Children with Attention Deficit Hyperactivity Disorder (ADHD): Reinforcement Sensitivity Theory, Executive Functioning Impairment and Avoiding Mental Effort

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A Thesis Submitted to the

Department of Psychology

City, University of London

for the Degree of

Doctor of Philosophy

2022

Abstract

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder that includes avoiding mental effort and executive functioning impairment. Reports demonstrate that abnormalities in inhibition, working memory, and reinforcement sensitivity play a role. However, the interplay of these factors in the observed executive impairment and frequently avoiding mental effort is not well understood. In this thesis, three investigations were undertaken to expand our understanding of the interplay of these specific impairments and, thus, underlying nature of ADHD.

In the first study, the Reinforcement Sensitivity Theory-Personality Questionnaire-Children (RST-PQ-C) version was translated in order to assess reinforcement sensitivity among Turkish speaking children. In total, 738 primary school students age ranging from 7 to 11 completed the RST-PQ-C as well as the Academic Motivation Scale. Data were analysed using confirmatory factor analysis, hierarchical multiple regression, and structural equation modelling techniques. The results confirmed the hypothesized three-factor structure and the expected relationships between the obtained factors and academic motivation. Evidence is provided to demonstrate that the translated RST-PQ-C is a reliable tool to assess reinforcement sensitivity among Turkish speaking children.

Study 2 was divided into two parts (Study 2a and Study 2b) reflecting the two problems under investigation. The whole study included one clinical group (40 children with ADHD, aged between 7-11 years) and one control group (40 children without ADHD, aged between 7-11 years). The same data set was used in both investigations of Study 2.

Study 2a aimed to investigate the role of inhibition in effort avoidance. A method that employs nine neuropsychological tests for quantifying avoidance behaviour (dependent variable) was developed. Data from the Go/no-go Task (independent variable) and the RST-PQ-C (the behavioural inhibition system, BIS, as the mediator) was analysed in a simultaneous predictive model using moderated mediation analysis. Results demonstrated that prepotent response inhibition had a significant indirect effect on the frequency of avoidance through the BIS and this effect was contingent on the ADHD diagnosis. Based on these findings it can be concluded that the weak prepotent motor response inhibition and the hypoactive BIS result in a higher rate of avoiding mental effort among children with ADHD.

Study 2b aimed to investigate the effect of working memory (WM) load and the fight, flight, freeze system (FFFS) of the revised reinforcement sensitivity theory on executive functioning. Data from the Go/no-go Task, the Working memory-switch Task and the RST-PQ-C were analysed. Mixed repeated measures ANOVA and ANCOVA results showed that the higher WM load and higher FFFS activity resulted in the impaired executive functioning performance among children with ADHD. Based on these findings it can be concluded that maintaining WM load consumes controlled attention resources and leads to a resource allocation problem that hinders the optimal executive functioning performance among children with ADHD. The theoretical implications and practical clinical implications of these results are discussed.

Key words: ADHD, Reinforcement sensitivity theory, inhibition, working memory, avoiding mental effort, impaired executive functioning

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Acknowledgements

I want to thank my supervisor Professor Philip Corr and my co-supervisor Dr Dino Krupić for their continuous support.

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CHAPTER ONE: INTRODUCTION

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder with an onset during childhood and it is marked by a persistent pattern of inattention and/or disinhibition. The Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5; American Psychological Association, 2013) describes three presentations: predominantly inattentive, predominantly hyperactive-impulsive, and combined. Symptoms of the inattentive presentation include avoiding tasks that require sustained mental effort, being easily distracted by extraneous stimuli, failing to pay close attention to details, having difficulty following instructions, and having trouble organizing tasks and activities. On the other hand, symptoms of hyperactivity-impulsivity include excessive motor activity, not being able to remain still when seated, excessive talking, and not being able to wait for his or her turn (see Appendix 1, for the full symptom list). According to the DSM-5 criteria, diagnosis of ADHD requires six or more symptoms from either presentation before age 12 years. Diagnosis of the combined presentation can be made if more than six symptoms exist from each presentation. Moreover, symptoms should be present in two or more settings for more than six months and clear evidence of functional impairment should be observed.

ADHD is one of the most often encountered childhood disorders and the prevalence rate is reported to be 5% on average, across the globe (Sayal et al., 2017). Co-occurring disorders are frequent among individuals with ADHD. For example, the co-existence of oppositional defiant disorder has been reported to be approximately 35% (Noordermeer et al., 2016). Anxiety and depressive disorders have been reported to co-occur about 18% (Jensen et al., 1997). Furthermore, 15% to 20% of children with ADHD have been found to exhibit some form of specific learning disorder (Somale et al., 2016).

The exact aetiology of ADHD is unknown, however existing findings indicate that both genetic and environmental factors play a role as the potential risk factors. For example, genes that are related to dopaminergic neurotransmission, particularly in the fronto-striatal circuits have been implicated in the neurobiology of ADHD (Durston & Konrad, 2007). Moreover, some structural brain abnormalities have been reported. For example, less white matter volume and cortical thickness (Castellanos & Tannock, 2002). Some studies using functional magnetic resonance imaging technique have reported reduced neuronal activity in several brain regions including the prefrontal cortex and basal ganglia (Fassbender & Schweitzer, 2006). On the other hand, environmental risk factors have been implicated that include prenatal exposure to heavy metals (Lee et al., 2018) and alcohol (Han et al., 2015).

Although a greater number of cases are identified during primary school years, reports show that ADHD persists into adolescence and adulthood (Fayyad et al., 2017). Existing studies in the literature demonstrate that the symptoms interfere with and reduce the quality of life among affected individuals (Kofler et al., 2017). For instance, ADHD has been linked with social rejection (Mikami, 2010), a higher rate of traffic accidents (Faraone et al., 2015), poor self-esteem (Harpin et al., 2013), poor occupational performance (Wehmeier et al., 2010), academic underachievement (Daley & Birchwood, 2010), and increased school dropout rates (Fredriksen et al., 2014; Soendergaard et al., 2015).

One of the functional impairments that children with ADHD experience is educational underachievement. Students with ADHD have been reported to give up easily when they are given an academic task and also to experience difficulty in completing and submitting homework (Power et al., 2006). Avoiding mental effort is one of the several symptoms of inattentive presentation. The DSM-5 states that children with ADHD "often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (e.g., schoolwork or homework; for older adolescents and adults, preparing reports, completing forms, reviewing lengthy papers)" (APA, 2013, p. 59). Evidence in the literature supports this statement. Kolk et al. (2015) reported that the children with a higher level of inattentive symptoms were more distracted and had a shorter on-task span during academic work that related to mathematics, language and science. However, this shorter on-task span was not present during music and arts. Results suggest that children with ADHD experience difficulty in cognitively demanding tasks and they have a tendency to avoid mental effort.

Importantly, Zoromski et al. (2021) investigated the relationship between specific ADHD symptoms and observed functional impairments. This study included a large sample of children with ADHD and the data were analysed using step wise multiple regression analysis to examine the magnitude of the influence of specific symptoms in functional domains. Results of this study showed that avoiding tasks that require mental effort was the strongest predictor of academic impairment and it also predicted the parent and teacher ratings of reading, writing, math, and overall school performance.

Based on the existing evidence, it can be concluded that avoiding activities that require sustained mental effort is a disabling behaviour in terms of school achievement. It can result in reduced study time, incomplete homework and eventually, academic impairment. At the current state of research and literature, the factors that are related to frequently avoiding mental effort among children with ADHD are mostly unknown.

1.1. The Current State of the Literature About Avoiding Mental Effort Among Children with ADHD

Very few studies have investigated the underlying factors for avoiding mental effort among individuals with ADHD. Some studies looked into the relationship between ADHD symptom rate and the level of mental effort exerted among healthy adults (lewis et al., 2015; Hsu et al., 2017). On the other hand, some studies investigated whether children with ADHD choose easier tasks with smaller rewards when compared to TD children (Hazel et al., 1999; Mies et al., 2019; Winter et al., 2019). For example, Lewis et al. (2015) investigated the relationship between ADHD symptoms, recall performance, and perceived mental effort among non-patient adults. Participants were located either in the low or high symptom groups depending on their self-rated scores of ADHD. Results of this study showed that individuals in the higher ADHD symptom group reported exerting a higher level of mental effort.

In a more recent study, Mies et al. (2019) investigated reward discounting (i.e., preferring fewer rewards for a less difficult task instead of a higher reward for a more difficult task) among children with ADHD and reported no differences between clinical and control groups. Authors interpreted the results to mean that the children with ADHD prefer difficult tasks with larger rewards as much as typically developing (TD) children. On the other hand, their results also showed some pupil dilation differences between the two groups. Children with ADHD had larger pupil dilation when compared to TD children. Previous studies have linked dilated pupils with higher mental effort exertion (da Silva Castanheira et al., 2021; Tapper et al., 2021). These findings suggest a compensatory cognitive effort. Consideration of weak neuropsychological variables that play a role in the process could help to explain frequently avoiding mental effort among these children.

The mechanism that underlies this problem is mostly unknown. For this reason, the underlying variables that play a role in this process require investigation, especially as these variables pertain to the avoidance of mental effort. As yet there has been no investigation or intervention that has addressed the neuropsychological aspects of the problem of frequently avoiding mental effort. Only when a clear understanding of the process is reached can targeted training approaches be developed to help to reduce avoiding mental effort among children with ADHD.

1.2. Merging Bottom-up and Top-down Processes for Investigating Avoiding Mental Effort

Research investigating bottom-up/motivational aspect of ADHD has revealed reinforcement sensitivity abnormalities. The majority of the studies in the literature have focused on approach behaviour and found an increased sensitivity to rewards (Fosco et al., 2015). However, only a few studies have investigated avoidance motivation among children with ADHD.

The revised reinforcement sensitivity theory (rRST; Gray & McNaughton, 2000) proposes three brain-behaviour systems (i.e., behavioural approach system; BAS; fight, flight, freeze system; FFFS, and behavioural inhibition system; BIS) to account for the approach, avoidance and cautious behaviours, respectively. The rRST describes the BIS as the mechanism that inhibits approach and avoidance motivation.

Inhibition of avoidance behaviour is a complex process and it can be reasoned that both motivational and executive constructs could play a role in production of adaptive behaviour. The BIS and the prepotent motor response inhibition are implicated in self-regulation. The BIS has been proposed to regulate avoidance behaviour and it can be reasoned that a stronger BIS could play a critical role in resisting avoidance motivation and facilitate a longer on task behaviour when facing a cognitively challenging task. Similarly, it has been demonstrated that a higher prepotent motor response inhibition performance is related to higher task persistence (Torgrimson et al., 2021; Karsdorp et al., 2014). The prepotent motor response inhibition is a top-down executive function that helps the individual adapt their behaviour in response to the context.

Studies have demonstrated that children with ADHD have a lower prepotent motor response inhibition performance (Wodka et al., 2007) and they find cognitive tasks more effortful than controls (Gaultney et al., 1999). Lower prepotent motor response inhibition can be related to perceiving tasks as being more difficult and it has been documented that task difficulty is related to avoiding mental effort (Gieseler et al., 2020). If a cognitive task is difficult and irritating then it could produce a significant amount of avoidance motivation. In such circumstances, the functioning of the BIS can be critical to resist escaping. Existing evidence suggests that children with ADHD have a hypoactive BIS (Randazzo et al., 2008) and this could negatively affect their ability to resist avoidance motivation.

Most of all, the literature includes evidence of a link between the prepotent motor response inhibition and the BIS among children with ADHD (Wiersema & Roeyers, 2009). That is why considering both cognitive and motivation related inhibition (i.e., the prepotent motor response inhibition and the rRST-BIS) in a simultaneous predictive model may be very useful for explaining the higher rate of avoiding mental effort. In the present thesis, Study 2a presents the investigation aimed at testing the mediating role of the BIS in the relationship between the prepotent motor response inhibition performance and the frequency of avoiding mental effort among children with ADHD.

1.3. Merging Bottom-up and Top-down Processes for Investigating Impaired Executive Functioning

Study results in the literature provide solid evidence that impaired executive functioning plays a major role in the functional impairments of children with ADHD. Researchers that focused on the top-down/cognitive aspect of the disorder found many executive functioning deficits. For example, Shallice et al. (2010) reported that children with ADHD obtained lower scores than their TD peers when they were evaluated by various tests of executive functioning. In a similar vein, Wodka et al. (2007) found lower prepotent motor response inhibition performance among children with ADHD, when compared to controls. The authors argued that their results support Barkley's (1997) proposition that the impaired prepotent motor response inhibition is the central executive function that underlies the symptoms of ADHD. Although the importance of the impaired prepotent motor response inhibition has been established, some scientists have questioned the proposition that it underlies the ADHD symptoms (Geurts et al., 2006).

Recently, Kofler et al. (2019) demonstrated that children with ADHD have a poorer working memory performance and the authors proposed that the working memory deficit underlies the inhibition impairment in ADHD. According to the current state of the literature, the relationship between working memory and executive functioning is unclear. Therefore, in the present thesis, one of the aims was to investigate the influence of the working memory load, on the executive functioning performance among children with ADHD.

Another one of the bottom-up brain-behaviour systems is the rRST - FFFS. It has been described as a defensive mechanism that reacts to aversive stimuli. Study results in the literature suggest a relationship between the FFFS and the working memory processes. Furthermore, some studies have demonstrated a link between the FFFS and executive functioning performance (Jackson et al., 2014). However, a gap in the literature exists about the interaction of the FFFS and working memory. Considering the reported links, it was further aimed to investigate the effect of the interaction of the FFFS and the working memory load, on the executive functioning performance among children with ADHD.

1.4. Structure of the Thesis

This thesis includes two major studies. In the first study, Reinforcement Sensitivity Theory-Personality Questionnaire-Children (RST-PQ-C; Cooper et al., 2017) was translated into the Turkish language and its psychometric properties were investigated. This study was carried out because there was no instrument for evaluating the reinforcement sensitivity among Turkish speaking children.

Study 2 was divided into two parts because two different problems were addressed. The first part involved an investigation of the role of the prepotent motor response inhibition and the rRST-BIS, in the appearance of mental effort avoidance. On the other hand, in the second part, initially, the effect of working memory load on the executive functioning performance and, then, the effect of the interaction between the working memory and the FFFS, on the executive functioning performance was investigated.

1.5. Summary

In sum, ADHD is a disorder with a persistent pattern of inattention and hyperactivity-impulsivity. Abnormal executive functioning and reinforcement sensitivity have been demonstrated to play a role in the symptom presentation of this disorder. Avoiding mental effort is a symptom of ADHD that exacerbate one of the functional impairments: academic underachievement (Zoromski et al., 2021). However, the factors that are related to avoiding mental effort are currently under-investigated. Study results in the literature suggest that both prepotent motor response inhibition and the rRST - BIS could play roles. However, the nature of their influence on the frequency of avoiding mental effort is not clear and needed to be investigated further - this is a major aim of this thesis.

