Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Psychology

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The Relationship between ADHD Traits, Emotion Regulation, Effort, and Stress.

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Supervisor: Francesca Parisi
Co-supervisor: Gerit Pfuhl
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Preface

This thesis is part of a bachelor project supervised by Francesca Parisi and Gerit Pfuhl. The project, planned by the supervisors, was established as being about the effortfulness of emotion regulation. The recruitment of participants for the study was done by the students, and the data collection was a cooperation between the students and the supervisors. The supervisors examined the data and provided the students with datasets which only included data for the variables we pre-registered that we wanted to test. Data analysis was performed by the individual students in line with the pre-registration. After presenting the idea for the research question, the supervisors helped with phrasing the hypotheses and limiting the scope. The supervisors have been very helpful through the entire process and have answered questions, as well as provided feedback on preliminary drafts of our theses.

I wish to thank my supervisors for guiding us through, and for making sure we stay the course. A special thanks to my fellow students, and I wish to emphasize the appreciation for the helpful and supportive environment that we created within the group. I want to especially thank my boyfriend and my mother for the endless support, dinners, encouragement, patience, and love throughout the writing process.

Abstract

ADHD traits such as impulsivity, hyperactivity, and inattention, have been linked to impairments in emotion regulation. However, the exact nature of the relationship has not been unraveled. There is a gap in the knowledge regarding the relationship between ADHD traits and emotion regulation in adults, especially in relation to effort and stress. The current study aims to examine the relationship between ADHD traits, emotion regulation, effort, and stress. This study contained a sample of 55 adults. ADHD traits were measured using the ASRS-v1.1 Symptom Checklist. Use of cognitive reappraisal and suppression were measured using the Emotion Regulation Questionnaire (ERQ). Experienced effort and frustration were measured using the NASA Task Load Index. Heart rate variability (HRV) as an indication of stress, was measured using PPG. Correlation analyses were conducted to examine the direction and strength of the relationships. I predicted that ADHD traits would be negatively correlated with HRV and cognitive reappraisal; and positively correlated with suppression, mental effort, and frustration. The results confirmed the hypotheses in terms of direction of the correlations, with one exception: ADHD traits were negatively correlated with suppression. The strongest relationship was between ADHD traits and mental effort ($\tau = .40$, $p < .001$). My findings indicate that there is a relationship between ADHD traits and emotion regulation, effort, and stress. Although this study contributes to expanding the knowledge about ADHD traits and emotion regulation, further research is needed to explore the nuances of the relationship – both in clinical and non-clinical samples.

Sammendrag

ADHD-trekk som impulsivitet, hyperaktivitet og uoppmerksomhet har blitt knyttet til vansker med emosjonsregulering. Nyansene i forholdet har derimot ikke blitt avklart. Det er mangler i kunnskapen om sammenhengen mellom ADHD-trekk og emosjonsregulering hos voksne, spesielt i forhold til mental anstrengelse og stress. Denne studien vil derfor undersøke sammenhengen mellom ADHD-trekk, emosjonsregulering, mental anstrengelse og stress. Utvalget besto av 55 voksne. ADHD trekk ble målt ved hjelp av ASRS-v1.1 Symptom Checklist. Bruk av kognitiv restrukturering («cognitive reappraisal) og undertrykking («suppression») ble målt ved hjelp av «Emotion Regulation Questionnaire» (ERQ). Hjerteratevariabilitet (HRV), som en indikasjon på stress, ble målt ved hjelp av PPG. Mental anstrengelse og frustrasjon ble målt ved hjelp av «NASA Task Load Index». For å undersøke retningen og styrken til forholdene ble det utført korrelasjonsanalyser. Jeg predikerte at ADHD-trekk ville være negativt korrelert med HRV og kognitiv restrukturering, og positivt korrelert med undertrykking, mental anstrengelse og frustrasjon. Resultatene bekreftet hypotesene når det gjelder retning på korrelasjonene, med ett unntak: ADHD-trekk var negativt korrelert med undertrykking. Den sterkeste sammenhengen var mellom ADHD-trekk og mental anstrengelse ($\tau = .40$, $p < .001$). Funnene mine indikerer at det er en sammenheng mellom ADHD-trekk og emosjonsregulering, mental anstrengelse og stress. Selv om denne studien bidrar til å utvide kunnskapen om ADHD-trekk og emosjonsregulering, er det nødvendig med ytterligere forskning for å utforske nyansene i forholdet – i utvalg både med og uten klinisk diagnostiserte individer.

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The actual emotions that people experience (e.g., negative, or positive emotions) play a certain part in the emotion regulation process. Moreover, the subjective intensity of the emotions, how rapidly emotions change, and previous experiences with feedback from others related to emotional reactions can influence how people choose to regulate and express emotions. If one is used to experiencing subjectively strong emotions (e.g., if your emotions equate a 10 on a scale from 1-10) - and reacting accordingly - stigma, criticism, and negative feedback from others following said reactions, may affect how one chooses to react in similar situations in the future (Beaton et al., 2022).

The overarching topical question for this bachelor project is “How effortful is emotion regulation”. “Emotion regulation concerns internal processes related to manipulation of physiological, subjective, and/or behavioral aspects of emotional responding” (Steinberg & Drabick, 2015, p. 953), and is important in terms of well-being and adaptive functioning (Bodalski et al., 2019). Effort, in this context, can be defined as the increase in mental activity aimed at achieving a specific goal (Inzlicht et al., 2018). Mental effort can also be defined as the subjective experience that accompanies the goal-oriented cognitive work or activity in question (Wolpe et al., 2024). Effortfulness, then, refers to the subjective experience of the effort exerted or required to achieving the individual´s goal.

As individuals differ - as well as situational demands vary - goals will be prioritized and change depending on several factors. Some of which are cognitive capacity (how much effort is available to expend), and physiological arousal (how stressed/activated is the individual) (Zsidó, 2024).

