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The State Regulation Theory in Students with ADHD: an Experimental Study

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Abstract

Undiagnosed adult attention deficit/hyperactivity disorder (ADHD) is a serious problem, which has not gathered a lot of attention from the general public. Recently, the role of executive functioning in ADHD has received substantial support. Executive dysfunction can significantly influence person's life, especially for students with undiagnosed ADHD, as they can suffer socially, emotionally, and academically from ADHD. For that reason, the present study investigates the link between ADHD and executive functioning (EF), with a focus on inhibition and motivation. Participants were psychology students from the Rijksuniversiteit Groningen. Participants completed the CAARS and EFI questionnaires, which measures ADHD symptomology and EF, respectively. Subsequently, they were invited to participate in a go/no-go task with a fast and slow event rate, to measure inhibition and motivation. Higher levels of ADHD were associated with worse EF; the subscale Impulse Control showed a moderate negative correlation with the ADHD Index, while Motivational Drive had a non-significant correlation with the ADHD Index. In the go/no-go task, students scoring high on the ADHD Index showed more motivational difficulties than the lower scoring group, while inhibition did not play a significant role between groups. Different reasons for these contrary results are discussed. However, it can be concluded that higher ADHD levels are linked to more EF difficulties. These results suggest that executive functioning should not be ignored when treating ADHD, and EF-focused therapies might help students overcome ADHD difficulties.

Keywords: ADHD, executive functioning, go/no-go task

The State Regulation Theory in Students with ADHD: an Experimental Study

Most people know what Attention-Deficit/Hyperactivity Disorder (ADHD) is, but do not grasp what it does to a person and his or her thoughts. The following quote from Hammerness (2008) shows how a person with ADHD might think:

> Are you paying attention? Ignore that person walking by you. Keep reading, but don't forget that you have a report to write after reading this. And, when you write the report, please spell the author's name carefully. If you must take a break (try to stick with this, it has only been a couple minutes so far!) do not misplace this book. Are you listening? Make sure you remember what time it is, and the other things you need to do today. OK, let's review, what were your instructions? The instructions were, again, to 1) pay attention; 2) don't get distracted; 3) don't forget about your report; 4) pay attention to details; 5) do not lose this book; 6) listen; and 7) be organized. Wait a minute, where are you going, sit back down! (p. 1)

ADHD is, as the name suggests, mainly a disorder of hyperactivity and an overall attention deficit (American Psychiatric Association [APA], 2022). The hyperactivity and attention deficit are easily spotted in the quote from Hammerness (2008), such as the constant distractions from future tasks and repeating of instructions just to remember them.

According to the DSM-5-TR (American Psychiatric Association [APA], 2022), there are five criteria you have to meet to get diagnosed with ADHD as an adult. The first criterion is a pattern of inattention and/or hyperactivity-impulsivity. Both inattention and hyperactivity-impulsivity have nine possible symptoms. Five of these symptoms in inattention and/or hyperactivity-impulsivity are needed for at least six months. Possible symptoms for inattention are 'often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or during other activities (…)' and 'often does not seem to listen when spoken to directly (…)'. Hyperactivity-impulsivity has possible symptoms such as 'often fidgets with or taps hands or feet or squirms in seat' and 'often unable to play or engage in leisure activities quietly'. The second criterion for ADHD specify that several symptoms in hyperactivity-impulsivity/inattention were present prior to age 12 and the third criterion demands that these symptoms are present in more than 2 situations. The fourth criterion specifies that the symptoms must interfere with the person's social, academic, or occupational life and the fifth and last criterion specifies that these symptoms are not caused by another disorder, such as schizophrenia, and are not better explained by another mental disorder, such as depression or anxiety.

Although the DSM-5-TR has clear criteria for diagnosing ADHD in both adults and children, the diagnosis is way more challenging in clinical practice. There is not one single method, test or interview that is said to be the best. There are a lot of different tests available, full clinical interviews for the patient and their friends and family have to be done, patients are screened for comorbidity, research into the history of the patient's family is done, and more. This means that there is huge variability between practitioners for diagnosing ADHD (Pettersson et al., 2018). Furthermore, only about 10-25% of adults having ADHD get diagnosed and treated sufficiently. This low percentage can be explained by the fact that symptoms of hyperactivity and impulsivity tend to diminish when people get older. Because of this, the disorder will be less obvious and might start to affect academic-, personal- or work-related areas of life. However, most undiagnosed adults do not think ADHD might be the cause for their issues, which further complicates the diagnosis (Adler et al., 2015). These problems of diagnosing ADHD are also seen by the medical professionals, as 72% of practitioners indicated it was more difficult to diagnose ADHD in adults compared to children and 75% reported that the current measures of diagnosing ADHD were either 'poor' or 'fair' in terms of quality and accuracy (Marshall et al., 2021). What further complicates the diagnosis of ADHD in adults is the fact that adults, unlike children, find ways to compensate for their symptoms, which makes ADHD in adults harder to spot (Canela et al., 2017).

Although adults might develop compensating strategies, most of them still experience impairments in daily life, such as impaired social skills, increased driving accidents, forgetfulness, and disorganization compared to healthy people (Canela et al., 2017). Research suggest that these impairments might be associated with deficits in executive functions (EF). EF are cognitive functions located in the prefrontal cortex that help to control behaviour (e.g., plan ahead, shift and focus our attention, emotional control, and inhibition) and attain our goals (Dvorsky & Langberg, 2019). EF might play a role in adults with ADHD because of the link between ADHD and poor self-regulation of emotions, behaviour, and attention. Additionally, childhood ADHD has been linked to poorer self-evaluated EF in adulthood compared to healthy adults (Rosello et al., 2020). However, there are still discussions about the measurements and definition of EF and its relation with ADHD (Halleland et al., 2019).

It can be concluded that EF-related issues can negatively influence a person's concentration, organization skills, and planning. As Johnson & Reid (2011) have mentioned, these issues can be especially debilitating for students, as universities have high cognitive demands for students, including high demands for EF (i.e., motivation, working memory, self-monitoring, organization, and planning). Even though there is limited knowledge about the factors that influence students with ADHD (Dvorsky & Langberg, 2019), research suggests that EF difficulties can result in poorer academic performance, greater psychological and emotional difficulties, and increased alcohol and drug use in students (Green & Rabiner, 2012; Taylor & Zaghi, 2022). Additionally, students with undiagnosed ADHD struggle with the same diagnosing difficulties as young adults with ADHD. However, compared to the typical population of young adults with ADHD, students with ADHD might have superior adaptation skills. As a result, they do not get the right ADHD treatment, even though they suffer socially, academically, and emotionally from the disorder (Green & Rabiner, 2012).

Different theories have been developed on the relationship between executive dysfunction and ADHD. A well-known theory developed by Barkley (1997) says that response inhibition is one of the core EF-related deficits in ADHD. It might be the cause for performance issues on tasks of vigilance, motor inhibition, and memory (Wiersema et al., 2006). Barkley's model links response inhibition to four executive functions: (a) working memory, (b) self-regulation of affect – motivation – arousal, (c) internalization of speech, and (d) reconstitution. This model predicts that people with ADHD have impairments in these four EF. Barkley's theory has been used extensively, but as Martella and colleagues (2020) have shown, Barkley's model has shown inconsistent evidence, and other researchers have suggested different theories and models; one of which is the cognitive-energetic model.

The psychophysiological model called the cognitive-energetic model (CEM) was developed by Sanders in 1983 (Sanders, 1983). He suggests that information processing is done through three levels; a cognitive level, an energetic level, and an evaluational level. Especially the energetic level, which include effort, arousal, and activation, are thought to be main cause for deficits observed in ADHD. CEM suggests that these deficits are caused by a failure to be aroused by boring or easy tasks such as the slow event rate part of a go/no-go task. As a form of self-stimulation, individuals might become hyperactive, which in turn deteriorates task performance (Sanders, 1983; Kuntsi et al., 2006; Ory, 2017).

The CEM model is used by van der Meere et al. (2010) to develop the state regulation model. This model states energy mobilization is needed to perform well during effortful situations. To make sure that performance does not decline when stressors are present, people are able to redirect more energy on their task. This allocation of extra energy is called effort or motivation. This motivation theory suggests that people with ADHD have poorer regulation of energy compared to control groups, resulting in worse performance on tasks where extra attention is needed (Van der Meere et al., 2010; Wiersema et al., 2006). One such task is the go/no-go task. In this task, participants are asked to respond by pressing a button when a ‘go’ stimulus is presented and withhold when a ‘no-go’ stimulus is presented. Although the go/no-go task is an inhibition task in its core, the use of a long and short event rate makes it useful for measuring motivation. Short intervals are easy to stay engaged with, but longer intervals make this more difficult. Individuals with ADHD might lack the extra attention that is needed for this engagement, which causes worse task performance. Therefore, the comparison between short and long event rates of a go/no-go task is a comparison of motivation, rather than inhibition (Metin et al., 2012).

As suggested above, motivation plays an important role in the performance of people with ADHD, which can be measured by manipulating the event rate of a stimuli in a go/no-go task; especially children with ADHD perform worse on tasks with longer intervals compared to shorter ones. They also tend to make more mistakes in very short intervals conditions compared to healthy children. This would suggest that people with ADHD do indeed have a harder time allocating energy for changing their current state and staying engaged with the task compared to healthy individuals (Sanders, 1983; van der Meere et al, 2010; Wiersema et al., 2006; Epstein et al., 2012).

