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Executive Functions and Adult ADHD, an Experimental Study

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Abstract

The symptoms of ADHD show differently in students compared to children when the demands of life change. At date the diagnosis of ADHD is developed for children and a more accurate diagnosis for adults might be necessary. The goal of the present study is to get more insight into the underlying factors of the symptoms of ADHD that could aid the development of a new diagnosis. To test the relationship between executive functions and ADHD symptoms two questionnaires, the CAARS and the EFI, were used with a sample of 394 participants. A GO/NO-GO task with event-rate manipulation is used to test the State Regulation Model of ADHD. The model proposes that the underlying factor of ADHD is motivation. The task has two conditions a fast event-rate and a slow event-rate, that way the GO/NO-GO task can be used to measure motivation. The conditions separately can measure impulsivity. The experiment was done with 40 participants. The results of the questionnaires show an association between executive functions and symptoms of ADHD that indicates that more ADHD symptoms are related to more problems with executive functions. With the GO/NO-GO task a partial indication is found for the State Regulation model with the mean reaction times, but not for the error-rate and the standard deviation of the mean reaction time. In other words, support is found that students with more ADHD symptoms have more problems with motivation.

Keywords: ADHD, executive functioning, GO/NO-GO task, EFI, CAARS

Executive Functions and Adult ADHD, an Experimental Study

Attention deficit/hyperactivity disorder (ADHD) is long considered a childhood disorder with a prevalence of 1-5% in children. However, 1-7% of adults are diagnosed with ADHD as well (Mulligan et al., 2011). The onset is often during childhood and in most cases, ADHD persists into adulthood (Caroll et al., 2022). Yet the current diagnosis for ADHD is originally developed for children and may not be sufficient for adults (Hechtman et al., 2011). It is important to do more research on ADHD in adults so an amended diagnosis for adults with ADHD can be developed.

ADHD diagnosis

According to the Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition Text Revision (DSM-5-TR) (American Psychiatric Association [APA], 2022) ADHD is characterized by the main symptom's inattention and/ or hyperactivity-impulsivity. To get the diagnosis of ADHD as a child you need to have six or more symptoms of at least one of the main symptoms. Adolescents and adults need at least five symptoms of one of the main symptoms to get the diagnosis. Other criteria are that the symptoms should have been present for at least six months. Several symptoms should have been present prior to the age of twelve. Several symptoms should be present in at least two settings, for example at work, with friends, at school et cetera. There should be clear evidence that the symptoms interfere with or reduce the quality of functioning in social/ academic or work-related situations, and the symptoms cannot be better explained by other mental disorders. Lastly, the symptoms should not only be present during a psychotic episode.

Executive Functions

While the DSM-5-TR describes ADHD as a disorder with inattention and/ or hyperactivity-impulsivity as the main symptoms, studies show that this explanation might not be complete for adults, an additional explanation with executive functions considered seems necessary. Executive functions are skills for intentional and goal-directed behavior. They can be defined on two levels, on the behavioral level and on the cognitive level. There is no congruence yet on the definition of executive functions categories on the behavior level yet (Alaghband-rad et al., 2021), but for the present study the five domains of EF defined in The Executive Function Index Scale (EFI), a questionnaire designed to measure the executive functions in daily life context, will be used. The five domains measured by the EFI are firstly motivational drive (MD) which measures behavioral drive, activity level and interest in novelty, secondly organizational skills which measure for example the ability to keep things in mind, multitask and sequence, thirdly impulse control which measures self-inhibition and social conduct and risk behavior, fourthly empathy which measures for example the concern someone has for others wellbeing and lastly strategic planning which measures for example thinking ahead, planning and the tendency to use strategies (Mohamed et al., 2020). Students with ADHD encounter problems with these executive functions. They don’t perform as well in school as their peers. These problems often don’t show or show less than before attending university. The reason for this might be because universities expect students to independently manage activities that require organizational skills and engaging in goal directed behavior. For example, students should stay on schedule, plan for exams, prioritize tasks and should have good time management. This behavior was not expected on this level before university (Mohamed et al., 2020). Consequently, students with ADHD have remarkably lower grades than their non-ADHD peers and have a lower chance of graduating (Dvorsky & Langberg, 2019). What this suggests is that the symptoms of ADHD show differently when people grow older, leave primary - and high school and attend university. In this study we will investigate EF in students with ADHD symptoms, to get a better insight if an amended diagnosis is needed. The focus lies on students because not enough research is done on the relation between EF and students with ADHD. Especially the higher-level cognitive processes of EF in ADHD students of which Dvorsky and Langberg (2019) even reported that prior to their study no research was done. Related to this is that the current diagnoses of ADHD, based on the DSM-5-TR is related to the behavioral problems that individuals with the diagnosis often encounter, but it is not clear what causes these symptoms. Studies on the cognitive processes of the executive functions might give us more insight into the underlying ADHD problem, which is important because at date most treatments for ADHD are based on the DSM diagnosis (Carroll et al., 2023). Of those treatments medication is the most effective treatment, but unfortunately 10-20% of patients do not respond to medication. Meta-analyses show that most other treatments without medication are even more limited in effect sizes (Buitelaar et al., 2022), and that confirms the need for more research on the underlying cognitive processes of executive functions.

On the cognitive level, three core executive functions are defined; inhibition, updating and shifting (Rodríguez-Nieto et al., 2022). Inhibition refers to the ability to regulate attention, behavior, thoughts, and/or emotions to overcome strong internal drives or external temptations, and instead take actions that are more appropriate or necessary (Coutinho et al., 2018). Updating refers to the ability to 'update' the working memory and shifting is the ability to be flexible in shifting cognitive states (Rodríguez-Nieto et al., 2022). Of these three core EF, the present study will solely focus on Inhibition.

Inhibition and Self-regulation theory

Barley (1997a) proposed the behavioral inhibition theory to explain the underlying factors of the main ADHD symptoms. His theory suggests that ADHD is mainly an inhibitory control deficit, related by impairments in the inhibitory system in the brain. This system includes the pre-frontal cortex, basal ganglia and other related brain structures. The problems in the system lead to problems in inhibitory control, which can be seen in several domains, including attentional control (inattention), behavioral control (impulsiveness), and problems with controlling emotions. Barkley (1997b) later proposed the self-regulation theory to expand on to the behavioral inhibition theory. In this theory, he includes other aspects of executive function as well. The theory proposes that next to problems in inhibition, ADHD is also characterized by difficulties in self-regulation. Barkley explains that problems in working memory, emotional regulation and motivation are because ADHD might be a self-regulation deficit disorder. Problems in working memory means that people with the disorder might have difficulties with holding and manipulating information and this can cause difficulties in following instructions, problem-solving and planning. Furthermore, emotional dysregulation refers to problems with emotional reactivity, impulsivity and adapting to emotional contexts. Lastly motivation explains that individuals with ADHD have problems with maintaining focus, task initiation and persistence, especially when the tasks are not immediately rewarding, problems with sustaining effort and consequently difficulties with, for example, goal-setting and future planning.

State-regulation model

In contrast to Barkley's theory that response inhibition deficit is the underlying factor of ADHD, the state-regulation model (See Figure 1A, Appendix A) proposes that ADHD might rather be characterized by problems with motivation. This model was developed by researchers who found that presentation rate, noise and motive may influence the psychophysiological state, increasing or decreasing the EF quality of people who were tested with GO/NO-GO tasks. The model explains that state control is a top-down skill whereby energy allocation is used to prevent an unwanted performance by changing their current state (non-optimal state) into the new state (target state). To make this change, a strategic decision is to be made when the current state is not optimal. Individuals may decide to invest energy to change their state to perform well or choose to change the criterium of the optimal response time (RT) and therefore accept a worse performance and this decision is about motivation. Motivation involves a motivation system (or effort system) in the brain. This system has control over two mechanisms: arousal and activation. Arousal is defined as a physiological response to input that works bottom-up and is time-locked and phasic. The arousal mechanism is the "what is it" reaction to input. The activation mechanism is the "what is to be done" reaction to input. This mechanism works bottom-up as well, but it is in contrast long-lasting and tonic. The arousal system in the brain involves the neurotransmitters serotonin and noradrenaline and the activation system involves the neurotransmitter dopamine (Van der Meere et al., 2010).

GO/NO-GO Task

The state regulation model as described above can be tested with a GO/NO-GO task with event-rate manipulation with a fast and a slow condition. When the presentation rate of the stimuli in a GO/NO-GO task increase, the activation level may increase to over-activation and when the presentation rate is slow there might be under-activation. In the fast condition, extra effort is needed to reduce the activation level and in the slow condition, the extra effort is needed to increase the activation level. If people with ADHD have problems with this effort-allocation, over-activation might explain impulsive and hyperactive behavior and under-activation might explain inattentiveness (Van der Meere et al., 2010).