Furthermore, both emotional and cognitive challenges have been associated with psychopathology related to inattention, impulsiveness, etc. (e.g., ADHD) (Christiansen et al., 2019). This can make emotion regulation more effortful and demanding for individuals struggling with such disorders, and/or individuals who exhibit many symptoms (Steinberg & Drabick, 2015).

1. Emotion Regulation

Emotion comprises cognitive processing, behavioral reaction, and physiological response (Zhu et al., 2019). Emotion regulation refers to how people handle their subjective experience of emotions for personal and social reasons (Thompson et al., 2008); and can be considered a vital skill that everyone needs to survive – socially and sometimes literally. Emotion regulation can be both extrinsic (i.e., regulating others´ emotions) and intrinsic (i.e., regulating own emotions) (Nigg, 2017). The scope of this thesis limits the objective to intrinsic emotion regulation. Further, the aspects of emotion regulation relevant to this thesis include physiological measurements (i.e., heart rate variability), emotion regulation strategies, and effort.

1.1 Heart rate variability (HRV)

Emotion regulation is influenced by physiological arousal, i.e., the body´s level of activation; and emotional arousal can be defined as a state of physiological arousal (Zsidó, 2024).

Subjective emotional arousal refers to the subjective experience of activation in relation to a stimulus, e.g., which feelings the stimulus elicited (Zsidó, 2024). When the activation is heightened, one can feel excited, nervous, or alert – which prepares the person for action. While decreased activation can prompt boredom or relaxation (Zsidó, 2024).

Objective emotional arousal associated with emotion regulation can be observed using physiological measurements to examine the functioning of the autonomic nervous system (ANS) (Bunford et al., 2017). Two branches of the ANS are relevant to emotion regulation: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). SNS is responsible for eliciting ´fight or flight´ responses in situations that requires one to activate fast, and produces excitatory effects on bodily systems (e.g., increasing the heart rate) (Bellato et al., 2020). PNS is responsible for ´rest and digest´ responses to preserve and maintain energy and produces slower and more variable heart rate (Bellato et al., 2020).

A physiological measurement often used to examine ANS functioning, is heart rate variability (HRV) (Zhu et al., 2019). HRV represents a measure of variations in heart rate over time, and reflects the parallel activation of the SNS and the PNS (Bellato et al., 2020). Sympathetic and parasympathetic influences on heart rate can yield information about autonomic flexibility, and thus represents the ability to regulate emotions effectively (Appelhans & Luecken, 2006).

Research and theory support the function of HRV as a marker of individual differences in emotion regulation capacity (Appelhans & Luecken, 2006; Zhu et al., 2019). Both the polyvagal theory and the model of neurovisceral integration hypothesize that the nervous system´s ability to track changes in the environment and respond with context-proportionate physiological arousal is critical to the expression and regulation of emotions (Appelhans & Luecken, 2006).

1.2 Emotion regulation strategies

Healthy adaptation to the environment requires flexibility in choosing regulation strategies in a way that responds to varying situational demands (Sheppes et al., 2014). There are several strategies one can engage in when regulating emotions. The strategies differ in how effective

they are considered to be, and at which temporal point of the emotion regulation process they are employed (Gross, 2001). Antecedent-focused strategies change the trajectory of the emotion early in the process, whereas response-focused strategies occur after generating a response and focus on altering the emotional output (Gross, 2001; Moore et al., 2008). Two of the most researched strategies are cognitive reappraisal and expressive suppression, where the former is an antecedent-focused strategy, and the latter is response-focused.

Cognitive reappraisal allows a person to change the way they think about the stimuli they perceive to reduce negative feelings (Gross, 2001). Cognitive reappraisal can also be used to alter the particular interpretation of strong emotional stimuli to change its emotional impact on experience, behavior, and/or physiology (Shahane et al., 2019). Expressive suppression is when one minimizes the emotional outward reaction, or emotional output, so that someone watching would not know what they are feeling (Gross, 2001).

Although regulation may be thought of as an explicit and conscious decision to alter subjective experience, emotion regulation can be done both habitually and implicitly (Shahane et al., 2019).

1.3 Effort

Regulating emotions requires mental/cognitive work, i.e., “the action performed by the cognitive apparatus to achieve a goal.” (Wolpe et al., 2024, p. 2). And for each individual this mental work is associated with mental effort, i.e., “the subjective experience that accompanies cognitive work” (Wolpe et al., 2024, p. 2). Mental effort is costly, but necessary to experience. In a way, mental effort can be considered the internal compass that informs us about the direct and indirect consequences of continuing the activity in question, and whether we should make a

behavioral change (e.g., stop and/or switch activities) (Wolpe et al., 2024). Thus, mental effort is adaptively valuable insofar that it is the brain´s *natural brakes*.

In the case of emotion regulation, individuals may flexibly choose regulation strategies based on situational demands, and/or a cost (e.g., effort)-benefit (e.g., downregulation of emotional arousal) calculation (Scheffel et al., 2021). Research indicates that when experiencing highly stressful or threatening situations, the regulatory strategies that require more effort become undesired compared to strategies that require less effort (Muraven & Baumeister, 2000 in Scheffel et al., 2021). For example, even though suppression is often labeled maladaptive and can entail negative long-term consequences, it may be beneficial in negative emotional states (Scheffel et al., 2021). Hence, if the goal is short-term alleviation of stress, extra effort can be expended despite its potential negative long-term effects.