The present study has been done to gain more insight in the relationship between ADHD and executive functioning, with a focus on motivation and inhibition. Because there is limited knowledge about the factors that influence the functioning of students with ADHD (Dvorsky & Langberg, 2019) and it is simple for our research team to gather a large sample of students, we will investigate if motivation and inhibition deficits also play key roles in students with ADHD. This will be done through two questionnaires and an experiment. The two questionnaires used are the EFI (meant for measuring executive functioning) and the

CAARS (meant for measuring ADHD level). The CAARS is a questionnaire that measures ADHD in a dimensional way, where higher scores mean more ADHD symptoms. The correlation between these questionnaire will show us if ADHD and executive dysfunction are related to each other. In the experiment, the participants will do a go/no-go task with a variable event rate, meant to test motivation and inhibition. The participants will then be compared to each other, either in groups or individually, depending on the turnout. I expect to see people with high ADHD scores to show worse task performance compared to the lower scoring group. This leads me to the research question of this paper, which is the following: “Do students scoring high in ADHD show more executive function deficits compared to students scoring low in ADHD?”. However, before I can properly answer the research question, our research team first needs to validate the task and questionnaires to see if they actually measure what they are supposed to measure. The two questionnaires are known questionnaires and are thus already validated (Christiansen et al., 2020; Spinella, 2005), but the go/no-go task is not. It will be validated using the following hypothesis: “I expect the reaction times and errors to be significantly different between the fast and the slow conditions”. I will test this using the main effect of a mixed ANOVA with repeated measures. If the result of these tests are significant, it means that there is a significant difference between the fast and slow condition and our go/no-go task is valid.

For the first question, I wonder if there is a correlation between the EF and ADHD, which can be measured using the EFI and the CAARS. Derived from the current knowledge of the correlation between the EFI and CAARS (Barkley, 1997; van der Meere et al., 2005), I think there could be a significant correlation between the questionnaires. Therefore, the first hypothesis is: “there will be a significant correlation between executive dysfunction, as measured by the EFI Total Score, and ADHD symptomology, as measured by the CAARS ADHD Index”.

For the second question, I want to get a more specific idea about the correlation between specific EF and ADHD. For this question, I will look at the correlation of the Motivational Drive and Impulse Control scale with the CAARS. Based on prior research on the effect of motivation and inhibition (Wiersema et al., 2006; Barkley et al., 1997), I expect that both subscales show significant correlations with the CAARS ADHD Index. Therefore, the second hypothesis is: “there will be a significant correlation between the Motivational Drive and Impulse Control subscales of the EFI, and the CAARS ADHD Index”.

The third question regards the experiment. In this experiment, I seek to further investigate the role of ADHD on motivation and inhibition. I will first investigate the reaction time of the participants on the fast and slow condition. I will do this because the comparison of the reaction time on the fast and slow condition is a measurement for how over- and understimulation affects the motivation of students to stay focused on the task (Metin et al., 2012). Because of prior research done on go/no-go tasks in people with ADHD (Metin et al., 2012; Kooistra et al., 2010; Wright et al., 2014), I expect that students high in ADHD will show faster responses on the fast condition, but slower responses on the slow condition. Therefore, the third hypothesis is: “students scoring high in ADHD will show faster responses in the fast condition of the go/no-go task, but slower responses in the slow condition of the go/no-go task, compared to students scoring low in ADHD”.

The fourth hypothesis is also linked to reaction times, but is focused on motivation and effort allocation. This is done because it is thought that people with ADHD have a harder time redirecting energy when necessary, resulting in poorer task performance where more energy is needed (Van der Meere et al., 2010; Wiersema et al., 2006). As mentioned before, effort allocation can be measured by comparing the variance of the mean reaction times of both groups (Epstein et al., 2012; Wiersema et al., 2006). Based on their results, I expect that people scoring high in ADHD will show higher variance of mean reaction times in both conditions of the go/no-go task. Therefore, the fourth hypothesis is: "students scoring high in ADHD will show higher standard deviations of the mean reaction times in the fast and slow condition of the go/no-go task compared to students scoring low in ADHD".

With the fifth and last hypothesis, I investigate the percentage of errors participants make in the go/no-go task. This is done because the percentage of errors participants make shows how well the participants can respond when a 'go' stimulus is show, and inhibit their response when a 'no-go' stimulus is shown, therefore measuring inhibition. Based on prior research (Metin et al., 2012; Kooistra et al., 2010; Wright et al., 2014), I expect students high in ADHD to make more mistakes on both conditions of the go/no-go task. Therefore, the fifth hypothesis is: "students scoring high in ADHD will make more mistakes on the fast and slow condition of the go/no-go task compared to students scoring low in ADHD".

Method

Participants

Subjects in our 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). Because of various data problems and invalid responses, 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 in 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.

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 at 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 are able to 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.

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, it's 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 is depended 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 number 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 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 3 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 B). 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 we computed sum scores and T-scores, and for the EFI we created sum scores and a total score. For analysing 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. From the test, as seen in Table A1 (see Appendix A), we can conclude that the distribution of all analysed variables is significantly deviated from a normal distribution. To test the linearity, we look at the Normal Q-Q plots (Figure A1 to A5, see Appendix A) of all analysed variables and it can be concluded that all variables are approximately linear.

Since the data is not normally distributed, we make use of non-parametric tests to look at the relations between the variables. Therefore, whether there is a negative relationship between ADHD symptoms and executive functions is tested through a Spearman correlation. For testing whether ADHD is negatively related to IC and MD, another Spearman correlation was conducted.

Go/No-Go Task

Our experiment follows a mixed design with one between subject factor (i.e., ADHD level) and one within subject factor (i.e, event-rate [ER]). 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. Responses to the letter Q were considered errors of commission (EOCs) while not responding to the 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 (percentage 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]) divided into two conditions (fast and slow). Data analyses will be done using these 6 variables on two groups; high and low ADHD level.

The main statistics used for the experiment will be a mixed ANOVA with repeated measures. The Shapiro-Wilk test has been used for checking the normality assumption. All variables except two (low ADHD group for both perc_errors_fast ($W(41) = 0.900$, $p = 0.18$) and perc_errors_slow ($W(41) = 0.898$, $p = 0.16$) showed non-significant results, meaning that they had a normal distribution (see table 2 in Appendix 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 ($F(1,39) = 0.017$, $p = 0.898$ and $F(1,39) = 0.419$, $p = 0.521$, respectively). These non-significant results were also seen for perc_error_fast and perc_error_slow ($F(1,39) = 1.536$, $p = 0.223$ and $F(1,39) = 0.451$, $p = 0.506$, respectively).

Results

Descriptive Statistics

The questionnaires subscales necessary for hypotheses 1 and 2 had 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 six variables on the experiment used for the hypotheses 3 and 4 had the following means and standard deviations: 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 $SD = 19.47$.

Hypotheses

Task Validation

The experiment was validated using the following hypothesis: "I expect the reaction times and errors to be significantly different between the fast and the slow conditions". The validation has been done by checking the main effect of the mixed ANOVA with repeated measures. This main effect measures the difference between event rate condition without accounting for group level. If there is a significant difference, it means that the event rate manipulation is valid and the task measures what it is supposed to measure. All variables had a significant main effect (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: $F(1,38) = 7.531$, $p = .009$, $\eta_p^2 = .165$), meaning that our task is valid. Therefore, the validation hypothesis has been confirmed.

The Correlation Between the EFI and the CAARS

To answer the first hypothesis "there will be a significant correlation between executive dysfunction, as measured by the EFI Total Score, and ADHD symptomology, as measured by the CAARS ADHD Index", the correlation between the EFI Total Score and the CAARS ADHD Index was measured. As table B1 shows (see Appendix B), EFI Total Score and CAARS ADHD Index had a significant correlation ($p < .001$) and had a moderate negative direction ($r = -.489$). This result indicates that high scores on the EFI Total Score are associated with low scores on the CAARS ADHD Index, and vice versa. Thus, when a person scores high on ADHD, they probably have more executive functioning deficits compared to a person scoring low in ADHD. This is in line with my expectations and confirms the first hypothesis.

Comparing Motivational Drive and Impulse Control with the CAARS

To answer the second hypothesis "there will be a significant correlation between the Motivational Drive and Impulse Control subscales of the EFI, and the CAARS ADHD Index", the correlation between Motivational Drive (MD), Impulse Control (IC), and the CAARS ADHD Index were measured. Table 1 shows all correlations. IC and MD had a significant correlation ($p < .001$) with a weak negative direction ($r = -.130$). This indicates that when a person has a high impulse control, their motivational drive might be lower compared to a person with lower impulse control. For IC and the CAARS ADHD Index, a significant correlation ($p < .001$) with a moderate negative direction ($r = -.353$) was found. This indicates that high scores on the IC subscale were associated with low scores on the CAARS ADHD Index, and vice versa. Therefore, when a person scores high on ADHD, this results suggest they have worse impulse control compared to a person scoring low in ADHD. This is in line with my expectations. For MD and the CAARS ADHD Index, a non-significant result was found ($r = -.14$, $p = .782$). This would mean that the ADHD level a person has, has no effect on the motivational drive of that person. This is not in line with my expectations. Therefore, only part of the second hypothesis is confirmed: IC and the CAARS ADHD Index, and IC and MD had a significant correlation, but MD and the CAARS ADHD Index were not significantly related.

