The Role of ADHD and Executive Functions in Self-Regulated Learning Skills of University Students

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Abstract

Research has found that university students with Attention Deficit Hyperactivity Disorder (ADHD) experience more academic problems than their peers. Two factors that might play a role in this are self-regulated learning and executive function. The present study therefore examined the relationship between ADHD symptoms, executive function and self-regulated learning strategies. University students (N = 160) were asked to fill out an online questionnaire. The data were analysed using a partial correlation analysis. Results showed a negative relationship between ADHD symptoms and cognitive learning strategies. However, this relationship disappeared when controlling for executive function. Executive function did however show a negative correlation with cognitive learning strategies when controlling for ADHD symptoms. Additionally, this study found a negative correlation between inattentive symptoms of ADHD and cognitive learning strategies, but no significant relation between hyperactive/impulsive symptoms and cognitive learning strategies. These findings suggest that students with ADHD, specifically students with inattentive symptoms of ADHD, use less cognitive learning strategies than their peers. Additionally, this study shows a mediating role of executive function in this relationship. These findings could help improve interventions for students with ADHD, thereby closing the academic gap between them and their peers.

Keywords: Attention Deficit Hyperactivity Disorder (ADHD), Executive Function, Self-Regulated Learning, University Students

The Role of ADHD and Executive Functions in Self-Regulated Learning Skills of University Students

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder characterized by increased levels of inattention, hyperactivity and impulsivity (American Psychiatric Association, 2013). ADHD is a well-researched subject, yet the research on university students with ADHD is relatively recent; most research on the topic has been published after the year 2000 (Shelton et al., 2019; Simon-Dack et al., 2016).

In general, university students face some unique challenges since they often have a higher workload and encounter increasingly difficult topics compared to high school students (Wolf, 2001). Moreover, they have to face these challenges with less support, structure and supervision than before (Wolf et al., 2009). However, this might be especially difficult for students with ADHD (Wolf, 2001; Wolf et al., 2009). Current estimates suggest that approximately 2 to 8 per cent of university students report having clinically significant levels of ADHD symptoms (DuPaul et al., 2009). Research shows that these students are more likely to struggle academically than their peers without ADHD. Fewer adults with ADHD complete a bachelor's degree or a postgraduate degree (Mannuzza et al., 1993). Also, during their academic career, students with ADHD have lower Grade Point Average (GPA) scores, withdraw more often from classes and are more often on academic probation (Advokat et al., 2011; DuPaul et al., 2009; Frazier et al., 2007; Heiligenstein et al., 1999). Additionally, ADHD symptoms are associated with decreased study skills, such as summarizing, outlining, test strategies and selecting main ideas (Reaser et al., 2009). Interestingly, inattentive symptoms of ADHD (such as easily being distracted, making careless mistakes and forgetfulness in daily activities) seem to have a particularly negative effect on academic performance compared to hyperactive/impulsive symptoms (Frazier et al., 2007; Norvilitis et al., 2010; Norwalk et al., 2009; Wolf et al., 2009). Surprisingly, one study found a positive relation between hyperactive/impulsive symptoms and study strategies, showing that those with more hyperactive/impulsive symptoms apply better study strategies (Shelton et al., 2019).

Because ADHD symptoms seem to have a significant impact on academic achievement, it is important to understand the mechanisms of this relationship. If the association between ADHD and academic performance is better understood, support for this group of students can be improved. Two factors that might influence this relationship are executive function and self-regulated learning (Dvorsky & Langberg, 2019; Sibley et al., 2019). Therefore, this study will explore if students with ADHD symptoms use less effective self-regulated learning strategies and how this relates to executive function.

Executive Function

Executive Function (EF) is commonly referred to in literature on ADHD as the neurocognitive processes that are involved in problem-solving and goal-directed behaviour (Barkley & Murphy, 2011). This generally refers to cognitive functions that are responsible for the planning, organizing and regulation of behaviour (Sheehan & Iarocci, 2019). Within the literature, there are many skills and components of EF identified (Bailey & Jones, 2019). Spinella (2005) distinguishes five main factors of EF: motivational drive, strategic planning, organization, impulse control and empathy.

These cognitive processes of EF slowly develop throughout life, from the first few years of childhood into young adulthood (Best & Miller, 2010). This reflects changes in the brain during this time, specifically of the prefrontal cortex (Diamond, 2002). An important developmental period occurs during adolescence, when EF skills such as planning, problem-solving and working memory further mature (Bailey & Jones, 2019). This, again, coincides with key developments in the prefrontal cortex, particularly related to myelination and synaptic density (Blakemore & Choudhury, 2006). Bailey and Jones (2019) propose a model of the development of EF in which several core processes of regulation develop into more complex behaviours over three different domains: cognitive, emotional and social. According to this model the core processes of EF are combined with specific knowledge, skills and experiences to form more sophisticated behaviour that is better suited to the increasingly complex demands of life. This is how EF supports fairly simple tasks in childhood, such as following multi-step directions or switching attention between activities, but develops to enable more complex tasks later in life like planning, multitasking and the portrayal of socially appropriate behaviour.

Because executive functions are related to these complex behaviours, they are absolutely necessary to thrive in academia. Several studies have found EF to be a predictor of academic performance in university (Dvorsky & Langberg, 2019; Rabin et al., 2011; Sheehan & Iarocci, 2019). Executive function, and particularly the organization aspects of EF, seems to be a predictor of GPA (Dvorsky & Langberg, 2019). Furthermore, research has found EF to be a predictor of academic procrastination as well as academic adjustment (Rabin et al., 2011; Sheehan & Iarocci, 2019).

ADHD has been linked to deficits in cognitive functioning (Boonstra et al., 2005; Willcutt et al., 2005). Meta-analytic studies have found differences in executive functioning between people with ADHD and without ADHD in several different domains, such as inhibition of behaviour, planning, set shifting, vigilance and working memory (Boonstra et al., 2005; Willcutt et al., 2005). Therefore, executive function is assumed to play an important role in ADHD (Willcutt et al., 2005).

Self-Regulated Learning

A similar but distinct factor that might influence the academic results of students is Self-Regulated Learning (SRL) (Garner, 2009). Self-Regulated Learning is the controlled, self-directed behaviour that a student applies to reach their desired academic goals (Pintrich, 1995). This learning behaviour takes place on three different dimensions: the dimension of directly observable behaviour, the dimension of cognition, and the dimension of motivation and affect. In short, SRL involves the control of resources, motivational beliefs, and cognitive learning strategies (Pintrich, 1995).

Self-Regulated Learning is especially suitable for university students, since they have a great deal of control over their own time management and study strategies (Pintrich, 1995). Furthermore, SRL can be taught and improved, unlike other characteristics such as personality traits (Pintrich, 1995). Adequate learning strategies are also extra important for university students since their workload is both higher and more difficult than before in high school (Wolf, 2001). Additionally, their level of external support is lower, which also increases the need for adequate learning strategies (Wolf et al., 2009). It is therefore not surprising that SRL is associated with better performance at university (Fokkens-Bruinsma et al., 2021).

There are few studies that have examined the relationship between Self-Regulated Learning and university students with ADHD (Shelton et al., 2019). The existing research suggests that university students with ADHD use fewer SRL strategies, such as expectancy strategies and value strategies (Shelton et al., 2019). Reaser et al. (2007) also found a negative relationship between ADHD and learning strategies, although this did not predict worse academic performance in their study. These findings are in line with studies in high school students, in which students with ADHD had less motivational and goal-directed strategies than their peers (Sibley et al., 2019). In that study, cognitive aspects of SRL were especially important predictors of academic success.

The Current Study

The current study will provide insight into the relation between ADHD symptoms, Executive Function and Self-Regulated Learning by answering the following question: Do university students with ADHD symptoms use less effective self-regulated learning strategies, specifically cognitive strategies for learning, and to what extent does this relate to Executive Functions? Additionally, the present study will compare the different domains of ADHD symptoms (inattentive and hyperactive/impulsive) and how they relate to Self-Regulated Learning. Previous research has found different effects of inattentive symptoms and hyperactive/impulsive systems on study skills and adjustment to university; only inattentive symptoms seem to have a negative influence (Norvilitis et al., 2010; Norwalk et al., 2019). Hyperactive/impulsive symptoms may even have a positive effect on learning strategies (Shelton et al., 2019).