2. Attention Deficit/Hyperactivity Disorder (ADHD)

2.1 Diagnosis and traits

Attention Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder that affects approximately 3-5% of the Norwegian population (Hannås, 2023). ADHD is characterized by impairing and age-inadequate levels of three core symptoms (hyperactivity, inattention, and impulsivity) (Christiansen et al., 2019). To obtain a clinical diagnosis, the symptoms must have been present since before the age of 7 according to ICD-10 (World Health Organization, 1993). Although there are some differences between the ICD-10 and DSM-5, this study will refer to the ICD-10 standard because it is the one we currently use in Norway (Hannås, 2023).

A trait is a characteristic or quality of a person, a more or less consistent pattern of behavior one could expect an individual with the characteristic to display in relevant circumstances (Colman, 2009). Following that definition, ADHD traits will in this thesis refer to the characteristic behaviors and core symptoms associated with ADHD. The ADHD traits measured by the ASRS questionnaire are hyperactivity, inattention, and impulsivity (Adler et al., 2019). Therefore, those are the traits that fall within the scope of this thesis.

Hyperactivity includes excessive fidgeting, restlessness, and difficulty staying seated or quiet (Barkley, 1997). Hyperactivity symptoms usually present differently in adults than in children; the symptoms are often more internal in adults, and may manifest as *feelings* of restlessness, talking too much, continuous mental activity, and difficulty relaxing properly (Kooij et al., 2019). Inattention includes difficulty sustaining attention, organizing tasks, following instructions, and completing tasks (Christiansen et al., 2019). Impulsivity includes acting without forethought, interrupting others, and engaging in risky or inappropriate behaviors (Adler et al., 2019). Impulsivity can also include impaired impulse control, which means difficulties inhibiting immediate responses or delaying gratification (Barkley, 1997). Impulsive behavior is often associated with interpersonal conflicts which may have consequences for relationships with friends, family, colleagues, and employers (Kooij et al., 2019).

ADHD is categorized into three subtypes based on which traits are most prominent: predominantly inattentive presentation, predominantly hyperactive-impulsive presentation, and combined presentation (Faraone et al., 2021).

2.2 Impact and impairment

Although ADHD is usually associated with childhood, the symptoms can persist into adulthood and affect both inter- and intrapersonal aspects of an individual´s life (Adler et al., 2019; Shaw et al., 2014). These aspects include e.g., physical- and mental well-being, emotion regulation, work productivity, stress management, and social interactions (Adler et al., 2019; Faraone et al., 2021; Öster et al., 2020).

Those individuals who exhibit many external symptoms of ADHD, or whose impairments due to the symptoms become visible to others, often report having experienced much negative feedback and criticism because of the way they act and interact with others (Beaton et al., 2020; Öster et al., 2020). Additionally, they often internalize this feedback and develop a negative self-image as a result (Beaton et al., 2022). Further, since ADHD has been linked to deficits or dysfunctions across both development and several life domains, it is also plausible that individuals who experience ADHD symptoms are more likely to experience stress (Combs et al., 2015). Taken together, these findings suggest that ADHD symptoms and stress are related to each other, as well as to emotion regulation.

3. ADHD Traits, Emotion Regulation, effort, and Stress

3.1 Overall relationship between ADHD traits, emotion regulation, effort, and stress

As we have seen, emotion regulation is important for well-being and social functioning. People may struggle with emotion regulation, for example if they have ADHD traits or are experiencing stress – or both. It has been proposed that the inattention, hyperactivity, and impulsiveness that follow from ADHD, reflect underlying deficits in emotional self-regulation (Barkley, 2015). Deficient emotional self-regulation is characterized by deficits in regulating

physiological arousal caused by emotions, inhibition-difficulties (e.g., inhibiting inappropriate expressions to positive and negative emotions), inability to refocus attention after experiencing strong emotions, and difficulties with coordinating behavior in response to emotional activation (Rash & Aguirre-Camacho, 2012). Difficulties with emotion regulation may also be related to strategy choice, and identification-problems (when to regulate which emotion – and how) (Christiansen et al., 2019). Some may struggle with feeling overwhelmed (over-activated) to the point where they may not feel as if they can regulate the emotional experience consciously or explicitly (Shahane et al., 2019).

3.2 ADHD traits and heart rate variability

ADHD symptoms may increase sensitivity to stressors, leading individuals to feel more easily stressed and experience a slower return to baseline after activation (Combs et al., 2015). Previous research suggests that higher HRV is often associated with greater flexibility in responding to emotional stimuli and adaptive emotion regulation (Appelhans & Luecken, 2006), while reduced HRV may indicate difficulties in modulating emotional arousal and regulating emotional responses (and rigid attentional processing of threat) (Appelhans & Luecken, 2006).

Difficulties regulating arousal according to situational demands may be part of what underlies ADHD symptoms (Bellato et al., 2020). For example, inability to increase arousal during monotonous or non-stimulating cognitive tasks might undermine the attentive behavior needed to complete e.g., schoolwork. Additionally, being unable to lower heightened arousal can lead to using ineffective strategies like running or shouting to manage it.

Further, it has been proposed by Geissler et al. (2014) that a core feature of ADHD is the reduced vigilance and attention to the environment, indicating a tonically hypo-aroused state.

And conversely, that hyperactive and impulsive behaviors might serve as self-regulatory efforts to increase arousal levels by creating a stimulating environment, thereby stabilizing vigilance.

3.3 ADHD traits, cognitive reappraisal, and expressive suppression

Previous research indicates that individuals with ADHD use expressive suppression as a regulatory strategy more often than cognitive reappraisal compared to healthy controls (Liu et al., 2022; Materna et al., 2019; Moore et al., 2008; Shushakova et al., 2018).

Liu et al. (2022) suggested that their findings indicate that for adults with ADHD, the less frequent use of cognitive reappraisal accounts for the expression of emotional dysregulation, and that the more frequent use of expressive suppression may potentially be compensatory because of its negative correlation with emotion dysregulation (Liu et al., 2022).