Goal of study

The goal of the present study is to get more insight into the relationship between EF and ADHD in students, where the focus will be on motivation and inhibition. I will test if motivation may explain ADHD better than problems with inhibition. I will do this with a GO/NO-GO task with a high event rate condition and a slow event rate condition and I will compare the performance on the task with scores on two questionnaires: the EFI and the CAARS. I will use the EFI to measure executive functioning in students and I will use the CAARS to measure ADHD symptoms. Through event-rate manipulation a GO/NO-GO task is meant to measure motivation.

The first two questions are about the association between executive functions and ADHD symptoms. The first question is whether an association between executive functions and ADHD in students can be found. A strong association between problems with executive functions and ADHD is within the current body of knowledge (Barkley, 1997; van der Meere et al., 2005). Leading to the first hypothesis; the total score of the EFI and the CAARS are statistically significant negatively correlated, meaning that people with high ADHD symptoms have worse executive functioning. The second question is whether the specific executive functions motivational drive and impulse control are associated with ADHD. Contrasting knowledge on the underlying problems of ADHD, inhibition or motivation, have led to this question (Barkley, 1997; van der Meere et al., 2005). The expectation is that motivational drive will have a statistically significant negative correlation with ADHD symptoms, and Impulse Control will correlate negatively less strong with ADHD symptoms.

The third question is whether the cognitive functions of motivation and inhibition measured by the GO/NO-GO task are associated with the level of ADHD symptoms. Based on current studies on the State Regulation Model of ADHD, the expectation is that the GNG-task with event-rate manipulation will show that people with high ADHD symptoms have problems with effort-allocation (Van der Meere et al., 2005). To test this, the participants who did the task were split into the high group (having more symptoms) and the low group (having less symptoms). Based on the current studies (Van der Meere et al., 2005) is expected that students with more ADHD symptoms will have problems with motivation and thus will have slower response times in the slow condition and additionally may have faster response times in the fast condition, compared to students with less ADHD symptoms (hypothesis 3A), furthermore that students with more ADHD symptoms will show less variability in the fast condition and more variability in the slow condition compared to students with less ADHD symptoms (hypothesis 3B) and that students with more ADHD symptoms will make more errors on the fast condition of the go/no-go task compared to students with less ADHD symptoms (hypothesis 3C).

Lastly, the fourth question is whether motivation and inhibition as measured by the task performance task is associated with self-reports of the questionnaires. Based on the State Regulation model (Van der meere et al., 2005) it is expected that more ADHD symptoms are related to more problems with motivation, meaning that the expectation is that the differentiation scores between the fast and the slow event rate condition of the MRT and the percentages of errors are related to the self-report score of ADHD symptoms.

Methods

Participants

The subjects in the study represent a convenience sample gathered predominantly via a portal called SONA, which serves as a site where psychology students earn credits for a practical course. The SONA portal contains approximately 700 subjects. Regarding conditions, all subjects had to be university students between the age of 17-31. The pool of participants consisted of 394 students with an average age of 20 (M = 20.14, SD = 2.12). In terms of sex, 296 were natal females (75.1%) and 98 natal males (24.9%), and 22 subjects have been officially diagnosed with ADHD.

The experimental part of the study consisted of participants who completed the questionnaires and were invited via the SONA portal (n = 32) and participants who were acquaintances of the researchers and met the criteria mentioned above (n = 17). The final sample size consisted of 40 participants of ages 18 to 27 (M = 21.90, SD = 2.307). A total of 20 natal males (50%) and 20 natal females (50%) participated. Six participants reported having an official ADHD diagnosis. Written consent was provided by all participants. It is important to mention that at first, participants scoring either low or high on the questionnaires were selected. However, because only a limited number of participants took part, the decision was made to invite everybody from the SONA pool who participated in the questionnaire's study. Furthermore, the study has been approved by the Ethical Committee of Psychology at the University of Groningen. Lastly, participants were split into groups based on their T score on the ADHD Index scale of the CAARS, as a criterion a T score of 60 was used, as scoring higher than 60 in CAARS could require clinical attention (Vizgaitis et al., 2023). Participants with an ADHD index score of 60 or higher were assigned to the High ADHD group, while participants with an ADHD index score lower than 60 were assigned to the Low ADHD group.

Research Materials

Conners' Adult ADHD Rating Scales–Self-Report: Long Version

The Conners' Adult ADHD Rating Scales–Self-Report: Long Version (CAARS-S:L) is a self-report structured measurement of ADHD symptomatology in an adult population (Conners et al., 1999). The test is oriented towards patients with suspected ADHD or related issues. The CAARS test has been developed by Keith Conners (Conners et al., 2002). The test exists in two variants- long and short, but for this study, we used the long version. Both versions of the test are considered to be reliable and cross-culturally valid measures of ADHD symptoms in adults (Christiansen et al., 2020). The test is suitable for assessing individuals' current functioning. Therefore, it does not include items questioning childhood onset of symptoms, which are necessary for a diagnosis and overall understanding of ADHD symptomatology within an individual (Conners, 2002).

CAARS-S:L is composed of 8 subscales. These subscales are Inattention/Memory Problems, Hyperactivity/Restlessness, Impulsivity/Emotional Lability, Problems with Self-Concept, DSM-5: Inattentive Symptoms, DSM-5: Hyperactive-Impulsive Symptoms, DSM-5: Symptoms Total, which together contain 66 questions. Part of the scale are also specific items, which can identify individuals who are at risk for having ADHD diagnosis. These specific items together create the ADHD Index subscale. All of the questions are organized on a Likert scale, ranging from option 0- 'Not at all, Never' to 3- 'Very much, Very frequently'. For this study, T-scores of each of all of the above-mentioned subscales and T-score of the overall score have been calculated. Overall score indicates levels of ADHD symptoms. In this case, high score indicates higher levels of ADHD symptoms, and low score indicates low levels of ADHD symptoms (Conners et al., 2002). The scale that was used for the analysis is the T-score of the ADHD Index scale.

The Executive Functioning Scale

The Executive Functioning Scale (EFI) is a self-report structured measurement scale of executive functioning oriented at a non-clinical adult population, originally made for college students (Spinella, 2005). This scale is deemed to be highly reliable with found correlational support with other executive functioning tests and neuroimaging techniques. Moreover, it demonstrates good internal consistency with Cronbach's alpha ranging from .69 to .82.

EFI is composed of five subscales which are Motivational Drive (MD) Impulse Control (IC), Empathy (EM), Organization (ORG) and Strategic planning (SP). The subscales add up to 27 items further divided into questions. Questions are organized on a Likert scale ranging from option 1- 'not at all' to 5- 'very much'. Because the present study mainly tries to expand evidence for the motivation theory, its focus will lie on the results of MD and IC.

Some of the questions in the test are reversed based on the sentence structure, therefore some of the scores indicate lower instead of higher executive functioning. Reversed questions are Question 4 from Motivational Drive Subscale, all questions from Organization and Impulse Control subscales and Question 12 from Empathy subscale. The EFI Total Score is calculated as the sum score of all subscales. For all scales, higher scores represent better EF performance. The scales that are used for the analysis are Impulse Control, Motivational Drive and EFI Total.

Go/No-Go Task

Materials and Apparatus. The experiment for our project was created using the Python programming language in Open Sesame (Mathot et al., 2011). It was conducted on a computer with a 1920 x 1080 mm HP display. The experiment ran in the laboratory owned by the University of Groningen and the data was first stored in the university computer, then sent through email and finally uploaded into the safe university drive where only the researchers of this study had access to in accordance with The General Data Protection Regulation (GDPR).

Task. To give their responses, participants had to either press "B" at the Go trials or withhold their response to press "B" at the No-Go trials (Figure 1). Failure to press "B" at a Go trial is an error of omission, while pressing "B" at a No-Go trial is an error of commission. In addition, our task consisted of two conditions (event rate manipulations; ER), as measured by the inter-stimulus-interval (ISI) duration of each trial (Metin, 2013). In the fast condition, the ER was 1.2 s while in the slow condition, the ER was 7.2 s. A 2-minute mandatory break was added between the two to counterbalance fatigue or primacy effects.

The fast condition started with one practice block consisting of 6 trials, 5 Go trials and 1 No-Go trial. This was preceded by one experimental block consisting of 4 Go trials and 1 No go trials that were repeated 20 times, resulting in a total of 100 trials. The trials in each block were presented in a randomized order to decrease order effects. In the slow condition, there was one practice block and one experimental block. The practice block consisted of 5 trials, 1 Go trial and 4 No-Go trials. Proceeding this, there was one experimental block with 4 Go trials and 1 No Go trial that repeated 10 times and resulted in a total of 50 trials. As mentioned above, all trials were presented in random order to counterbalance order effects.