To answer this research question, the current study will use an online questionnaire to collect data on the ADHD symptoms of university students, as well as their executive functioning and self-regulated learning strategies. This data will then be analysed using a dimensional approach. This approach has several advantages. First, a dimensional approach will be more meaningful in a non-clinical population and no information will be lost due to an artificial cut-off score. Second, a dimensional approach will have more statistical power, which has statistical advantages. And finally, the majority of people in clinical populations have comorbid disorders (Katzman et al., 2017). The findings in studies of clinical ADHD populations may therefore be highly influenced by comorbidity, whereas a dimensional approach does not have this disadvantage.

Method

Participants

The target group of this study were first year psychology students at the University of Groningen. The study consisted of two surveys which were administered at two separate times. Only participants who completed both questionnaires at both times were included in the analysis. In the first part of the study, 303 people participated. Of this group, 257 people also participated in the second part of the study. Due to duplicate and unfinished cases, the combined group consisted of 350 cases. Of these cases, 50 were removed because they were duplicates. Additionally, 95 were removed because at least one questionnaire was unfinished. Four other cases were removed, because the participant was younger than 18 years old. After checking for reliable responding, eight more cases were removed because they did not meet the requirements of the infrequency index of the Conners' Adult ADHD Rating Scales (CAARS), while 27 cases were removed because they did not meet the requirements of the inconsistency index. Finally, six cases were removed, because they failed to correctly answer the check-up questions of the Motivated Strategies for Learning Questionnaire (MSLQ). The final sample consisted of 160 participants with ages ranging from 18 years to 35 years old (M = 19.73, SD = 2.074). Of these participants, 128 identified as female and 32 identified as male.

All the participants for this study were recruited through SONA. This is an online research platform where students can participate in scientific research in exchange for credits, as part of a course. To participate in this study, the students had to be enrolled in the course 'Introduction to Psychology', because the surveys contained questions about this course. Additionally, the students had to be at least 18 years old, because the CAARS does not have norm scores for people younger than 18. Before participating, all participants were informed of their rights, the confidentiality of their data and were given an outline of the study. They were then asked for their consent, based on this information. Before recruitment took place, the study was approved by the Ethics Committee of the Psychology Department of the University of Groningen (PSY-2021-S-0054).

Research design and procedure

The present study has a correlational design, and investigates connections between levels of ADHD symptoms, executive functioning and cognitive self-regulated learning strategies through the use of quantitative analysis methods. As such, we made no predictions about the causality of these associations. In particular, a correlational analysis was chosen in order to reflect on the dimensional nature of the studied variables. This approach allowed us to analyse the differences in the strength of association between ADHD, EF and different cognitive SRL strategies in a more nuanced way and it is further relevant because of the use of a non-clinical sample.

Data was collected through the online questionnaire platform Qualtrics, which participants were redirected to after signing up for the study through SONA, using their university login information. As mentioned before, participants completed two different surveys at separate times. The first survey measured their levels of ADHD symptoms and took approximately 60 minutes to complete. The second survey measured their executive functioning and asked them about the learning strategies they typically employ while studying. The total time needed to complete this survey was estimated to be around 40 minutes and participants were compensated with SONA credits for their participation. The study was available on SONA from January 25 until February 14 2023. Participants were free to sign up for and complete the study at any time within this period.

Measures

CAARS

The Conners' Adult ADHD Rating Scales (CAARS) was used to measure the ADHD-symptoms. The CAARS is a self-rating scale intended for adults aged 18 and up who present with ADHD-symptoms (Conners et al., 1998). It makes use of a four-point Likert scale (0 = never; 1 = occasional; 2 = often; 3 = very often). The CAARS consists of two types of forms, a self-report rating and an observer rating. For this study the long version of the self-report CAARS (CAARS-S:L) was used. This list consists of 66 items which represent nine different subscales. The long form of the CAARS will take most adults less than 30 minutes. If participants finish the questionnaire within 10 minutes, a haphazard response can be expected.

Four of the subscales test for the behavioural symptoms of ADHD: 1. Inattention/Memory Problems (12-item); 2. Hyperactivity/Restlessness (12-item); 3. Impulsivity/Emotional Lability (12-item); 4. Self-concept problems (6-item). For the subscale Inattention/Memory Problems examples of questions are: "I don't plan ahead." and "I can't get things done unless there's an absolute deadline.". Examples of questions for the subscale Hyperactivity/Restlessness are: "I like to be doing active things." and "I can't sit still for very long.". Examples of questions from the subscale Impulsivity/Emotional Lability are: "I blurt out things" and "My moods are unpredictable.". For the subscale problems with Self-Concept example questions are: "I get down on myself." and "I wish I had greater confidence in my abilities.". The three remaining scales measure ADHD-symptomatology in keeping with the guidelines of the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 1994): DSM-IV Inattention Symptoms subscale (9-item), DSM-IV Hyperactivity-Impulsivity symptoms subscale (9-item) and the DSM-IV ADHD-symptoms total scale. To report on the total degree of adult ADHD-symptomatology and to assess an individual's overall risk of being diagnosed with ADHD (Mohamed et al., 2016), the questionnaire uses the ADHD index subscale (12-item). Example questions of the DSM-IV Inattentive Symptoms list are: “I lose things necessary for tasks or activities.” and “I don’t like homework or job activities where I have to think a lot.”. Example questions from the DSM-IV Hyperactive-Impulsive Symptoms are: “I talk too much.” and “I am restless or overactive.”. For the ADHD Index the following questions are examples of questions included: “I am always on the go, as if driven by a motor.” and “I can’t keep my mind on something unless it’s really interesting.”.

The total score of the CAARS varies between 0 and 198. For the analysis, the raw scores of the CAARS subscales first had to be converted into T-scores, a standard score with a mean of 50 and a standard deviation of 10 across all scales in every sample. Using T-scores helps to compare subscale results. The correct gender and age category column was used.

The CAARS manual dictates that a T-score of 65 or higher falls into the clinically significant range and therefore signals an above average representation of ADHD-symptomatology in an individual (Conners et al., 1998). When the T-score is below 60, it often indicates no ADHD-symptomology. A T-score above 80 can be a possible indicator of invalidity because of exaggeration or malingering of symptoms (Conners et al., 1998; Suhr et al., 2011). Overall, the higher the T-score, the higher the presented ADHD-symptomatology.

The CAARS questionnaire has shown to have a good internal consistency, acceptable test-retest reliability and holds a high sensitivity towards distinguishing between healthy control groups and individuals diagnosed with ADHD (Christiansen et al., 2012; Erhard et al., 1999). This study has found a Cronbach’s alpha of .96. Other studies have found the Cronbach’s alpha of the CAARS self-report measures to fall in between .66 and .90 (Conners et al., 1998). The Total Infrequency Index (CII) for the CAARS-S-L, created to detect possible feigning, has a Cronbach’s alpha of .86. A score of 20 or less occurred in 90.1% of the ADHD group (Suhr et al., 2011). Therefore, a cut-off score of 21 was used for this study.

The CII has a general modest sensitivity (30%) and a high specificity (95%) (Wallace & Walls, 2020). Additionally, the CAARS-S-L contains an Inconsistency Index to identify inconsistency in responses. For this study, the recommended cut-off score of 8 was used. Using this cut-off score, the Inconsistency Index has a high sensitivity (96%), as well as a high specificity (96%) (Conners et al., 1998).

MSLQ

The Motivated Strategies for Learning Questionnaire (Pintrich et al., 1991) is a self-report scale used to assess academic motivation and the different learning strategies in university students. This scale consists of two sections: Motivation scales and Learning Strategies scales, which cover 15 different subscales (Intrinsic Goal Orientation, Extrinsic Goal Orientation, Task Value, Control of Learning Beliefs, Self-Efficacy for Learning and Performance, Test Anxiety, Rehearsal, Elaboration, Organization, Critical Thinking, Metacognitive Self-Regulation, Time and Study Environment, Effort Regulation, Peer Learning and Help Seeking). They are assessed using a seven-point Likert response option format (from 1 = not at all true of me to 7 = very true of me).