Both healthy adults and people with ADHD who experience high emotional intensity, favor regulation strategies that prevent emotional processing (e.g., suppression) over strategies that require in-depth processing (e.g., reappraisal) (Shushakova et al., 2018).

Inattention involves difficulties related to sustaining attention, organizing tasks, and completing tasks. In relation to emotion regulation, these deficits can also be seen as struggling to recognize- or pay attention to emotional stimuli (Shaw et al., 2014).

Impulsivity is associated with a preference for small, immediate rewards over larger, delayed ones, even when the choice does not reflect one´s own goals and desires - which reflects an aversion to delayed reward (Sagvolden et al., 2005). With regard to regulation strategies, suppression offers more immediate effects, compared to reappraisal which offers long-term benefits (Shushakova et al., 2018). Thus, it is plausible to think that impulsivity - and/or impaired impulse control - is associated with an inclination towards suppression rather than

reappraisal because of the difficulties related to inhibiting immediate responses (i.e., reducing negative arousal) and delaying gratification.

3.4 ADHD traits, effort, and frustration

Task persistence is effortful, and the urge to switch tasks / the uncertainty of whether to stop or switch task may be inherently stressful and taxing (Wolpe et al., 2024). Individuals with ADHD often struggle with task persistence, specifically when the task is not stimulating or no incentives/rewards are present to spark their motivation (Bellato et al., 2020). Moreover, individuals with ADHD often have a heightened aversion to effort, and reduced motivational drive (Chong et al., 2023). Tasks that healthy people perceive as less effortful may thus be perceived by someone with ADHD as more effortful because the motivation to exert effort is reduced.

Taken together, these findings make it plausible that experiencing more ADHD symptoms may lead to an increased level of experienced effort and frustration during task performance.

The Present Study

Emotion regulation is important for well-being and is crucial for interacting with the people around us. Living with ADHD traits such as impulsivity, hyperactivity, and inattention, can negatively impact these individuals´ lives. Although these traits have been linked to impairments in emotion regulation, the exact nature of the relationship has not been unraveled. The present study seeks to fill a gap in the research and expand the knowledge in the field of emotion regulation in the context of ADHD, by evaluating the relationship between ADHD traits, emotion regulation, effort, and stress. More specifically, the goal is to investigate which

direction- and how strongly ADHD traits correlate with heart rate variability, emotion regulation, and experienced mental effort and frustration.

Heart rate variability relates to stress and emotion regulation; the NASA Task Load Index subscales *frustration* and *effort* function as proxy for stress and measure of effort, respectively; and the Emotion Regulation Questionnaire measures emotional experience and emotional expression. In line with my pre-registration (https://osf.io/ac2eh), I hypothesize as follows:

H1: More ADHD traits are associated with lower HRV.

H2: More ADHD traits are associated with more use of suppression and less use of cognitive reappraisal.

H3: More ADHD traits are associated with a higher level of experienced effort and higher level of experienced frustration.

Methods

Participants

56 participants have been recruited. However, one was excluded because they did not meet the inclusion criteria. The final sample was 55 participants. The participants were recruited by the bachelor students working on the project. Inclusion criteria included being over the age of 18, not having any psychological or neurological diagnoses (e.g., Parkinson´s disease, severe depression, brain tumor, epilepsy), and not currently taking any nervous system medication or drugs. Participants were native Norwegian speakers fluent in English with one exception, who

was a native French speaker and for this reason questionnaires/tests in Norwegian were excluded for this participant. 29 of participants were women, 26 were men. The age of the participants ranged from 20-42 years, with the mean age being 24.7 years, (*SD* = 4.4).

Procedures and design

Participants were invited to take part in a study as part of a bachelor thesis project. All participants were informed of their rights and the nature of the experiment, and signed consent forms before the testing commenced. All the data registered was stored electronically.
Prior to the testing phase in the lab, the study was approved by the ethics committee at NTNU and SIKT.

All participants were assigned to the same single condition, namely the laboratory experiment. Each test-session was designed to accommodate only one participant at a time and lasted for about 90 minutes per participant. The experiment consisted of self-report questionnaires, tests, and physiological measures, and was divided into two parts (https://osf.io/g9cwf/?view_only=54027d1f69f14ea09b4c7a8d9684ed19). In the first part, there were mostly two people administering the tests (testers), while in the second part, there was only one tester. Both parts took place on the same day, but they differed in terms of the lab setting and the experimenter present. The testing took place over the course of five weeks.

Equipment/Materials/Measurement instruments

This was a laboratory study that included several questionnaires, tests, and physiological measures. The aim of this thesis was to examine the relationship between ADHD traits, emotion regulation, effort, and stress.

ADHD traits were measured using the ASRS-v1.1 Symptom Checklist (Adler et al., 2019). This questionnaire consists of 18 items to measure attention hyperactivity traits. Heart rate variability (HRV) was measured using the PPG. Cognitive reappraisal and suppression were measured using the Emotion Regulation Questionnaire (ERQ, Gross & John, 2003). Experienced effort and frustration were measured using the NASA Task Load Index (Hart & Staveland, 1988); although the participants evaluated their experiences with the NASA Task Load Index after several of the tests, this study will only use the scores from the evaluation of the emotional Stroop-task.

Self-reported questionnaires

Demographic questionnaire

In this project we registered the participants´ age and gender (woman, man, or non-binary).

Emotion Regulation Questionnaire

Participants completed the Norwegian version of the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003), which measures two dimensions of emotion regulation using a 7-point Likert scale ranging from 1 = “Strongly disagree” to 7 = “Strongly agree”. The Norwegian version was received via personal communication by A. Haver on 2023-12-14 (see also Haver et al., 2023).

The questionnaire comprises two subscales: Cognitive Reappraisal and Expressive Suppression. For the Cognitive Reappraisal subscale, scores range from 6 to 42, while for the

Expressive Suppression subscale, scores range from 4 to 28. Higher scores indicate a greater use of the respective emotion regulation strategy.