Trial. In the fast condition, the stimuli screen is always presented for 200 ms after a fixed ISI screen of 300 ms, and is followed by two identical screens of 700 s (350 ms each).

The trials are preceded by one practice trial consisting of one trial sequence. In the slow condition, every trial starts with a fixed ISI of 5000 ms before the stimulus is presented. The stimuli is presented for 200 ms, followed by two identical screens of 1000 ms each. The trials in each condition were composed of a fixed ISI, the stimuli screen of 200 ms, and two identical screens in which participants' responses on each screen are recorded. The time between each trial depends on the response of the participant. If there was a keyboard response (keyboard press "B") prior to the ending of the stimulus screen of 200 ms, the stimulus screen would end with the press.

Stimuli. All stimuli in the Impulsivity Experiment are shown against a white screen. Due to the possibility that a fixation dot would interfere with our experimental manipulations and that the stimuli will always be presented in the middle of the screen, there is no fixation dot on the screen before the start of each trial. Thus, at the beginning of each trial, a white empty screen with 32 x 32 px grid is presented, followed by the stimuli screen. For the purpose of our research, a Go/No-Go task with event-rate manipulations was used (Borger & Van Der Meere, 2000). Therefore, our experiment has two types of stimuli, an O (the Go stimuli) and a Q (the No-Go stimuli). The letters were always presented in the middle of the screen (x = 0, y = 0) and had a black color, HTML format and mono font, to contrast the white screen. Moreover, in the practice block as well as the experimental block, there were always 20% No-Go stimuli and 80% Go stimuli.

Reaction Time and Error Calculation. Reaction time was measured from the start of the stimulus until the button press. Only correct trials were considered valid reaction times. Mean reaction time and mean standard deviation were calculated of all correct responses. Correct responses shorter than 150 ms were considered as pre-emptive and were not used to calculate mean reaction time and mean standard deviation. To calculate percentage of error the number of commissions was divided by the total number of No-Go trials times 100.

Procedure

The participants filled in the questionnaires online, beginning with the CAARS-S:L and ending with the EFI. The first page of the CAARS-S:L was informational, followed by a consent page, where the participants had to agree in order to be included in this study. The next page asked for their SONA number. Then participants indicated their age, biological sex, job (if applicable), first language, diagnosis of a physical, psychiatric or neurological condition and whether they are taking medication with the option to mention which one(s). The next 4 pages contained the CAARS-S:L questionnaire where participants rated agreement to each item from 0- ‘Not at all, Never’ to 3-‘Very much, Very frequently’. The page after that asked for optional consent to process a student’s grades. There was one more page asking for the participants' student numbers and finally a page where participants could mention any comments or questions they had for the researchers.

The EFI questionnaire started with a page informing participants that they can now fill in the second questionnaire, followed by a page that asked for a consent. Then they were asked to provide their SONA number again. On the next page they filled in the EFI questionnaire, rating their agreement to each item on a scale from 1- ‘not at all’ to 5- ‘very much’. On the next page they could indicate possible comments they had.

For the experiment, we worked together with an honours bachelor thesis group who researched ADHD and inhibition. The results from the inhibition experiment will not be discussed in this paper, and we have no reason to suspect that the inhibition experiment influenced the results of the impulsivity experiment.

The participants were invited to the lab to carry out the go/no-go, which took about 15 minutes per participant, and inhibition experiment, which took about 5 minutes per participant. They sat behind a computer in a room without any distractions, where the lighting and the sounds were controlled for. Before starting the experiment, the participants had to read the information sheet about our experiment and sign a consent form (see Appendix A). After the consent form was signed, the participants were instructed to fill in their personal number at the beginning of the experiment. Furthermore, in order to counterbalance fatigue or primacy effects the participants started with either the inhibition task or the go/no-go task, decided with a randomly generated number between 1 and 2.

For the go/no-go task, the participants were first presented with a welcome screen, which is followed by a brief informed consent screen in which they have the possibility to opt not to participate. Next, an instruction screen appeared, where the participants were informed that either an ‘O’ or a ‘Q’ would appear on screen. Whenever the participant saw an ‘O’, they had to press the ‘B’ key. When a ‘Q’ appeared, they had to withhold their response. The main goal of the task was to react as fast and as accurately as possible. Following that, the participants were directed to the practice block to become acquainted with the task. Afterwards, the participants were notified that the practice block ended and that the main experiment would begin, as well as reminded of the instructions. For the purposes of our experiment, the participants received no feedback once the practice and experimental blocks were completed. When the participant finished both experiments, they were asked about their experiences, and could leave. The experimenter would then send the questionnaires to the participant, depending on if the participant had already filled them out or not.

Data analysis

Questionnaires

For the CAARS the T-scores of the scales were calculated, and for the EFI we created sum scores per subscale and the EFI Total Score (the sum of all subscale scores). For analyzing the questionnaires, we used the T-scores of the ADHD Index (ADHD symptoms) and the DSM Total (ADHD DSM symptoms) from the CAARS and the sum scores of the Impulse Control (IC) and Motivational Drive (MD) scales, plus the Total score from the EFI (executive functions). The statistical software platform called SPSS (version 28) was used for doing the analysis.

Determining the distribution of the variables (T-scores of ADHD Index and DSM Total, and subscales IC, MD and EFI Total) is important for choosing the appropriate test. Therefore, the assumption of normality has been tested using the Shapiro-Wilk test. According to the test, as seen in Table B1 (see Appendix B), the distribution of all analyzed variables significantly deviated from a normal distribution ($p > .01$). To test the linearity, the Normal Q-Q plots were inspected (Figure B1 to B5, see Appendix B) of all analyzed variables and it was concluded that all variables are approximately linear.

Since the data is not normally distributed, non-parametric tests are used to test the relations between the variables. Therefore, hypothesis 1 and 2, whether there is a negative relationship of ADHD symptoms with (1) the total executive functions and with (2) specifically the IC and MD EFI scales is tested through a Spearman correlation. For all correlations tested the number of data points was 394.

Go/No-Go Task

The experiment has a mixed design with one between subject factor (i.e., ADHD Group: High ADHD group and Low ADHD group) and one within subject factor (i.e, event rate [ER]: fast event-rate and slow event rate). Thus, each participant with either high or low levels of ADHD was exposed to both the fast and the slow condition, which represent levels of the independent variable; event-rate. In the impulsivity task, responses to the No-Go stimulus (letter Q) were considered errors of commission (EOCs) while not responding to the Go stimulus (letter O) was considered an error of omission (EOO). Moreover, reaction times (RTs) in milliseconds were measured after each screen excluding the fixed ISI prior to the beginning of each trial. Accuracy was also measured for each screen by the percentage of correct answers (correct = 1) to wrong answers (correct = 0). In total, there were three variables for the performance (percentages error [perc_error], mean reaction time for correct answers [mrt_correct], and the standard deviation of the reaction time for correct answers [sd_rt_correct]); all three variables were calculated per condition (fast and slow event rate) and per group (High and Low ADHD group). In addition, difference scores (between fast and slow event rate) were calculated for RT, SD of RT and Accuracy per Group.

For the third hypothesis about the task performance of the High and Low ADHD group, the main statistic used will be repeated measures ANOVA. The Shapiro-Wilk test has been used for checking the normality assumption. All variables except two (low ADHD group for both perc_errors_fast ($W(40) = .916$, $p = .004$) and perc_errors_slow ($W(40) = .906$, $p = .029$) showed non-significant results, meaning that they had a normal distribution (see table 3B in Appendix B for all Shapiro-Wilk test results). For the homogeneity of variance, we used Levene's test. We only tested mrt_correct and perc_error for homogeneity of variance, because sd_rt_correct is already a measure of variance. Both mrt_correct_fast and mrt_correct_slow had non-significant results ($F(1,38) = .064$, $p = .802$ and $F(1,38) = .282$, $p = .589$, respectively). These non-significant results were also seen for perc_error_fast and perc_error_slow ($F(1,38) = 1.971$, $p = .168$ and $F(1,38) = .352$, $p = .557$, respectively). This indicated that the variances are homogeneous.

For the fourth hypothesis about the association between the task performance (difference scores) and the questionnaires (ADHD index of the CAARS, IC and MD of the EFI) correlations are tested. Because the variables of the questionnaires are not normally distributed (see the above paragraph Questionnaires) the non-parametric Spearman correlation test was used.

Results

Questionnaires

Descriptive Statistics

The questionnaires total scores and subscales that were used for hypotheses 1 and 2 have the following means and standard deviations: CAARS ADHD Index, $M = 56.56$ and $SD = 12.41$; EFI Total, $M = 92.92$ and $SD = 10.75$; Impulse Control (IC), $M = 16.34$ and $SD = 3.57$; Motivational Drive, $M = 14.92$ and $SD = 3.25$.