Table 1

Correlations

Variable	n	M	SD	1	2	3
1. CAARS_TscoreADHDIndex	394	52.57	10.69	-		
2. EFI_total	394	94.98	10.26	-.489**	-	
3. IC	394	16.78	3.38	-.353**	.602**	-
4. MD	394	14.45	2.64	-.014	.253**	-.130**

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

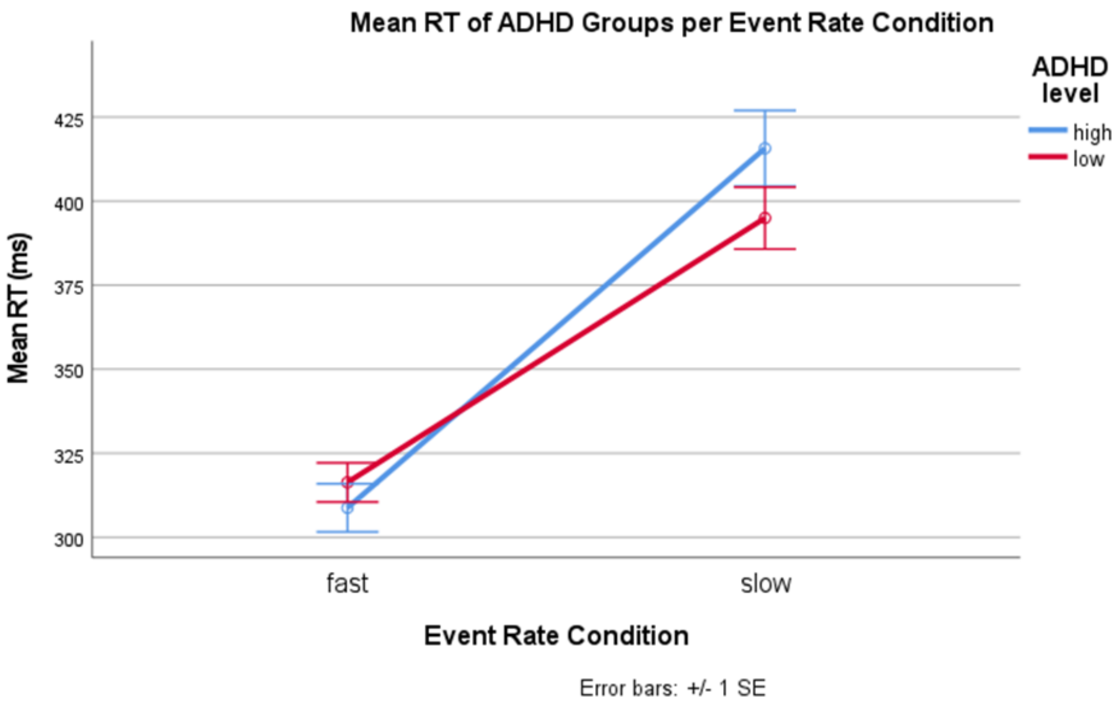
Note. CAARS = Conner's Adult ADHD Rating Scale; EFI = Executive Function Index Scale; IC = Impulse Control; Motivational Drive = MD

The Effect of ADHD on the Reaction Time in the Go/No-Go Task

For the third hypothesis "students scoring high in ADHD will show faster responses in the fast condition of the go/no-go task, but slower responses in the slow condition of the go/no-go task, compared to students scoring low in ADHD", I first compared the mean reaction times (MRT) of the participants in the fast condition (M = 313.31) and the slow condition (M = 403.27), which measures the main effect of event rate. As mentioned under task validation, I found a significant results ($F(1,38) = 236.4$, $p < .001$, $\eta_p^2 = .862$), which indicates that both groups had faster reaction times on the fast condition compared to the slow condition. I also measured the main effect of both ADHD groups. A non-significant result ($F(1,38) = 0.386$, $p = .538$, $\eta_p^2 = .010$) was found, meaning that the ADHD groups did not differ from each other per event rate condition. To see if ADHD level and event rate interacted with each other, I looked at the interaction effect of the mixed ANOVA with repeated measures. This showed a significant effect ($F(1,38) = 5,496$, $p = .024$, $\eta_p^2 = .126$), which means that the effect of event rate on MRT can no longer be understood without taking into account what ADHD level the participant has. In other words, the ADHD level of a participants influenced how well they quick they reacted on the go/no-go task. When someone scores high in ADHD, it is expected that they have faster responses in the fast condition, but slower responses in the slow condition. Figure 1 shows this relationship. These results are in line with my expectations and confirm the third hypothesis.

Figure 1

Profile plot of mrt_correct

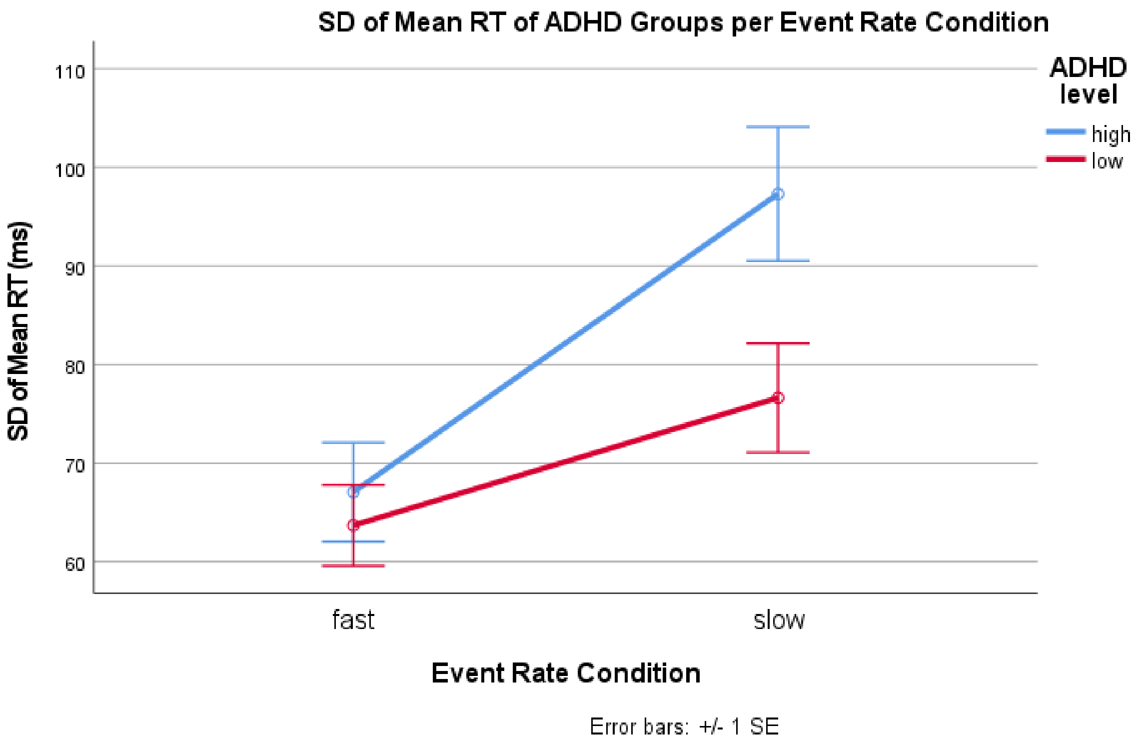


The Effect of ADHD on the Variance of Reaction Time in the Go/No-Go task.

For the fourth hypothesis "students scoring high in ADHD will show higher standard deviations of the mean reaction times in the fast and slow condition of the go/no-go task compared to students scoring low in ADHD", I first compared the standard deviations of the mean reaction times (sdMRT) between the fast (M = 65.04) and slow (M = 84.90), which measures the main effect of event rate. As was seen during the task validation, a significant main effect ($F(1,38) = 23.52$, $p < .001$, $\eta_p^2 = .382$) was found, which means that both groups had more variability in the slow condition compared to the fast condition. I also measured the main effect of ADHD group. I found a non-significant result ($F(1,38) = 3.656$, $p = .063$, $\eta_p^2 =$ .088), which means that the ADHD groups did not differ from each other. However, the p-value of 0.063 shows a tendency for a main effect of ADHD. This will be further investigated in the discussion. To see whether ADHD and event rate interacted with each other, I also measured the interaction effect. I did not find a significant interaction effect ($F(1,38) = 3.777$, $p = .059$, $\eta_p^2 = .090$), which means that, strictly speaking, ADHD level has no effect on sdMRT. Figure 2 shows this relationship. These results were not in line with my expectations, and the fourth hypothesis is therefore rejected. However, the p-value of 0.059 shows a significant tendency for an interaction effect, and will be further investigated in the discussion.