The internal consistency (Cronbach's coefficient) of the original English version had an α = .75 for Cognitive Reappraisal and α = .68 for Expressive Suppression. In the current study internal consistency for the Cognitive reappraisal subscale was McDonald's ω = .842 (95% CI .778;.907), and Cronbach's α .836 (95% CI: .755; .895). For the suppression subscale McDonald's ω = .785 (95% CI: .691; .879) and Cronbach's α = .77 (95% CI: .652; .854).

The ASRS-v1.1 Symptom Checklist

Participants completed the Norwegian version of the 18-item ASRS-v1.1 Symptom Checklist (ADHD-selvtest voksne, 2005; Adler et al., 2019) to self-assess ADHD symptoms in adults, by rating the frequency of symptoms experienced over the past 6 months on a scale of 0 to 4: 0 = "never", 1 = "rarely", 2 = "sometimes", 3 = "often", and 4 = "very often".

The ASRS-v1.1 consists of two subscales: Inattention (subscale A) and Hyperactivity-Impulsivity (subscale B). Items 1, 2, 3, 9, 12, 16, and 18 were scored by assigning one point for ratings of "sometimes", "often", or "very often" (with "never" or "rarely" assigned zero points). For the remaining 11 items, one point was assigned for ratings of "often" or "very often" (with "never", "rarely", or "sometimes" assigned zero points). The range score is 0-18, with higher scores indicating more ADHD symptoms.

The internal consistency of the original English version had Cronbach's α = .88 (Adler et al., 2006). In this study internal consistency had McDonald's ω = .912 (95% CI: .878; .947) and Cronbach's α = .911 (95% CI: .869, .942).

NASA Task Load Index

Participants completed the Norwegian version of the six-item NASA Task Load Index (N-TLX; (Hart & Staveland, 1988) to assess the perceived workload of doing the Stroop task. The six items measure; mental effort, physical effort, temporal demand, effort, perceived performance, and frustration in relation to the task. Each item was scored on a visual analog scale having “very low” and “very high” to the two extremes. Although multiple N-TLX assessments were conducted (see OSF link), my study exclusively analyses data from the mental effort- and frustration items of the N-TLX assessment of the emotional Stroop task (in PsychoPy v2023.2.3) with a range from 1-100. Higher scores indicated a higher perceived workload.

Mental demand: how mentally demanding was this task? (“Hvor mentalt krevende var oppgaven”)

Frustration: how insecure, discouraged, irritated, stressed, and frustrated were you? (“Hvor usikker, motløs, irritert, stresset og frustrert var du?»)

Physiological measures

PPG

Photoplethysmography (PPG) is a non-invasive technology utilizing a light source and a photodetector placed on the skin´s surface to measure volumetric changes in blood circulation. These PPG signals can indicate variations in blood volume underneath the skin, which are then analyzed to evaluate heart rate activity (Park et al., 2022). Prior to recording, participants wore the BioPac PPG sensor on the index finger of their left hand and were instructed to remain still. PPG recording was performed on AcqKnowledge 5.0 and lasted a minimum of five minutes. Data processing involved automatic detection of R-wave times of heartbeat, followed by visual

inspection. Any missed actual peaks were added, identified peaks were deleted, and noise was removed. Missing data estimation was omitted to ensure reliance solely on actual R-wave times, thereby avoiding potential effects introduced by estimated data. The root mean square of successive interbeat interval differences (rMSSD) was computed as the primary time-domain measure to assess vagally mediated changes reflected in heart rate variability (HRV).

Data analyses

Prior to data analyses, all variables were examined to check for outliers and noise. Outliers, missing data (false "0" values), and data with too much noise, was removed from the data set before statistical testing. All statistical analyses were performed using JASP version 0.18.3.

Bivariate correlation analyses using Kendall´s Tau (τ) were conducted to examine the relationships between ADHD traits and emotion regulation, effort, and stress. The decision to use Kendall´s Tau was based on the nature of the data, specifically that the data was non-normally distributed.

To test the first hypothesis (H1: More ADHD traits are associated with lower HRV), I conducted a predicted negative correlation analysis for ASRS score and rMSSD score.

To test the second hypothesis (H2: More ADHD traits are associated with more use of suppression and less use of cognitive reappraisal), I conducted two separate correlation analyses; the first being a predicted negative correlation analysis for ASRS score and the score from the cognitive reappraisal subscale of the ERQ, and the second being a predicted positive correlation analysis for ASRS score and the score from the suppression subscale of the ERQ.

To test the third hypothesis (H3: More ADHD traits are associated with a higher level of experienced effort and higher level of experienced frustration), I conducted two separate correlation analyses; the first being a predicted positive correlation analysis for ASRS score and the score of the mental effort subscale of NASA-TLX, and the second being a predicted positive correlation analysis for ASRS score and the score of the frustration subscale of NASA-TLX.

Results

The average ASRS score (N = 52) was M = 6.4 (*SD* = 4.29), ranging from 0 to 18. Most participants reported few symptoms. The valid data for HRV were 48, with the average score (rMSSD) being M = .056 (*SD* = 0.028), ranging from .014 to .148 seconds. For both subscales of the ERQ, the valid data were 54. The average score of the cognitive reappraisal subscale was M =26.6 (*SD* = 6.6), with scores ranging from 6-37. For the suppression subscale, the average score was M = 13.1 (*SD* = 4.5), scores ranging from 4-21. For both subscales of the NASA-TLX, the valid data were 53. The average score for the frustration subscale was M = 36.1 (*SD* = 22.5), with scores ranging from 0 to 99.3. The average score for the mental effort subscale was M = 55.8 (*SD* = 25.8), with scores ranging from 6.4 to 100.

Hypothesis 1: More ADHD traits are associated with lower HRV.