The first section assesses motivation with 31 items and asks for goals-value beliefs, control beliefs and self-efficacy. The second section, which assesses learning strategies, includes 31 items to assess different cognitive and metacognitive strategies. This part further includes 19 items to assess for resource management. Additionally, six check-up questions were included to check for reliable responding. Examples of questions from the Motivation scale are: “In a class like this, I prefer course material that really challenges me so I can learn new things.” and “Getting a good grade in this class is the most satisfying thing for me right now.”. Examples of questions from the Learning Strategies scales are: “When I study for this class, I practice saying that material to myself over and over.” and “When I study for this class, I pull together information from different sources, such as lectures, readings, and discussions.". Overall, the entire questionnaire takes about 20-30 minutes for completion but it is possible to only administer individual subscales for assessment.

Subscales of the MSLQ are scored by summing up the scores of individual items and taking the average. The score of the "reversed" items have to be reversed. For example, an individual scoring a 1 on an item now receives a 7. Generally, a higher score like 4, 5, 6, and 7 is better than a lower score like 1, 2, or 3. An exception is the Anxiety scale, where a higher score is more worrying. For this study, the subscales of Cognitive and Metacognitive Strategies were used (Rehearsal, Elaboration, Organization, Critical Thinking and Metacognitive Self-Regulation).

The MSLQ has so far demonstrated a good reliability of its subscales, as well as reasonably good predictive validity of performance (Pintrich et al., 1993). Past research has reported the Cronbach's alpha of the MSLQ to fall in between .52 and .93 (Pintrich et al., 1993). This study has found a Cronbach's alpha of .89. Given the sample characteristics, the MSLQ is an appropriate and well fit research tool (Davenport, 2003).

EFI

The Executive Function Index Scale (EFI; Spinella, 2005) is a self-assessment scale created to measure executive functions used in daily life (Mohamed et al., 2021). It utilizes a five-point Likert scale response format (1 = not at all, to 5 = very much) for 27 items. Those items are representative of five subscales: motivational drive (motivation, energy levels), organization (multitasking, sequencing), impulse control (self-inhibition, propensity for risky behaviour), empathy (interest in the well-being of others, pro-social behaviour), and strategic planning (planning, thinking ahead, making use of strategies) (Spinella, 2005). Questions for this scale include: "I save money on a regular basis" or "I think about the consequences of an action before I do it".

The total score of the EFI is calculated using the sum of all items. Here, a lower score is indicative of poorer executive functioning. With an increase in score, the executive functioning improves as well (Spinella, 2005). For the analysis of this study, the total score of the EFI was used.

Different studies have reported the internal consistency to be acceptable (Spinella, 2005; Gwenny et al., 2009). Originally, the reported alpha for the EFI scale falls in between .70 to .82 (Spinella, 2005). In comparison, this study reports a Cronbach's alpha of .75, thereby showing a good reliability of the scale.

Data Analysis

After extracting the raw data from the Qualtrics software, results from the CAARS, EFI, and MSLQ were analysed. First, the data were analysed for outliers by using boxplots. In this analysis, one outlier was detected in the MSLQ data (see Appendix A). Because the outlier did not seem to have a strong effect on the data, it was decided to keep the outlier in the analysis.

To test the first hypothesis, a Pearson correlation analysis was planned. For the second and third hypotheses, a multiple linear regression analysis was planned. Before performing these analyses, the assumptions of linearity, normality, multicollinearity and homoscedasticity were tested. The data met the conditions of the linearity and homoscedasticity assumption (see Appendix A). However, the QQ-plot and Shapiro-Wilks tests showed that the CAARS data deviated slightly from normality (see Appendix A). Therefore, the assumption of normality was not met. However, the deviation was small, since the skewness and kurtosis values were between -1 and +1.

Additionally, the assumption of multicollinearity was violated. It was found that the CAARS data and EFI data correlated too strongly, since the variance inflation factor (VIF) was above 1 (see appendix A). Additionally, for the third hypothesis it was found that the scales for inattentive symptoms and hyperactive/impulsive symptoms correlated too strongly (see appendix A). Therefore, it was decided not to use a regression analysis for the second and third hypotheses. Instead, a partial correlation analysis was performed. A partial correlation analysis does not require that the variables show no multicollinearity and is therefore suitable for the data.

Results

Hypotheses

First, the following hypothesis was tested: There is a negative association between ADHD symptoms and self-regulated learning strategies, specifically cognitive strategies. To test this hypothesis, a correlation analysis was performed. This analysis confirmed the first hypothesis: Participants who scored higher on the CAARS had lower scores on the cognitive scale of the MSLQ (see Table 1).

Table 1

Correlations

Variable	1	2	3	4	5
1. MSLQ_COG	-	-.166*	.385**	-.186*	-.093
2. CAARS_TscoreDSM_Total	-	-	-.518**	.918**	.867**
3. EFI_total	-	-	-	-.546**	-.365**
4. CAARS_TscoreDSM_Inattention	-	-	-	-	.602**
5. CAARS_TscoreDSM_HypImp	-	-	-	-	-

Note. MSLQ_COG = Cognitive learning strategies, CAARS_TscoreDSM_Total = Total ADHD symptoms, EFI_total = Executive function, CAARS_TscoreDSM_Inattention = Inattentive symptoms of ADHD, CAARS_TscoreDSM_HypImp = Hyperactive/impulsive symptoms of ADHD

* $p < .05$

** $p < .01$

Then, the second hypothesis was tested: Executive function has a significant effect on the relationship between ADHD symptoms and cognitive learning strategies. This was tested by performing a partial correlation analysis. Without controlling for variables, there was a significant negative correlation between ADHD symptoms and cognitive learning strategies (see Table 1). However, when controlling for executive function, the correlation between ADHD symptoms and cognitive learning strategies disappeared ($r(157) = .042$, $p = .596$). Yet, a moderate positive correlation between executive function and cognitive learning strategies was found when controlling for ADHD symptoms ($r(157) = .354$, $p < .001$). This supports the hypothesis that executive function influences the relationship between ADHD symptoms and cognitive learning strategies.

Finally, the third hypothesis was tested: There is a negative association between inattentive ADHD symptoms and cognitive learning strategies, but there is no significant association between hyperactive/impulsive ADHD symptoms and cognitive learning strategies or there is even a positive association. To test this hypothesis, a partial correlation analysis between inattentive ADHD symptoms, hyperactive/impulsive ADHD symptoms and cognitive learning strategies was performed. As expected, students with more inattentive ADHD symptoms showed less cognitive learning strategies, when controlling for hyperactive-impulsive symptoms ($r(157) = -.163$, $p = .040$). Additionally, there was no significant relationship between hyperactive/impulsive ADHD symptoms and cognitive learning strategies when controlling for inattentive symptoms ($r(157) = .024$, $p = .766$). This supports the hypothesis that inattentive ADHD symptoms negatively affect cognitive learning strategies, while hyperactive/impulsive symptoms do not.

Discussion

This study examined the relationship between ADHD symptoms, executive function and cognitive learning strategies among university students. Consistent with the first hypothesis, it was found that there is a negative relation between ADHD symptoms and cognitive learning strategies. This finding corroborates previous research on the relationship between ADHD and learning strategies (Reaser et al., 2007; Shelton et al., 2019). Additionally, this finding adds to the existing research due to its specific focus on cognitive learning strategies, suggesting that students with ADHD use less cognitive learning strategies. This includes various study skills like elaboration, organization and metacognitive self-regulation. Since learning strategies have been associated with academic performance, this finding may explain why students with ADHD face more academic problems than their peers (Fokkens-Bruinsma et al., 2021; Sibley et al., 2019).