Figure 2

Profile plot of sd_rt_correct

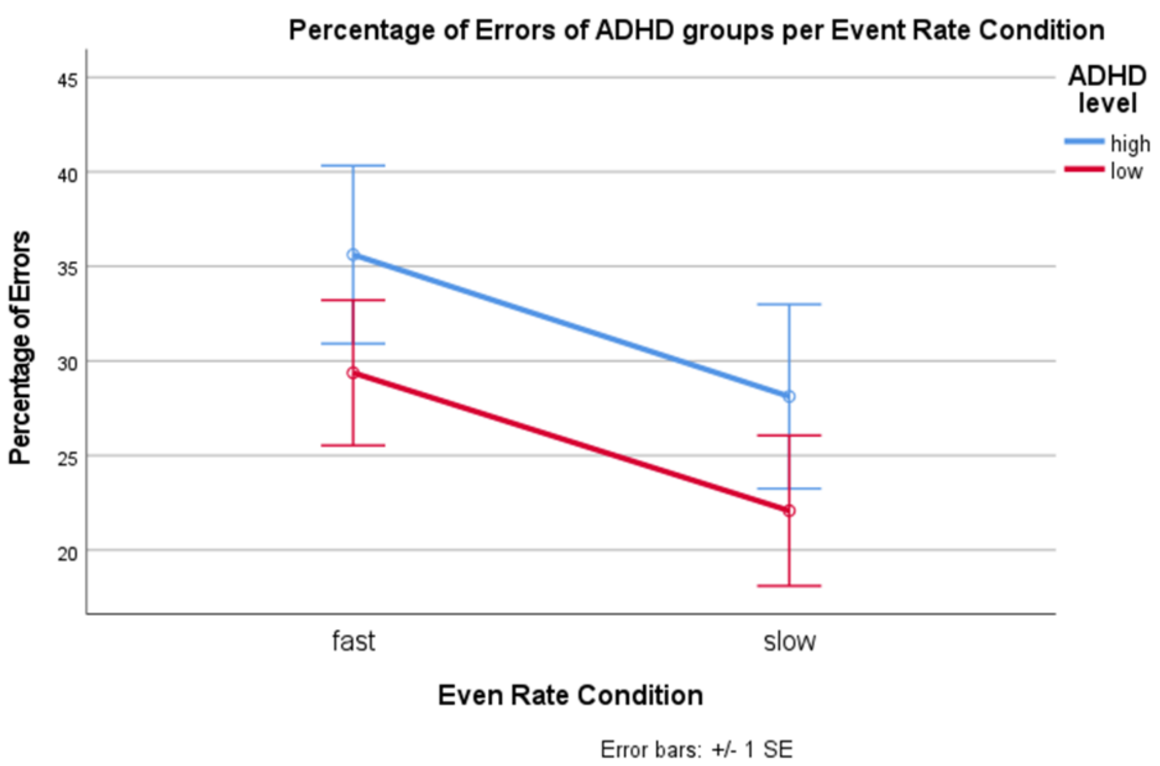


The Effect of ADHD on the Accuracy in the Go/No-Go task

To answer the last hypothesis “students scoring high in ADHD will make more mistakes on the fast and slow condition of the go/no-go task compared to students scoring low in ADHD”, I first compared the number of errors all participants made between the fast (M = 31.87) and slow (M = 24.50) condition, thus measuring the main effect of event rate. Although the percentage of errors had a non-normal distribution, the sample size of n = 40 was still big enough for a mixed ANOVA with repeated measures (Blanca et al., 2023). As was shown under task validation, the analysis showed significant results ($F(1,38) = 7.531$, $p = .009$, $\eta_p^2 = .165$), meaning that both ADHD groups made more errors in the fast condition compared to the slow condition. I also measured the main effect of ADHD group, which showed a non-significant effect ($F(1,38) = 1.219$, $p = .276$, $\eta_p^2 = .031$). It can be concluded that the ADHD groups did not significantly differ from each other. To see if ADHD and event rate interacted with each other, the interaction effect was also measured. This did not show a significant effect ($F(1,38) = 0.001$, $p = .969$, $\eta_p^2 = .000$), which means that ADHD level is not the reason the effect of event rate was seen. Therefore, we cannot say people high in ADHD will make more mistakes in either condition compared to the low ADHD group. Figure 3 shows this relationship. This was not in line with my expectations, which means that my fifth hypothesis is rejected.

Figure 3

Profile plot of perc_error



Discussion

Do Students Scoring High in ADHD Show More EF Deficits?

The research question of the present study is “do students scoring high in ADHD show more executive function deficits compared to students scoring low in ADHD?”. The simple answer to this question is ‘yes’. In general, students high in ADHD showed more EF deficits compared to students scoring low. However, the questionnaires and experiment both showed some different results, which is very particular. From the questionnaires we could say that inhibition might be the main EF deficit, while the experiment showed that motivational problems are more debilitating. Although this is not the result I hoped to find, it is very interesting to discuss why this happens. However, before this will be further investigated, the results of the questionnaires and experiment will first be discussed.

Questionnaires

The present study investigates the link between ADHD and executive functioning, with a particular focus on motivation and inhibition. Let us first discuss the questionnaire results. The first hypothesis looked at the correlation between EF and ADHD. The total score of EFI was significantly related to the ADHD Index, with a moderate correlation between the two. This means that people scoring high in ADHD will probably have more problems with executive functioning compared to people scoring low in ADHD. This result is in line with prior research on the link between ADHD and executive dysfunction (Barkley, 1997; van der Meere, 2005). Therefore, it is fair to say that executive dysfunction cannot be ignored in the diagnostic and therapeutic setting of ADHD treatment in students, as well as the overall ADHD symptomology in adults.

To get a better understanding of the role of inhibition and motivation in this relationship, we can look at the second hypothesis, which discusses the correlations of Impulse Control (IC) and Motivational Drive (MD) with the CAARS ADHD Index. Only IC had a significant correlation with the CAARS ADHD Index, with a moderate negative correlation. The difference in significance between MD and IC is very interesting, and there are different reasons for why this is the case. Firstly, it might be possible that inhibition is the EF deficit that is more prominently present in students with ADHD compared to motivation. As mentioned in the introduction, students have superior adaptation skills compared to non-students (Green & Rabiner, 2012). This, in addition with the fact that universities expect high motivational skills (Johnson & Reid, 2011), could suggest that students with ADHD have adapted a good motivational drive. As impulse control is not as important for a good academic performance, it might be less developed. A second possible reason is that there is an unequal distribution of ADHD subtypes in the sample of the present study. As Sobanski and colleagues (2008) have shown, there is a possible difference between ADHD symptomology expression for the two main types of ADHD (inattentive and hyperactive/impulsive); inattentive ADHD might come with different deficits than the hyperactive/impulsive type does. Impulse control could thus be a deficit seen in the hyperactivity/impulsivity type, which could be the better represented subtype of ADHD in the present study. The inattentive subtype, in which motivation plays a bigger role, might thus be underrepresented in the sample of this study.

It is also interesting to see that there is a weak correlation between IC and MD, which can suggest that they might exclude each other. When a persons with ADHD shows good impulse control, these results suggest that their motivational drive is probably worse, and vice versa. However, because the present study does not focus on the role of different executive dysfunctions in different types of ADHD, this should be researched more before conclusions can be made.

Experiment

The main goal of the experimental part of this study was to further investigate the role of motivation and inhibition in students with different levels of ADHD. This was done using a go/no-go task with a fast and slow event rate. As mentioned in the introduction, the go/no-go task is mainly an inhibition task, but when there is both a slow and fast condition, it also measures motivation (Metin et al., 2012). This has been used in the present study, and its results will be discussed here.

Mean Reaction Time

The third hypothesis of this study looked at the mean reaction time (MRT). MRT did not show a significant main effect for ADHD, but a significant main effect for event rate was found. This means that both groups had faster reaction times on the fast condition compared to the slow condition. The direction of this relationship can be seen in figure 1. However, MRT also showed an interaction effect, which changes the meaning of these results. Because of this interaction, the effect of event rate on MRT can no longer be understood without taking into account what ADHD level the participant has. In other words, when a participant has a high ADHD level, it is expected that their reaction times are faster in the fast condition, but slower in the slow condition compared to a low ADHD level participant. This results shows a motivation deficit in students with high ADHD levels, caused by the over- and understimulation effect of the manipulated event rate. In the fast condition, the high ADHD group has no problem being stimulated by the task. A lot is happening on the screen and it is easy to stay engaged with that much information. However, in the slow condition, there is a long time between each stimuli. As is in line with Sanders' (1983) CEM model, the high ADHD group might get bored and search for different ways to be stimulated. Therefore, a significant increase in mean reaction times was seen. The low ADHD group shows this effect in a less significant way, as they have more motivation to stay engaged with the task and do not need the same amount of stimulation as the high ADHD group.

Variance of Mean Reaction Time

The fourth hypothesis was made to investigate the standard deviation of the mean reaction time (sdMRT). This variable also showed a significant main effect for event rate, which means that both groups had a lower sdMRT score on the fast condition compared to the slow condition. The direction of this relationship can be seen in figure 2. There was no significant main effect for ADHD level, but the p-value of 0.063 is interesting. This p-value showed a tendency for a main effect of ADHD level, meaning that the ADHD groups almost significantly differed from each other. There are two ways to interpret this: it could be possible that the ADHD groups do not differ from each other, and we found a low p-value by accident. However, it is also possible that the ADHD groups do differ from each other, but our sample did not show this effect significantly. A reason for this can be seen in figure 2. In the fast condition, the groups had about the same amount of variance, but in the slow condition the difference is vast. This is also in line with prior research (Epstein et al., 2012; Metin et al., 2012; Wiersema et al., 2006), that the variance of the high ADHD group in the slow condition is greater than in the fast condition compared to the low ADHD group. This, combined with results of MRT, is evidence for the fact that the high scoring group has more difficulties in the slow condition of the go/no-go task.