On the other hand, it has been well established that impaired executive functioning underlies some of the ADHD symptoms. Moreover, accumulating evidence suggests that a working memory deficit could underlie the observed executive functioning impairment among these children. To date, the nature of the interaction between the executive functions and working memory is not clear. Similarly, the influence of the working memory load on the executive functioning performance of children with ADHD is under-investigated. Moreover, a gap exists in terms of the effect of the interaction between the working memory load and the FFFS on the executive functioning performance. The lack of this information in the literature can be argued to be a setback that slows down the production of efficient rehabilitation strategies that targets impaired executive functioning in this population.

1.6. Thesis Outline

In the first chapter of this thesis, a general overview of ADHD is provided and the scene is set for the forthcoming studies aimed at investigating avoiding mental effort and impaired executive functioning among children with ADHD. The second chapter includes a critical review of the literature to define the main concepts and presents the important studies in the literature. It should be noted that each study has its own background section and these sections offer an in-depth analysis and discussion of the most relevant design, tasks and potential weaknesses of the relevant studies. The third chapter presents details of the investigation of the psychometric properties of the Turkish language translation of the RST-PQ-C. Chapter four provides information about a moderated mediation model that is proposed for explaining frequently avoiding mental effort among children with ADHD. Chapter five presents information about the investigation that aims to demonstrate the effect of the working memory load and the reinforcement sensitivity on the impaired executive functioning performance of children with ADHD. Chapter six provides a general discussion of the findings, including clinical implications, theoretical implications and future research directions.

1.7. Statement of the Problems and the Aims

The first problem was the lack of an instrument for measuring the reinforcement sensitivity among Turkish speaking children. For this reason, the RST-PQ-C was translated from English into the Turkish language. The first study, primarily, aimed to investigate the factor structure of the Turkish version of this instrument and provide internal consistency reliability evidence, for showing that it is appropriate to use among Turkish speaking children.

The second problem addressed in the present thesis was the gap in our knowledge about the factors that influence the frequent avoidance of mental effort among children with ADHD. Children with ADHD have been observed to avoid cognitively effortful tasks and choose to engage in activities such as playing games or watching TV that does not demand mental effort. Reports show that children with ADHD do not present a motivational impairment about engaging with effortful tasks however, they find cognitive tasks more effortful when compared to their TD peers. Findings in the literature demonstrate a prepotent motor response inhibition and reinforcement sensitivity abnormality among these children however, the role of these variables in frequently avoiding mental effort has not been investigated. Hence, the second aim of the present thesis was to investigate the roles of the prepotent motor response inhibition and the rRST - BIS in the frequently avoiding mental effort among children with ADHD. For this purpose, a moderated mediation model was proposed and tested. It was important to find out and investigate the critical variables that contribute to avoiding mental effort in this population because studies in the literature showed that frequently avoiding mental effort results in academic underachievement.

The third problem tackled was the gap in the literature regarding the effect of a working memory process (i.e., maintaining information) on the reported executive functioning impairment among children with ADHD. Importantly, there is an ongoing debate about the relationship between working memory and executive functioning. Furthermore, the place and centrality of these constructs concerning observed pathology among children with ADHD recently have attracted a lot of scientific attention with mixed results. Findings indicate an abnormality in maintaining information in their working memory. Moreover, in the current state of the literature, the effect of the interaction between the FFFS and the working memory on the executive functioning performance is not clear. Recent reports suggest that the rRST - FFFS could influence the executive functioning performance via its interaction with the working memory system. Hence, the third aim of the present thesis was to investigate the roles of the working memory load and the rRST - FFFS on the executive functioning performance among children with ADHD. Impaired executive functioning has been linked to functional impairments in ADHD. Hence, it was important to extend the knowledge about the relationships between working memory, the FFFS and the executive functions for facilitating better neuropsychological rehabilitation interventions.

CHAPTER TWO: LITERATURE REVIEW

This chapter examines the scientific literature regarding the revised reinforcement sensitivity theory (rRST), executive functioning, working memory (WM), and avoiding mental effort in relation to ADHD. Children with ADHD often avoid mental effort and also have an executive functioning impairment but the critical variables that play a role in these phenomena are mostly unknown. Reports in the literature suggest that both impaired neuropsychological functioning and abnormal reinforcement sensitivity may play a role but to date, no study that employed a single-level approach has managed to explain the reasons for avoiding mental effort or impaired executive functioning. Therefore, considering both the executive and the reinforcement sensitivity-related constructs can provide a deeper insight into these issues.

In the present chapter, information about the critical theories and the constructs that are related to frequently avoiding mental effort and impaired executive functioning among children with ADHD are presented. Overall, the aim of the present chapter is to demonstrate how some critical constructs relate to each other and why the roles of variables at different levels of functioning should be considered together to account for frequently avoiding mental effort and the impaired executive functioning, among children with ADHD.

2.1. Historical Progression of the DSM-5 and Current Diagnosis of ADHD

In 1902, a condition named the morbid defect of moral control was described by British paediatrician, Sir George F. Still. This condition was very similar to our current description of ADHD and 43 clinical cases of children were presented who had serious problems with sustaining attention and self-regulation. It was in 1968 when the condition was included in the Diagnostic and Statistical Manual of Mental Disorders 2 (APA, 1968), for the first time. The condition was called the hyperkinetic reaction of childhood and described the children who were overactive, restless, distractible, and had a short attention span. When the DSM-3 was published in 1980, only then the description included two subtypes: attention deficit disorder with hyperactivity and attention deficit disorder without hyperactivity. This time, the name was changed to attention deficit disorder. Later, DSM 3-R changed the condition's name to attention deficit hyperactivity disorder and recognized a third subtype (i.e., combined) where the hyperactivity and the inattentiveness were seen together.

In the DSM-5 (i.e., the latest edition of the DSM; 2013), ADHD was moved from the pervasive childhood disorders section to the neurodevelopmental disorders section. Moreover, there has been an extended recognition of adults with ADHD and it has been stated that for individuals over 17, only five symptoms are enough for a diagnosis (APA, 2013).

2.2. Theories of ADHD

In this section, three major theories (i.e., the dual-pathway model, the cognitive energetic model and the behavioural activation/inhibition model) that aim to explain symptoms of ADHD will be discussed. However, two other influential theories (i.e., the inhibition theory and the working memory theory of ADHD) will be discussed in detail in the later sections of this chapter.

2.2.1. Dual-pathway theory

The dual-pathway theory has been proposed by Sonuga-Barke (2002) and it attempts to account for both cognitive (e.g., low performance in a cognitive task) and motivational impairments (e.g., starting to deal with a task but leaving it uncompleted when it gets less interesting) that are observed among individuals with ADHD. Executive functioning impairment and delay-aversion are the two central concepts in this theory. The central assumption of the dual-pathway model is that cognition and motivation are dissociable at the neurobiological level. Sonuga-Barke (2002) argued that these two constructs are sub-served by two distinct neural pathways. An abnormality of dopaminergic activity in any of these pathways was proposed to result in the cognitive or motivational problems of ADHD (Sonuga-Barke et al., 2010).

The dual-pathway model addresses the heterogeneity seen in ADHD by proposing that each child belongs to one of two sub-groups: cognitive or motivational. The model predicts that although the reasons are different, both groups should experience a problem with task engagement. The children in the motivational impairment group are not expected to have an inherent cognitive impairment. It has been proposed that they do not want to engage with tasks because they are delay aversive. The most innovative element in this model can be argued to be the delay-aversion and it has been hypothesized to be experienced only in the motivational group. Delay aversion has been described as preferring a smaller immediate reward over a larger but delayed reward. The level of delay-aversion has conventionally been evaluated using delay discounting tasks. Some studies provided evidence that children with ADHD prefer small, immediate rewards over larger but later rewards (Karalunas & Huang-Pollock, 2011; Marco et al., 2009).

On the other hand, it has been hypothesized that children in the cognitive group have an inherent executive functioning impairment and this impairment is caused by the weak inhibition ability. Hence, children in this group should fail to effectively engage with tasks that require executive skills. At the present a gap in the literature exists about the link between executive impairment and task engagement difficulty. It can be argued that this theory's proposition that inhibitory based executive functioning impairment underlies task disengagement suggest that weak inhibition ability can play a role in frequently avoiding mental effort among children with ADHD.

2.2.2. Cognitive-energetic model

The cognitive energetic model proposes that impairments that are associated with ADHD occur at multiple levels of functioning. The first level of information processing includes encoding, visual search, decision and orientation to stimuli. The second level includes energetic pools: effort, arousal and activation. Sergeant et al. (2003) described that the effort pool provides the energy that is needed for dealing with a task and this is closely related to motivation and cognitive load. The arousal pool has been proposed to be related to the novelty and intensity of a stimulus and according to this model, novel stimuli should trigger increased arousal. Finally, the activation pool has been proposed to be related to a physiological readiness to respond.

According to this model, poor allocation of the energetic resources can be related to deficits observed in ADHD (Sergeant, 2004). Studies in the literature support the notion of abnormal resource allocation in this population. For instance, Dörrenbächer and Kray (2019) demonstrated a link between abnormal resource allocation and WM deficit among children with ADHD. It can be argued that the term energetic resource is vague and it can be difficult to operationalize for investigating resource allocation abnormality in ADHD. On the other hand, cognitive psychology has produced a similar but better-defined concept for explaining allocation of cognitive resources. In a similar vein, central executive (CE) component of WM has been proposed to be a controlled attention resource. It has been argued that the CE is a limited resource pool and the resources of this construct can be allocated to multiple simultaneously activated cognitive functions but leaving fewer resources to be allocated elsewhere. Recent study results suggest that CE could play a role in the observed executive functioning impairment among children with ADHD (Fosco et al., 2020). Hence, at the present, further investigation is needed for clearing the relationship between allocation of CE resources and efficiency of executive functioning.

2.2.3. The behavioural activation/inhibition model of ADHD

Based on Gray's (1982) neuropsychological theory (i.e., reinforcement sensitivity theory), Quay (1993) has proposed that an under-responsive behavioural inhibition system (BIS) and overactive behavioural approach system (BAS) play roles in ADHD symptoms. Within the framework of this theory, over-activity of the BAS has been proposed to be related to the impulsivity-hyperactivity aspect of the disorder. Findings of studies in the literature supported this notion by demonstrating that higher BAS activity is related to the externalizing symptoms of ADHD (Colder & O'Connor, 2004).

Quay (1997) further proposed that the children with ADHD have a hypoactive BIS and this results in a response inhibition deficit. Iaboni et al. (1997) provided evidence for under-responsive BIS by showing that children with ADHD do not exhibit increased skin conductance levels during the extinction phase of a repetitive motor task and hence, remain at the same level of arousal. Moreover, reports in the literature support the notion of a response inhibition deficit among these children (Oosterlaan et al., 1998). However, at the present state of the literature, there is a gap in terms of the relationship between the hypoactive BIS and the observed response inhibition deficit among children with ADHD. An in-depth discussion of reinforcement sensitivity and its relation to ADHD symptoms is presented in the following section.

2.3. Reinforcement Sensitivity Theory

Reinforcement sensitivity theory (RST) is a neuropsychological theory that tries to connect the reinforcement systems of the brain to behaviour (Corr, 2004). It considers and centralizes some concepts such as reinforcement, approach and avoidance. The RST has a multilevel approach to behaviour and it is a continuously developing theory (Corr, 2009). In its effort to explain behaviours and traits, it considers neurophysiology and neuroanatomy. At the neurobiological level, the RST focuses on specific innate biological systems. It postulates that individual differences in these systems' sensitivities to reinforcing stimuli is related to motivation, and result in the approach or avoidance tendencies (Corr, 2004).

When the historical progression of the RST is considered, it appears that Eysenck's valuable work established a base for the neuroscience account of the personality and the RST. Eysenck (1967) claimed that introverts and extroverts differ in terms of their cortical arousal levels. Introverts are marked by higher arousal, whereas extroverts are marked by a lower level of arousal. Interestingly, it was proposed that introverts conditioned easier when compared to extroverts. Accumulated empirical data challenged Eysenck's assumptions and one of his students, Gray (1970), later claimed that Eysenck's proposition of the easier conditionability of introverts should be replaced by the hypothesis that introverts are relatively more sensitive to punishment and frustrative non-reward.

Carrying Eysenck's work further, Gray (1970) published work that was later to become the fully-fledged RST as a neuropsychological theory of personality. Gray (1982) proposed three specific brain-behaviour systems. Behavioural approach system (BAS): proposed to react to conditioned appetitive stimuli and produce positive emotions. Behavioural inhibition system (BIS): proposed to react to conditioned aversive stimuli and result in negative emotionality. Fight or Flight System (FFS): proposed to react to unconditioned aversive stimuli and result in fear. Accumulated empirical data challenged this assumption and as a response, Gray and McNaughton (2000) substantially revised the RST (see Figure 1).

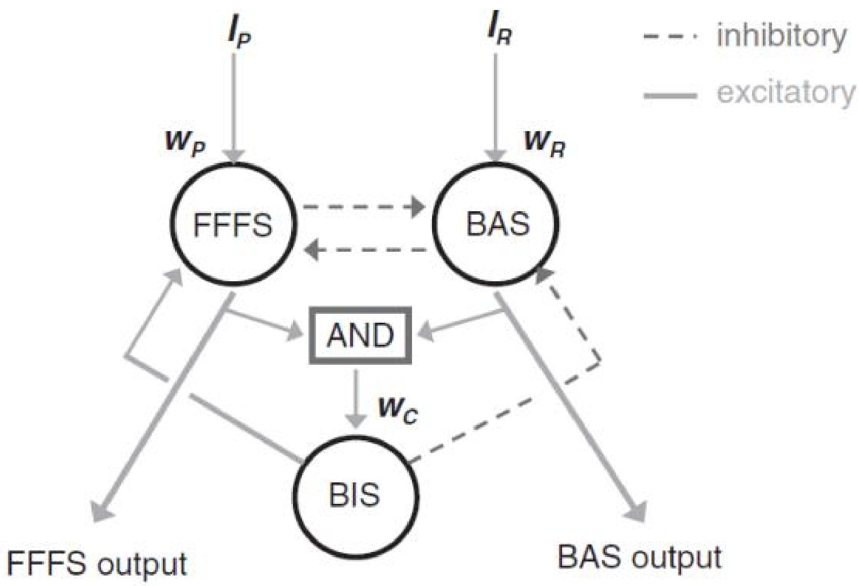

Figure 1. Dynamics of RST dimensions. IP and IR - punishment and reward input stimuli; wR, wP and wC reaction of the reward, punishment and conflict system, respectively; 'AND' in the middle of the figure represents the interaction between the BAS and FFFS that evokes conflict and consequently the BIS. Depending on the strength of the stimuli, the BIS would resolve the conflict in favour of the BAS or FFFS (taken from Smillie et al., 2006).