Additionally, it was hypothesized that executive function would have a significant effect on the relationship between ADHD symptoms and cognitive learning strategies. Our results showed that the significant correlation between ADHD symptoms and cognitive learning strategies disappeared when controlling for executive function. Executive function itself had a positive correlation with cognitive learning strategies when controlling for ADHD symptoms. This suggests that the relationship between ADHD symptoms and cognitive learning strategies is for a large part explained by executive function. Executive function is therefore an important mediating factor in this relationship. This fits with existing research that shows that executive function plays an important role in ADHD (Boonstra et al., 2005; Willcutt et al., 2005), while also being a predicting factor of Self-Regulated Learning in young school children (Davis et al., 2021). Our findings add to this research by showing a mediating effect of executive function on the relationship between ADHD and cognitive learning strategies in a university student population.

The third hypothesis stated that inattentive ADHD symptoms have a negative relationship with cognitive learning strategies, while hyperactive/impulsive ADHD symptoms do not have a significant relationship with cognitive learning strategies or even a positive relationship. Consistent with the hypothesis, the data showed a negative correlation between inattentive ADHD symptoms and cognitive learning strategies, but no significant correlation between hyperactive/impulsive ADHD symptoms and cognitive learning strategies when controlling for each other in the analysis. These findings are in line with a study by Norwalk et al. (2019), who compared the effects of inattentive and hyperactive ADHD symptoms on study skills. However, our findings are not in line with the findings of Shelton et al. (2019). In their study, a positive association between hyperactive/impulsive ADHD symptoms and self-regulated learning strategies was found. This difference could be explained by a difference in the statistical methods. Shelton et al. (2019) studied the correlation between ADHD symptoms and self-regulation (mainly focusing on metacognitive regulation and effort regulation), instead of cognitive learning strategies like in the present study (focusing on a broad range of cognitive strategies and metacognitive regulation). Hyperactive/impulsive ADHD symptoms could have a protective effect on self-regulation, but not on a broader range of cognitive learning strategies. Moreover, Shelton et al. (2019) control for both inattentive ADHD symptoms as well as Sluggish Cognitive Tempo (SCT). This last variable could play a significant role in the relationship between hyperactive/impulsive ADHD symptoms and SRL, thereby influencing the outcomes, particularly since all predictors were highly intercorrelated (which may have affected multicollinearity). Future studies into hyperactive/impulsive ADHD symptoms and learning strategies could further the understanding of this relationship.

Strengths and weaknesses

This study has several strengths and weaknesses. First, an important strength of this study is the use of a dimensional approach. A dimensional approach can sometimes be more meaningful than a categorical approach, because it uses all the available data. A major drawback of the categorical approach is that it has to divide people into different categories using artificial cut-off scores, thereby losing much data in the process. A dimensional approach does not have this disadvantage. This is especially salient in this study, since a non-clinical population is studied. Another advantage of the dimensional approach is that it is less sensitive to contamination caused by comorbid psychopathological traits or medication use. The majority of people in a clinical population have comorbid disorders (Katzman et al., 2017). A categorical approach, which divides the population in clinical and non-clinical groups, is therefore more likely to be influenced by the presence of comorbid disorders compared to a dimensional approach.

Another strength of this study is the use of valid and reliable instruments. As mentioned previously, the CAARS has been found to have a good internal consistency, an acceptable test-retest reliability and adequate levels of sensitivity and specificity (Christiansen et al., 2012; Erhard et al., 1999). The MSLQ has shown to have a good reliability of its subscales, as well as a reasonably good predictive validity (Pintrich et al., 1993). Additionally, the EFI has shown a strong convergent validity when compared to other thoroughly studied instruments, as well as an acceptable internal consistency (Spinella, 2005; Gwenny et al., 2009). Finally, responses were thoroughly checked for reliability. For the CAARS the infrequency and inconsistency index were used to check for unreliable responding, while check-up questions were used for the MSLQ.

One limitation of this study is the somewhat homogenous participant group. This limitation means that the results can be less representative of university students other than psychology students. Psychology students might differ from other students, thereby influencing the results. Psychology might require different character traits and learning skills than other study programmes, resulting in a group of students that have slightly different self-regulated learning skills than other students. For example, differences have been found between the cognitive styles of students of social and physical sciences (Billington et al., 2007; Groen et al., 2017). Second, the majority of the participants of this study were female (80%); meaning that male students were underrepresented. Additionally, the reference group of the surveys did not include scores for people that do not fall into binary gender categories and non-binary people could therefore not be included in this study. Future studies could address this limitation by collecting data from students with different (academic) backgrounds.

Finally, in this study executive function was measured using a self-rating scale. One strength of this research method is that it allows executive function to be measured over a longer period of time. This means that the results of this measure probably have a higher ecological validity than executive function tests, which only measure executive functions over a one-time assessment (Barkley & Murphy, 2011). Since executive functions are responsible for planning and goal setting behaviour, it makes sense to measure these functions over a longer period of time. In everyday life, long term goals can sometimes span several months or years, which cannot be measured in a neuropsychological executive function test. However, self-rating scales for executive function also have a disadvantage. To accurately measure executive function using self-rating scales, individuals need to have a good insight into their executive functioning. Yet, research has found that individuals with ADHD show significant unawareness of executive dysfunction in daily life (Fisher et al., 2022). Specifically, they have a tendency to overestimate their executive functioning. The participants of this study that scored high on the CAARS could therefore have shown a higher level of executive functioning on the EFI than they actually have. Nevertheless, strong correlations are found between CAARS scores and the EFI.

Implications

First, the findings have clinical implications. The negative correlation between ADHD symptoms and cognitive learning strategies shows that university students with ADHD use less self-regulated learning skills. Since self-regulated learning skills are associated with better academic outcomes, it could be especially beneficial for students with ADHD to improve their learning skills (Fokkens-Bruinsma et al., 2021). Interventions based on cognitive learning strategies could thereby help close the gap between the academic results of students with ADHD and their peers (Advokat et al., 2011; DuPaul et al., 2009; Frazier et al., 2007; Heiligenstein et al., 1999). However, the mediating role of executive function in the relationship between ADHD symptoms and cognitive learning strategies implies that it might be more difficult for students with ADHD to use and learn self-regulated learning skills than for their peers. Therefore, potential SRL-based interventions should take into account that the use of cognitive learning strategies may require extra attention and training for this group. Lastly, the findings of this study show that specifically inattentive ADHD symptoms are negatively correlated with cognitive learning strategies. This suggests that students with inattentive symptoms might benefit especially from interventions based on self-regulated learning.

Second, the findings have implications for future research. This study found executive function to be an important mediating factor in the relationship between ADHD and self-regulated learning. Future research could further study this relationship to deepen the understanding of the role of executive function. Furthermore, this study is one of the few studies that examines the relationship between ADHD symptoms and self-regulated learning in a university student population. The negative association found between ADHD symptoms, specifically inattentive symptoms, and cognitive learning strategies adds to existing research on ADHD and learning skills. However, much is still unknown about this relationship, especially in a student population. Future research could add to the existing knowledge by studying other aspects of self-regulated learning, such as motivational aspects, and their relationship with the different domains of ADHD symptoms.

Conclusion

Research has found that university students with ADHD face more academic difficulties than their peers. However, there are relatively few studies investigating this population. This study tried to fill this gap by studying the underlying mechanisms of the relationship between ADHD, executive function and cognitive learning strategies. The findings show that students with ADHD symptoms, particularly students with inattentive symptoms, use less cognitive learning skills, such as elaboration, organization and metacognitive self-regulation. Additionally, it was found that this relationship is mediated by executive functions, showing that cognitive functions such as motivational drive and strategic planning for a large part explain the association between ADHD and cognitive learning skills. These findings could help improve interventions for students with ADHD, thereby improving their academic functioning.