The interaction effect of ADHD group and event rate showed the same results as the main effect of ADHD. Although there was no significant interaction effect, the almost significant p-value of 0.059 should not be ignored; this p-value shows that sdMRT also has a tendency for an interaction effect. As is with the main effect of ADHD group, there are two different ways to interpret this: firstly, it is possible that the variance of the mean reaction time does not differ between groups, and we found a low p-value by accident. If this is the case, then both groups would have about the same amount of variance on each condition of the go/no-go task, and the effort allocation only differs per event rate condition, not ADHD level. However, there is also a second option. It is possible that effort allocation actually differs between high and low ADHD levels, but our sample did not show this effect strong enough for a significant p-value. This would mean that students high in ADHD have a harder time allocating their energy to the task, but did not differ that much from the low ADHD group. A reason for this result might be because our research team did not compare a diagnosed ADHD group to a control group, but rather measured ADHD on a dimensional scale. Therefore, the differences between the groups might be smaller compared to studies using an ADHD vs control group design. It might be interesting to investigate this in future research.

Percentage of Errors

The fifth and last hypothesis in the present study explored the percentage of errors (PE). PE also showed a significant main effect for event rate: both groups had less mistakes in the slow condition compared to the fast condition. There was no significant main effect for ADHD group, nor a significant interaction effect between ADHD group. Therefore, event rate is the only variable which can account for these differences. This means that ADHD level does not explain why the number of errors differs between conditions. For the relationship between EF and student ADHD, it could mean that inhibition might play a smaller role than expected. This is not what I hypothesized beforehand, and is also not in line with prior research or the results of the questionnaires. There are different reasons for why this results was found. For example, it can be that the difference in inhibitory control between high and low is not that big in our sample. As is the case with sdMRT, the dimensional approach to ADHD might lower the difference between the high and low ADHD group, which means that the groups do not differ as much as they would with an ADHD vs control setting. If this approach would have been used, a significant difference between the number of errors of both groups might have been found, as other research has (Epstein et al., 2012; Metin et al., 2012). However, other studies have also had difficulties finding a significant difference between groups for number of errors (Metin et al., 2016). Metin et al. (2016) mentioned a moderate sample size (n = 54) as a possible explanation, which might also be the case in the present study.

Motivation or Inhibition?

A very surprising finding from the present study is the discrepancy between the questionnaires' results and the experiment's result. Both suggest that executive dysfunction is an important part of ADHD symptomology, but the questionnaires suggest inhibition as the main deficit, while the experiment suggests motivation as the main deficit. Sadly, I can only hypothesize about how I come to find these contradictive results. A good possibility is that students high in ADHD find ways to compensate for their motivational deficits, but inhibition is harder to compensate. Therefore, motivation might not appear as a deficit in their behaviour (measured in the questionnaires), but does appear at the cognitive level (measured in the experiment). Another option is that there might be a difference in the meaning of motivation between the EFI and the experiment. Motivation is, in and of itself, a difficult term to explain and even psychologist disagree on the meaning of motivation (Bahromov, 2022). In the experiment, motivation is thought of as the ability to stay engaged with the task and perform well, while the meaning of motivation in the EFI is the "behavioral drive, activity level, and interest in novelty." (Spinella, 2005, p. 660). The experimental definition of motivation is at the cognitive level, while the questionnaires' definition is a more general, behavioural definition, not focused on task performance. The different ideas about what motivation is might be the cause for why we have not found similar results in the questionnaires and experiment.

There is also another interesting debate possible about motivation: is motivation more stimulated by external forces (i.e., rewards, incentives), or is motivation better explained as an internal force; a skill which you are born with and develops as a person grows? Or could it be a combination of both, where both the person's nature and their surroundings influence how motivated they are? And how would the difference between these approaches influence what motivation is and how it relates to task performance and one's own idea about motivation? These philosophical debates about motivation make it harder to understand what the reasons behind the contradictive results are.

Limitations

The present study does also have its limitations. First of all, the questionnaires are self-report. Therefore, the participants might have a biased opinion about their executive functioning or ADHD symptomology, which might influence the results of these questionnaires. Using both self-report questionnaires and interviews with a close relative might have been better. However, because of the short deadline for this study, self-report questionnaires were the best option. The experiment has a more objective view compared to the questionnaires, but it is also only a representation of how the participant was at that moment. There are a lot of factors that can influence a performance, such as a bad night sleep, anxious feelings, hunger or thirst, and many more. It could be a possibility to measure go/no-go performance at multiple times, but due to time and a possible learning effect, this has not been done.

The sample used in this study can be another limitation. Participants have been invited through a course they had to finish to complete their first year. In this course, they have to fill out questionnaires and do experiments to receive credits. However, fair or honest performance are not measured. Therefore, the researchers have to trust that participants are honest during questionnaires and try their best during experiments. When this does not happen, it could influence the results, therefore not representing the real world. However, this is something that cannot be prevented, as most behavioural research is based upon the trust that the participant acts like they would in real life. In addition, the sample consists of psychology students only. Therefore, the results cannot be generalized to other types of students or non-students. However, because we wanted to know more about how ADHD influences executive functioning in students, this limitation is not as important for the present study.

The aforementioned dimensional approach to ADHD could also classify as a limitation. The present study used an ADHD Index score, but also divided the groups in high and low according to a certain level (an ADHD Index score of 60). Therefore, the high and low groups could lie closer together compared to using a diagnosed ADHD vs control group setting. However, because we are also interested in the effect of undiagnosed ADHD, the dimensional approach could also be beneficial. Most of the participants who scored high on the ADHD Index were not diagnosed with ADHD. This could mean two things: either a lot of students in our sample were not diagnosed with ADHD, although they had a lot of ADHD symptoms, or the CAARS ADHD Index is not a good measure for actual ADHD, only ADHD symptomology. Both of these can be real possibilities, and might even exist together. However, this is about the validity of the CAARS itself, which is not discussed in detail in the present study.

The Future of adult ADHD and Executive Functioning

Although the present study found contradictory results for motivation and inhibition, the overall importance of EF deficits in ADHD cannot be ignored. But what does that mean for the future of adult ADHD and executive functioning? Where should research focus on when investigating this subject?

There are different ways the results can stimulate future research. First of all, it is important to clear up why these contradictive results between the questionnaire and experiment were found. A direct replication of this study can be done to see if the results stay the same. It might also be interesting to use an ADHD vs control group setting, using the same questionnaires and experiment, to see if that makes a difference. It could also be a possibility to get more detailed information through brain imaging. EEG, fMRI, MEG, and other techniques could all give a better insight into how motivation and inhibition work during go/no-go task, and how this differs from healthy students.

There are also other executive functions that can be investigated in students with ADHD. As mentioned before, universities have high demands for executive functions such as working memory, planning & time management, self-monitoring, and organization. Because students with ADHD might lack proficiency in all of these functions, their academic performance could suffer. It is therefore interesting to see if students struggle with these EF as well. Because most studies tend to measure EF deficits with questionnaires (Weyandt et al., 2013; Dvorsky & Langberg, 2019), it would be interesting to see experimental manipulation for different EF. There are many ways to manipulate different EF (Davidson et al., 2006), which can help investigate the precise mechanics behind other EF deficits and how they relate to healthy control groups.

The use of medication is also interesting to study in ADHD. There are several different drug treatments for ADHD (Adler & Nierenberg, 2010), but studies investigating their use for relieving EF deficits is scarce (Kempton et al., 1999; Miklos et al., 2019), especially for students. Therefore, it could be interesting to see if and how medication can benefit students struggle with ADHD and EF deficits. Comparing students with ADHD receiving medication, students with ADHD receiving a placebo, and students without ADHD could reveal interesting information about how medication influences EF deficits compared to placebos or healthy controls.

It might also be beneficial to investigate the difference between students and non-students on how ADHD impacts EF. As mentioned before, students tend to adapt better to their difficulties compared to non-students, so it could be interesting to see if this is also applicable for EF deficits. Comparing students to non-students of a similar age, both with ADHD, could reveal if students do adapt better to EF deficits compared to their peers. If this is done, looking at different EF at the same time could reveal if students have better adapted EF. It might even be possible to see what EF have adapted better. For example, it sounds reasonable that planning & time management is developed better in students because a good planning & time management is essential for good academic performance.

Implications

For medical practitioners, it is interesting to see how EF can benefit them in the diagnostic and therapeutic setting. Because EF deficits are a part of more psychological profiles than ADHD (Rabinovici et al., 2015), there should not be an extreme focus on EF deficits for the diagnosis; because students tend to adapt very well to their ADHD deficits (Green & Rabiner, 2012), an extreme focus on EF deficits might even be detrimental for the diagnosis. However, in addition to standard diagnostic practices, screening for EF deficits can still be a good tool to understand how debilitating ADHD is for the patient and what kind of help the patient needs. For the therapeutic setting, executive dysfunction should definitely be addressed. As prior research (Green & Rabiner, 2012; Taylor & Zaghi, 2022; Dvorsky & Langberg, 2019) has shown, EF deficits can undermine a students' ability to perform well academically, emotionally, and socially. When a patient with ADHD is treated, medical practitioners should therefore not only focus on the inattention and/or hyperactivity/impulsivity symptoms. The value of proficient executive functioning might be equal to relieving the inattention and/or hyperactivity/impulsivity symptoms, if not more valuable. Therefore, it might be a good idea for ADHD therapies to include EF improvement training. There are different ways to improve executive functioning, such as Goal Management Training (Stamenova & Levene, 2019), focused video games (Mayer et al., 2019), and EF-focused interventions in childhood (Traverso et al., 2015). Even for students with ADHD, there are interventions that tend to improve executive functioning, such as the use of 'gamified interventions' aimed at improving EF (Alabdulakareem & Jamjoom, 2020). If executive dysfunction in ADHD would become a bigger focus point in the therapeutic setting, interventions like these could significantly benefit the patient and help them deal with the EF deficits they struggle with.

