilized diverse paradigms, such as the Emotional Stroop, Affective Go/No-Go, and other emotional distraction tasks, which activate distinct neural networks, making direct comparisons difficult. Furthermore, many of the primary studies relied on small sample sizes, which reduces statistical power and increases the risk that reported effects are specific to those samples rather than generalizable to the broader ADHD population. On top of these inherent data limitations, the specific inclusion criteria employed here, such as restricting the search to neuroimaging studies published within the last 15 years and excluding behavioral-only research, inevitably shaped the conclusions. A different set of search terms or database selections could yield a distinct set of papers, potentially leading another reviewer to different conclusions regarding the mechanisms of emotional attention.

Due to time and resource constraints inherent to an undergraduate project, this study was conducted as a narrative review rather than a systematic review or meta-analysis. Consequently, the literature search and data extraction were performed by a single reviewer, which increases the possibility of selection bias compared to studies involving multiple independent reviewers. Furthermore, while efforts were made to be comprehensive, the restriction to English-language publications and specific databases means that relevant data published in other languages or indexed elsewhere may have been missed. These factors suggest that while the trends identified here are consistent with current literature, they should be interpreted as a qualitative synthesis rather than a quantitative confirmation of neural deficits. The following subsections dive deeper into the constraints of the primary research.

4.3.1 Developmental and demographic factors

A portion of the variability in the reviewed results can likely be attributed to the wide age range of the participants and the gender imbalance in study samples. ADHD is a neurodevelopmental disorder, meaning its neural presentation changes as the brain matures. Consequently, comparing findings from children directly with those from adults may obscure distinct developmental stages of the disorder.

Studies involving children and adolescents reported patterns of neural hyper-responsivity or over-recruitment. For instance, studies on adolescents and children by Posner *et al.* (2011), Vetter *et al.* (2018) and by Karalunas, Weigard and Alperin (2020) suggest an "over-eager" bottom-up capture of attention. These findings paint a picture of the young ADHD brain as being easily flooded by emotional stimuli and working overtime to compensate.

In contrast, two studies on adults with ADHD revealed neural hypo-function or a failure to engage necessary regions. Schulz et al. (2014) found that adults did not show the hyper-active amygdala response seen in children; instead, they lacked the adaptive modulation of the amygdala that controls used to process sad faces. Furthermore, Ojha et al. (2024) found that adults with persisting ADHD showed reduced activity in the lateral prefrontal cortex during emotional interference, rather than compensatory over-recruitment. This discrepancy suggests that while the core behavioral deficit (distractibility) remains constant, the underlying neural mechanism may evolve from a state of chaotic hyper-arousal in childhood to a state of inefficient hypo-function or "neural exhaustion" in adulthood.

4.3.2 The influence of gender

A critical limitation in generalizing these findings is the heavy over-representation of male participants. Several key studies, such as those by Vetter et al. (2018) and López-Martín et al. (2013), recruited exclusively boys. This bias is problematic because ADHD presentation is known to differ by gender; females often present with more inattentive symptoms and fewer hyperactive/impulsive behaviours compared to males; this has been researched recently by Mowlem *et al.* (2019). Therefore, the findings of "hyper-active" salience networks or impulsive motor responses found in all-male samples may not accurately reflect the neural reality of females with ADHD. It is possible that the emotional attention deficits in females manifest through different neural pathways, perhaps more closely linked to internalizing networks, but the current literature lacks sufficient data to verify this.

5 Topics for future research

The findings of this review highlight significant gaps in our understanding of the neural mechanisms underlying emotional attention in ADHD. To advance the field and translate these insights into effective clinical interventions, future research should prioritize the following areas presented in this chapter.

5.1 Addressing the gender gap

A critical limitation in the current literature is the severe under-representation of female participants. As noted in this review, studies such as Vetter et al. (2018) and López-Martín et al. (2013) relied exclusively on male samples. Since ADHD in females often presents with a distinct symptom profile, characterized more by inattention than hyperactivity, it is plausible that their neural mechanisms of emotional attention also differ. Future studies must explicitly recruit balanced cohorts or focus specifically on females to determine if the "hyper-arousal" models derived from male brains are universally applicable

5.2 Longitudinal studies

The apparent contradiction between neural hyper-responsivity in children (e.g., Hwang et al., 2015) and neural hypo-function in adults (e.g., Schulz et al., 2014) suggests a dynamic developmental shift. However, cross-sectional comparisons are insufficient to confirm this. Longitudinal studies are required to track the same individuals over time, examining how neural compensatory mechanisms evolve from childhood through adolescence to adulthood. Such research could reveal whether adult hypo-function represents a "burnout" of compensatory systems or a distinct adaptive strategy.