In the light of new data and insights, the revised RST (rRST) postulated three systems and clarified the distinction between fear and anxiety. In the rRST, it has been claimed that the fight, flight, freeze system (FFFS) reacts to all conditioned or unconditioned aversive stimuli and not only to unconditioned aversive stimuli. When an organism is faced with an aversive situation, this system activates and could elicit the emotion of fear. Its activation is mainly related to avoidance motivation and escape. On the other hand, the behavioural approach system (BAS) reacts to all conditioned or unconditioned appetitive stimuli. Activation could elicit joy and the organism wants to approach the stimuli. This is the least changed system in the rRST. The third system is the behavioural inhibition system (BIS). The BIS was postulated to be a comparator system: it activates when an organism faces aversive stimuli (i.e., obstacles) while aiming for the desired goal. This system has been proposed to be responsible for the resolution of goal conflict which could arise between the BAS and the FFFS. It detects discrepancy and its activation facilitates cautious approach and could elicit anxiety. Before the revision, this system was thought to be responsible for the reaction to aversive stimuli but in the rRST, it has been redefined as a mediator system between the BAS and the FFFS (Corr & McNaughton, 2008; Gray & McNaughton, 2000).

It was proposed that the nature of some stimuli often leads to output behaviour reflecting the systems' simultaneous activation. Corr (2002) proposed the 'joint subsystems hypothesis', which postulated that reward and punishment systems often produce joint as much as separate effects. Gray and McNaughton (2000) argued that the BIS and the FFFS are likely to co-vary as they can trigger each other's activation. Furthermore, Corr (2004) elaborated, arguing that the personality dimension of high neuroticism and low extraversion reflect the combined higher functioning of the BIS and the FFFS.

A large number of studies in the literature established associations between the abnormal level of reinforcement sensitivity and psychopathology. For example, Colder and O'Connor (2004) reported that the higher level of the BAS was related to the higher level of externalizing behaviour problems. Moreover, the higher sensitivity of the BIS was found to be associated with an increased level of internalizing behaviour problems. Bacon et al. (2018) reported that a higher BAS level was associated with an increased amount of antisocial behaviours. Tull et al. (2010) investigated the associations between the BAS, BIS, FFFS and emotion regulation. They defined emotion regulation as the ability to control behaviours at the time of emotional distress. Their study's results showed that abnormal levels of these systems were related to emotional regulation difficulty and contributed to psychopathology.

2.3.1. Measurement of reinforcement sensitivity

Many adult questionnaires were developed for assessing reinforcement sensitivity (Corr, 2016; Krupić et al., 2016). However, these instruments had some drawbacks. For example, the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001) was not developed based on the rRST and it did not separate between the BIS and the FFFS. On the other hand, as the most prominent measure of the reinforcement sensitivity, the Reinforcement Sensitivity Theory-Personality Questionnaire (RST-PQ; Corr & Cooper, 2016) was developed with respect to the rRST and it separated the BIS from the FFFS.

There are relatively fewer instruments for measuring reinforcement sensitivity among children. The most famous instruments are the Behavioural Inhibition/Behavioural Activation Scales (Carver & White, 1994) and the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (Colder & O'Connor, 2004). It is worth noting that both measures are the modification of the adult scales (Blair, 2003; Pagliaccio et al., 2016; Vervoort et al., 2015). For example, Colder and O'Connor (2004) adapted the SPSRQ to be used by caregivers. But the original questionnaire was a self-report form. Furthermore, neither the original nor the adaptation complied with the rRST. On the other hand, the Reinforcement Sensitivity Theory-Personality Questionnaire-Children version (RST-PQ-C; Cooper et al., 2017) was developed for the assessment of the sensitivity of three reinforcement systems: the BIS, the BAS and the FFFS. This questionnaire complied with the rRST and psychometric evidence for the three-factor structure was provided.

Precise assessment of these systems in children is important because abnormal levels have been reported to be associated with psychopathology (Schiltz et al., 2018). In the present thesis, the RST-PQ-C was intended to be used for the first time in a patient population (i.e., children with ADHD) and the sensitivity of three reinforcement systems

(BAS, BIS and FFFS) were aimed to be compared between clinical and control groups. Importantly, the separation between the BIS and the FFFS can allow investigation of the unique effects of the individual systems in avoiding the sustained mental effort and the executive functioning impairment among children with ADHD. However, before it can be used among Turkish speaking children, this questionnaire needed to be translated into the Turkish language and its factor structure needed to be investigated. It was very important to show that the translated questionnaire had three factors as the original instrument. That is why the first question of this thesis was whether the Turkish translation of the RST-PQ-C had adequate psychometric properties for being used reliably in the Turkish speaking child population. The details of this translation process are presented in the third chapter of the present thesis.

2.3.2. Revised reinforcement sensitivity theory and ADHD

According to the rRST, reinforcement sensitivity is related to individual differences in motivation and approach/avoidance tendencies. Over-activity and under-activity of the BAS, BIS or FFFS have been shown to relate to some behavioural pathologies among children and adolescents (Slobodskaya, 2016). Abnormal levels of reinforcement sensitivity have been reported in ADHD and scientists argued that this phenomenon can be one of the hallmarks of this condition (Sadeghi, 2019).

In a meta-analytic review, Gomez and Corr (2014) examined the personality dimensions in relation to ADHD symptom domains. They analysed 40 data sets that involved the five-factor and the integrated five-factor model which incorporates dimensions of multiple other personality models. Results of this study showed that in general, ADHD had a negative relationship with Tellegen's constraint, FFM agreeableness and conscientiousness, and Cloninger's persistence, cooperation, and self-directedness.

Two studies that administered the SPSRQ and the ADHD rating scale to non-patient adults have reported that the BAS was positively correlated with the hyperactive-impulsive symptoms of ADHD (Hundt et al., 2008; Mitchell & Nelson-Gray, 2006). In a similar vein, Gomez and Corr (2010) investigated the relationships between the inattentive/hyperactivity-impulsivity symptom groups and three personality instruments, among 254 non-patient adults. Results of this study showed that hyperactivity-impulsivity was found to be positively related to reward responsiveness, sensitivity to reward and positive emotionality. On the other hand, the inattentive presentation was related positively to the BIS, sensitivity to punishment and negative emotionality.

Studies in the literature consistently showed that rRST - BAS is related to hyperactivity-impulsivity symptoms of ADHD. This is conceivable because the BAS activates for appetitive stimuli and produces an approach motivation. When the BAS activation is unusually high then an individual could tend to approach appetitive stimuli impulsively. On the other hand, the BIS has often found to be related to inattentiveness symptoms of ADHD. According to rRST, the BIS is both related to BAS-approach and the FFFS-avoidance. Considering the scarceness of the studies that investigated the BIS and ADHD relationship, it can be argued that the function of the BIS regarding the ADHD symptoms is less clear.

Quay (1988, 1997) was the first researcher to explicitly apply the RST to ADHD. Quay's account proposed that hyperactive-impulsive ADHD behaviours result from an underactive BIS. The rationale behind this assumption was that the weak BIS may have difficulty inhibiting the strong BAS activation hence, impulsive behaviours could appear. On the other hand, there has been very few attempts for explaining the BIS's role in the specific inattentive symptoms of ADHD.

Existing research found that hypoactivity of BIS is related to dysregulation of hypothalamic pituitary adrenal axis and inattentive symptoms of ADHD. Authors argued that a low cortisol response associated with an underactive BIS may underlie the most severe cases of inattentive ADHD (Corominas et al., 2012; Randazzo et al., 2008).

However, these studies have two problems. First, they defined the BIS according to the old RST: "the BIS is sensitive to and is activated in response to punishment and non-reward" (Randazzo et al., 2008, p. 28). Second, they used the terms the BIS activation level and the prepotent motor response inhibition performance interchangeably. Reports in the literature suggest that these are related but separate inhibitory capacities (Morein-Zamir et al., 2004).

In the rRST, the BIS has been proposed to be a mediating system between the BAS and the FFFS. The BIS activation provides a cautious approach and it could inhibit both the BAS and the FFFS related behaviour until the conflict is resolved. It can be argued that when the BIS activity is low then an organism could have a weakness in inhibiting the FFFS related motivation and behaviour. This could mean that the organism may lack the required capacity to endure the stress of aversive stimuli and try to avoid or escape the situation prematurely which could hinder the reach of a better and more desired consequence.

The DSM-5 states that children with ADHD avoid tasks that require sustained mental effort. It is plausible to propose that the BIS can play a role in avoiding mental effort because exerting mental effort is aversive for the majority of individuals hence, resisting avoidance motivation can be a critical part of sustained cognitive engagement. Importantly, study results in the literature suggest a lower BIS activity among children with ADHD when compared to their TD peers (Wiersema et al., 2009; Randazzo et al., 2008). For this reason, a negative correlation between the BIS activation level and the frequency of avoiding mental effort can be expected among children with ADHD.

The present study aims to further clarify the relationship between executive inhibition (i.e., prepotent motor response inhibition) and motivational inhibition (i.e., BIS). Obtaining separate values for the BIS and the prepotent motor response inhibition can provide an opportunity for observing their individual effects on avoidance behaviour.

In the next section, information about executive functioning will be presented. The possible role of impaired executive functioning - particularly the prepotent motor response inhibition- in terms of frequently avoiding mental effort among children with ADHD will be discussed.

2.4. Executive Functioning

Human behaviour involves both automatic and controlled processes (Nigg, 2017). Automatic processes relate to habitual behaviours and they are performed with little effort because they are routine reactions that appear in familiar situations. For example, an individual could drive to work in the morning without giving any thought to how to drive or how to get to the place of work. This state of affairs has been named the default mode (Sridharan et al., 2008). On the other hand, an individual can face a new or unfamiliar situation that cannot be resolved with habitual reactions. Such situations demand new behaviours for solving problems. For example, if the usual way to the place of work is blocked, a new route will have to be figured out. In such instances stopping, evaluating and planning is required. This state has been named as transcending the default mode where an individual obtains an opportunity for less stimulus-bound and non-routine behaviours (Mesulam, 2002).

Solving novel problems require the use of executive functions. The executive functions can be defined as the higher-level cognitive functions that can be used intentionally to overcome habitual responses for configuring new and goal-directed behaviours. These functions enable us to function effectively when solving a problem and reaching a goal is required (Alvarez & Emory, 2006; Ardila, 2008; Elliott, 2003). Prepotent response inhibition, task-switching, reasoning, planning, emotion regulation and monitoring are some of the executive functions that are widely investigated in the literature (see Figure 2).

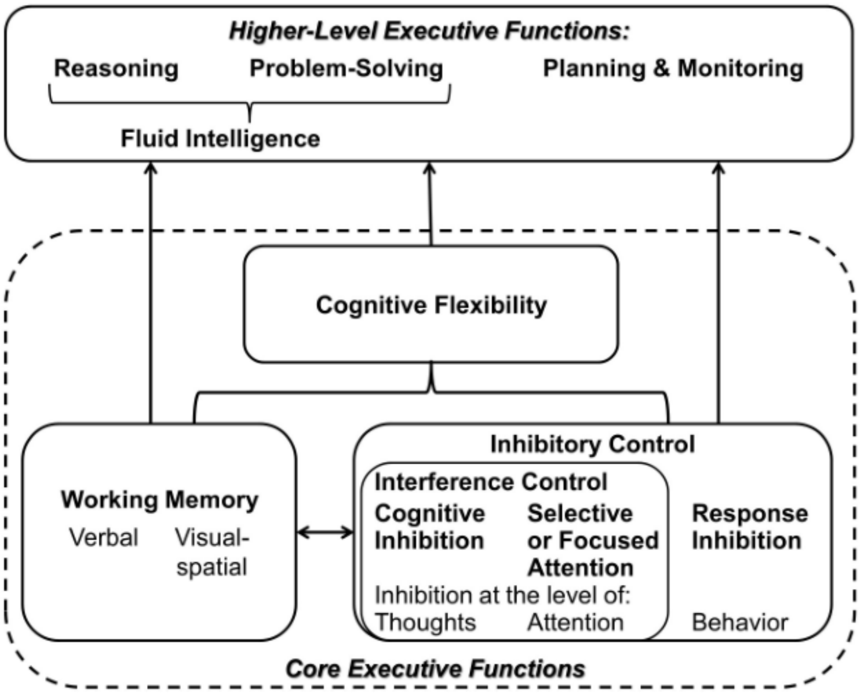

Figure 2. Core executive functions (adapted from Diamond, 2013 by Lemke & Scherpiet, 2015). The diagram shows the interaction of the WM and the executive functions for facilitating higher-level cognitive processing (taken from Lemke & Scherpiet, 2015).

A growing body of research suggests that these higher cerebral functions are managed by the frontal lobes. More specifically the dorsolateral prefrontal cortex, ventrolateral prefrontal cortex, orbitofrontal cortex and anterior cingulate (Nejati et al., 2018). Furthermore, some recent studies demonstrated that several posterior cortical regions and subcortical brain structures are related to executive functioning (Carpenter et al., 2000). Studies indicate that the prefrontal cortex (PFC) has widespread connections to other brain areas for efficient coordination of thought and behaviour.

Lesion studies provided further evidence about the localization of executive functions. Study results showed that lesions in the prefrontal cortex among the traumatic brain injury patients were related to impaired reasoning about emotional material (Goel et al., 2017; Kroes et al., 2019), decision impulsivity (Lv et al., 2019), impaired attentional control (Kam et al., 2018) and word fluency deficit (Piai et al., 2016). Furthermore, fMRI and transcranial direct current stimulation studies showed that particularly the dorsal lateral prefrontal cortex was related to the working memory, maintenance of information (Balderston et al., 2017), prepotent motor response inhibition (Dubreuil-Vall et al., 2019), and task-switching (Tayeb & Lavidor, 2016).

Conditions such as schizophrenia, depressive disorders and ADHD are known to affect the frontal lobes and result in impaired executive functioning. In each condition, different constellations of executive functions have been observed to be impaired. For example in schizophrenia: cognitive flexibility and planning (Laloyaux et al., 2018). In the ADHD: WM, response inhibition and task-switching (Froehlich et al., 2018; Kofler et al., 2019). The impact of the impairment in daily life activities has been reported to depend on symptom severity (Ponsford et al., 2003). Some patients reported having serious difficulty in facing novel situations but they have been observed to be more functional along the routine lines of familiar activity (Gilboa et al., 2019; Schwartz, 2014). Because of the diminished daily functionality, some patients face the danger of losing their occupations and sometimes they experience interpersonal difficulties. The consequence can be a great amount of psychological and economic pressure on the patient, family and governmental services. That is why any attempt for understanding the mechanism of executive functioning impairment is very valuable.