Conclusion

The present study aimed to investigate the relation between executive dysfunction and ADHD level in students, with a focus on motivation and inhibition. Using two questionnaires, the EFI and CAARS, and a go/no-go task with a fast and slow condition, this study investigated whether students scoring high in ADHD differed in motivation and inhibition compared to low scoring students. In general, it can be concluded that students scoring high in ADHD show more executive functioning deficits compared to low scoring students. The questionnaires showed that impulse control was significantly lower in the high scoring group than in the lower scoring group, but motivation did not differ between both. The experiment showed that motivation was the main deficit seen in students scoring high in ADHD, while inhibition did not differ between ADHD levels. A possible reason for these contrary results is that students might be able to compensate for their motivational problems at a behavioural level, but not at a cognitive level. Motivation at the behavioural level, as measured in the EFI, might therefore not be a significant deficit, while motivation at the cognitive level, as measured in the go/no-go task, might still be influential.

Future research can focus on various different aspects of this study. First of all, further investigation on motivation, inhibition, and ADHD is needed to see how they influence each other. Other executive functions, such as working memory, organization, and self-monitoring, can also be studied in people with and without ADHD. Doing this might strengthen the evidence for EF deficits in ADHD, which in turn can lead to better understanding and treatment of ADHD. Different brain imaging techniques can also help investigate how ADHD influences EF, by showing a more in-depth view of the functioning of ADHD and EF.

As this study suggests, the role of EF in students scoring high in ADHD should not be underestimated. It is therefore important that medical practitioners also take EF deficits into account when treating ADHD. EF deficits can be very debilitating when not addressed, and should be implemented in the treatment of ADHD. When doing so, the patient might be able to better control their EF deficits, thus improving their day-to-day life and their ability to adequately handle living with ADHD.

References

Adler, L., Shaw, D., Kovacs, K., & Alperin, S. (2015). Diagnosing ADHD in children and adults. In L. Adler, T. Spencer, & T. Wilens (Eds.), Attention-Deficit Hyperactivity Disorder in Adults and Children (pp. 16-23). *Cambridge: Cambridge University Press.* https://doi.org/10.1017/CBO9781139035491.003

Adler, L. D., & Nierenberg, A. A. (2010). Review of medication adherence in children and adults with ADHD. *Postgraduate medicine*, *122*(1), 184–191. https://doi.org/10.3810/pgm.2010.01.2112

Alabdulakareem, E., & Jamjoom, M. (2020). Computer-assisted learning for improving adhd individuals' executive functions through gamified interventions: a review. *Entertainment Computing*, *33*. https://doi.org/10.1016/j.entcom.2020.100341

American Psychiatric Association. (2022). Diagnostic and statistical manual of mental disorders: dsm-5-tr. (M. B. First, Ed.) (Fifth edition, text revision). *American Psychiatric Association Publishing*.

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*(1), 65–94. https://doi.org/10.1037/0033-2909.121.1.65

Bahromov, O. T. (2022). The problem of motivation and the meaning of the concept "motiv". *Galaxy International Interdisciplinary Research Journal*, *10*(1), 546-549. https://www.giirj.com/index.php/giirj/article/download/1077/1018

Blanca, M. J., Arnau, J., García-Castro, F. J., Alarcón, R., & Bono, R. (2023). Non-normal Data in Repeated Measures ANOVA: Impact on Type I Error and Power. *Psicothema*, *35*(1), 21–29. https://doi.org/10.7334/psicothema2022.292

Canela, C., Buadze, A., Dube, A., Eich, D., & Liebrenz, M. (2017). Skills and compensation strategies in adult adhd - a qualitative study. *Plos One*, *12*(9), 0184964. https://doi.org/10.1371/journal.pone.0184964

Conners, C. K., Erhardt, D., & Sparrow, E. (2002). Conners' Adult ADHD Rating Scales–Self-Report: Long Version (CAARS–S: L). *Toronto, Canada: Multi-Health Systems*. https://paa.com.au/wp-content/uploads/2022/04/CAARS_Self-Report_InterpretiveReport_Sample.pdf

Conners, C. K., Erhardt, D., Epstein, J. I., Parker, J. W., Sitarenios, G., & Sparrow, E. M. (1999). Self-ratings of ADHD symptoms in adults I: Factor structure and normative data. *Journal of Attention Disorders*, *3*(3), 141–151. https://doi.org/10.1177/108705479900300303

Christiansen, H., Kis, B., Hirsch, O., Matthies, S., Hebebrand, J., Uekermann, J., Abdel-Hamid, M., Kraemer, M., Wiltfang, J., Graf, E., Colla, M., Sobanski, E., Alm, B., Rösler, M., Jacob, C. K., Jans, T., Huss, M., Schimmelmann, B. G., & Philipsen, A. (2012). German validation of the Conners Adult ADHD Rating Scales (CAARS) II: Reliability, validity, diagnostic sensitivity and specificity. *European Psychiatry*, *27*(5), 321–328. https://doi.org/10.1016/j.eurpsy.2010.12.010

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078. https://doi.org/10.1016/j.neuropsychologia.2006.02.006

Dvorsky, M. R., & Langberg, J. M. (2019). Predicting impairment in college students with adhd: the role of executive functions. *Journal of Attention Disorders*, *23*(13), 1624–1636. https://doi.org/10.1177/1087054714548037

Epstein, J. N., Langberg, J. M., Rosen, P. J., Graham, A., Narad, M. E., Antonini, T. N., Brinkman, W. B., Froehlich, T., Simon, J.O., & Altaye, M. (2012). Evidence for Higher Reaction Time Variability for Children With ADHD on a Range of Cognitive Tasks Including Reward and Event Rate Manipulations. *Neuropsychology*, Vol. 25, No. 4, pp. 427–44. https://doi.org/10.1037/a0022155

Green, A. L. & Rabiner, D. L. (2012). What Do We Really Know about ADHD in College Students? *Neurotherapeutics 9*, 559–568. https://doi.org/10.1007/s13311-012-0127-8

Halleland, H. B., Sørensen, L., Posserud, M. B., Haavik, J., & Lundervold, A. J. (2019). Occupational Status Is Compromised in Adults With ADHD and Psychometrically Defined Executive Function Deficits. *Journal of attention disorders*, *23*(1), 76–86. https://doi.org/10.1177/1087054714564622

Hammerness, P. G. (2008). Adhd. *ABC-CLIO, LLC.*

Johnson, J., & Reid, R. (2011). Overcoming Executive Function Deficits With Students With ADHD. *Theory into Practice*, *50*(1), 61–67. https://doi-org.proxy-ub.rug.nl/10.1080/00405841.2010.534942

Kempton, S., Vance, A., Maruff, P., Luk, E., Constin, J., & Pantelis, C., (1999). Executive function and attention deficit hyperactivity disorder: Stimulant medication and better executive function performance in children. *Psychological Medicine, 29*(3), 527-538. https://doi.org/10.1017/S0033291799008338

Kooistra, L., van der Meere, J. J., Edwards, J. D., Kaplan, B. J., Crawford, S., & Goodyear, B. G. (2010). Preliminary fMRI findings on the effects of event rate in adults with ADHD. *Journal of neural transmission (Vienna, Austria : 1996)*, *117*(5), 655–662. https://doi.org/10.1007/s00702-010-0374-y

Kuntsi, J., McLoughlin, G. & Asherson, P (2006). Attention deficit hyperactivity disorder. *Neuromol Med 8*, 461–484. https://doi.org/10.1385/NMM:8:4:461

Marshall, P., Hoelzle, J., & Nikolas, M. (2021). Diagnosing attention-deficit/hyperactivity disorder (adhd) in young adults: a qualitative review of the utility of assessment measures and recommendations for improving the diagnostic process. *The Clinical Neuropsychologist (Neuropsychology, Development and Cognition: Sec, 35*(1), 165–198. https://doi.org/10.1080/13854046.2019.1696409

Martella, D., Aldunate, N., Fuentes, L. J., & Sánchez-Pérez, N. (2020). Arousal and Executive Alterations in Attention Deficit Hyperactivity Disorder (ADHD). *Frontiers in psychology*, *11*, 1991. https://doi.org/10.3389/fpsyg.2020.01991

Mathôt, S., Schreij, D., & Theeuwes, J. (2011). OpenSesame: An open-source, graphical experiment builder for the social sciences. *Behavior Research Methods, 44*(2), 314–324. https://doi.org/10.3758/s13428-011-0168-7

Mayer, R. E., Parong, J., & Bainbridge, K. (2019). Young adults learning executive function skills by playing focused video games. *Cognitive Development, 49,* 43-50. https://doi.org/10.1016/j.cogdev.2018.11.002