The association between Executive Functions and ADHD Symptoms

To test the first hypothesis "the total score of the EFI and the CAARS are statistically significant negatively correlated" and the second hypothesis "Motivational drive will have a statistically significant negative correlation with ADHD symptoms, and Impulse Control will correlate negatively less strong with ADHD symptoms".

The correlations between the total score of the EFI, the EFI subscales MD and IC, and the ADHD index scale of the CAARS were measured. The data displayed in Table 2 depict the correlations that indicate the relationship of multiple subscales plus the overall score of the EFI in relation to the results of the ADHD index of the CAARS. The correlation between the total score of the EFI and the ADHD index of the CAARS is correlated statistically negatively moderate ($r = -.49$, $p < .001$). This indicates that more ADHD symptoms relate to worse overall EF, this is in line with the first hypothesis. The impulse control (IC) subscale showed a moderate negative correlation with the ADHD index scale ($r = -.35$, $p < .001$), however the motivational drive (MD) was not statistically significantly correlated with the ADHD index scale ($r = -.014$, $p = .782$).

With these results only part of the second hypothesis is confirmed. This indicates that the ADHD level of a person is not related to motivational drive. The IC and MD subscales were found to have a weak statistically significant negative correlation ($r = -.13$, $p < .001$), indicating that lower IC scores were associated with higher MD scores, and vice versa. Furthermore, IC displayed a moderate correlation with the overall EFI score ($r = .60$, $p < .001$) and MD was found to have a weak correlation with the overall EFI score ($r = .25$, $p < .001$). Both subscales are associated with a lower overall EFI score.

Table 1

Correlations

Variable	CAARS_TscoreADHDIndex	EFI_total	IC	MD
1. CAARS_TscoreADHDIndex	-			
2. EFI_total	-.489**	-		
3. IC	-.353**	.602**	-	
4. MD	-.014	.253**	-.130**	-

**Correlation is significant at the .01 level (2-tailed).

Note. CAARS_TscoreADHDIndex = Conner's Adult ADHD Rating Scale- T-score of ADHD index subscale; EFI = Executive Function Index Scale; IC = Impulse Control- subscale of EFI; MD = Motivational Drive -subscale of EFI

Experiment

Descriptive statistics

The means and standard deviations from the six variables of the GO/ NO-GO task are; mrt_correct_fast, $M = 313.31$ and $SD = 28.46$; mrt_correct_slow, $M = 403.27$ and $SD = 45.73$; rt_sd_correct_fast, $M = 65.04$ and $SD = 19.91$; rt_sd_correct_slow, $M = 84.90$ and $SD = 28.69$; perc_error_fast, $M = 31.87$ and $SD = 18.83$; perc_error_slow $M = 24.50$ and $SD = 19.47$.

Task Validation

The validation of the test was tested using the hypothesis "there is a significant difference in errors and reaction times between the fast and the slow condition." For the validation, I checked the main effects of the event-rate for the MRT, SD of the MRT, and the error percentages to check the difference between the event rate conditions without taking the group level into account. The task was found to be valid as all variables had a significant main effect of Event Rate (mrt_correct: $F(1,38) = 236.4$, $p < .001$, $\eta_p^2 = .862$; sd_mrt_correct: $F(1.38) = 23.52$, $p < .001$, $\eta_p^2 = .382$; perc_error: $F(1.38) = 7.531$, $p = .009$, $\eta_p^2 = .165$). This means that the response times were slower and more variable and that more errors were made in the slow condition compared to the fast condition.

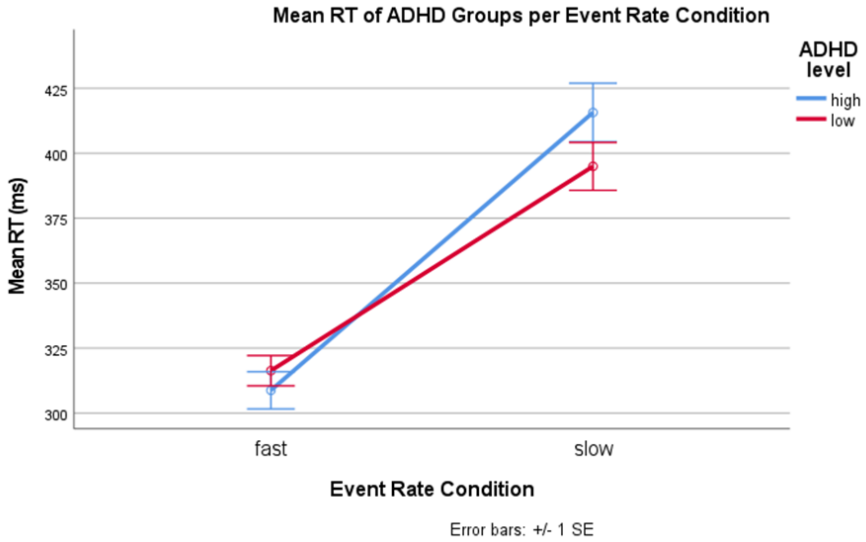
Then I checked the normality with the Shapiro-Wilk Test of Normality and MRT and the SD of the MRT were found to be normally distributed, but the percentages of errors were not (Table B3, Appendix B). A mixed ANOVA with repeated measures, however, is robust against non-normality when the sphericity assumption is met (Blanca et al., 2023). The assumption is met for the present study as shown in Table B7,
Table B8 and Table B9 (See Appendix B), so a mixed ANOVA with repeated measures, could be done for all variables.

The Effect of ADHD symptoms on the Mean Reaction Times

For hypothesis 3A "Students scoring high on ADHD symptoms will have slower response times in the slow condition and additionally may have faster response times in the fast condition, compared to students scoring low on ADHD symptoms", A mixed ANOVA with repeated measures is done to test the hypothesis. The ANOVA showed a significant main effect of Event Rate (F(1,38) = 236.4, $p < .001$, $\eta_p^2 = .862$). This means that both groups had faster reaction times in the fast condition compared to the slow condition. The main effect of both ADHD groups was not found to be significant (F(1,38) = .386, $p = .538$, $\eta_p^2 = .010$). This indicates that the ADHD groups do not differ from each other with the mean reaction times, when both conditions are taken into account. Furthermore, a significant interaction effect of Group by Event Rate for MRT, with F(1,38) = 5.496, $p = .024$, and $\eta_p^2 = .126$ was found. That means that the main effect of Event Rate can only be interpreted with the ADHD level considered and that the level of ADHD influences the reaction times. This means that the high ADHD group responded faster in the fast condition and slower in the slow condition, compared to the low ADHD group (See Figure 1). This could indicate more problems with motivation. The results are in line with hypothesis 3A.

Figure 1

Profile plot of mrt_correct

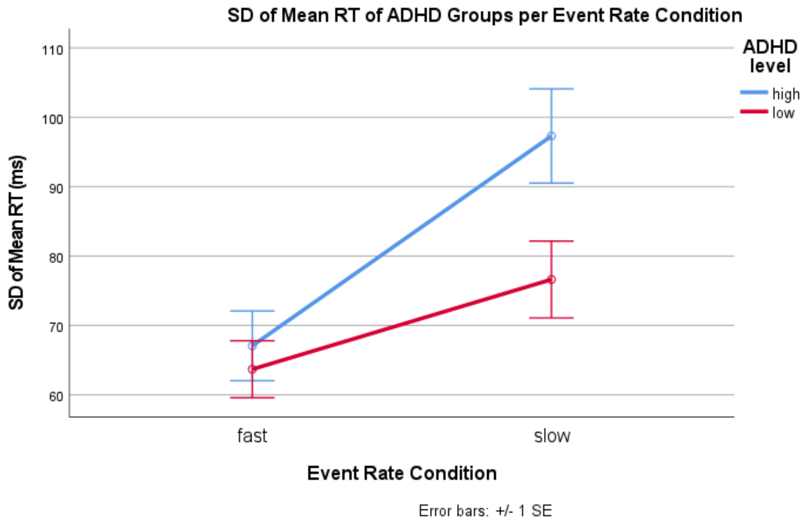


The Effect of ADHD on the Standard Deviation of the Mean Reaction Time

For hypothesis 3B "Students scoring high on ADHD symptoms will show less variability in the fast condition and more variability in the slow condition compared to students scoring low on ADHD symptoms." A significant main effect of Event Rate was found for the SD of the MRT with $F(1,38) = 23.52$, $p < .001$, and $\eta_p^2 = .382$. This means that both groups showed a greater variability in the slow condition compared to the fast condition. The main effect of both ADHD groups was not found to be significant ($F(1,38) = 3.656$, $p = .063$, $\eta_p^2 = .088$). This indicates that the ADHD groups do not differ from each other with the standard deviation of the mean reaction times, with both conditions taken into account. Furthermore, no significant interaction effect of Group by Event Rate with the SD was found; ($F(1,38) = 3.777$, $p = .059$, $\eta_p^2 = .090$), this means that the level of ADHD symptoms do not influence the variability of the mean reaction times, in other words the high ADHD group and the low ADHD group did not differ in variability per event rate condition (See Figure 2). This is not in line with the hypothesis; thus, hypothesis 3B is rejected.