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Appendix A

Figure A1

Boxplot of ADHD Symptoms (CAARS_TscoreDSM_Total)

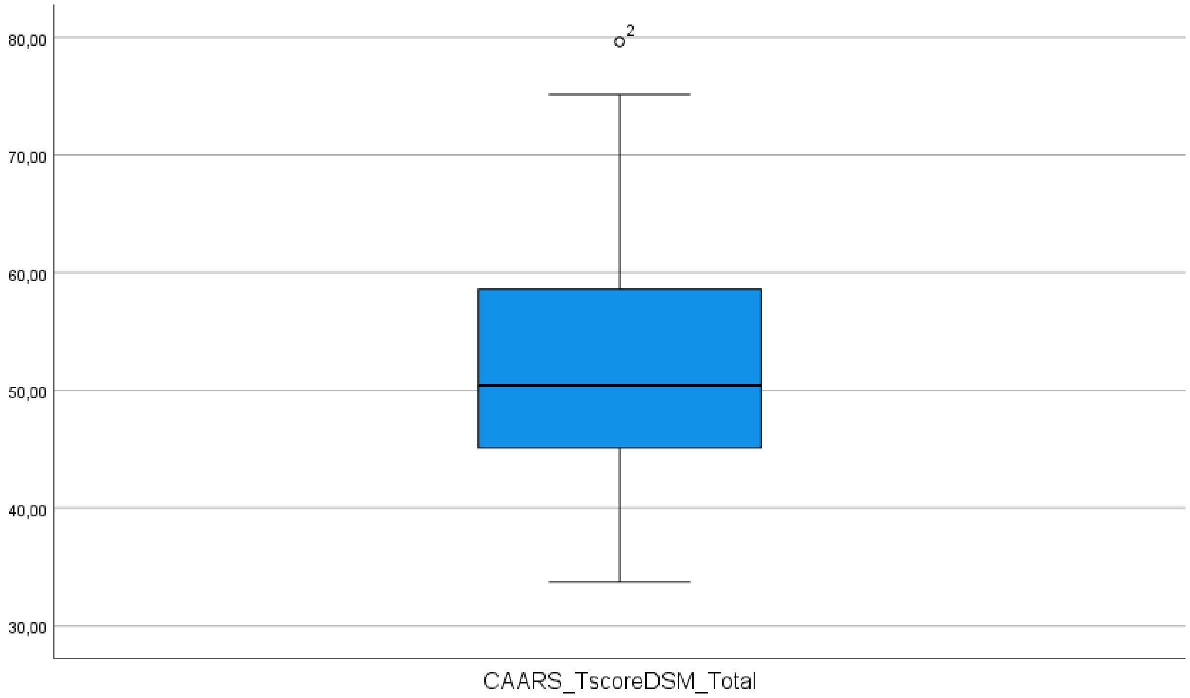

Figure A2

Boxplot of executive function (EFI_total)

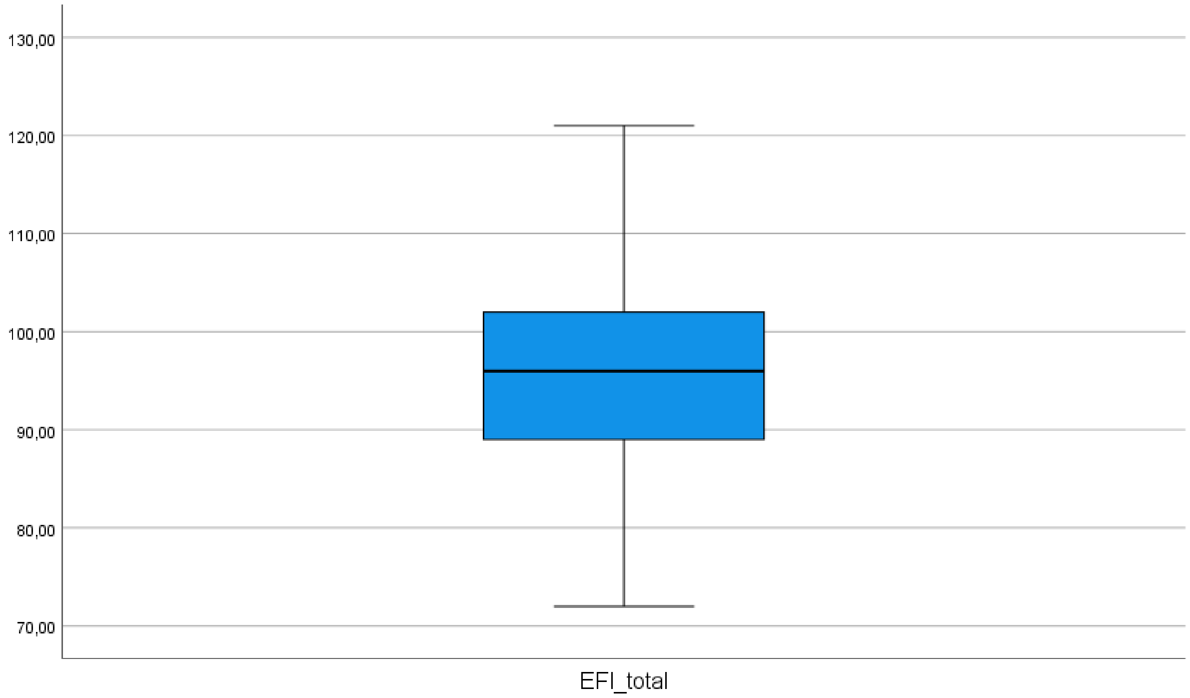

Figure A3

Boxplot of cognitive learning strategies (MSLQ_COG)

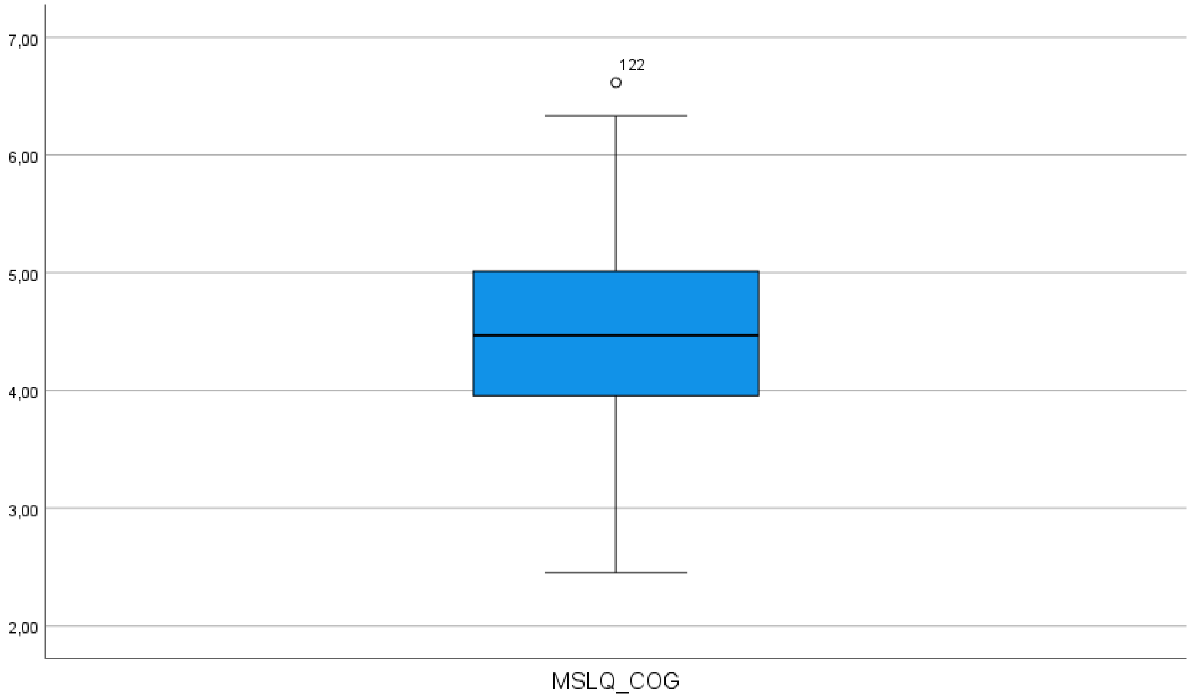

Figure A4

Scatterplot of ADHD Symptoms (CAARS_TscoreDSM_Total) and Cognitive Learning Strategies (MSLQ_COG)