Importantly, individuals with ADHD face similar risks because they have been reported to experience executive functioning impairments (Roselló et al., 2020). For example, Szuromi et al. (2013) investigated the relationship between ADHD symptoms and functional difficulties among non-patient adults. Results of this study showed a positive correlation between ADHD symptoms and functional impairments. In a similar and more recent study, Dvorsky and Langberg (2019) investigated if parent-ratings and self-ratings of executive function predicted the academic and overall functioning of college students with ADHD. The study results showed that the level of executive functioning impairment predicted academic success. Findings in the literature clearly show that the ADHD symptoms and the executive functioning impairment are related. Hence, developing training techniques for improving executive functioning can be very beneficial for people with ADHD as they suffer from reduced daily functionality (Schwörer et al., 2020).

Rehabilitation interventions aimed at improving executive functioning have targeted three major domains: emotional self-regulation, self-monitoring, and goal maintenance. Study reports showed that emotional self-regulation training facilitated better problem orientation and improved problem-solving performance (Turner et al., 2020). It was concluded that decreased emotional over-reactions helped patients to confront situations rather than deny or avoid them. On the other hand, self-monitoring interventions often involved structured feedback and cueing techniques. For example, Lamberts et al. (2017) aimed at increasing the level of awareness of the executive deficits among the patients. Results showed that training had a positive impact on the inattention measures through improved self-monitoring. Lastly, goal management training has been shown to be beneficial among patients with traumatic brain injury. It cannot be possible for an individual to organize his or her behaviours without a goal in mind. Levine et al. (2000) applied goal management training which was based on Duncan's (1996) goal-neglect theory. They stopped patients frequently and reminded them about their goals and sub-goals. Study results showed that intervention was successful in improving patients' daily functionality. These studies show that rehabilitation of executive functioning is possible.

Literature includes studies that aimed at improving executive functioning among individuals with ADHD, with some positive results (Dörrenbächer & Kray, 2019; Farias et al., 2017). Cortese et al. (2015) conducted a meta-analysis for investigating the neuropsychological outcomes of cognitive training among children with ADHD. Study results showed that training was effective for improving the performance in the tests of WM. It was also found that there was an increase in the parent ratings of executive functioning after the training. However, there was no improvement in academic performance and ADHD symptoms.

In conclusion, scientists concluded that impaired executive functioning underlie some of the observed daily-life problems of individuals with ADHD (Dvorsky & Langberg, 2019). Attempts have been made for improving the executive functioning performance among ADHD patients but with limited success. The reason can be that the executive functioning is a complex system and the dynamics of executive functioning have not been understood to an adequate level yet. Further research is required for uncovering the nature of executive functions and the role that impaired executive functioning plays in ADHD pathology. In the following section, three major theories that tried to explain the dynamics of executive functioning will be discussed.

2.4.1. Theories of executive functioning

It has been documented that PFC controls behaviours in the process of goal formulation, action selection, and goal monitoring (Duncan et al., 1996). In the famous goal selection theory, Duncan et al. (1996) proposed that human behaviour is goal-directed. Goals are used in the activation or inhibition of behaviours that lead to organized behaviour. In this theory, active maintenance of a goal representation is given a great deal of importance and it has been claimed that only actively maintained goals can lead to organized behaviour.

According to Duncan et al. (1996), the behaviour of the patients with executive functioning deficits becomes disorganized because they experience difficulty in maintaining the goals in an active state. Active maintenance of information has been stated to be a skill that is managed by the WM system. The CE part of this system was proposed to play a major role in the attentional control of maintaining information during mental operations (Baddeley, 1997). Importantly, there are studies in the literature that indicate an abnormality in the maintenance process of WM among children with ADHD (Lenartowicz et al., 2014).

Norman and Shallice (1986) have proposed a schema-based, two-level system for explaining automatic and controlled cognitive processes. In familiar situations, specific schemas are activated as a response to specific environmental triggers. Shallice and Burgess (1993) called this state the lower level, where an automatic response is produced for a routine situation. On the other hand, when a novel problem requires thoughtful control of action then a higher-level control mechanism called the supervisory attention system (SAS) is involved. They proposed that disturbance in the supervisory attention system accounts for the disorganized behaviour of individuals with executive functioning impairment.

Definitions of the SAS and the CE overlap. Both constructs are proposed to be engaged when controlled action is required. However, the concept of attentional resources has been more often pronounced within the CE framework. On the other hand, attentional control has been more frequently emphasized within the SAS framework. Importantly, Baddeley (1996) argued that patients with executive functioning impairment can have impaired executive resources that obstruct the intentional control of behaviour via the SAS. The concept of the SAS was adopted and integrated into the WM system as the CE (Baddeley, 1996). That is why these terms are being used interchangeably in the current state of the literature.

2.5. Executive Functioning and ADHD

Executive functions are needed for solving problems. In its most general form, problem-solving is a five-step process and different executive functions are used in each step. Children with ADHD are impaired in some of the key functions that are critical in the problem-solving process such as response inhibition (Wright et al., 2014), planning (Patros et al., 2019), implementation of a plan (Boyer et al., 2018) and monitoring for errors (Groom et al., 2013). On the other hand, mental flexibility which underlies generating solution alternatives was not found to be impaired (Ludyga et al., 2020).

There is convincing evidence in the literature to argue that individuals with ADHD experience difficulty in organizing their behaviour and this is related to an impairment in the executive functioning that is controlled by the frontal lobes of the brain (Barkley, 2001). This argument is in line with the brain imaging studies that linked impaired executive functioning to smaller volumes in several brain regions among children with ADHD (Seidman et al., 2005). Pennington and Ozonoff (1996) aimed to investigate the association between executive functions and ADHD and carried out a meta-analysis that included eighteen different studies. Authors reported that obtained scores of children with ADHD were lower on all the executive functioning measures that were employed, providing evidence for the presence of executive dysfunction in this population.

Executive functioning deficits have been proposed as one potential predictor of social problems and children with ADHD were found to experience difficulties in the interaction with peers (Dupaul et al., 2001) and teachers (Whalen et al., 1980). Clark et al. (2002) investigated the relationship between executive functioning performance and social competence among adolescents with and without ADHD. Results showed that lower scores in executive functioning performance were significantly related to lower social competence among adolescents with ADHD. Reports in the literature demonstrate that impaired executive functioning which is evidently related to poor self-regulation contributes to observed social problems among children and adolescents with ADHD. Having difficulties in establishing optimal social ties can be particularly devastating in a school setting and it can affect the school adjustment and academic performance adversely.

Biederman et al. (2004) found that poor executive skills were an important risk factor for academic failure and grade retention among children with ADHD. Mahone et al. (2002) further showed that parent-reported executive functioning impairment measured by the Behavioural Rating Inventory of Executive Function (BRIEF) was significantly related to lower math achievement in a sample of children with ADHD. All in all, these findings demonstrate that executive functioning impairment contributes to ADHD symptoms and it plays a role in the academic underachievement of these children.

Two main views exist in the literature in terms of the place of impaired executive functioning in ADHD. The first group of scientists argue that all children with ADHD exhibit some form of executive function impairment (Brown & Casey, 2016). On the other hand, the second group of scientists propose that only some of the children with ADHD exhibit executive functioning impairment and ADHD is a heterogeneous condition (Boyer et al., 2018; Willcutt et al., 2005).

Recent and innovative studies that investigated executive functions in-depth (Tsermentseli & Poland, 2016) have categorized them as cool executive functions: reasoning, planning, prepotent response inhibition, task-switching, WM, and hot executive functions: emotional and motivational regulation. The studies that investigated executive functioning from the cool and hot executive functioning perspective could offer a resolution to the heterogeneity problem in ADHD. Castellanos et al. (2006) claimed that hyperactivity-impulsivity is associated with the impairment in the hot executive functions. Furthermore, they argued that inattention is related to the impairment in the cool executive functions. In this thesis, a similar stand was taken that all the children with ADHD experience executive functioning impairment. However, some of them exhibit problems related to the cool executive functions and some of them exhibit problems related to the hot executive functions. Additionally, some children could experience both difficulties together.

2.5.1. Executive functioning and avoiding mental effort among children with ADHD

According to DSM-5, children with ADHD dislike and try to avoid cognitively effortful tasks. At the current state of the literature, it is not clear why children with ADHD avoid tasks that require a sustained mental effort. Hsu et al. (2017) examined if participants with more ADHD symptoms experience a cognitive task as more taxing and uncomfortable. Adult university students were divided into two groups depending on their low or high level of ADHD symptoms. They completed an adapted version of the Paced Auditory Serial Addition Test which measures information processing capacity. The task involved five runs with a varying number of blocks. Participants were asked to rate the effort required and discomfort they experienced during the task. Results showed that the high symptom group reported exerting higher mental effort and experiencing higher discomfort. Furthermore, when they were asked to do the working memory task again, in the end, they were less willing when compared to the low-level ADHD symptom group.

It can be reasoned that not being willing to do a task again because of the experienced discomfort can be identified as avoiding mental effort behaviour. No study in the literature has clearly defined this concept with an intention to quantify the avoidance behaviour yet. Hsu et al. (2017) and Mies et al. (2019) both used only one WM task with varying levels of difficulty. They asked participants to rate how much effort they exerted after a specific number of trials. This means that they focused on one mental capacity (i.e., WM) and measured the amount of difficulty that a participant experienced. Using a single task with varying difficulty levels is a plausible design for measuring the experienced subjective difficulty. However, it can be argued that using a multi-domain approach can be more appropriate if the aim is to quantify avoidance behaviour objectively.

It can be speculated that using several tests for assessing multiple cognitive domains consecutively can provide an objective measure of avoiding mental effort and allow quantifying it. An individual could have some of his or her cognitive capacities impaired but the rest can be intact as every individual has their strength and weakness in terms of cognitive ability. Hence, when multiple tests are applied it can be expected that some of the obtained scores of an individual can be below or above average. Based on the evidence in the literature, it can be predicted that if an individual finds a task effortful then he or she will tend to avoid it. That is why using some tests that tax cognitive functions from different domains can set the occasion for avoidance behaviour to occur. Asking how difficult a test was after completion, and then looking at how many times an individual avoided the domain where a difficult task belonged to can allow quantifying avoidance behaviour. In the present thesis, such an approach will be used for objectively quantifying avoidance behaviour in Study 2a.

All in all, intact executive functioning is necessary for an efficient organization of behaviour. Inhibition is a critical executive function in terms of control because habitual behaviours should be inhibited before any organizational attempt can be made. Torgrimson's et al. (2021) study demonstrated that impaired inhibition play a role in avoiding mental effort among TD elementary school students. However, at the current state of the literature, it is not clear if the reported difficulty in exerting mental effort is caused by a widespread cognitive functioning weakness or if it is a specific executive function that is responsible for this symptom (i.e., prepotent motor response inhibition). One way of addressing this problem can be obtaining a cognitive composite that replaces the prepotent motor response inhibition score in the analyses. In the present thesis such action will be taken in Study 2a, for evaluating the proposed critical role of the prepotent motor response inhibition in the frequency of avoiding mental effort.

Evidence in the literature suggests that impaired inhibition can be related to experiencing cognitive tasks as more effortful and a natural outcome of this experience could be more frequently avoiding mental effort. In support of this argument, Gaultney et al. (1999) found slower reaction times in an inhibition task (i.e., Stroop Task) among children with ADHD and speculated that these children find cognitive tasks more effortful than their TD peers. The authors of this study further argued that this could be related to more frequent avoidance of cognitive tasks.

When study results are considered together it appears that particularly in the inhibition tasks children with ADHD have slower reaction times, experience higher discomfort, and exert higher effort for an optimal inhibition performance. Hence, based on the reports, a negative correlation between the prepotent motor response inhibition and frequency of avoiding mental effort can be expected. A further discussion of how the prepotent motor response inhibition and mental effort avoidance are linked to each other is provided in the background section of Study 2a, in chapter four. The aim of offering more in-depth information about the link of these variables in this mentioned section is to provide a solid and clear rationale before presenting the hypotheses.

2.5.2. The centrality of inhibition and working memory in observed executive functioning impairment among individuals with ADHD

There is an ongoing debate about the relationship between inhibition control and executive functioning ability among children with ADHD. According to Barkley’s inhibition theory, impaired control of inhibition results in executive functioning difficulty and, in turn, executive dysfunction underlies the symptoms of ADHD (Barkley, 1997). This theory proposes that the prepotent motor response inhibition is the most important executive ability and all the executive functioning difficulties in ADHD arise secondary to the inhibition deficit. According to this theory, impaired response inhibition affects the working memory, internalization of speech, regulation of arousal, emotion, motivation, and information synthesis. The secondary impairment in these functions results in the symptoms of ADHD (Barkley, 2014; see Figure 3).

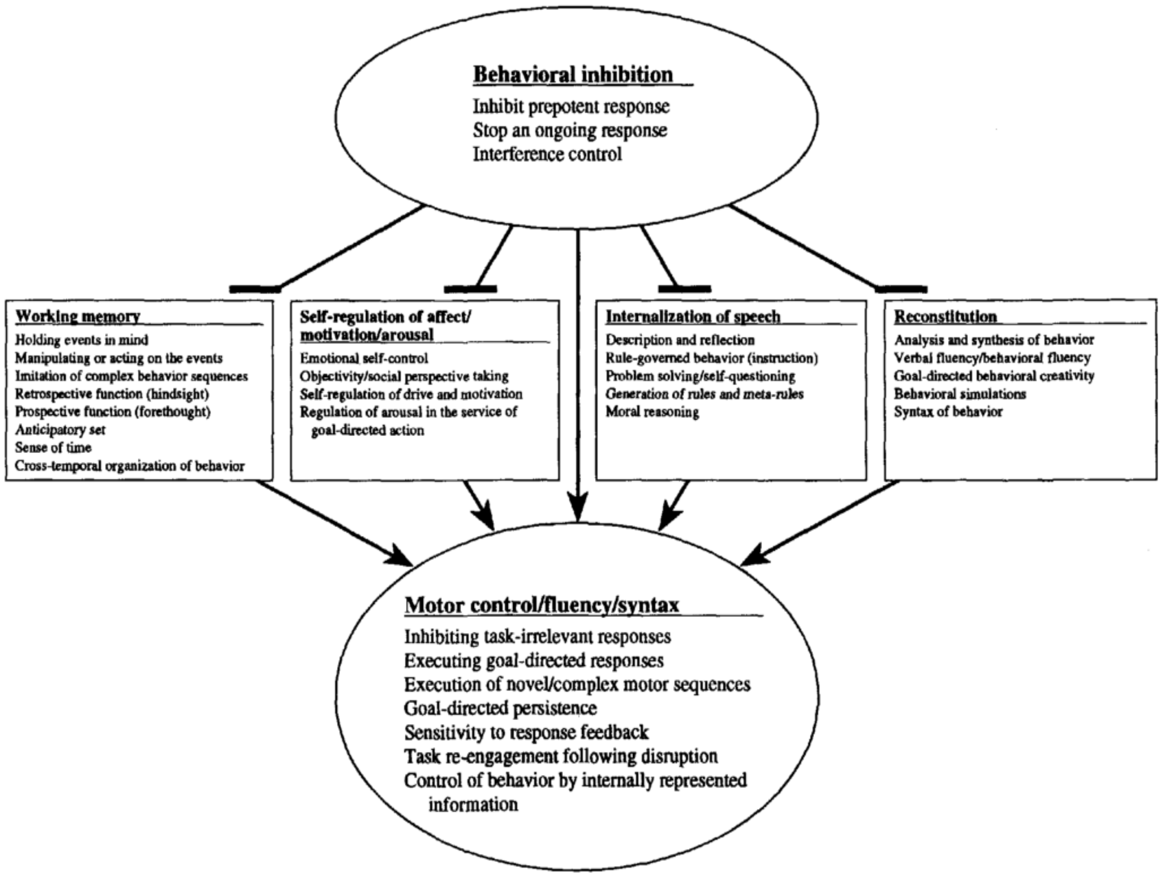

Figure 3. A schematic representation for the inhibition theory of ADHD (taken from Barkley, 1997).