Figure 2

Profile plot of sd_rt_correct

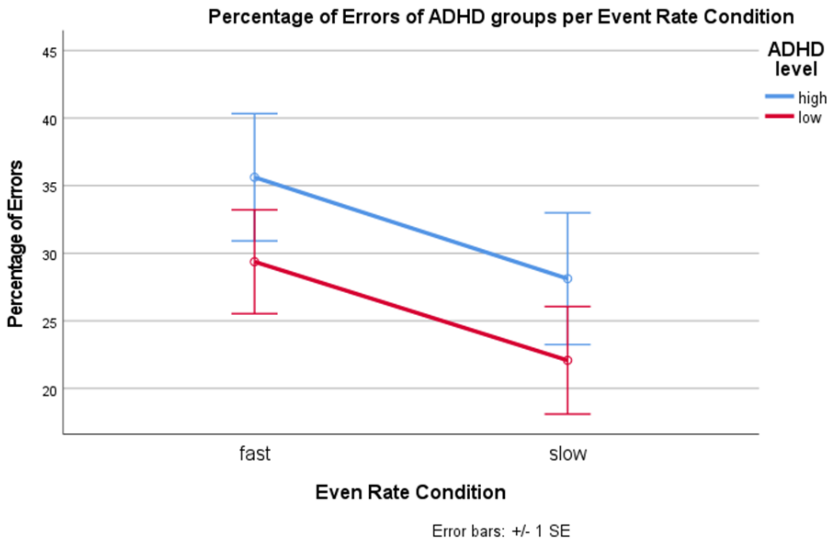


The Effect of ADHD on the Accuracy in Task Performance

For hypothesis 3C “students with more ADHD symptoms will make more errors on the fast condition of the go/no-go task compared to students with less ADHD symptoms” I found a significant main effect of Event Rate with the percentages of errors ($F(1,38) = 7.531$, $p = .009$, and $\eta_p^2 = .165$). This indicates that both groups had more EOC in the fast condition compared to the slow condition. The main effect of Group for percentages of errors was not significant ($F(1,38) = 1.219$, $p = .276$, $\eta_p^2 = .031$, meaning that the ADHD groups did not significantly differ in accuracy, with event rate not taken into account. Furthermore, there was no significant interaction effect for Group by Event Rate for the errors with ($F(1,38) = .001$, $p = .969$, $\eta_p^2 = .000$), which indicates that the level of ADHD symptoms do not influence the accuracy, in other words both groups did not differ in accuracy in the fast and in the slow condition (see Figure 3). This is not in line with hypothesis 3C; thus, the hypothesis is rejected.

Figure 3

Profile plot of perc_error



Association ADHD symptoms and task performance

Firstly, for the fourth hypothesis "the differentiation scores between the fast and the slow event rate condition of the MRT and the percentages of errors are related to the self-report score of ADHD symptoms", I used Spearman's Rho correlations with the differentiation score of the reaction times, the differentiation score of the SD of the reaction times, the differentiation score of the percentages of errors and the ADHD groups. Firstly, I compared the differentiation score of the MRT of the fast and slow conditions and the ADHD index scale of the CAARS. The correlation was not found to be significant, but it showed a tendency ($r = .299$, $p = .061$). This indicates that problems with motivation might have contributed to the performance of the task for people with more ADHD symptoms, because the more ADHD symptoms might have contributed to a bigger difference in response time of the fast condition compared to the slow condition.

Secondly, I looked at the correlation of the differentiation score of the percentages of error and the ADHD index scale of the CAARS. The correlation was not found to be significant ($r = - .037$, $p = .820$), this indicates that more ADHD symptoms are not related to a difference in the number of mistakes in the fast condition compared to the slow condition. This means that the hypothesis is not confirmed, however the tendency found in the relationship of the difference in the MRT in the fast and slow condition with ADHD index scale of the CAARS indicates that motivation might play a role.

Discussion

Questionnaires

The present study examines the relationship between ADHD symptoms and Executive Functions (EF) in students. Specifically, whether a higher level of ADHD symptoms relate to more problems with the EF. Motivational Drive (MD) and Inhibitory Control (IC) are two executive functions that were of special interest with the questionnaires, but we examined the total score of EF as well.

In line with our first hypothesis the study found a moderate relationship between the total EF score and symptoms of ADHD, meaning that students who reported a higher amount of ADHD symptoms also reported having more difficulties with executive functioning compared to their peers with less symptoms. A weak negative relationship between MD and IC was found, indicating that a better motivational drive relates to worse inhibitory control. This could mean that there are different mechanisms behind the two.

For the second hypothesis, the relationship between MD was found to be weak and negative and the relationship between symptoms of ADHD was found to be moderate and negative. This could be interpreted as that moderate support for Barkley's self-regulation and inhibition theory (1997) was found and weak support for the State Regulation theory of Van der Meere et al., (2005). This was an unexpected finding as we expected that a motivational deficit might explain ADHD symptoms better than a pure deficit in inhibitory control. A study by Sonuga-Barke (2002) has an interesting finding that might give some insight into why we found this. He investigated the idea that deficits in motivation and inhibitory control in ADHD are two independent and co-existing factors of ADHD and found evidence that the combined type of ADHD might have two distinct subtypes where in one a deficit in motivation is a characteristic and in the other a deficit in inhibitory control is a characteristic. He found that this is because ADHD can manifest in problems in two different pathways of the dopamine system in the brain. This difference in manifestation might be linked to whether the origin of ADHD is genetic or non-genetic in the diagnosed person. In the current study, we also found evidence for the idea that there might be different underlying mechanisms for IC and MD, and I found that they both negatively correlated with ADHD symptoms, which suggests they might both be related. And the stronger evidence for IC might be explained by the origin of the symptoms in the participants, but this is of course unknown but interesting for future research.

Experiment

The experimental part of the study is meant to further investigate the role of motivation and inhibition with symptomatology of ADHD in students with a GO/NO-GO task that has an event-rate manipulation. The event-rate manipulation ensures that the task measures motivation and not just impulsivity. The three variables used to test hypothesis three are the mean of the reaction times, the SD of the mean reaction times and the percentages of errors.

The results of the first variable, namely MRT showed a significant main effect of Event Rate and a significant interaction effect. The significant interaction effect by Event Rate changes the meaning of the main effect, because it cannot be interpreted without taking the ADHD levels into account. The interaction effect indicates dependance of the MRT and the ADHD level, meaning that having more or less ADHD symptoms might influence the MRT. The results of the second variable, the SD of the MRT only showed a significant main effect of Event Rate and not a significant interaction effect by Event Rate. And the results of third variable, the percentages of errors show a significant main effect by Event Rate, but not a significant interaction effect by Event Rate. All the significant results that are found in the present study have a large effect size as $\eta^2_p < .14$ is considered large (Lakens, 2013).

An explanation for the findings of the third hypothesis could be that people with ADHD have a problem with motivation, and not with impulsivity because the results indicate that people with more ADHD symptoms have different reaction times in order to prevent mistakes compared to people with less ADHD symptoms. It might be possible that this is a strategy and that problems with motivation can be compensated as well, possibly leading to more mistakes. These findings are different than the findings from the questionnaires. The explanation with the theory of Sonuga-Barke (2002) might apply here as well, since the theory suggests that motivation and inhibition could both be problems of ADHD showing in two different subtypes of the combined type of ADHD. It could be that the bigger sample used in the questionnaire consisted of people that had more problems with inhibition and that the remaining part of the sample that participated in the experiment had more problems with motivation. The findings may also be explained by the limitations of the study.

Association

The results of the fourth hypothesis indicate that the differentiation scores of the MRT and errors in the fast and slow conditions are not related to the ADHD index scale of the

CAARS. While a tendency was found for the MRT, the results are not a strong indication. To get more insight into why these results are found, I did a post-hoc analysis to see if these findings might be related to different strategies. For example, Kooistra et al. (2010) found that people with ADHD have slower reaction times and the same number of errors and Epstein et al. (2011) found that children with ADHD show great variability in MRT in GO/NO-GO tasks. This could indicate that people with ADHD might adjust their strategy, for example have slower reaction times to prevent errors, or have faster reaction times with more errors (more problems with inhibition). To test this, I looked at the association between the differentiation score of the MRT and the differentiation score of the percentages of error this association was not found to be significant, but it showed a tendency (r = .237, p = .088). This indicates that there might be a relationship between the difference in reaction times in the fast and slow condition and the percentages of error, that could indicate different strategy use. I also looked at the correlations between the MRT and the percentages of errors in the fast and slow condition and they were also not found to be significant (Fast: r = .202, p = 212; Slow r = -.131, p = .420). These results do not indicate the use of strategy. These correlations can be found in Table B10 (See Appendix B).