A predicted correlation analysis ($N = 46$) showed that there was a negative association between ADHD traits and HRV, $\tau = -.08$, 95% CI [-1.000, 0.082], $p = .217$.

Hypothesis 2: More ADHD traits are associated with more use of suppression and less use of cognitive reappraisal.

The second hypothesis was examined by conducting two separate Kendall´s Tau correlation analyses, both analyses included 52 participants. There was a negative association between ADHD traits and suppression, $\tau = -.03$, 95% CI [-0.176, 1.000], $p = .616$. And a significant negative association between ADHD traits and cognitive reappraisal, $\tau = -.17$, 95% CI [-1.000, 0.007], $p = .049$.

Hypothesis 3: More ADHD traits are associated with a higher level of experienced effort and higher level of experienced frustration.

The third hypothesis was explored by conducting two separate Kendall´s Tau correlation analyses, both analyses included 51 participants. There was a significant positive correlation between ADHD traits and Frustration, $\tau = .20$, 95% CI [0.023, 1.000], $p = .022$. And there was a significant positive correlation between ADHD traits and Mental Effort, $\tau = .40$, 95% CI [0.269, 1.000], $p < .001$.

Discussion

The purpose of this study was to evaluate the relationship between ADHD traits and emotion regulation, effort, and stress. Specifically, the goal was to investigate which direction- and how strongly ADHD traits correlate with heart rate variability, emotion regulation, and experienced mental effort and frustration. The results of the analyses showed that ADHD traits were negatively correlated with HRV and cognitive reappraisal, and ADHD traits were positively correlated with mental effort, frustration, and suppression. These findings generally support the

proposed hypotheses, at least in terms of the direction of the relationships between ADHD traits and the other variables. There is one exception, namely the relationship between ADHD traits and use of suppression; contrary to the hypothesis, the correlation analysis for these variables showed a negative relationship, rather than a positive one. In terms of strength, only the relationship between ADHD traits and mental effort passed the threshold for moderate strength ($\tau > .26$); with a $\tau = .40$, this association is bordering on strong ($\tau > .49$).

Hypothesis 1: More ADHD traits are associated with lower HRV.

The analysis revealed a negative association between ADHD traits and HRV. The correlation coefficient ($\tau = -.08$) suggests a weak negative relationship, and the p-value ($p = .217$) indicates that this association is not statistically significant. Although this study did not find a statistically significant association between ADHD traits and HRV, my findings may still prove valuable.

Previous research has proposed alterations in autonomic nervous system activity in individuals with ADHD (Bellato et al., 2020), yet the findings from my study indicate that this relationship may not manifest as a direct association with HRV. This divergence highlights the need for further exploration into the mechanisms underlying autonomic functioning in individuals with ADHD traits.

It is worth mentioning that in this study, we only measured resting state HRV. We did not measure HRV during task performance (i.e., when stimuli are presented and responded to). A growing body of research suggest that changes in HRV can be observed during cognitive tasks in individuals with ADHD compared to healthy controls (Bellato et al., 2020), especially when a reward or incentive is presented (Zsidó, 2024). Furthermore, seeing as ADHD traits have been

suggested to reflect underlying deficits in emotional self-regulation, such as difficulties regulating physiological arousal following emotions (Rash & Aguirre-Camacho, 2012), measuring HRV during task performance holds the potential to explore this relationship "in action".

While HRV is often considered a marker of physiological regulation and emotional well-being (Thayer et al., 2012), its weak association with ADHD traits in this study suggests that other factors, such as lifestyle factors, medication use, or comorbid conditions, may play a role in shaping autonomic nervous system functioning in people with ADHD (Bellato et al., 2020).

Additionally, individual differences in ADHD symptom severity and presentation may contribute to variability in HRV measurements within this population (Rash & Aguirre-Camacho, 2012). Results from a study by Musser et al. (2013) indicate that ADHD is heterogenous, both clinically and in relation to physiological manifestations of emotion and regulation. Thus, it may be fruitful to examine- and account for the role of individual differences in future research on this topic. Specifically, it could be interesting to explore whether there are differences between the different subtypes of ADHD.

Overall, future research should consider the factors mentioned above to gain a comprehensive understanding of the interplay between ADHD traits, HRV, and autonomic functioning, and its implications for overall health and well-being.

Hypothesis 2: More ADHD traits are associated with more use of suppression and less use of cognitive reappraisal.

This study investigated the association between ADHD traits and emotion regulation strategies, specifically suppression and cognitive reappraisal. Contrary to the hypothesis, the

correlation analysis revealed a small negative association between ADHD traits and suppression (τ = -.03), but this association was not statistically significant (p = .616). Although previous research suggested that individuals with ADHD report using suppression more frequently than cognitive reappraisal (Liu et al., 2022), the results of this study show that as the self-reported amount of ADHD traits increased, self-reported use of suppression decreased.

It is possible that my findings diverge from previous research because of limitations related to the sample. Firstly, the sample size was rather small, and most participants reported having few symptoms. Secondly, the sample did not include individuals with clinically diagnosed ADHD and a control group for comparison. Most studies that report more use of suppression for individuals with ADHD used samples with clinically diagnosed individuals. Future research should focus on traits and symptom severity in individuals with clinically diagnosed ADHD, to further explore the relationship between ADHD and use of suppression as a regulation strategy. Moreover, it may be interesting to investigate whether there are differences in habitual strategy-usage between the subtypes of ADHD as well. Findings from studies with more representative samples are more likely to be generalizable to the ADHD population.

In contrast to the non-significant association between ADHD traits and suppression, my findings revealed a significant negative relationship between ADHD traits and cognitive reappraisal (τ = -.17). This indicates that individuals with more ADHD traits tend to use less cognitive reappraisal. However, the effect size is small to moderate, and the significance level (p = .049) indicates that this association is only marginally significant, considering that the threshold for significance is $p < .05$.