Some studies supported Barkley's proposition by providing evidence that most children with ADHD experience difficulty in inhibiting prepotent responses (Friedman & Miyake, 2004; Michel et al., 2005; Quay, 1997). On the other hand, some scientists have argued against this notion and speculated that inhibition is not the main reason for executive functioning impairment (Shallice, 2010). For example, Geurts et al. (2006) reported that they did not find any response inhibition deficit among children with ADHD. More recently, Kofler et al. (2014) proposed that the WM deficiency underlies the inhibition impairment and this, in turn, results in the symptoms of ADHD (see Figure 4). Despite the arguments of opposing camps, there is evidence in the literature to suggest that WM and inhibition processes are not so separate in causing ADHD symptoms.

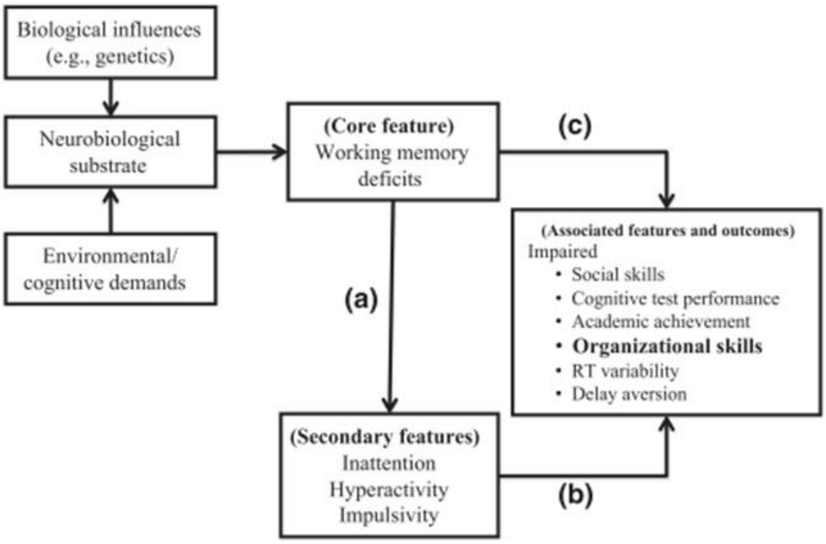

Figure 4. Diagram shows working memory deficit as the primary impairment in ADHD (taken from Kofler et al., 2011).

Recent studies showed that WM and response inhibition are related and they both play a critical role in the occurrence of ADHD symptoms. For example, it was found out that the combined assessment of the WM and the response Inhibition can provide the best information for being able to discriminate between the children with and without ADHD (Holmes et al., 2010; Kofler et al., 2008). Furthermore, Klingberg et al. (2005) had a randomized controlled trial study and implemented computerized WM training among children with ADHD. Results of this study showed that training WM resulted in improved response inhibition, demonstrating a clear and robust connection between the WM and response inhibition.

In the same vein, Clark et al. (2007) aimed at investigating the relationship between response inhibition and WM. The Stop-Signal Reaction Time Test and the Spatial Working Memory Test were administered to adults with and without ADHD. Results of this study showed that the test scores were related only among the individuals with ADHD but not in the control group. The authors of the study concluded that "response inhibition and working memory impairments in ADHD may stem from a common pathologic process rather than being distinct deficit" (Clark et al., 2007, p.1395).

Pioneers of this research line have argued that the WM and the response inhibition are distinct but related domains and both functions could rely on a common pool of attention resources (Voorde et al., 2011; Verté et al., 2006). Findings in the literature suggest that abnormality in the WM processes can lead to impaired inhibition performance. Nevertheless, the details of this relationship are not clear. A better understanding of this relationship can lead to potentially more effective training strategies. Currently, further research about how these separate constructs could rely on the same controlled attention source is needed. Fifth chapter of the present thesis reports the results of such an investigation.

2.6. Working Memory

WM is an online processing area that maintains information for a limited time while performing goal-directed activities (Baddeley & Hitch, 1974). According to Baddeley and Hitch's (1974) influential multi-component model, the WM system is comprised of four main components (see Figure 5). The phonological store provides the ability to temporarily store auditory information. The visuospatial store provides the ability to temporarily store visual information. The episodic buffer handles episodic representations. Finally, the CE part is involved in the attentional control of the subsidiary systems. The CE is a controller that facilitates the intentional coordination of information. The CE has been proposed to interact with the executive functions and facilitate the manipulation of information in the WM buffers (Carpenter et al., 2000). Baddeley and Hitch's (1974) model provides a good theoretical ground for investigating interactions between WM components and executive functions.

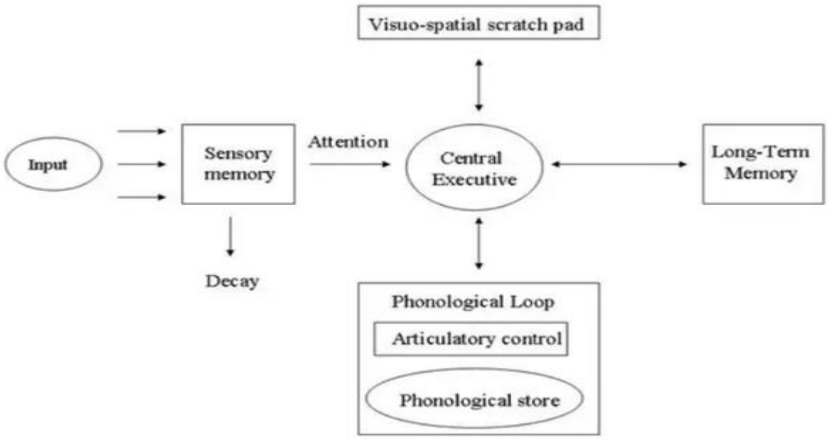

Figure 5. Working memory model components. The figure shows incoming information reaching the central executive through sensory memory. Then the information reaches one of the working memory components depending on the modality. The information then may be transferred to the long term memory store for a permanent stay. The figure is taken from Baddeley and Hitch (1974).

2.6.1. Central executive and executive functions

For investigating the relationship between the WM and the executive functions, McCabe et al. (2010) administered multiple executive functioning and WM tests to a healthy adult sample. Results of this study showed strong positive correlations between these constructs. The authors of the study concluded that the WM and the executive functions share a common executive attention component.

Executive functions are used for the coordination of complex cognition and behaviour, particularly in novel situations (Cristofori et al., 2019). On the other hand, the CE has been proposed to handle controlled processing of information in the WM buffers, including but not limited to maintaining task goals, directing attention, and memory retrieval. Definition of CE implies that the CE is involved both in the maintenance and manipulation of the information. However, it can be argued that the manipulation of the information is a responsibility of the executive functions. Hence, the line between the CE and the executive functions is not clear at the present. Importantly, the dual nature of the CE needed to be further investigated.

The reason for this duality can be argued to relate to the simple fact that maintenance and manipulation are simultaneous processes and both processes require intentional control of attention. CE is a construct that has been described in its relation to both the WM's maintenance and the PFC's executive functions. It can be speculated that the CE is evolved in such a way to connect the maintenance capacity of WM and the manipulation ability of executive functions. This way, an organism can acquire the ability to maintain important information while making the required manipulations on it. In this thesis, a position was taken which supports that the executive functions and the WM are separate constructs but they share a common ground: the CE.

2.6.2. Working memory, maintaining information, and ADHD

WM impairment was found to be related to inattentive behaviour, hyperactivity, organizational problems and academic underachievement among children with ADHD (Fried et al., 2016; Kofler et al., 2018; Orban et al., 2018). One important issue raised was the need for dissociating roles of the short-term memory and the WM in the observed impairments. Gibson et al. (2010) found that when the functioning of WM buffers was isolated, no impairment was detected in the temporary information holding capacity. The authors of the study concluded that the short-term memory mechanism is not deficient among children with ADHD. For investigating the possible role of WM, Rapport et al. (2008) used a task with four different levels of memory load and compared children with and without ADHD in terms of their phonological and visuospatial WM performance. Results of the study showed that all the components of the WM system were impaired among the children with ADHD but the largest deficit was in the CE component. To date, the nature of the CE weakness and its relation to executive functioning impairment among children with ADHD remains inconclusive.

Keeping information in an active state (i.e., maintenance) has been proposed to be a critical ability of the CE (Nador et al., 2020). There is evidence in the literature that points to an abnormality in the WM's maintenance process among individuals with ADHD. For example, Liu et al. (2016) investigated the neural indices of WM maintenance in adults with and without ADHD. The posterior alpha activity was measured during the Visual delayed-match-to-sample Task. Results of this study showed that adults with ADHD exhibited lower posterior alpha power which was interpreted to present an abnormality in the maintenance processes.

Studies which investigated the maintenance ability and its relation to behavioural outcomes in ADHD are scarce. On the other hand, this issue is more extensively investigated among traumatic brain injury patients. Study results showed that an abnormality in maintenance of mental representations resulted in the inattentiveness symptoms of the patients who sustained pre-frontal cortex injury (Newsome et al., 2008). Importantly, research has established similarities between the symptoms of traumatic brain injury and ADHD (Thaler et al., 2010). Study results suggest that abnormality in the maintenance process can be related to executive functioning performance. However, the relationship between the maintenance process and the observed executive functioning impairment has not been investigated among children with ADHD.

When the existing information is considered (e.g., abnormality in maintaining information among individuals with ADHD) then it can be predicted that higher WM load can be a factor that affects the executive functioning performance adversely among children with ADHD. Detailed information about the most related studies in the literature and a discussion of their approach and design is presented in the background section of chapter five, before stating the hypotheses of the investigations that took place in Study 2b.

2.6.3. Maintenance ability of CE and the rRST - FFFS

Evidence in the literature suggests that cognition and reinforcement sensitivity interact. It has been proposed that situations that are judged to be dangerous or technically difficult can initiate the CE engagement (Bayliss & Roodenrys, 2000; Norman & Shallice, 1986). Similarly, these types of situations have been proposed to activate the rRST - FFFS as well. According to the rRST, potentially dangerous situations or aversive stimuli activate the FFFS (Corr & Perkins, 2006). Based on this information, it can be reasoned that an aversive situation could result in simultaneous activation of CE and the FFFS. This suggests a possible connection between these systems. Because of this possible connection, it is plausible to propose that the activation of the FFFS could influence the processes of the CE.

It is well known that there are individual differences in terms of sensitivities of the rRST behavioural systems (Krupić & Corr, 2020). This suggests that some individuals have a higher activation level in a system at any given time. To date, no study examined how the activity level of one of these systems could affect the functioning of the CE. That is why in the present thesis, it was also aimed to investigate the interaction between the FFFS and one of the CE processes (i.e., maintaining information). The question of this investigation was whether the activation level of a reinforcement system (i.e., FFFS) could interact with the maintained WM load and eventually influence the efficiency of executive functioning.

2.7. Summary

ADHD starts in childhood and it results in several functional impairments. Children with ADHD have been reported to more frequently avoid mental effort when compared to their TD peers. Study results in the literature showed that this symptom is related to uncompleted academic tasks and it is a factor that plays a role in the reported lower academic performance (Zoromski et al., 2021). Studies investigated avoiding mental effort in the child ADHD population are scarce.

Existing studies in the literature demonstrated that these children find cognitive tasks more effortful but they do not choose the low effort-low reward option in the effort discounting tasks any more than their TD peers (Addicott et al., 2019; Winter et al., 2019). This finding suggests that the problem is not due to an effort application difficulty. Moreover, some results suggest that these children exert greater effort in the inhibition tasks for reaching an optimal performance when compared to their TD peers (Mies et al., 2019; Poulton, 2015; Jennings et al., 1997).

Reports in the literature suggest that impaired prepotent motor response inhibition can play a role in frequently avoiding mental effort among these children because inhibiting prepotent motor responses has been claimed to be a precursor for efficient cognitive processing (Barkley, 1999). Furthermore, deficient response inhibition has been reported to be a hallmark of ADHD and result in further cognitive impairments (Slaats-Willemse et al., 2003). The inefficient inhibition ability can be expected to influence cognitive performance adversely and to be related to experiencing cognitive tasks as more challenging and aversive. Hence, a negative relationship between the prepotent motor response inhibition performance and the frequency of avoiding mental effort can be expected.

The influence of impaired inhibition has been a central theme within the ADHD research line. Scientists argued that more than one kind of inhibition can be impaired in

ADHD and explaining the underlying mechanism of specific symptoms could require studying more than one type of inhibition from different levels (i.e., executive and motivational systems). One of the behavioural systems of the rRST, namely the BIS, has been hypothesized to be hypoactive and to play a role in the ADHD symptom presentation (Quay, 1997; Sadeghi et al., 2019). However, currently, the exact role of this system in ADHD pathology is not clear.

According to rRST, the BIS is a construct that facilitates cautious approach by inhibiting BAS or FFFS related motivation. Dealing with a cognitive task can be aversive and the activity of the BIS can be a critical factor in resisting avoidance motivation. It can be reasoned that higher BIS activation could influence longer on-task behaviour when dealing with a challenging cognitive task. For this reason a negative correlation between the activity level of the BIS and the frequency of avoiding mental effort can be expected.

Literature includes evidence of a link between the prepotent response inhibition and the BIS. The details of the prepotent motor response inhibition and the BIS connection and these two constructs' possible link to avoiding mental effort will be presented and further discussed in the background section of Study 2a, in chapter four. Additional information will help to provide a solid rationale before presenting the hypothesis for a simultaneous predictive model.