Limitations

The present study has a few limitations. Partly, because the study is a bachelor thesis, and this accounts for a limited amount of time, resources and knowledge. The first limitation of the study is that we investigated the EF with ADHD symptoms in students. The results of the study might be different if we used a group of participants diagnosed with ADHD and a control group that scores low on ADHD symptoms. With the present study, we cannot say anything about the relationship with ADHD, only with the symptoms score of the CAARS, and it makes the relevance of the study less strong. Furthermore, we did not specifically ask participants to report what subtype of ADHD they have, if they have a diagnosis, the subtypes might influence the results. Another limitation of the study is that we don't know if there are participants in our sample that use stimulant ADHD medication. The study of Trommer et al. (1991) shows that the use of methylphenidate improves the performance (decreases in EOC) in GO/NO-GO tasks with people diagnosed with the inattentive type of ADHD significantly, even with a small dose. Without knowing that participants scoring high on ADHD symptoms are medicated, the results may be biased because it might seem that they don't make more impulsive EOC compared to the control group, and it might also result in not finding evidence for a significant interaction effect between an event-rate manipulation and ADHD symptoms.

Future directions

To get a better understanding of the role of motivation in students with ADHD, future research could investigate the state-regulation model with students that have a diagnosis of ADHD. That way, the sample will be more representative and consequently give more insight than the present study. Based on the study of Sonuga-Barke (2002) it might also be interesting for future research to do studies with people diagnosed with the combined type of ADHD and investigate the dual-pathway model of motivation and inhibition in this ADHD type. Lastly, more research is needed on an emended diagnosis for adult ADHD, and it might be interesting for future research to investigate if some or all EF should be included in the diagnosis by comparing the current diagnosis to amended diagnosing options and find a more accurate way for adults.

Conclusion

The present study found partial support for the State Regulation model, in other words students with ADHD symptoms show problems with motivation. This support is found with the MRT variable of the GO/NO-GO task, but not with the SD of the MRT and the percentages of error. However, the results of the experiment are not in line with the results of the EFI and the ADHD index scale of the CAARS, where support for problems with Impulse Control is found.

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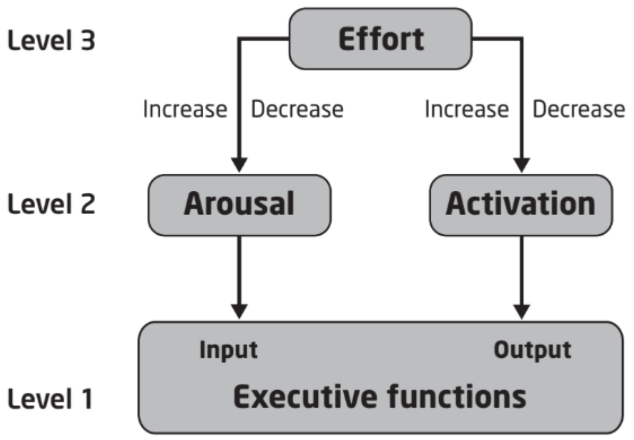
Appendix A

Figure A1



Appendix B

Table B1

Shapiro-Wilk Normality Test

Scales	Shapiro-Wilk		
	Statistic	df	Sig.
CAARS_TScoreInat	,975	394	<,001
CAARS_TScoreHyper	,973	394	<,001
CAARS_TscoreImpul	,961	394	<,001
CAARS_TscoreSelfconc	,973	394	<,001
CAARS_TscoreDSM_Inattention	,974	394	<,001
CAARS_TscoreDSM_HypImp	,948	394	<,001
CAARS_TscoreDSM_Total	,956	394	<,001
CAARS_TscoreADHDIndex	,978	394	<,001
EFI_total	,990	394	,010
SP	,990	394	,007
MD	,981	394	<,001
IC	,976	394	<,001
ORG	,987	394	,001
EM	,935	394	<,001

Table B2

Correlations

Variable	n	M	SD	1	2	3	4
1. CAARS_TscoreADHDIndex	394	52,57	10,69	-			
2. EFI_total	394	94,98	10,26	-,489**	-		
3. Impulse Control	394	16,78	3,38	-,353**	,602**	-	

Variable	n	M	SD	1	2	3	4
4. Motivational Drive	394	14,45	2,64	-,014	,253**	-,130**	-

**Correlation is significant at the 0.01 level (2-tailed).

Note: CAARS = Conner's Adult ADHD Rating Scale; EFI = Executive Function Index Scale