Metin, B., Roeyers, H., Wiersema, J. R., van der Meere, J., & Sonuga-Barke, E. (2012). A meta-analytic study of event rate effects on Go/No-Go performance in attention-deficit/hyperactivity disorder. *Biological psychiatry*, *72*(12), 990–996. https://doi.org/10.1016/j.biopsych.2012.08.023

Metin, B., Wiersema, J. R., Verguts, T., Gasthuys, R., van Der Meere, J. J., Roeyers, H., & Sonuga-Barke, E. (2016). Event rate and reaction time performance in ADHD: Testing predictions from the state regulation deficit hypothesis using an ex-Gaussian model. *Child neuropsychology : a journal on normal and abnormal development in childhood and adolescence*, *22*(1), 99–109. http://dx.doi.org/10.1080/09297049.2014.986082

Miklós, M., Futó, J., Komáromy, D., & Balázs, J. (2019). Executive Function and Attention Performance in Children with ADHD: Effects of Medication and Comparison with Typically Developing Children. *International Journal of Environmental Research and Public Health*, *16*(20), 3822. https://doi.org/10.3390/ijerph16203822

Ory, J.H. (2017). Executive Dysfunction or State Regulation: A Dimensional Comparison of Two Neuropsychological Theories of Attention Disorder Symptoms Using RDoC Paradigms. *LSU Doctoral Dissertations*. 4094. https://doi.org/10.31390/gradschool_dissertations.4094

Pettersson, R., Söderström, S., & Nilsson, K. W. (2018). Diagnosing adhd in adults: an examination of the discriminative validity of neuropsychological tests and diagnostic assessment instruments. *Journal of Attention Disorders, 22*(11), 1019–1031. https://doi.org/10.1177/1087054715618788

Rabinovici, G. D., Stephens, M. L., & Possin, K. L. (2015). Executive dysfunction. *Continuum (Minneapolis, Minn.)*, *21*(3 Behavioral Neurology and Neuropsychiatry), 646–659. https://doi.org/10.1212/01.CON.0000466658.05156.54

Rosello, B., Berenguer, C., Raga, J. M., Baixauli, I., & Miranda, A. (2020). Executive functions, effortful control, and emotional lability in adults with adhd. implications for functional outcomes. *Psychiatry Research, 293*. https://doi.org/10.1016/j.psychres.2020.113375

Sanders A. F. (1983). Towards a model of stress and human performance. *Acta psychologica*, *53*(1), 61–97. https://doi.org/10.1016/0001-6918(83)90016-1

Sobanski, E., Brüggemann, D., Alm, B., Kern, S., Philipsen, A., Schmalzried, H., Heßlinger, B., Waschkowski, H., & Rietschel, M. (2008). Subtype differences in adults with attention-deficit/hyperactivity disorder (adhd) with regard to adhd-symptoms, psychiatric comorbidity and psychosocial adjustment. *European Psychiatry*, *23*(2), 142–149. https://doi.org/10.1016/j.eurpsy.2007.09.007

Spinella, M. (2005). Self-rated executive function: Development of the executive function index. *International Journal of Neuroscience, 115*(5), 649-667. https://doi.org/10.1080/00207450590524304.

Stamenova, V., & Levine, B. (2019). Effectiveness of goal management training® in improving executive functions: A meta-analysis. *Neuropsychological rehabilitation*, *29*(10), 1569–1599. https://doi.org/10.1080/09602011.2018.1438294

Taylor, C. L., & Zaghi, A. E. (2022). The interplay of adhd characteristics and executive functioning with the gpa and divergent thinking of engineering students: a conceptual replication and extension. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.937153

van der Meere, J. (2005). State Regulation and Attention Deficit Hyperactivity Disorder. In: Gozal, D., Molfese, D.L. (eds) Attention Deficit Hyperactivity Disorder. Contemporary Clinical Neuroscience. *Humana Press*. https://doi.org/10.1385/1-59259-891-9:413

van der Meere, J. J., Börger, N. A., & Wiersema, J. R. (2010). ADHD: State Regulation and Motivation. *Current Medical Literature. Psychiatry*, *21*(1), 14-20.

Vizgaitis, A. L., Bottini, S., Polizzi, C. P., Barden, E., & Krantweiss, A. R. (2023). Self-Reported Adult ADHD Symptoms: Evidence Supporting Cautious Use in an Assessment-Seeking Sample. *Journal of Attention Disorders*. https://doi.org/10.1177/10870547231172764

Weyandt, L., DuPaul, G. J., Verdi, G., Rossi, J. S., Swentosky, A. J., Vilardo, B. S., O'Dell, S. M., & Carson, K. S. (2013). The performance of college students with and without ADHD: Neuropsychological, academic, and psychosocial functioning. *Journal of*

Psychopathology and Behavioral Assessment, *35*(4), 421–435. https://doi.org/10.1007/s10862-013-9351-8

Wiersema, R., van der Meere, J., Antrop, I., & Roeyers, H. (2006). State regulation in adult ADHD: an event-related potential study. *Journal of clinical and experimental neuropsychology*, *28*(7), 1113–1126. https://doi.org/10.1080/13803390500212896

Wright, L., Lipszyc, J., Dupuis, A., Thayapararajah, S. W., & Schachar, R. (2014). Response inhibition and psychopathology: a meta-analysis of go/no-go task performance. *Journal of abnormal psychology*, *123*(2), 429. https://psycnet.apa.org/doi/10.1037/a0036295