A study by Young (2005) found that the ADHD group in their sample positively reappraised stressful situations. Further, Young suggested that how people with ADHD interact is

associated with their cognitive ability, meaning they may continually assess, re-assess, compensate, and adapt.

Expressive suppression may be used by individuals with ADHD to shield themselves from criticism and negative feedback, reducing stress associated with interpersonal interactions (Shushakova et al., 2018). Hypothetically, suppression may represent a minimization of themselves (i.e., their natural expression of emotions) through minimizing the emotional output. To counteract the negative consequences of suppression, they may engage in retrospective- or subsequent reappraisal. Subsequent reappraisal of a negative emotional experience may help reinterpret the experience positively (Uusberg et al., 2019).

Despite its potential drawbacks, such as effort expenditure and frustration, the sequence of suppression followed by reappraisal may represent a flexible use of strategies to reduce stress in overwhelming (i.e., high emotional intensity) emotional experiences (Shushakova et al., 2018). Thus, people with ADHD, or ADHD traits, may engage in this sequential type of regulation to self-regulate; first decreasing the arousal level by suppression, and reducing negative effects of suppression by reappraising when they no longer perceive the situation as threatening or stressful.

Future research should explore this idea, and consider utilizing HRV measurements to examine physiological aspects of regulated emotional responding (Appelhans & Luecken, 2006); e.g., during tasks where participants are instructed to suppress and not subsequently reappraise, and compare with participants who are instructed to suppress and then reappraise.

Hypothesis 3: More ADHD traits are associated with a higher level of experienced effort and higher level of experienced frustration.

This study also examined the relationship between ADHD traits and subjective experiences of mental effort and frustration following the Emotional Stroop task. Consistent with the third hypothesis, there were significant positive associations between ADHD traits and both experienced frustration ($\tau = .20$, $p = .022$) and mental effort ($\tau = .40$, $p < .001$). I.e., individuals with more ADHD traits reported higher levels of frustration and exerting more mental effort during task performance. These findings concur with previous research and suggest that individuals with ADHD traits may perceive tasks as more mentally effortful and experience greater frustration in completing them (Bellato et al., 2020; Chong et al., 2023).

Individuals with ADHD often report being labeled as lazy, incompetent, or "not trying hard enough" by e.g., peers, teachers, parents, despite exerting the same- or more effort than the ones they´re being compared to (Beaton et al., 2022). It is likely that these individuals internalize this feedback and develop a negative self-image as a result (Beaton et al., 2020). Confirmation of the associated notion that even though they make an effort, they do not reach their goal (e.g., receiving validation, obtaining results, not being labeled as "lazy"), reinforces the negative self-image they may have developed (Newark & Stieglitz, 2010). Moreover, with these individuals being reward-driven, not receiving a reward for their effort can entail an assignment of negative valence towards effort (Chong et al., 2023). Their aversion to effort (or the decision on when it is worth it to expend effort) may be linked to how much they value both the effort itself, and the product of the effort (i.e., the reward) (Inzlicht et al., 2018). It is thus possible that this criticism may influence their willingness or motivation to exert effort in similar situations in the future.

Future research could shed light on this by including questionnaires or tasks in their studies that measure the willingness to exert effort, as well as further exploring the nature of motivational forces driving effort-based decision-making. In the context of ADHD, it could also be particularly interesting to examine physiological and cognitive measures of stress and arousal in comparison to healthy controls.

Strengths and limitations of the current study

In addition to the strengths and limitations already discussed regarding the sample and measurement of HRV, there are a few more general strengths and limitations worth discussing.

Sample

The final sample consisted of 55 participants. The age-range was 20 to 42 years, with a mean age of 24.7. This can be considered a strength because the aim of this study was to examine adults; and as the sample mainly consist of young adults, they represent a distinct age-group. Another strength is the gender distribution, with 53% females and 47% men. Differences related to neither age nor gender were of relevance for my objectives, but I will encourage future research to explore this further.

A possible limitation of this study is that we did not account for potential variations in how people from different cultures and religions regulate emotions. It could be interesting for future studies to include more demographic information on participants, and explore how such differences (e.g., culture or religion) may influence various aspects of emotion regulation.

Out of the 55 participants, data analysis of ASRS score included 52 participants, the mean score being 6.4, with scores ranging from 0 to 18. This study did not use a sample of individuals

with clinically diagnosed ADHD, which can be considered both a limitation and a strength. On one hand, it could be a strength because it allows for examining a more diverse sample, and thereby it may function as a pilot study on the subject. On the other hand, most participants reported few symptoms, and larger or different samples may be more representative or informative.

Future studies should consider including a sample of individuals who have been clinically diagnosed with ADHD and a healthy control group, to further investigate the relationship between ADHD traits, emotion regulation, effort, and stress. Such studies may have the potential to further illuminate the complex relationship, as well as the underlying mechanisms contributing to the processes of emotion regulation in the context of ADHD. Future studies are also encouraged to measure ADHD traits, symptom severity, and symptom presentation in individuals who have a clinical diagnosis of ADHD. This allows for a more thorough examination of the specific contributions of the individual traits. Doing so in a clinically diagnosed sample may increase the ecological validity by assuring that the sample inherently have more ADHD traits. It also opens for the possibility to distinguish between the different traits and their individual relationships with various aspects of emotion regulation, effort, and stress.

Methodology & study design

Regarding methodology and study design, there are both strengths and limitations. In this study, the analyses relied heavily on data from self-report questionnaires. Self-reported answers can be unreliable seeing as participants may have certain biases or may not want to be honest – despite anonymity. Additionally, it is difficult to quantify a subjective experience, such as mental effort or frustration. Future studies should therefore keep this in mind, and consider

choosing a different design (e.g., interviews to capture the essence of the participants´ experiences, or a mix of self-report and interviews).