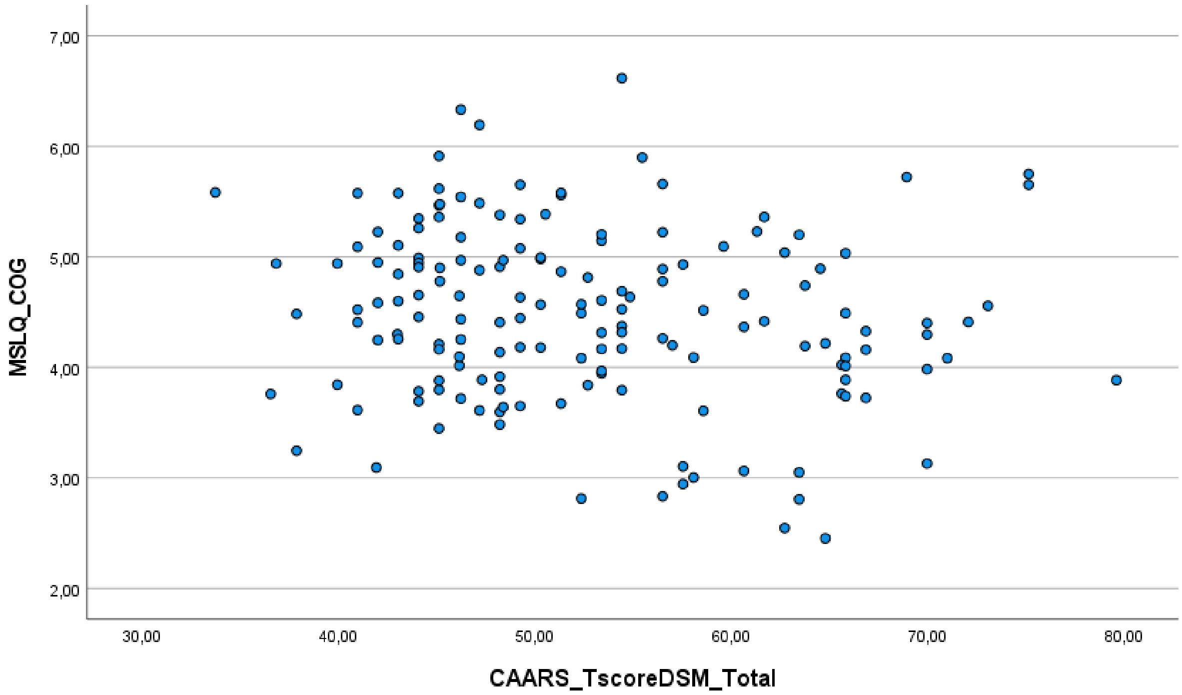

Figure A5

Scatterplot of executive function (EFI_total) and cognitive learning strategies (MSLQ_COG)

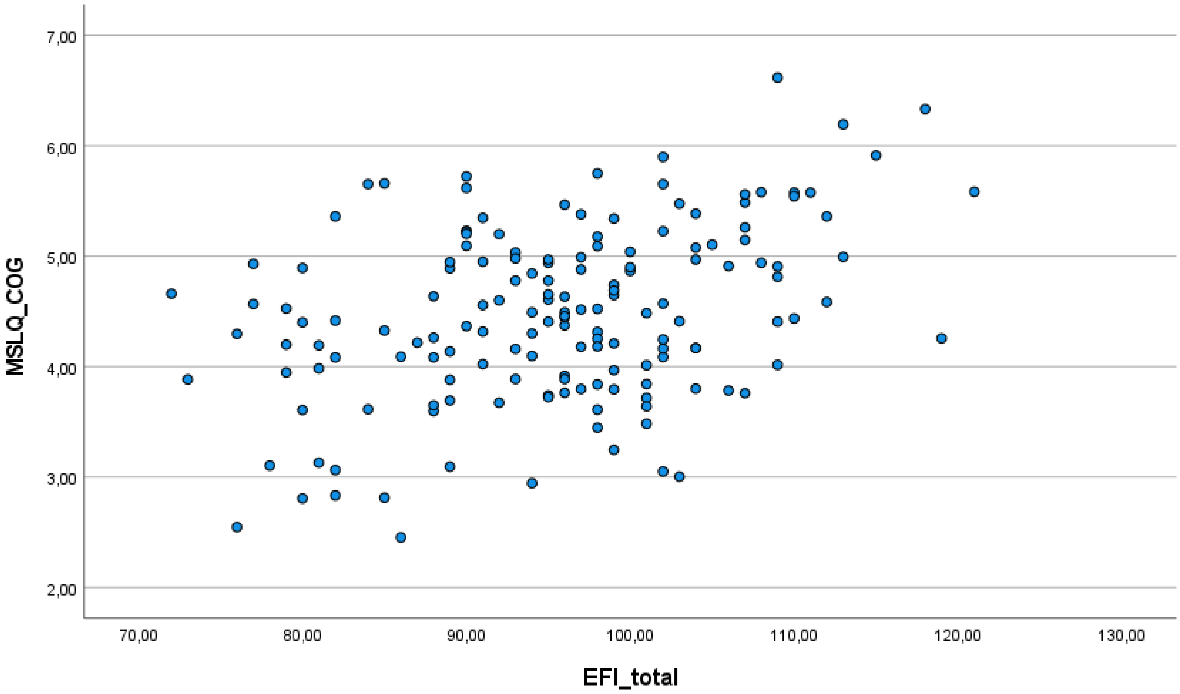

Figure A6

Scatterplot of inattentive ADHD symptoms (CAARS_TscoreDSM_Inattention) and cognitive learning strategies (MSLQ_COG)

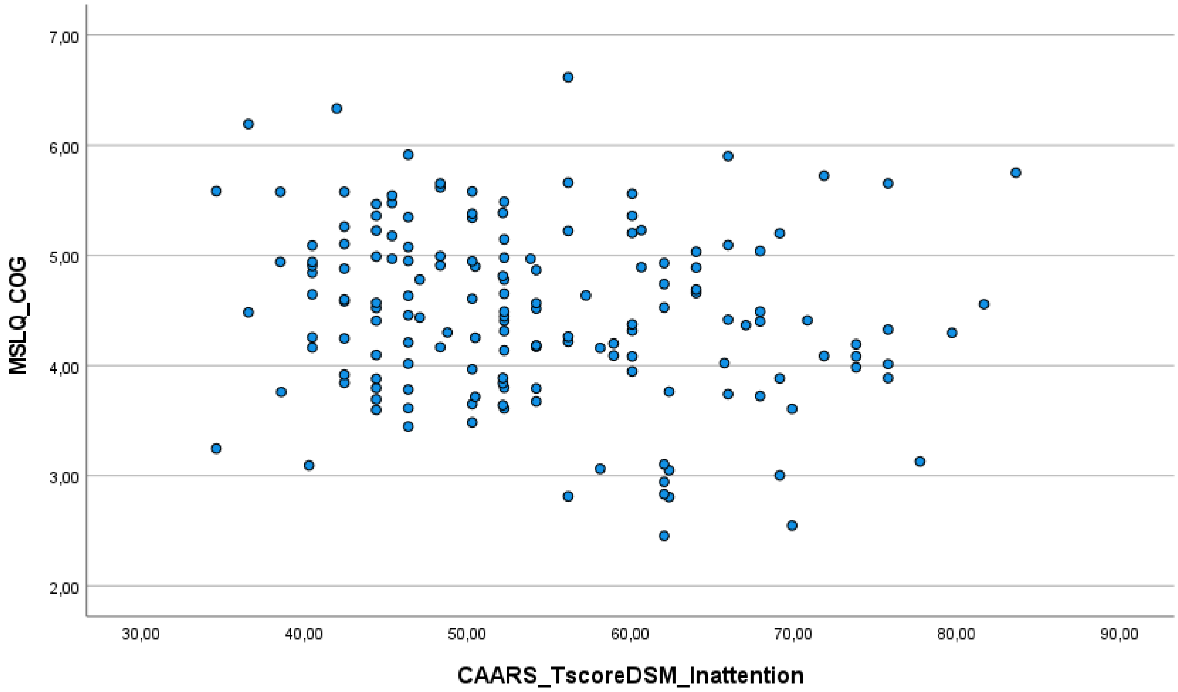

Figure A7

Scatterplot of hyperactive/impulsive symptoms of ADHD (CAARS_TscoreDSM_HypImp) and cognitive learning strategies (MSLQ_COG)