Figure B1

Normal Q-Q Plot of CAARS_TscoreDSM_Total

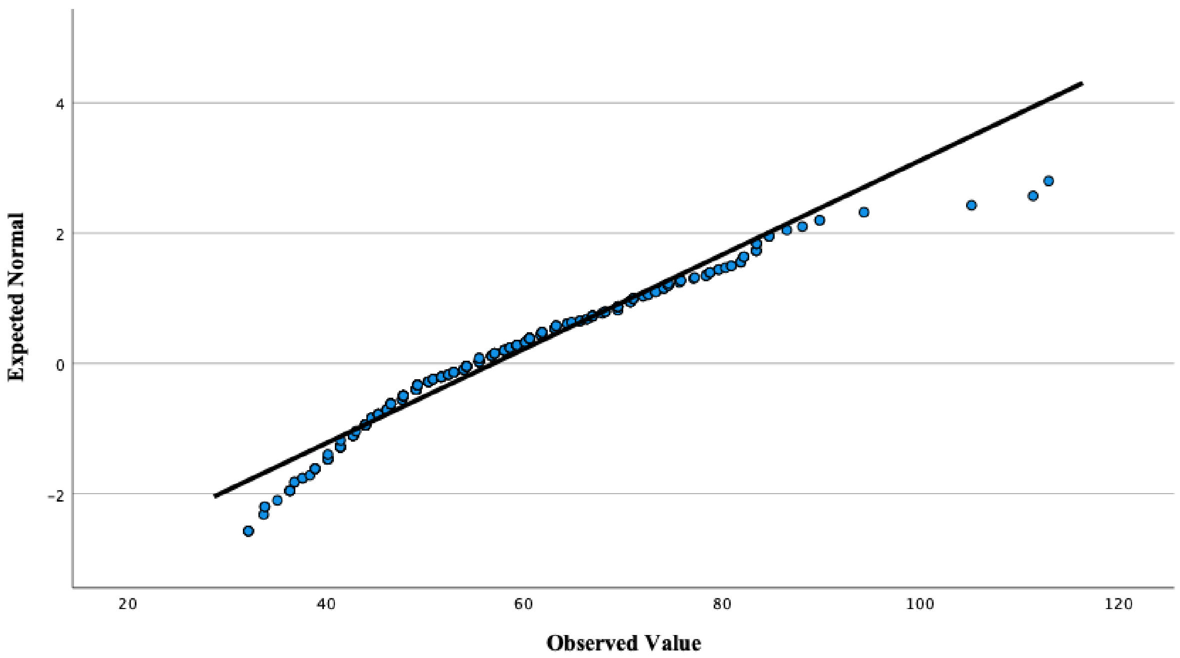


Figure B2

Normal Q-Q Plot of CAARS_TscoreADHDIndex

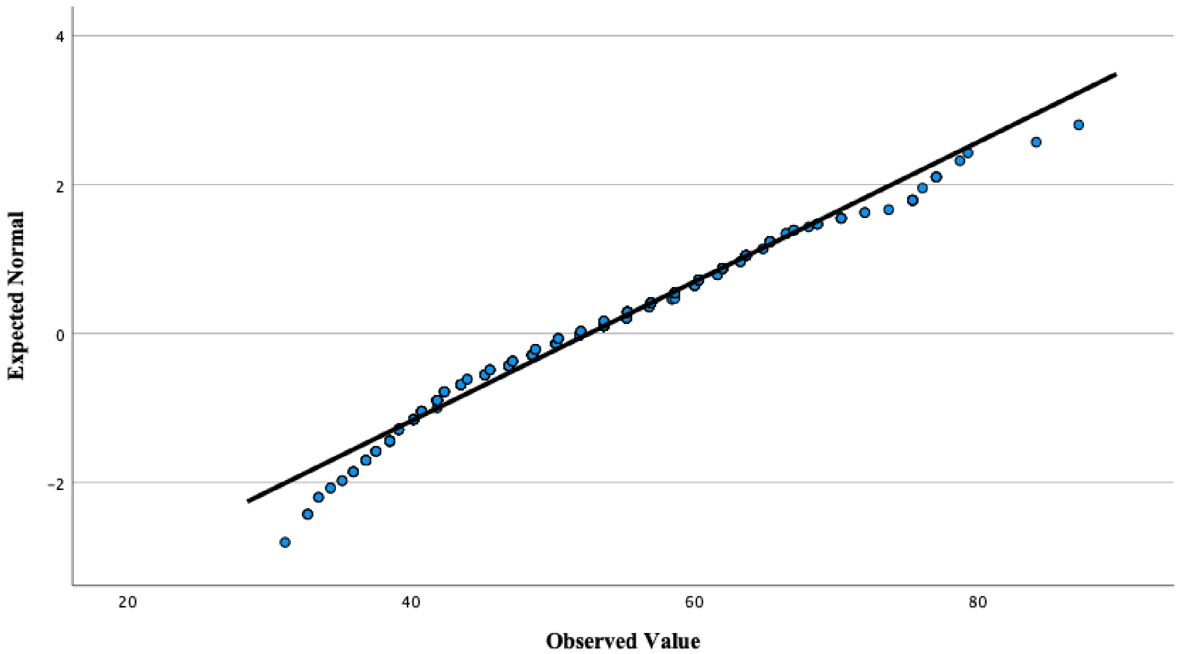


Figure B3

QQ-plot of the EFI total

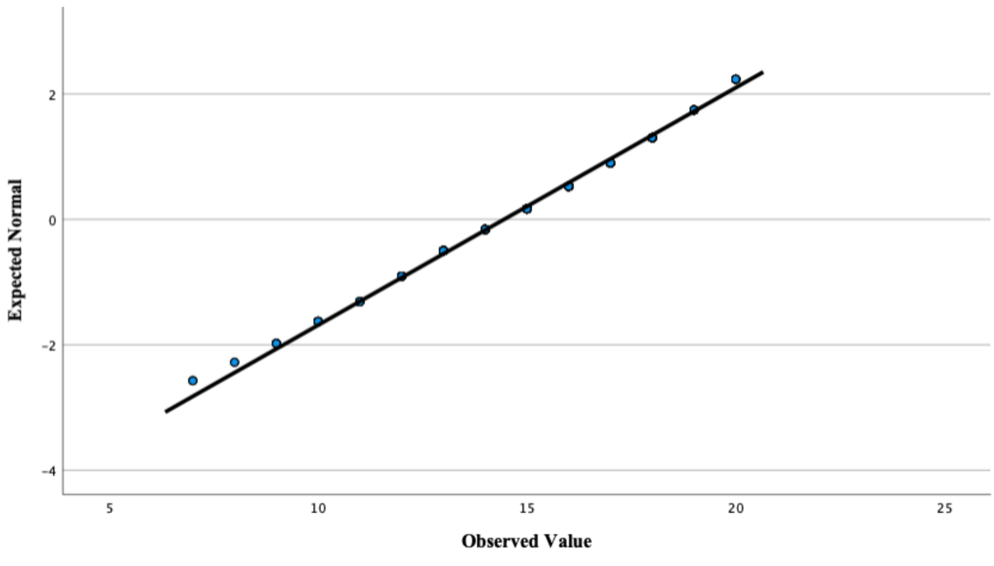


Figure B4

Normal Q-Q plot of the IC

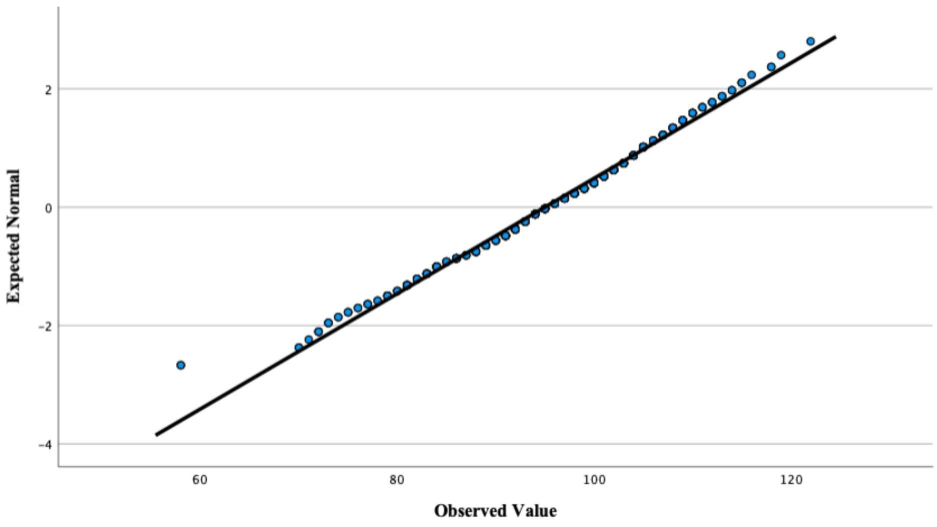


Figure B5

Normal Q-Q Plot of MD

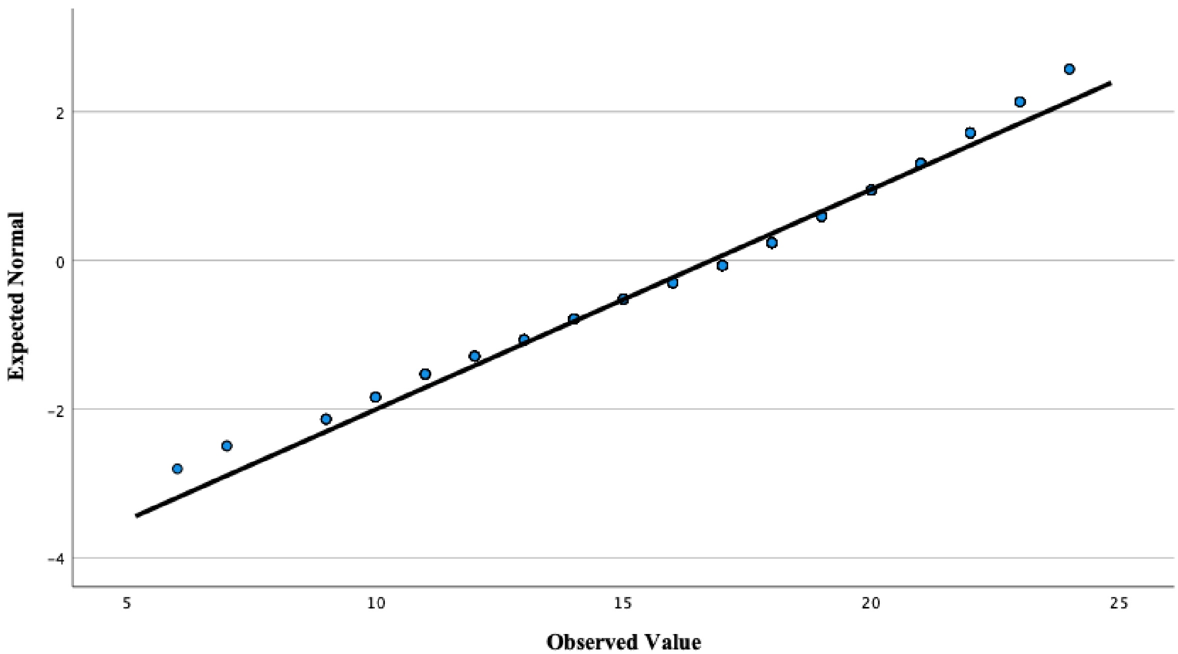


Table B3

Tests of Normality

		Shapiro-Wilk		
	ADHD_level			
mrt_fast_corr	1	,940	16	,350
	2	,941	24	,168
perc_errors_fast	1	,916	16	,148
	2	,862	24	,004
mrt_slow_corr	1	,956	16	,582
	2	,950	24	,267
perc_errors_slow	1	,917	16	,150
	2	,906	24	,029
RT_SD_corr_slow	1	,939	16	,337
	2	,983	24	,943
rt_SD_fast_correct	1	,920	16	,166
	2	,946	24	,224

Table B4

Levene's Test of Equality of Error Variances[a]

		Levene Statistic	df1	df2	Sig.
mrt_fast_corr	Based on Mean	,064	1	38	,802
	Based on Median	,048	1	38	,828
	Based on Median and with adjusted df	,048	1	38,000	,828
	Based on trimmed mean	,056	1	38	,814
mrt_slow_corr	Based on Mean	,282	1	38	,598
	Based on Median	,160	1	38	,691
	Based on Median and with adjusted df	,160	1	36,673	,692
	Based on trimmed mean	,269	1	38	,607