Executive functions attracted a considerable amount of attention among ADHD researchers. These are higher-level brain functions that enable us to control our behaviour in the service of reaching a goal. The majority of these functions found to be impaired among children with ADHD. Despite the decades of research, the reasons for executive functioning impairment are still not clear. The most popular explanation remains to be the inhibition hypothesis of Barkley, even though some children may not have impaired inhibition (Geurts et al., 2006). On the other hand, a more contemporary trend is the investigation of the WM processes as the primary reason for the inhibition impairment and the ADHD symptoms (Alderson et al., 2010).

Executive functions have been reported to be related to the CE part of WM. The CE is the attentional controller of the WM system where the information is maintained and manipulated. Executive functions and WM were found to share some similar ground but the nature of their relationship is not clear. Studies in the literature suggest that impairment in the CE can play a role in the reported executive functioning difficulty (Kofler et al., 2010). Maintaining information is one of the primary responsibilities of the CE and some studies that used electrophysiological measures indicate an abnormality in this process among individuals with ADHD (Lenartowicz et al., 2014). To date, no study investigated the effect of systematically increased WM load in the reported executive functioning impairment among children with ADHD. When considering the reports, a trade-off between maintaining WM load and executive functioning performance can be expected.

Additionally, some studies in the literature have established a link between reinforcement sensitivity and WM (Baskin-Sommers et al., 2010). Hence, the current thesis also aimed to investigate the effect of the interaction between reinforcement sensitivity (the FFFS in particular) and the WM load on the executive functioning performance among children with ADHD. A negative relationship between the FFFS activation level and executive functioning performance was expected. Chapter five gives details of the investigation that was undertaken for demonstrating the role of the WM load and the FFFS activation level in the executive functioning performance among children with ADHD.

2.8. Research Questions

Reinforcement Sensitivity Theory-Personality Questionnaire- Children version (RST-PQ-C) is a recent instrument and evidence of the good psychometric properties for this instrument has been provided, in its original development study (Cooper et al., 2017). Testing the hypotheses of Study 2 of the present thesis demands the measurement of the activity levels of the rRST behavioural systems. Hence, the RST-PQ-C was intended to be translated into the Turkish language. However, evidence of good psychometric properties has to be provided for the translated instrument before it can be used reliably among Turkish speaking children. Hence, the first question of the present thesis is whether the Turkish translation of the RST-PQ-C has adequate psychometric properties for being used reliably in the Turkish speaking child population.

Reports in the literature suggest that the prepotent motor response inhibition and the BIS are implicated in frequently avoiding mental effort. Prepotent motor response inhibition has been demonstrated to affect cognitive performance (Berlin et al., 2003) among children with ADHD. For this reason it can be related to perceived task difficulty, avoidance motivation and the rate of avoidane. On the other hand, the BIS has been proposed to be related to resisting avoidance motivation and hence it can affect the rate of avoidance.The existing evidence in the literature shows that the prepotent motor response inhibition is a central construct that is linked to some other kinds of inhibition in the brain (Verbruggen et al., 2004). Furthermore, the results of the electrophysiological studies suggest that the prepotent motor response inhibition and the BIS are related only among children with ADHD (Wiersema & Roeyers, 2009). Considering the reported relationships the question of Study 2a is whether the effect of the prepotent motor response inhibition on the rate of mental effort avoidance is mediated by the BIS and whether this mechanism is contingent up on the ADHD diagnosis. In other words, if the prepotent response inhibition's indirect effect on avoidance through the BIS is moderated by the diagnosis status.

The third question is related to impaired executive functioning among children with ADHD. Studies that used electroencephalography have reported an abnormality in the process of maintaining information in this population. At the present, the effect of this abnormality on the executive functioning performance among these children is not clear. That is why the third question of the present thesis is whether the reported abnormality in the maintenance process results in impaired executive functioning performance among children with ADHD. In other words, whether maintaining WM load results in impaired executive functioning. Furthermore, some reports in the literature suggest a link between reinforcement sensitivity systems and WM. Moreover, higher FFFS activity has been reported to affect executive functioning performance adversely. However, the nature of the interaction between the WM and reinforcement sensitivity is not clear. That is why it was also asked whether the interaction of working memory load and the FFFS level affect the executive functioning performance among children with ADHD.

The two behavioural systems (i.e., the BIS and the FFFS) had a critical role in the investigations that took place in Study 2 of the present thesis. However, there was no instrument in the Turkish language for assessing the activation levels of these systems. For this reason, the RST-PQ-C was intended to be translated into the Turkish language. The next chapter presents the details of this translation process.

CHAPTER THREE: STUDY 1

The Psychometric Properties of the Turkish Language Reinforcement Sensitivity Theory - Personality Questionnaire – Children

This chapter includes information about the psychometric properties of the Turkish language translation of the Reinforcement Sensitivity Theory - Personality Questionnaire – Children (RST-PQ-C; Cooper et al., 2017). Initially, the adult and children questionnaires will be reviewed and later, some information about the relationship between reinforcement sensitivity and motivation will be given. Finally, the method, discussion, and conclusion sections will be presented.

3.1. Background

According to the revised reinforcement sensitivity theory (rRST; Gray & McNaughton, 2000), three specialized reinforcement systems (behavioural approach system, BAS; fight, flight, freeze system, FFFS; and behavioural inhibition system, BIS) react to salient reinforcing stimuli (see page 33 in the previous chapter for a detailed description). Individual differences in these systems' sensitivities have been reported to relate to different personality types and sometimes to psychopathology (Bacon et al., 2018; Satchell et al., 2018). Many questionnaires exist for measuring reinforcement sensitivity among adults and children. Torrubia et al. (2008) argued that neither the numbers of dimensions measured by each questionnaire nor the number of scales per dimension are homogeneous and further investigations are needed.

3.1.1. Instruments based on the RST for adults

Two categories of adult questionnaires can be described. The first category includes the instruments which do not separate the BIS and the FFFS in respect to the rRST. On the other hand, the instruments in the second category have better compliance with the assumptions of the rRST. The majority of the reinforcement sensitivity questionnaires fall into the first category (Corr, 2016). For example, the Behaviour Inhibition Scale (MacAndrew & Steele, 1991) includes 30 items and it was developed for the assessment of anxiety-related phenomena. The biggest pitfall of this questionnaire is not separating between the BIS and the FFFS. Furthermore, it does not have a BAS scale.

Another example is the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001) and this is one of the most frequently used questionnaires of reinforcement sensitivity. The original questionnaire has only two factors: one BIS and one BAS. It lacks the FFFS scale and it does not fractionate the BAS into its subcomponents. The SPSRQ attracted a lot of scientific attention. For example in a study, Cooper and Gomez (2008) eliminated some poorly fitting items and produced a short version of this questionnaire (i.e., SPSRQ-S). They reported improved global fit values and good discriminant and convergent validity.

Another one of these instruments is the Behavioural inhibition/Behavioural activation scales (BIS/BAS; Carver & White, 1994) and it is a widely preferred and used measure of reinforcement sensitivity. It has a BIS factor and three BAS factors: drive, reward responsiveness and fun-seeking. Heym et al. (2008) compared the original one-factor solution of the BIS scale with an alternative two-factor solution, separating the BIS-Anxiety and the FFFS-Fear. Confirmatory factor analyses of the original BIS scale showed that the hypothesized two-factor model of BIS-Anxiety and FFFS-Fear was the best fit to the data. In a later study, using the BIS/BAS scale, Heym et al. (2015) also demonstrated that ADHD-inattention was only linked to increased anxiety (BIS). On the other hand, ADHD-hyperactivity/impulsivity was linked to increased impulsivity (BAS-fun seeking), anxiety (BIS) and punishment sensitivity (FFFS).

Studies continue to investigate psychometric properties of the SPSRQ and the BIS/BAS scales, resulting in a steady improvement of these instruments. It is important to note that both instruments are modified for being used among children and the information about children's measures will be given in the following paragraphs of this section, after the review of the remaining adult questionnaires.

The second category of adult questionnaires includes the measures which were developed according to the requirements of the rRST. Jackson-5 (Jackson, 2009) is an example, this questionnaire separates the BIS from the FFFS and also has a BAS scale. However, the BAS scale does not have any subcomponents and this can be argued to be a pitfall when the theoretical framework of the rRST is considered. Using this questionnaire, Hannan and Orcutt (2013) found that the FFFS predicted the level of emotion dysregulation, in a sample of undergraduate students who had experienced one or more traumatic events.

Another instrument that is developed according to the rRST is the Reinforcement Sensitivity Questionnaire (Smederevac et al., 2014). It includes three factors: BAS, FFFS and BIS scales. Mihić et al. (2015) used this questionnaire in a study that included non-patient adult participants. They found that the BIS, the flight, and the freeze subscales predicted different types of anxiety (physical, social, cognitive), and BIS and flight also predicted prospective anxiety.

The Reinforcement Sensitivity Theory - Personality Questionnaire (RST- PQ; Corr & Cooper, 2016) is one of the most recently developed tools for assessment of reinforcement sensitivity among adults and it appears as a measure that complies with all the requirements of the rRST. It has a six-factor structure: one BIS factor, one FFFS factor and four BAS factors (impulsivity, reward reactivity, goal-drive persistence and reward interest). Gomez et al. (2020) examined the psychometric properties of this instrument using confirmatory factor analysis and exploratory structural equation modelling. Moreover, they investigated the relationships of the rRST constructs within the ADHD symptom groups. The authors reported that structural equation modelling results supported the six-factor structure better than the confirmatory factor analysis results. Furthermore, they found that both the BIS and the BAS were positively associated with the inattentive and hyperactive-impulsive presentation of ADHD.

Krupić et al. (2016) evaluated the psychometric properties of the five rRST measures and concluded that the convergence evidence obtained for the BAS, the FFFS and the BIS scales among these questionnaires was weak. This poses a problem in terms of comparison of the results from the studies that used different rRST questionnaires.

3.1.2. Instruments based on the RST for children

Some questionnaires for measuring the reinforcement sensitivity among children have been developed but fewer children scales exist when compared to the number of adult RST scales. Children scales too, suffer from certain drawbacks. Two pitfalls can be argued to slow down the rRST research among children at the current state. The first one is the adopted scales where the items are directly transferred from an adult questionnaire. The second one is the scales that have not been developed according to the rRST and lack the sophistication for separating the BIS from the FFFS (e.g., BIS and BAS factor; Carver & White, 1994). Separating these systems is important in the light of the rRST. Pharmacological evidence support this distinction (McNaughton & Corr, 2004) and study findings indicate that they could play different roles in the different pathological conditions (Bijttebier et al., 2009; Colder et al., 2011).

Two popular questionnaires have been used for measuring the reinforcement sensitivity among children, and both instruments are the modification of the adult scales. The first one of these questionnaires is the SPSRQ. As mentioned earlier in this section, this instrument was developed for adults and had two factors: the BIS and the BAS. This questionnaire was not developed according to the rRST and it did not have a scale for measuring the FFFS. Colder and O'Connor (2004) adopted this instrument to be used with children where they included 63 children aged between 9 and 12 in a validation study. Although the original questionnaire was a self-report form, the children's version (i.e., SPSRQ-C) was modified in such a way to be a parent report form. The children's version also did not separate between the BIS and the FFFS. However, in a later revision, Colder et al. (2011) attempted to align the SPSRQ-C with the rRST and the confirmatory factor analysis results demonstrated one FFFS, one BIS and three BAS factors: drive, reward responsiveness and impulsivity/fun-seeking. In a study, Becker et al. (2013) used SPSRQ-C and investigated if personality dimensions are differentially related to ADHD and sluggish cognitive tempo. The study's results showed that sensitivity to reward (and impulsivity/fun-seeking specifically) was associated with the ADHD and broadband externalizing symptoms, whereas sensitivity to punishment (and fear/ shyness specifically) was associated with sluggish cognitive tempo and broadband internalizing symptoms.

The second questionnaire that has been used for measuring reinforcement sensitivity among children is the BIS/BAS scale (Carver & White, 1994). This questionnaire was developed as a self-report form for adults and it did not separate between the BIS and the FFFS which can be seen as a conceptual drawback. It had a four-factor structure: one BIS and three BAS scales (drive, fun-seeking and reward responsiveness). Muris et al. (2005) adapted this scale for the assessment of the reinforcement sensitivity in the children population. The children's version was also self-report but it did not include an FFFS scale. The original questions used in the adult questionnaire were simplified for making the items more understandable for children. However, the appropriateness of the content can be questioned as the adults and children can perceive the situations from very different perspectives. In the same vein, Blair (2003) modified the questions of the original adult BIS/BAS scales to be used as a parent-report form for children. The sample in this study included 42 children. It can be argued that this is a small number for running a factor analysis for a questionnaire that had 20 items (Floyd & Widaman, 1995). This could be the reason why Cronbach's alpha values for the scales were not reported in the published study. Additionally, this version of the scale had only one BAS and one BIS factor.

However, in a more recent study, Gray et al. (2016) investigated the factor structure of the BIS/BAS scales (Carver & White, 1994) among individuals aged between 11-30 years and reported that their findings supported the five-factor structure. The authors concluded that the BIS had a two-factor structure: BIS-anxiety and BIS-fear. However, these findings needed to be treated with caution as Weydmann et al. (2020) argued against the five-factor structure and the stability of the fear factor of the BIS/BAS scales. The authors argued that reversed items from the BIS scale only cluster on a different factor from the remaining BIS items because of acquiescence.

Many studies in the literature used the mentioned questionnaires and measured the systems' sensitivities in both patient and non-patient child populations. The rRST is an important account in personality psychology and the reinforcement sensitivity found to be related to certain personality traits. For instance, among typically developing (TD) children, neuroticism was found to be positively associated with the BIS. On the other hand, extraversion was found to be negatively related to the BIS activation but positively to the BAS activation (Muris et al., 2005). Moreover, a high level of impulsivity and fun-seeking were found to be associated with externalizing behaviour problems that is seen in ADHD and ODD (Colder & Connor, 2004).

Among children with ADHD, the BAS activation level was reported to be higher when compared to TD children (Cremone et al., 2018). On the other hand, electrophysiological evidence indicated that the BIS activation level was lower among children with ADHD (Iaboni et al., 1997). Study results suggest that the systems' sensitivities can differ among patient and non-patient populations. Scientists argued that the BIS and the BAS can have a joint influence on the behaviours in non-patient populations, but they can function independently in the clinical samples (Vervoort et al., 2010).