5.3 Naturalistic tasks

The heterogeneity of experimental tasks, ranging from emotional words to static faces, complicates the generalization of results. Furthermore, highly controlled laboratory paradigms like the Emotional Stroop task often fail to capture the complex, dynamic nature of emotional distractions in the real world. Future research should employ more valid methods, such as virtual reality (VR) environments or video-based social scenarios, to assess emotional attention. This would allow researchers to observe how the ADHD brain prioritizes emotional information in contexts that mimic the sensory richness and unpredictability of daily life.

5.4 Differentiating ADHD subtypes

These neuroimaging studies treat ADHD as a homogeneous entity, frequently pooling participants with different presentations (Inattentive vs. Combined). Future research should systematically differentiate between these subtypes to investigate whether emotional attention deficits are specific to one presentation. For example, it remains to be seen whether the "bottom-up" emotional capture is more prevalent in the hyperactive/impulsive presentation, while "top-down" regulatory deficits are more characteristic of the Inattentive presentation.

6 Summary and conclusions

This thesis reviewed recent neuroimaging literature to elucidate the neural mechanisms governing emotional attention in ADHD. While the clinical definition of ADHD emphasizes general inattention and hyperactivity, recent studies suggest that the disorder is also characterized by a dysfunction in how the brain prioritizes emotional information. The results indicate that the "attention deficit" is not merely a failure to focus, but rather a specific impairment in resolving the competition between goal-directed focus and emotionally salient distractions.

The evidence points to a dual mechanism of dysfunction: a "bottom-up" hypersensitivity to emotional stimuli paired with a "top-down" deficit in cognitive control. Neuroimaging reveals that individuals with ADHD often exhibit heightened reactivity in salience-processing regions, such as the amygdala and anterior insula, particularly when faced with negative stimuli (Vetter et al., 2018). Electrophysiological data supports this, showing that emotional cues capture attention earlier and more automatically in the ADHD brain than in neurotypical controls (Karalunas et al., 2020). Simultaneously, the prefrontal networks responsible for regulating this input often show reduced activation or inefficient connectivity, leading to a failure in suppressing emotional interference (Hwang et al., 2015; Schulz et al., 2014).

A critical insight from this review is the identification of a compensatory neural mechanism. Two studies found that individuals with ADHD could achieve behavioral performance comparable to controls, but by exerting greater neural effort. For example, children with ADHD showed over-recruitment of the anterior cingulate and orbitofrontal cortices to maintain inhibitory control during emotional tasks (López-Martín et al., 2015). This suggests that "intact" behavior in ADHD may mask a fragile state of high neural expenditure, leaving the individual vulnerable to cognitive fatigue or failure when task demands increase.

Furthermore, the mechanisms of emotional attention appear to shift throughout development. While children and adolescents typically display patterns of neural hyper-arousal and over-recruitment, adults with ADHD often exhibit neural hypo-function, characterized by a failure to recruit lateral prefrontal regions during emotional interference (Ojha et al., 2024). This may indicate that the adult ADHD brain transitions from a state of chaotic reactivity to one of inefficient under-engagement or "neural exhaustion." However, the generalizability of these conclusions is currently limited by the small sample sizes and the significant over-representation of male participants in the literature.

In conclusion, emotional attention in ADHD is mediated by an imbalance between an over-active limbic detection system and an under-active or over-burdened prefrontal control system. This finding challenges the traditional view of ADHD as a purely cognitive disorder and highlights the central role of emotional processing in its pathology. Future research must address the gender gap and utilize longitudinal designs to confirm the developmental trajectory of these mechanisms. Ultimately, these insights suggest that effective clinical and educational interventions for ADHD should not only target general focus but also specifically address the regulation of emotional priority.

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8 Appendix

Year and Author (s)	Title	Number of Participants and Demographic	Neuroimaging method	Type of Test	Results
Hwang et al. (2015)	Executive attention control and emotional responding in attention-deficit/hyperactivity disorder — A functional MRI study	61 Total: 26 ADHD (Mean age 14.53), 35 Healthy Controls (Mean age 13.91). Children/Adolescents.	fMRI	Affective Stroop paradigm (viewing emotional images under cognitive load).	ADHD youth showed reduced recruitment of the dorsomedial frontal cortex during high cognitive demand and increased responses to positive stimuli in temporal cortical regions compared to controls.
Karalunas et al. (2020)	Emotion-cognition interactions in ADHD: Increased early attention capture and weakened attentional control in emotional contexts	130 Total: 61 ADHD (Mean age 13.9), 69 Controls (Mean age 13.8). Adolescents.	EEG	Emotional Go/No-Go task (positive, negative, neutral faces).	ADHD adolescents exhibited increased early reactive attention capture (larger P1, faster drift rates) to positive stimuli, which exacerbat