Note: Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]

a. Design: Intercept + ADHD_level

Within Subjects Design: event_rate

Table B5

Levene's Test of Equality of Error Variances[a]

		Levene Statistic	df1	df2	Sig.
RT_SD_corr_slow	Based on Mean	5,291	1	38	,027
	Based on Median	5,235	1	38	,028
	Based on Median and with adjusted df	5,235	1	27,621	,030
	Based on trimmed mean	5,269	1	38	,027
rt_SD_fast_correct	Based on Mean	,000	1	38	,997
	Based on Median	,015	1	38	,904
	Based on Median and with adjusted df	,015	1	37,787	,904
	Based on trimmed mean	,000	1	38	,994

Note: Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]

a. Design: Intercept + ADHD_level

Within Subjects Design: event_rate

Table B6

Levene's Test of Equality of Error Variances[a]

		Levene Statistic	df1	df2	Sig.
RT_SD_corr_slow	Based on Mean	5,291	1	38	,027
	Based on Median	5,235	1	38	,028
	Based on Median and with adjusted df	5,235	1	27,621	,030
	Based on trimmed mean	5,269	1	38	,027
rt_SD_fast_correct	Based on Mean	,000	1	38	,997
	Based on Median	,015	1	38	,904
	Based on Median and with adjusted df	,015	1	37,787	,904
	Based on trimmed mean	,000	1	38	,994

Note: Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]

a. Design: Intercept + ADHD_level

Within Subjects Design: event_rate

Table B7

Mauchly's Test of Sphericity of percentages errors

					Epsilon[b]	
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt
event_rate	1,000	,000	0	.	1,000	1,000

Mauchly's Test of Sphericity[a]

	Epsilon
Within Subjects Effect	Lower-bound
event_rate	1,000

Note: Tests the null hypothesis that the error covariance matrix of the orthonormalized

a. Design: Intercept + ADHD_level

Within Subjects Design: event_rate

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table B8

Mauchly's Test of Sphericity of MRT

					Epsilon[b]	
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt
event_rate	1,000	,000	0	.	1,000	1,000

Mauchly's Test of Sphericity[a]

	Epsilon
Within Subjects Effect	Lower-bound
event_rate	1,000

Note: Tests the null hypothesis that the error covariance matrix of the orthonormalized

a. Design: Intercept + ADHD_level

Within Subjects Design: event_rate

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table B9

Mauchly's Test of Sphericity of SD of the MRT

					Epsilon[b]	
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt
event_rate	1,000	,000	0	.	1,000	1,000

Mauchly's Test of Sphericity[a]

	Epsilon
Within Subjects Effect	Lower-bound
event_rate	1,000

Note: Tests the null hypothesis that the error covariance matrix of the orthonormalized

a. Design: Intercept + ADHD_level

Within Subjects Design: event_rate

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table B10

Correlations

			CAARS_TScoreADHDIndex	mrt_fast_corr	perc_errors_fast	mrt_slow_corr	rt_SD_fast_correct	perc_errors_slow	RT_SD_corr_slow
Spearman's rho	CAARS_TScoreADHDIndex	Correlation Coefficient	--						
		Sig. (2-tailed)	.						
		N	40						
	mrt_fast_corr	Correlation Coefficient	-,191	--					
		Sig. (2-tailed)	,237	.					
		N	40	40					
	perc_errors_fast	Correlation Coefficient	,263	-,202	--				
		Sig. (2-tailed)	,101	,212	.				
		N	40	40	40				
	mrt_slow_corr	Correlation Coefficient	,099	,424**	,191	--			
		Sig. (2-tailed)	,544	,006	,238	.			
		N	40	40	40	40			
	rt_SD_fast_correct	Correlation Coefficient	,098	,277	,677**	,445**	--		
		Sig. (2-tailed)	,548	,083	<,001	,004	.		
		N	40	40	40	40	40		
	perc_errors_slow	Correlation Coefficient	,288	-,437**	,562**	-,131	,308	--	
		Sig. (2-tailed)	,071	,005	<,001	,420	,053	.	
		N	40	40	40	40	40	40	
	RT_SD_corr_slow	Correlation Coefficient	,243	,007	,315*	,638**	,390*	,322*	--
		Sig. (2-tailed)	,130	,967	,048	<,001	,013	,043	.
		N	40	40	40	40	40	40	40

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix C

INFORMATION ABOUT THE RESEARCH

VERSION FOR PARTICIPANTS

"EXECUTIVE FUNCTIONS AND ADHD, AN EXPERIMENTAL STUDY"
PSY-2021-S0094

- **Why do I receive this information?**

You are being invited to participate in this bachelor thesis research that explores executive functioning in students scoring low or high on the symptoms of ADHD.
You are eligible to participate in this research when you have received an invitation email via the SONA-pool or when you have received a personal invitation. Also, to participate you need to be at least 18 years old.
Our research team consists of Dr. Nobert Börger, Daria Bacsin, Koen Busschers, Nidarshana Ganesan, Deniz Koerts and Nora Sippel. All members of the team are involved in data collection, analysis, retention, sharing and publication.

- **Do I have to participate in this research?**

Participation in the research is voluntary. However, your consent is needed.

Therefore, please read this information carefully.

Ask all the questions you might have in case you do not understand something. Only after these doubts are clarified to you, proceed with answering the questionnaires

If you decide **not to participate**, you do not need to explain why, and there will be no negative consequences. You have this right at all times, including after you have consented to participate in the research.

- **Why this research?**

The purpose of this research is to gain a better understanding of the role of executive functioning in adult ADHD. Specifically, we will focus on performances of two cognitive tasks measuring inhibition and motivation and on the two questionnaires, Conners' Adult ADHD Rating Scale (CAARS) and Executive Function Index (EFI).

- **What do we ask of you during the research?**

  - Before starting the research, you as a participant will be provided with necessary information about the study. Next, you will be asked for your consent to participate, and will have the liberty to make an informed decision. Your answers will and shall remain anonymous.
  - The research solely contains two cognitive tasks completed on a computer. You will first receive instructions on how to complete the first task and then be asked to complete the second task. After that, you will receive instructions for the second task

and will then be asked to complete the second task. You will also be asked to fill in some general information, like age and gender.

- In total, the study will take approximately 30 minutes (each task will take approx. 15 minutes).
- Participants that are in the first-year students SONA-pool will receive 1.5 Credits when completing the study. The participants who volunteer will receive a coffee after completing the tasks.

- **What are the consequences of participation?**

There are no negative consequences associated with the two cognitive tasks employed in this study.

- **How will we treat your data?**

Data processing will take place for educational purposes of the researchers who will use the data to write their bachelor thesis. The performance of the two cognitive tasks will be stored and shared only among the researchers involved in the project. The data stored is pseudonymised, meaning that the researchers involved can only see your SONA-number but not your name. If you wish to access, modify, or remove your personal data you can do so until 1 August 2023 by contacting the principal investigator via email (n.a.borger@rug.nl). Note that this will lead to your identification.

- **What else do you need to know?**

You may always ask questions about the research: now, during the research, and after the end of the research. You can do so by speaking with one of the researchers present right now or by emailing (d.bacsin@student.rug.nl, n.sippel@student.rug.nl, d.koerts@student.rug.nl, k.busschers@student.rug.nl, n.ganesan@student.rug.nl) one of the researchers involved.

Do you have questions/concerns about your rights as a research participant or about the conduct of the research? You may also contact the Ethics Committee of the Faculty of Behavioural and Social Sciences of the University of Groningen: ec-bss@rug.nl.

Do you have questions or concerns regarding the handling of your personal data? You may also contact the University of Groningen Data Protection Officer: privacy@rug.nl.

As a research participant, you have the right to a copy of this research information.

INFORMED CONSENT

"EXECUTIVE FUNCTIONS AND ADHD, AN EXPERIMENTAL STUDY"
PSY-2021-S0094

1. I have read the information about the research. I have had enough opportunities to ask questions about it.

☐ YES ☐ NO

2. I understand what the research is about, what is being asked of me, which consequences participation can have, how my data will be handled, and what my rights as a participant are.

☐ YES ☐ NO

3. I understand that participation in the research is voluntary. I myself choose to participate. I can stop participating at any moment. If I stop, I do not need to explain why. Stopping will have no negative consequences for me.

☐ YES ☐ NO

Below I indicate what I am consenting to.

Consent to participate in the research:
☐Yes,I consent to participate; this consent is valid until 01-08-2023
☐No, I do not consent to participate

Consent to processing my personal data:
☐Yes, I consent to the processing of my personal data as mentioned in the research information. I know that until 01-08-2023 I can ask to have my data withdrawn and erased. I can also ask for this if I decide to stop participating in the research.
☐No, I do not consent to the processing of my personal data.

The researcher declares that the participant has received extensive information about the research.

You have the right to a copy of this consent form.