3.1.3. Reinforcement sensitivity theory and motivation

Motivation can be described as the driving force behind any given behaviour. Individual can be intrinsically or extrinsically motivated. Intrinsic motivation was described as doing an activity for the pleasure and enjoyment it brings (Locke & Schattke, 2019). Vallerand et al. (1992) argued that the intrinsic motivation to know is a critical component for an individual for enjoying the learning process. For example, a student has intrinsic academic motivation when he or she attends a class for learning interesting information and joining a stimulating discussion. Walker et al. (2006) reported that in their study, the students persisted longer when they were faced with an academic challenge and exhibited a higher academic performance if they were intrinsically motivated. On the other hand, a student can be argued to have extrinsic academic motivation when he or she studies to gain the approval of a teacher or parents. An extrinsically motivated student will work for some form of external reward (e.g., grade, money or an award).

Achievement motivation can be included under the category of intrinsic motivation. It is a critical variable in terms of improving one's skills (Locke & Schattke, 2019; Vallerand, 1992). Elliot and Thrash (2002) further divided achievement goals into two components: performance-approach goals (attaining competence) and the performance-avoidance goals (avoiding failure). Study results showed that both the BAS and the BIS activation levels were related to intrinsic motivation. Importantly, the BAS was found to be related to attaining competence whereas the BIS appeared to be related to avoiding failure.

Evidence in the literature demonstrates that activation levels of the BAS and the BIS are related to academic motivation. Van Beek et al. (2013) investigated how individual differences in BIS and BAS levels are related to exhaustion and intention to quit one's studies. They hypothesized that the individuals with higher BIS levels should be motivated to pursue goals that lead to avoiding negative academic outcomes and this should be positively related to exhaustion. Moreover, individuals with higher BAS levels should be motivated to pursue goals that relate to the development of competence and task-mastery that are linked to achieving positive academic outcomes and should have less exhaustion. University students completed BIS/BAS scales, over-commitment, and engagement scales. Results of this study demonstrated that students with higher BIS, studied obsessively which resulted in more exhaustion and intention to quit one's studies. On the other hand, students with higher BAS levels had less exhaustion and less intention to quit. The authors argued that the students with higher BIS activation are motivated to pursue goals that lead to avoiding negative evaluations. On the other hand, the students with higher BAS activation are motivated to pursue goals that are linked to achieving positive evaluations. The findings show that both the BAS and the BIS are related to intrinsic academic motivation however, results also suggest that the BIS's relationship with intrinsic academic motivation can be weaker than the BAS.

In a validation study, Deemer et al. (2010) administered the BIS/BAS scales and the Academic Motivation Scale to university students. Results of this study showed that BAS was positively related to intrinsic motivation. On the other hand, the BIS was positively related to both intrinsic and extrinsic motivation. However, the relationship of the BIS to intrinsic motivation was weaker and limited. Because it had a significant but modest correlation only with the intrinsic motivation to accomplish but it did not relate to the intrinsic motivation to know and the intrinsic motivation to experience stimulation.

Studies in the literature consistently showed that the BAS and the BIS are related to intrinsic academic motivation. However, the relationship with the BIS has been shown to be weaker when compared to the relationship with the BAS in relation to intrinsic motivation. Moreover, the BIS has been shown to relate to extrinsic academic motivation, however this relationship appears to be even weaker. On the other hand, the function of the FFFS is currently unknown. These previously established correlational relationships suggest that the scales of the RST-PQ-C should be able to predict the level of intrinsic and extrinsic academic motivation.

Based on the previous study results, in the present thesis, it was expected that the BAS and the BIS should predict intrinsic academic motivation. However, the regression coefficient for the BIS should be smaller when compared to the BAS. Furthermore, the BIS should predict the extrinsic academic motivation, but this relationship should be weaker than its relationship with the intrinsic motivation. Literature includes no information regarding the FFFS's relationship to academic motivation. Hence, no specific prediction was made.

3.1.4. Summary

The original SPSRQ for adults was a self-report form and had one BAS and one BIS factor. Colder et al. (2011) adopted this instrument as a caregiver report form for children. They also modified this instrument to better align with the rRST and they provided psychometric properties for a five-factor structure that included separate BIS and FFFS scales. However, it can be argued that the fear related factor was composed of a relatively narrow spectrum of the FFFS-related behaviour. Because many of the items that loaded on the FFFS factor were related to shyness.

Another popular instrument for measuring reinforcement sensitivity is the BIS/BAS scales and the original BIS/BAS scales for adults had one BIS and one BAS subscale. Studies that adopted this instrument as a self-report form (Muris et al., 2005) and as a parent-report form (Blair, 2003) for children have reported a similar factor structure without an FFFS scale. Later, Gray et al. (2016) reported a five-factor structure with separate BIS- anxiety and BIS-fear for this instrument. However, the fear factor is defined by only three items and there is an ongoing debate about the FFFS dimension of the BIS/BAS scales (McNaughton & Corr, 2008). Moreover, in the Vervoort et al.'s (2010) study, although two factor BIS appeared, the internal reliability of the putative FFFS factor was very low, as it was comprised of only two items. Thus, the integrity of the FFFS scales of these instruments can be questioned in the context of the rRST.

On the other hand, the RST-PQ-C was specifically developed as a children's questionnaire. It complied with the requirements of the rRST and it was not modified from an adult's measure. Item development was theory-driven, based on the most up-to-date version of RST (see Corr & Cooper, 2016). The ambiguity associated with the saturation of factors with specific emotion words was avoided. Multiple methods were used in the item generation, including focus groups with children to discover what they associate with the specific defensive and approach situations. Employing such a structured approach, provided a balance between the principles of the rRST and the everyday experiences of children. Every attempt was made for complying with the rRST's assumptions and the evidence for a solid FFFS scale was provided. Based on the existing information, it can be argued that the RST-PQ-C has certain advantages when compared to other child reinforcement sensitivity measures.

3.2. Justification of the Study, Aims, Questions and Hypotheses

Childhood is a period with many unique characteristics and reinforcement sensitivity is one of these variables that is different among children when compared to adults. Hence, its relation to various occurrences such as personality traits or psychopathology should be investigated for a better grasp of this period. Importantly, neurodevelopmental disorders have an onset in childhood and abnormal reinforcement sensitivity has been implicated in some of these disorders (e.g., ADHD). For example, Luman et al. (2012) found that ADHD was characterized by high scores in reward responsivity. Hence, having an instrument with good psychometric properties is critically important for investigating the reinforcement sensitivity's role in developmental trajectories. The RST-PQ-C is a recent instrument that is developed in accordance with the rRST and the original validation study demonstrated that it has a three-factor structure with good psychometric properties.

The present study aimed to translate the RST-PQ-C into the Turkish language and investigate the translated instrument's psychometric properties. This action was motivated by the fact that there was no questionnaire for measuring reinforcement sensitivity among Turkish speaking children. Moreover, when the content of the items of this questionnaire is considered, it can be argued that there is nothing unfamiliar in terms of the animals, objects or situations that are mentioned in the original instrument hence, this questionnaire can be proposed to be appropriate for being easily understood within the Turkish language speaking children in Cyprus.

It was important to translate the RST-PQ-C into Turkish and to provide evidence for its internal consistency. This effort can stimulate further research as the abnormal levels of the reinforcement system sensitivities are implicated in neurodevelopmental disorders, including ADHD. Furthermore, this instrument was intended to be used in the planned investigations of this thesis (i.e., Study 2a and Study 2b).

The questions asked were (a) whether the translated instrument has a three-factor structure that is similar to the original questionnaire. (b) Does the model have a good fit with the collected data, and does it have adequate Omega values. (c) Whether the translated RST-PQ-C scales have a utility in predicting intrinsic and extrinsic academic motivation.

For achieving research goals, seven bilingual individuals were included in the translation process for acquiring a conceptually sound translation. A large number of primary school students from four different schools participated in the data collection. Collected data were analysed using statistical techniques: Pearson's correlation coefficient, confirmatory factor analysis (CFA), hierarchical multiple regression, and structural equation modelling.

It was hypothesized that the translated instrument should have a three-factor structure and good fit values when compared to the commonly accepted fit indices. Furthermore, each scale should have an adequate Omega value, and the translated instrument's scales should be able to predict the academic motivation that is measured by the Academic Motivation Scale (AMS).

3.3. Method

3.3.1. Participants

In the translation study of the RST-PQ-C, the participants consisted of 738 primary school students (383 boys and 355 girls). Five governmental schools were chosen randomly from a list that included all the school names in Nicosia, Cyprus. Children aged between 7 and 11 were recruited from these schools. All the children who participated in the study were located in or around the city of Nicosia, Cyprus. Inclusion criteria were being present in the class on the day of data collection, being a Turkish language speaker and expressing willingness for participation in the study. Exclusion criteria were having visual or auditory difficulties, a mental disability or a reading disorder that would interfere with reading, understanding or answering questions. Descriptive statistics are presented in Table 1.

3.3.2. Instruments

3.3.2.1. Reinforcement sensitivity theory-personality questionnaire-children (RST-PQ-C)

RST-PQ-C is a short self-report questionnaire that is based on the rRST. This scale is not a modification of an existing scale for adults. Item development was theory-driven. The approach for the development of the items was based on the development process of the adult version of the Reinforcement Sensitivity Theory-Personality Questionnaire (RST-PQ; Corr & Cooper, 2016). The RST-PQ-C included 21 items and three subscales (see Appendix 2). Three factors were extracted and showed good internal consistency. Cronbach's alpha values for these scales were the BIS = .80, the FFFS = .76, and the BAS = .68. The FFFS and the BIS were moderately correlated (r = .53). BAS was uncorrelated with both the FFFS and the BIS (Cooper et al., 2017). The following statement is an example item from the FFFS scale, "I would be frozen to the spot if there was a snake or spider in the bathroom with me". The following statement is an example item from the BIS scale, "I am careful when doing something that might hurt me". Following is an example item from the BAS scale, "I am training to be better at sport/things I like doing". Items are rated on a 4-point Likert scale (0 = never to 3 = always), with a possible score ranging from 0 to 21 on each scale. A higher score indicates a higher level of activation and sensitivity in a system. Each one of the items in the RST-PQ-C was translated into the Turkish language and the translated items formed the Turkish version of this instrument.

3.3.2.2. The translation process of the RST-PQ-C into the Turkish language

Initially, English language items of the RST-PQ-C were given to three senior lecturers in Near East University's Department of Psychology in Cyprus. They translated the items from English to Turkish. All three of these individuals were fluent in both English and Turkish. Each of these people translated the items from English to Turkish individually. Eventually, three different documents were produced. Subsequently, two other senior lecturers in the Department of Psychology compared the documents and after minor modifications they agreed on the most conceptually accurate translation of the items. Afterwards, the Turkish language items were back-translated to the English language by two senior lecturers in the English language teaching department of Near East University. These two individuals were not involved in the translation process of the original English items into the Turkish language. Later, a bilingual professor from the Near East University's Department of Psychology assessed and confirmed the two documents for equivalency. Subsequently, the documents were sent to one of the original authors (Professor Philip Corr) to obtain final confirmation for the back-translated English language items.

3.3.2.3. Academic motivation scale

The Academic motivation scale (AMS; Harter, 1981) is a 33-item self-report measure that is used to assess intrinsic and extrinsic academic motivation. This questionnaire has been widely used for assessing the academic motivation of students in elementary and middle school years (Lepper et al., 2005). Items are rated on a 5-point Likert scale (0 = never to 4 = always), with a possible score ranging from 0 to 132. Higher scores in the intrinsic motivation scale indicate a higher level of intrinsic academic motivation. Higher scores in the extrinsic motivation scale indicate higher extrinsic academic motivation. AMS was translated into the Turkish language and psychometric properties were investigated by Bacanli and Sahinkaya (2011). The extrinsic motivation scale is formed of the three sub-dimensions that include easy work (α = .77), pleasing teacher (α = .73), and depending on teacher (α = .67). An extrinsic motivation score is obtained by summing up the scores of these three sub-dimensions. Similarly, the intrinsic motivation scale is formed of the three sub-dimensions that include challenge (α = .71), curiosity (α = .65) and independent mastery (α = .70). An intrinsic motivation score is obtained by summing up the scores of these three sub-dimensions. Satisfactory Cronbach's alpha values for the extrinsic motivation scale (α = .71) and the intrinsic motivation scale (α = .78) were obtained. An example item from the intrinsic academic motivation scale is 'I like to try figuring out how to do school assignments on my own' and an example item from the extrinsic academic motivation scale is 'I read things because the teacher wants me to'. In the present study, the intrinsic academic motivation score and the extrinsic academic motivation score were used by summing up the scores of the related sub-dimensions.

3.3.3. Procedure

3.3.3.1. Data collection and administration of the Turkish version of the RST-PQ-C

The data for the translation study of the RST-PQ-C was collected from four different primary schools in Nicosia/Cyprus. Data collection was planned to take place in five schools, but one of these schools refused to participate. The data was collected in the remaining four primary schools during school hours. The classes included 25-35 students in each school. The investigator of the present study and 10 assistant students from the Near East University's Department of Psychology collected the data. The assistants were briefed before the data collection for each school. The RST-PQ-C and the AMS were printed out and inserted into the envelopes before arrival at schools. On arrival, the headmaster was contacted and the assistants that were responsible for data collection were sent to the classes.

Children, who were present at the school on the day of data collection, participated in the study. The classes in which the data collection took place were assigned and shown by the headmaster randomly and then the teachers in the classes were requested to assist. The same instructions were given in each class. The children were instructed to read and answer all the questions in the questionnaires. They were advised to ask for help if they could not read the questions or did not understand any of the items. They were told that there were no right or wrong answers and they should choose the answer that best described them. If they made a mistake, they were told to put a cross sign on the mistakenly marked choice and then circle the appropriate answer. Afterwards, the first questionnaire was distributed and the completion process was monitored. After the completion of the first questionnaire, the second questionnaire was distributed. Children were able to find help whenever they needed it. Assistants sometimes had to read all the questions to the children aged seven or eight when they had difficulty in reading. In each class, the RST-PQ-C was given first and upon completion, the AMS was distributed. The average time required for filling these two questionnaires in a class was half an hour.

3.3.4. Preliminary Data Analysis

3.3.4.1. Missing values

Two scales were given to a total of 782 children. One child did not want to answer any questions and two children did not want to continue after answering half of the questions in the RST-PQ-C. The forms of these children were discarded.

After completing RST-PQ-C, 17 children did not want to continue with the AMS because they stated that they were tired. These children were at different schools and in different classes. Not willing to continue might be due to difficulty in reading. Alternatively, they might have a problem with exerting sustained mental effort and concentration hence, filling out the questionnaires would have been difficult for them. They only completed one form and for this reason, both forms that were given to them were discarded from the study.