Data collection and analysis

Regarding data collection, I wish to emphasize that having different testers administering the experiment may influence the study both positively and negatively. One of the testers present during the experiment was usually someone the participants knew - or knew of. This could, on one hand, help the participant feel calmer during the process. On the other hand, this could also affect the experiment in ways we cannot be certain about. Measures were taken to counteract possible effects of this; for example, all data was anonymized, and the supervisors were the ones that reviewed the data prior to analyses.

Reliability, validity, and generalizability

To the best of my knowledge, the data was reliable, and I measured what I set out to measure quite well. As for validity, because of a thorough plan for data collection and analysis - from the pre-registration to the results - I was able to measure what I thought I measured. The data was valid for the objectives of the research question. It is important to note that the results of this study can in no way claim causality, the statistical tests can only indicate whether there is a correlational relationship between the dimensions measured. Additionally, this study uses only the total score of the ASRS-questionnaire (i.e., measure of overall symptom experience/burden), and does not distinguish between the three subtypes or core symptoms in the data used for the analysis. Therefore, any results will not qualify for special inferences (neither correlational, nor

causational) regarding whether - or which – symptom/trait is responsible for the relationships between ADHD traits and the other variables.

Conclusion

In summary, there is a relationship between ADHD traits and emotion regulation, effort, and stress. The correlations were mostly weak to moderate, except for the moderate to strong association between ADHD traits and mental effort. My findings generally support previous research in the notion that having more ADHD traits may entail difficulties with emotion regulation; and additionally, that more ADHD traits may entail subjectively experiencing tasks as more effortful. Alternative explanations, strengths, and limitations, as well as implications for further research has been discussed. Although this study contributes to expanding the knowledge about ADHD traits and emotion regulation, more research is needed to explore the nuances of the relationship – both in clinical and non-clinical samples.

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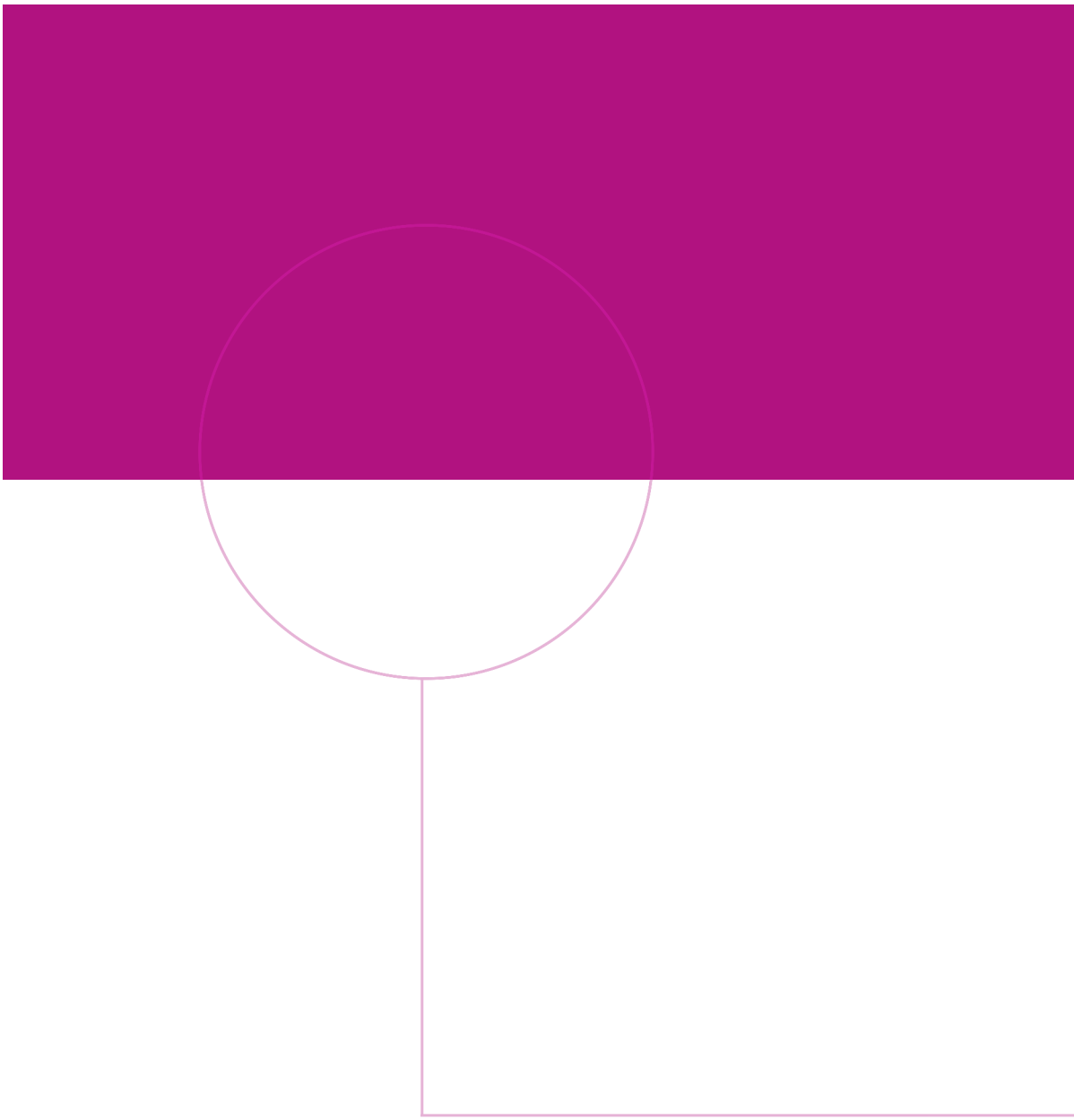

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