					ed impairments in downstream attentional control (reduced N2 amplitude).
Leon et al. (2025)	Investigating Emotional Interference as a Potential Endophenotypic Marker in Attention-deficit Hyperactivity Disorder: A QEEG Study	100 Total: 43 ADHD (Mean age 12.3), 17 Siblings (Mean age 12.3), 40 Controls (Mean age 12.9). Children.	EEG	Emotional Stroop Task (Word-Face variant).	Behavioral delays and increased pre-response neural activation in frontal and temporal regions were found in ADHD and siblings compared to controls, with specific microstates identified as state (Map 2) and trait (Map 3) markers.
López-Martín et al. (2013)	Emotional distraction in boys with ADHD: Neural and	40 Total: 20 ADHD Combined type (Mean age 11.35), 20	EEG	Digit Categorization with Emotional Distractio	ADHD boys showed longer reaction

	behavioural correlates	Healthy Controls (Mean age 10.65). Boys.		n (irrelevant emotional backgrounds).	times and larger anterior N2 amplitudes for emotional distracters compared to neutral ones, suggesting enhanced susceptibility to emotional distraction driven by bottom-up processing.
López-Martín et al. (2015)	Emotional response inhibition in children with attention-deficit/hyperactivity disorder: neural and behavioural data	48 Total: 24 ADHD (Ages 8-13), 24 Healthy Controls (Ages 8-13). Children.	EEG	Modified Emotional Go/No-Go task	ADHD children displayed greater activation of inhibition-related mechanisms (enhanced No-Go P3 amplitudes and orbitofrontal cortex activity) to maintain performance levels similar to controls, especially

					during emotionally arousing contexts.
Ojha et al. (2024)	Altered Lateral Prefrontal Cortex Functioning During Emotional Interference Resistance Is Associated With Affect Lability in Adults With Persisting Symptoms of Attention-Deficit/ Hyperactivity Disorder From Childhood	182 Total: 47 Persisting ADHD, 93 Desisting ADHD, 42 No ADHD history. Adults (Mean age ~35).	fMRI	Emotional Face N-Back (EFNBACK).	Reduced activation in the dorsolateral and ventrolateral prefrontal cortex during high cognitive load with emotional distractors was associated with greater affect lability in adults with persisting ADHD.
Posner et al. (2011)	The attenuation of dysfunctional emotional processing with stimulant medication: An fMRI study of adolescents with ADHD	30 Total: 15 ADHD (Ages 11-16), 15 Healthy Controls (Ages 11-16). Adolescents.	fMRI	Emotional Stroop and Cognitive Stroop tasks.	Unmedicated ADHD adolescents demonstrated atypical activity in the medial prefrontal cortex during the emotional Stroop (greater

					activation for positive, greater deactivation for negative), which was attenuated by stimulant medication.
Réthelyi et al. (2025)	Affective Go/NoGo fMRI study of adults living with ADHD reveals differential BOLD activation in ACC, insula, and secondary visual cortex	53 Total: 34 ADHD (Mean age 37.3), 19 Healthy Controls (Mean age 30.2). Adults.	fMRI	Affective Go/No-Go task.	ADHD subjects showed increased BOLD activation in the Dorsal- and Ventral-Attention Networks and higher deactivation of the Default Mode Network in all conditions compared to controls.
Schulz et al. (2014)	Emotional bias of cognitive control in adults with childhood attention-deficit/hyperactivity disorder	28 Total: 14 Probands with childhood ADHD (Mean age 23.3), 14 Comparison subjects (Mean	fMRI	Face Emotion Go/No-Go task.	Probands showed reduced functional connectivity between the right

		age 22.8). Young Adults.			dorsolateral prefrontal cortex and limbic regions compared to controls, and lacked the valence-dependent activation in limbic regions seen in controls.
Vetter et al. (2018)	Anterior insula hyperactivation in ADHD when faced with distracting negative stimuli	50 Total: 25 non-comorbid ADHD (Mean age 14.26), 25 Typically Developing (Mean age 14.02). Adolescent Boys.	fMRI	Emotional Attention task (matching pictures while ignoring emotional distractors).	ADHD boys showed increased activation in the left anterior insula/inferior frontal gyrus and left amygdala specifically during negative emotional stimuli relative to controls, suggesting altered saliency processing.
Vosough et	Facial Affect Recognition and Executive	300 Total: 117 ADHD (Mean age 24.22), 183	EEG	Emotional Continuous	ADHD subjects demonstra

al. (2025)	Function Abnormalities in ADHD Subjects: An ERP Study	Healthy Controls (Mean age 29.23). Age range 6-60.		Performance Test (ECPT) [Go/No-Go variant].	ted lower P3d amplitudes (inhibition marker) and lower N170 amplitudes (face processing marker) compared to controls, alongside significant behavioral deficits (longer RTs, more errors).