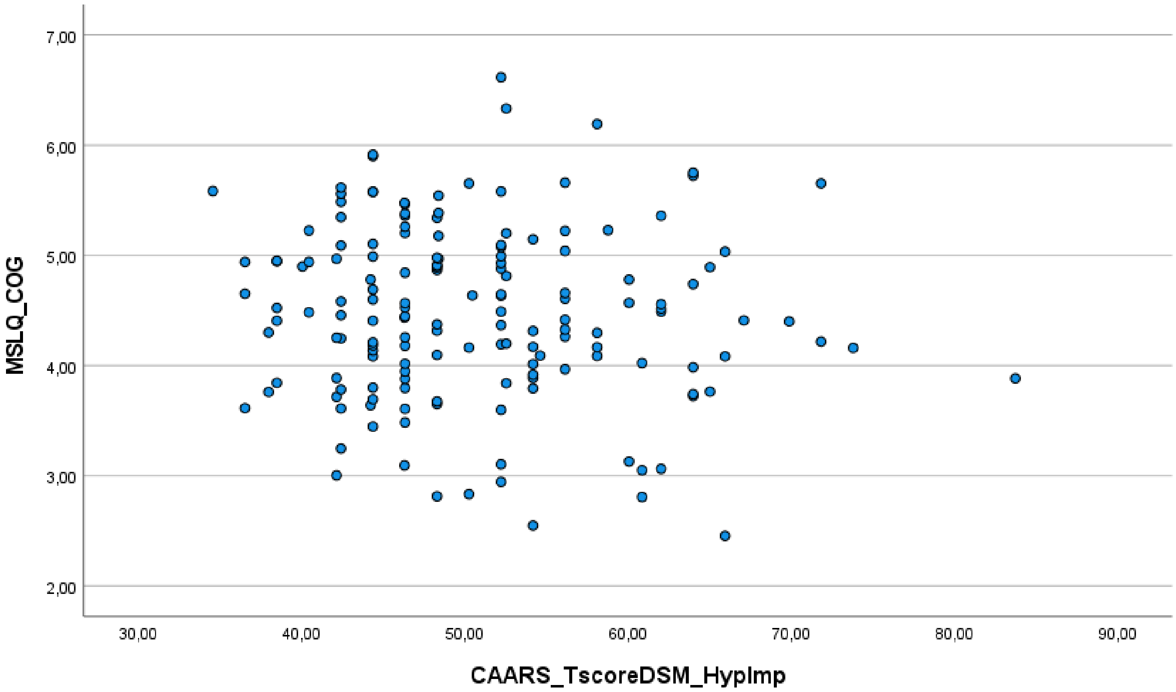

Figure A8

Q-Q Plot of ADHD symptoms (CAARS_TscoreDSM_Total)

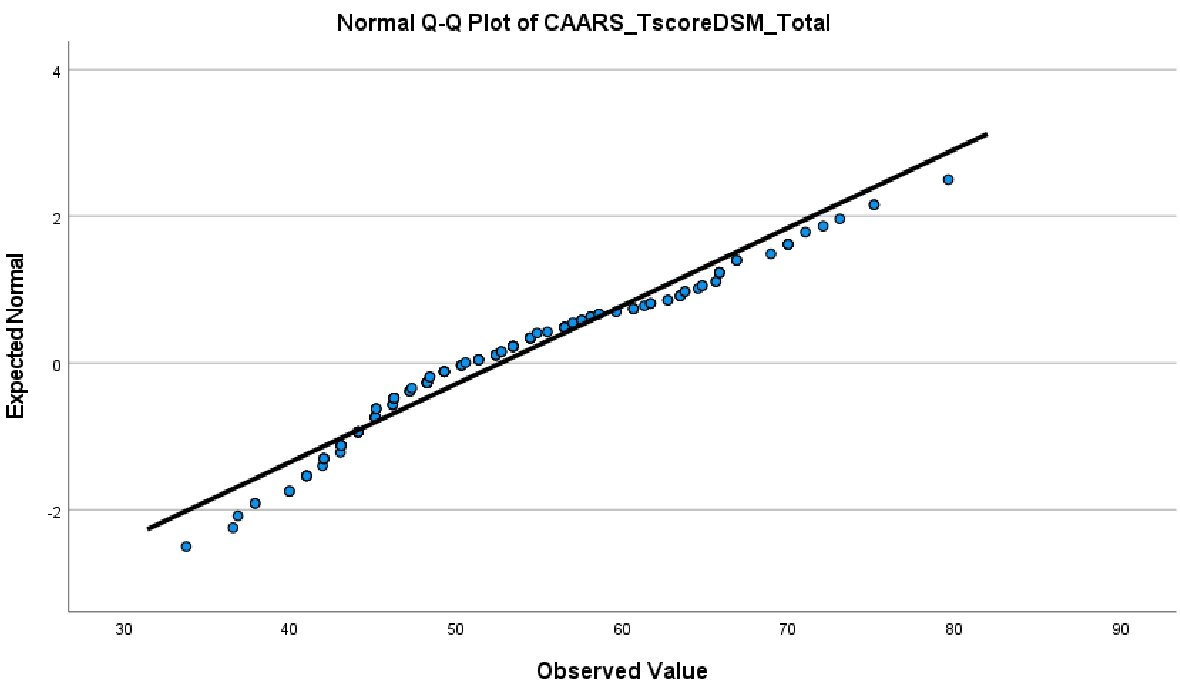

Figure A9

Q-Q Plot of executive function (EFI_total)

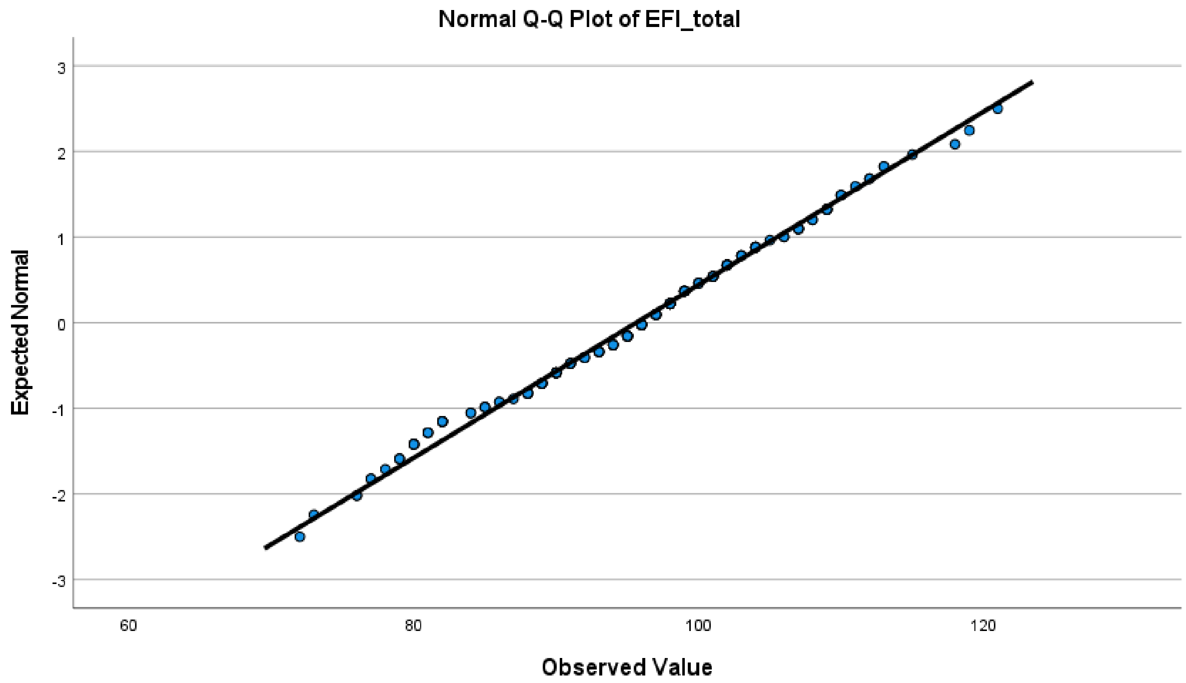

Figure A10

Q-Q Plot of cognitive learning strategies (MSLQ_COG)