Appendix A

Assumption Tables and Figures

Table A1

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 A2

Tests of Normality

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

Note: Under ADHD_level; 1 = high, 2 = low

Figure A1

Normal Q-Q Plot of CAARS_TscoreDSM_Total

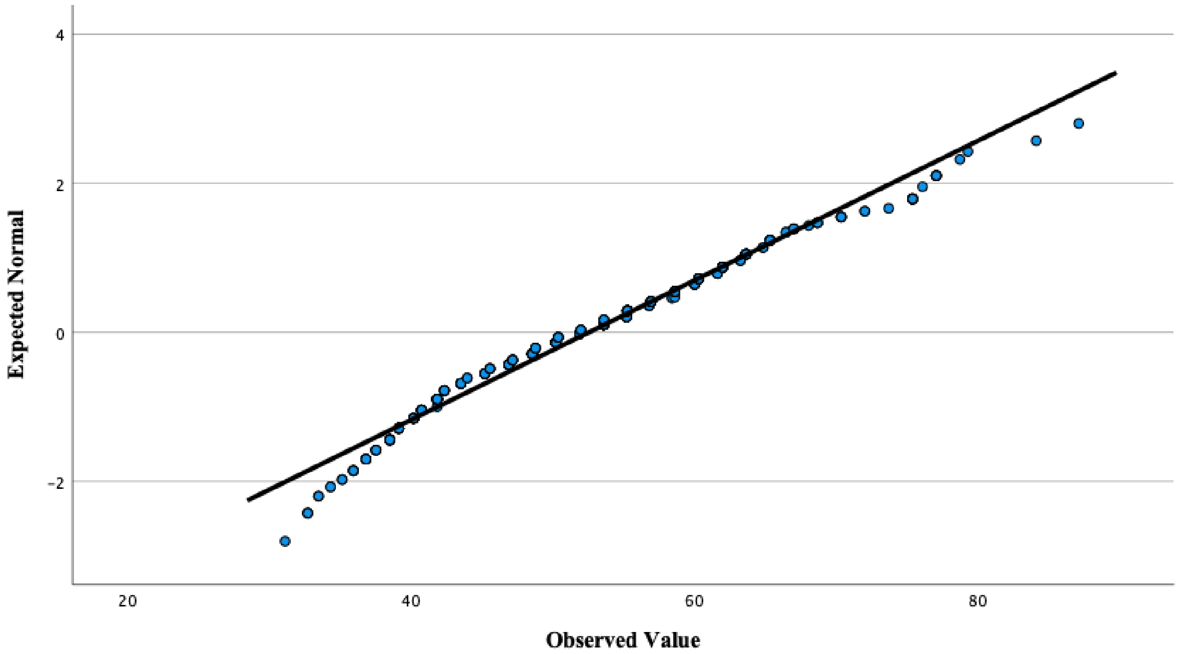


Figure A2

Normal Q-Q Plot of CAARS_TscoreADHDIndex

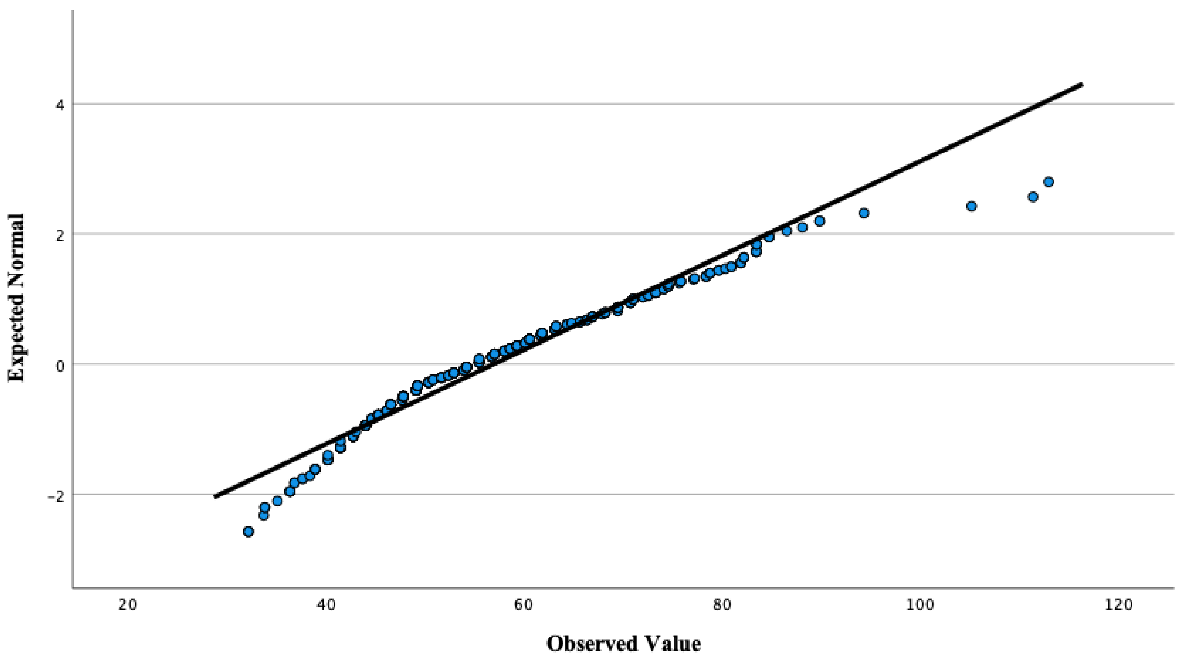


Figure A3

Normal Q-Q Plot of EFI_total

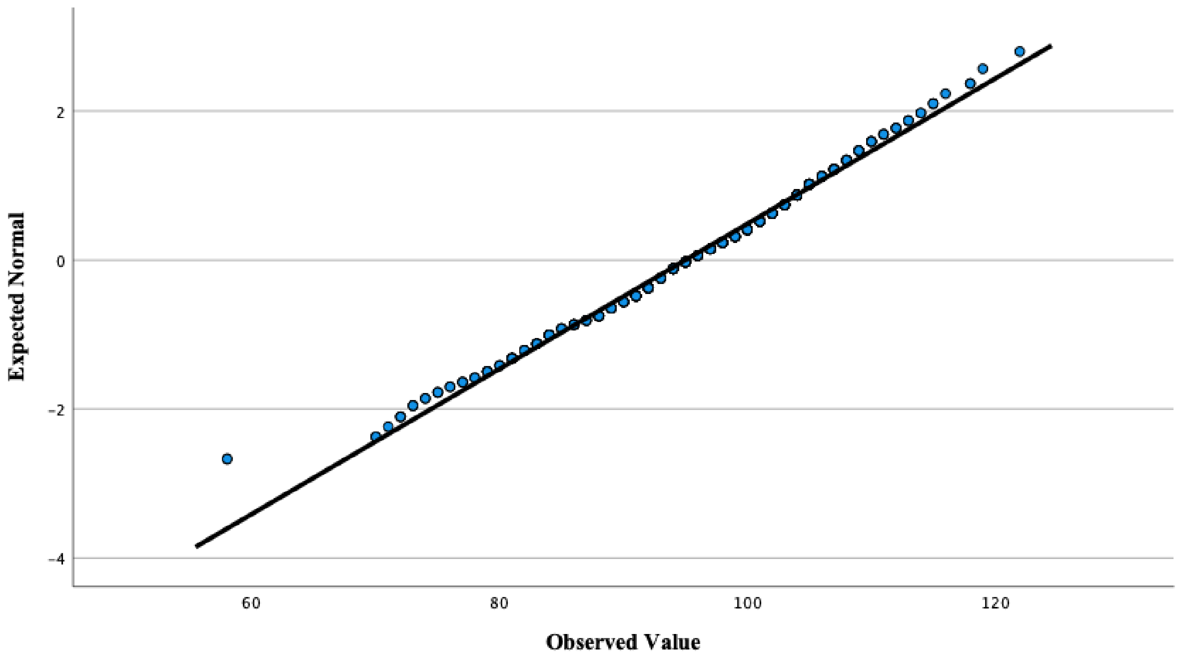


Figure A4

Normal Q-Q Plot of MD

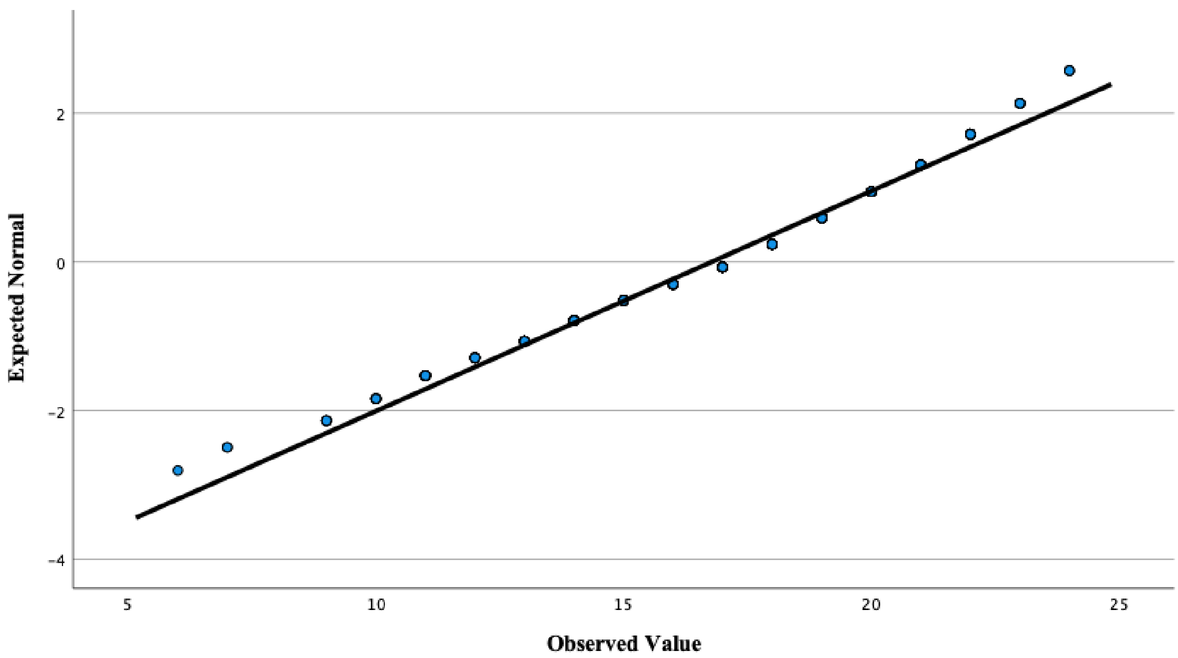
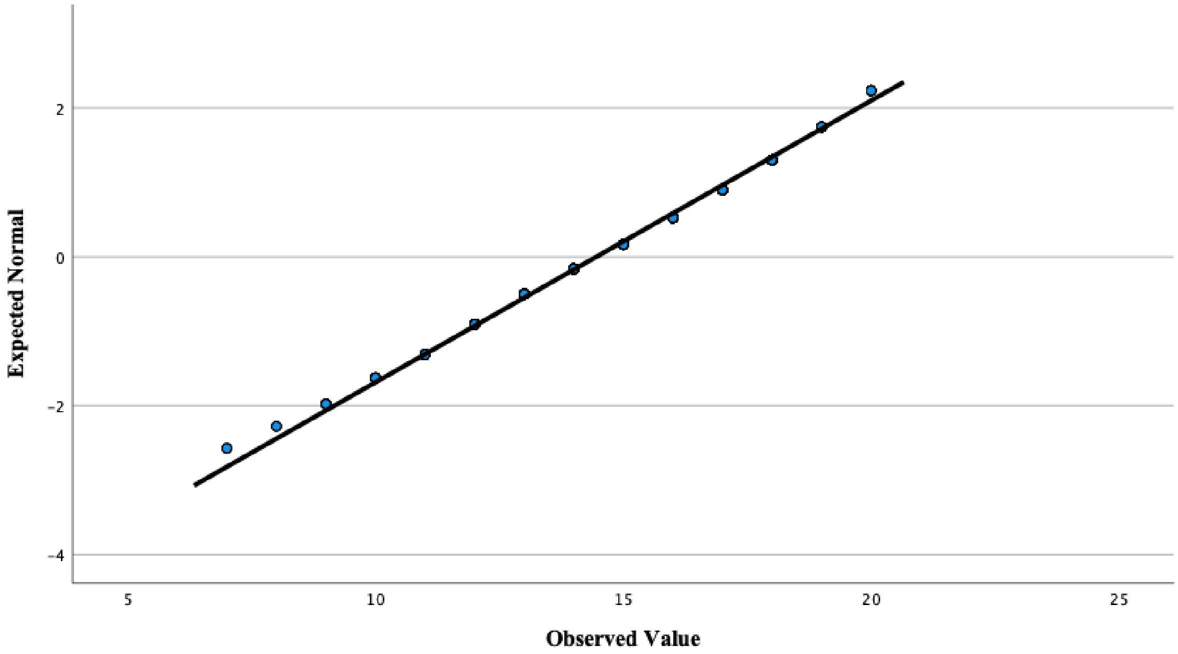


Figure A5

Normal Q-Q Plot of IC



Appendix B

Informational Sheet and Consent Form

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.