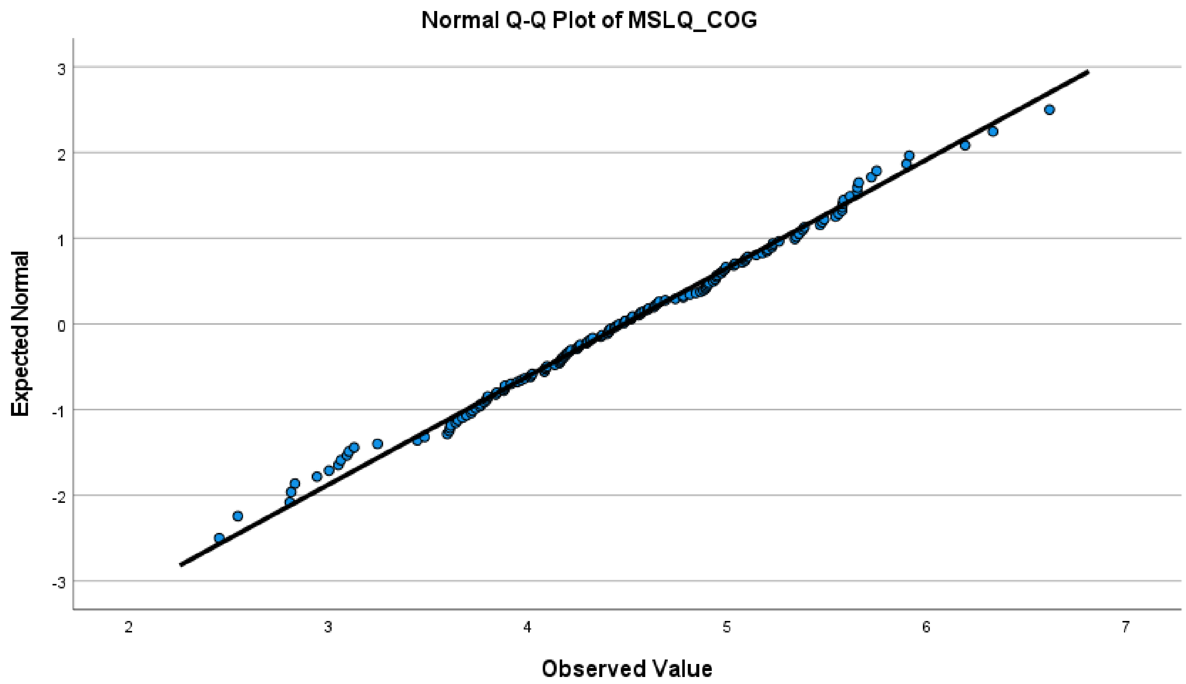

Figure A11

Q-Q Plot of inattentive ADHD symptoms (CAARS_TscoreDSM_Inattention)

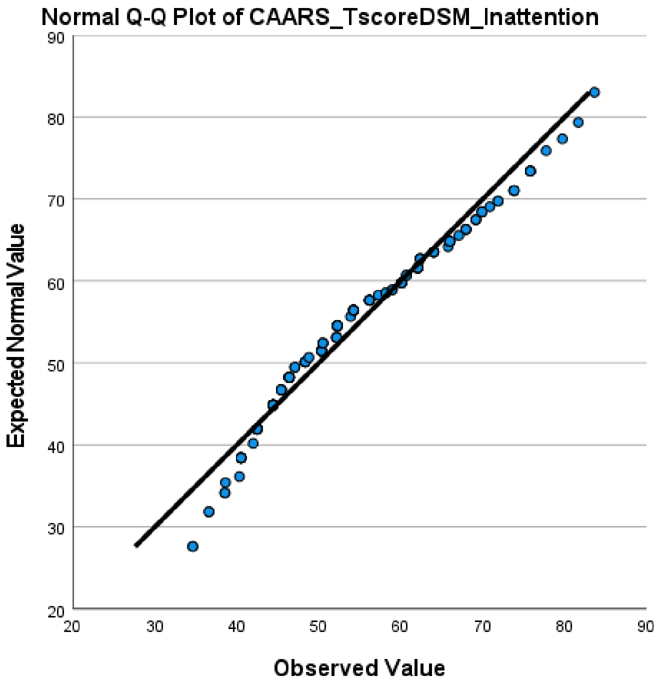

Figure A12

Q-Q Plot of hyperactive/impulsive ADHD symptoms (CAARS_TscoreDSM_HypImp)

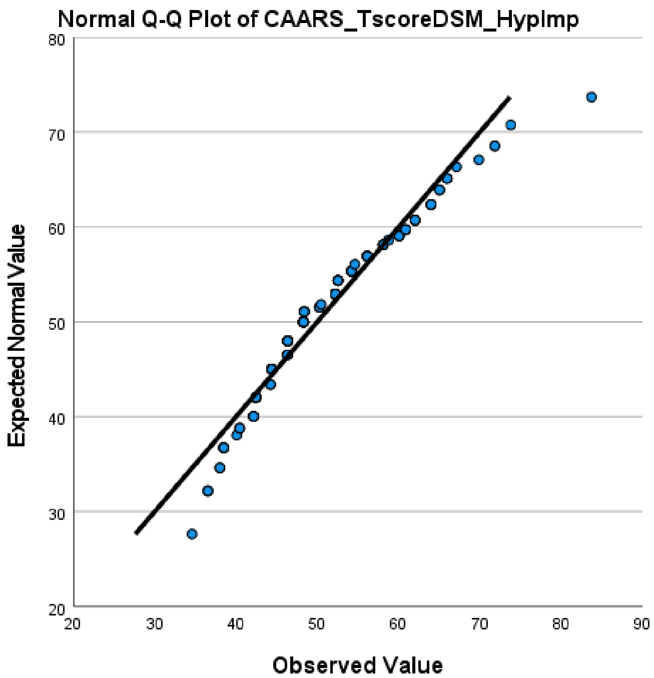

Table A1

Shapiro-Wilk test for ADHD symptoms

	Shapiro-Wilk		
Variable	Statistic	df	Sig.
CAARS_TscoreDSM_Total	.958	160	<.001
CAARS_TscoreDSM_Inattention	.963	160	<.001
CAARS_TscoreDSM_HypImp	.953	160	<.001

Note. CAARS_TscoreDSM_Total = Total ADHD symptoms, CAARS_TscoreDSM_Inattention = Inattentive ADHD symptoms, CAARS_TscoreDSM_HypImp = Hyperactive/Impulsive ADHD symptoms

Table A2

Skewness and Kurtosis values for ADHD symptoms

Variable		Statistic	Std. Error
CAARS_TscoreDSM_Total	Skewness	.580	.192
	Kurtosis	-.383	.381
CAARS_TscoreDSM_Inattention	Skewness	.541	.192
	Kurtosis	-.402	.381
CAARS_TscoreDSM_HypImp	Skewness	.801	.192
	Kurtosis	.665	.381

Note. CAARS_TscoreDSM_Total = Total ADHD symptoms, CAARS_TscoreDSM_Inattention = Inattentive ADHD symptoms, CAARS_TscoreDSM_HypImp = Hyperactive/Impulsive ADHD symptoms

Table A3

Multicollinearity of ADHD symptoms (CAARS_TscoreDSM_Total), executive function (EFI_total), and cognitive learning strategies (MSLQ_COG)

		Collinearity Statistics	
Model		Tolerance	VIF
1	CAARS_TscoreDSM_Total	,731	1,367
	EFI_total	,731	1,367

Note. Dependent Variable: MSLQ_COG

Table A4

Multicollinearity of inattentive ADHD symptoms (CAARS_TscoreDSM_Inattention), hyperactive/impulsive ADHD symptoms (CAARS_TscoreDSM_HypImp), and cognitive learning strategies (MSLQ_COG)

		Collinearity Statistics	
Model		Tolerance	VIF
1	CAARS_TscoreDSM_Inattention	.637	1.569
	CAARS_TscoreDSM_HypImp	.637	1.569

Note. Dependant Variable: MSLQ_COG

Figure A13

Scatterplot of residuals