In the AMS, 24 children only answered half of the questions. Further investigation of the issue showed that all these children were in the same class. It appeared that the assistant who collected the data had arrived at the class late and hence, the data collection started late. While the data were being collected, the school bell rang and the students in this class rushed out for a break therefore, there was not enough time for completing the AMS. Any forms that were given to these children were discarded and not included in any of the statistical analyses. Hence, the data that can be subject to a systematic error were completely removed.

Initially, two forms were given to 782 students. For the reasons that have been explained above, 44 children's RST-PQ-C and AMS forms were discarded. Remaining 738 children's (383 males, M_{age} = 9.24, SD = 1.28; 355 females, M_{age} = 9.32, SD = 1.30) forms were included in the statistical analyses. Among these forms, only a few had one or two missing values (11 missing values in total). It can be argued that some children just missed some questions and these missing values can be attributed to inattention and the data were missing at random. These few missing values were imputed using the mean substitution method.

3.3.5. Statistical Analyses

Confirmatory factor analysis (CFA) was conducted by Lisrel 9.2 for assessing the factor structure of the Turkish version of the RST-PQ-C. The hypothesized model was produced according to the original factor structure of the RST-PQ-C, English version. The RST-PQ-C English version had three latent variables and 21 observed variables that were loading on to one of these factors. The participants responded on a 4-point Likert scale, hence the model was tested with a robust estimator, using weighted least square mean and variance adjusted (WLSMV). The model was over-identified (df = 186). Model fit was ascertained using Sattora-Bentler scaled chi-square (χ^2) (Satorra & Bentler, 1999), the root mean square error of approximation (RMSEA; obtaining a number below .050 indicates good fit; McDonald & Ho, 2002), the comparative fit index (CFI; obtaining a number above .90 indicates good fit; Hu & Bentler, 1998), Tucker-Lewis Index (TLI; obtaining a value greater than .90 indicates good fit; Hu & Bentler, 1998), and standardized root mean square residual (SRMR; obtaining a value below .08 indicates good fit; Chen et al., 2008). Internal consistency was assessed by the McDonald's Omega values. Figure 6 represents the hypothesized three-factor model and the standardized values for the Turkish version of the RST-PQ-C. Each factor was measured by seven items.

Pearson's product-moment correlation coefficient was used for investigating the relationships between the scales of the RST-PQ-C and the scales of the AMS. Hierarchical multiple regression analysis was conducted for investigating the predictive roles of the BAS, BIS, and FFFS on intrinsic and extrinsic academic motivation. Moreover, a structural model including the BAS, BIS, FFFS, AMS-intrinsic, and AMS-extrinsic motivation as the latent variables were hypothesized for further demonstrating the predictive utility of the RST-PQ-C scales. These latent variables were analysed via structural equation modelling, using SPSS Amos 22. First, a measurement model was produced and then the latent variable scores were computed. Model fit was evaluated using the chi-square goodness-of-fit test (good fit when chi- square/df ratio ≤ 3.0; Loehlin, 1998), the comparative fit index (good fit when CFI ≥ .95; Bentler, 1990), the root mean square error of approximation (good fit when RMSEA ≤

.06; Steiger, 1990; Kline, 2005), standardized root mean squared residual (good fit when SRMR ≤ 0.08; Chen et al., 2008), and Tucker–Lewis Index (better fit when TLI ≥ 0.95; Hu & Bentler, 1999).

3.4. Results

In the AMS, a total of 11 questions were not answered by the participants and these missing values were replaced by using the mean substitution method. The final value was calculated by summing up the response scores in the scale to which the missing value belonged and then the resulting value was divided by the number of the items that the scale had. In the RST-PQ-C, the skewness and kurtosis values for all items ranged from -1.63 to 0.09, and -1.53 to 0.18, respectively. According to Curran et al. (1996) skewness and kurtosis values of 0 – 2, and 0 – 7 can be taken as descriptive parameters of univariate normality. The value that the computer program Prelis yielded was 1.070 for the multivariate kurtosis, which was relatively small. This indicated that the multivariate distribution was reasonably normal. When we looked at the reliability for each construct, the McDonald's Omega for the FFFS factor was .65, for the BIS factor was .73, and for the BAS factor was .85. Correlation coefficients between the total scores of the RST-PQ-C scales are presented in Table 2.

Table 1

Descriptive statistics for the Turkish version of the Reinforcement Sensitivity-Personality Questionnaire-Children scales and the Academic Motivation scales

	Mean	SD	Skewness	Kurtosis	Omega
Age	9.3	1.3	-2.29	-.99	
BAS	14.6	5.0	-.57	-.39	.85
BIS	10.6	4.1	.07	-.73	.73
FFFS	7.01	4.4	.53	-.01	.65
Intrinsic motivation	70.8	14.1	-1.31	1.23	.93
Extrinsic motivation	56	13.8	-.45	-.02	.89

Note. FFFS = fight, flight, freeze system. BIS = behavioural inhibition system. BAS = behavioural approach system. Omega = Mc Domald's omega coefficient.

Table 2

Correlations between total scores of the Turkish version of the Reinforcement Sensitivity-Personality Questionnaire-Children scales

	1	*2*	*3*
1. BAS	1		
2.FFFS	.36**	1	
3.BIS	.57**	.55**	1

Note. FFFS = fight, flight, freeze system. BIS = behavioural inhibition system. BAS = behavioural approach system.
**p < .001

3.4.1. Factor Structure

The hypothesized model was a three-factor model with the BIS, FFFS, and BAS factors. The model fit was investigated with the most commonly used indices of model fit. Obtained values were Satorra-Bentler-scaled $\chi 2$ (df = 186, N = 738) = 372.46, p < .00; CFI = .99; RMSEA = .037; TLI = 0.99 and SRMR = .05. When taken together, these values demonstrated a good model fit.

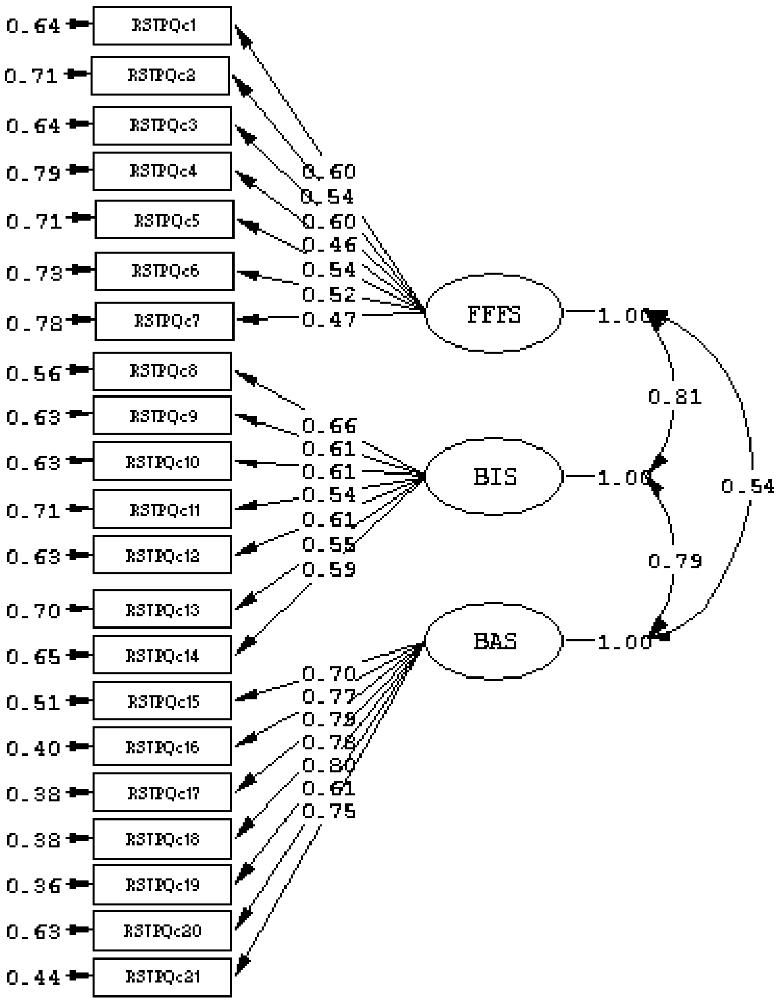

Figure 6. Theoretically derived model. FFFS = fight, flight, freeze system. BIS = behavioural inhibition system. BAS = behavioural approach system. RST-PQ-C = reinforcement sensitivity theory - personality questionnaire-children version

3.4.2. Predictive Utility of the Translated RST-PQ-C for Academic Motivation

When the relationships between the RST-PQ-C and the AMS total scores were investigated, some significant correlation values were obtained. There were significant positive relationships between the BAS, FFFS and BIS scales and the intrinsic motivation scale of the AMS. On the other hand, only the FFFS and the BIS were significantly but weakly related to the extrinsic motivation. Correlation coefficients are presented in Table 3.

Table 3

The correlations between Turkish version of the Reinforcement Sensitivity-Personality Questionnaire-Children and the Academic Motivation Scale

RST-PQ-C-Tr scales	AMS scales	
	Intrinsic motivation	Extrinsic motivation
BAS	$.43^{**}$	.06
FFFS	$.08^{*}$	$.14^{**}$
BIS	$.25^{**}$	$.17^{**}$

Note. RST-PQ-C-Tr = Reinforcement Sensitivity-Personality Questionnaire-Children-Turkish language version. AMS = Academic Motivation Scale. BAS = behavioural approach system. FFFS = fight, flight, freeze system. BIS = behavioural inhibition system.
$^{*}p < .05$, $^{**}p < .001$

To examine the predictive utility of the translated RST-PQ-C scales for academic intrinsic and extrinsic motivation, a hierarchical multiple regression analysis was conducted (summarized in Table 4). Separate regressions were computed for the intrinsic motivation scale and the extrinsic motivation scale. In the first part, a two-step hierarchical regression analysis was employed. The age and the gender were entered in the first step, and the BAS, the FFFS, the BIS were added in the second step. Intrinsic motivation was entered as the criterion variable. The results from the first step revealed that age and gender together accounted for 4.3% of the variance in the intrinsic motivation scores, $F(2,735) = 16.43$, $p < .001$. The strongest individual predictor of intrinsic motivation was age ($\beta = .19$, $p < .001$).

The results for the second step revealed that when the BAS, FFFS, and BIS were entered in block 2, this accounted for an additional and significant 12.4% of the variance, in the intrinsic motivation scores, ΔF (3,732) = 36.2, $p < .001$. In this model, the BAS was the strongest predictor of the intrinsic motivation scores ($\beta = .32$, $p < .001$). The BIS ($\beta = .10$, $p = .025$) and the FFFS ($\beta = -.01$, $p = .021$) also emerged as significant but relatively weaker predictors.

In the second part, age and gender were entered in the first step and the BAS, the FFFS, and the BIS were added in the second step. This time, extrinsic motivation was entered as the criterion variable. The results from the first step revealed that age and gender together accounted for 1.6% of the variance in the extrinsic motivation scores, $F\ (2, 735) = 6.0$, $p = .003$. Age appeared to be a significant predictor of the extrinsic motivation ($\beta = -.13$, $p < .001$). On the other hand, gender was not a significant predictor. The results for the second step revealed that 3.4% of the variance was accounted for when the BAS, FFFS and BIS were added, $\Delta F\ (3,732) = 8.634$, $p < .001$. In this model, the BIS was a significant but weak predictor of extrinsic motivation ($\beta = .15$, $p = .002$). The BAS and the FFFS were not significant predictors of the extrinsic motivation scores.

Table 4

Summary of the hierarchical regression analysis, predicting scores on the intrinsic motivation scale and the extrinsic motivation scale

Predictors and step		Intrinsic motivation				Extrinsic motivation			
		β	R^2	ΔR^2	ΔF	β	R^2	ΔR^2	ΔF
1	Gender	$-.09^{*}$	.04	.04	16.433^{***}	.01	.02	.02	6.007^{**}
	Age	$.19^{***}$				$-.13^{**}$			
2	Gender	-.03	.17	.12	36.190^{***}	.04	.05	.03	8.634^{***}
	Age	$.14^{***}$				$-.12^{**}$			
	FFFS	$-.10^{*}$				.05			
	BIS	$.10^{*}$				$.15^{**}$			
	BAS	$.32^{***}$				.003			

Note. FFFS = fight, flight, freeze system. BIS = behavioural inhibition system. BAS = behavioural approach system.
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Moreover, a structural model was tested for further evaluating the predictive utility of the RST-PQ-C scales for the AMS scales. The structural model demonstrated a good fit to the data: $X^2/df = 2.30$, CFI = 0.93, RMSEA = .042, SRMR = 0.05, TLI = 0.93. The standardized path coefficients are presented in Figure 7. As illustrated in figure 7, the BAS significantly predicted the intrinsic academic motivation but not the extrinsic academic motivation. The BIS predicted both intrinsic and extrinsic academic motivation. The FFFS negatively predicted intrinsic academic motivation but not extrinsic academic motivation.

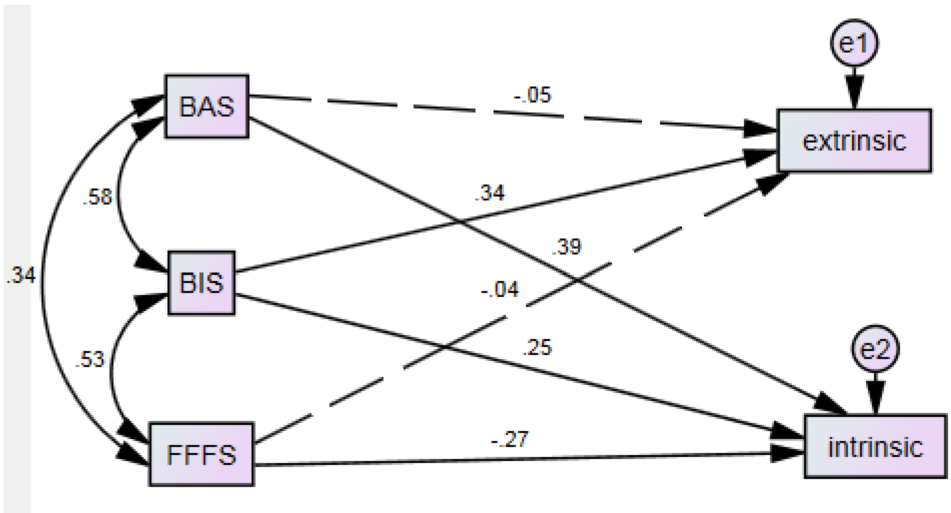

Figure 7. Structural equation model depicting the Turkish version of the Reinforcement Sensitivity Theory-Personality Questionnaire-Children scales, predicting the Academic Motivation. Paths that are shown with the dashed lines are not significant. BAS = Behavioural approach system, BIS = Behavioural inhibition system, FFFS = Fight, flight, freeze system; Extrinsic = extrinsic academic motivation; Intrinsic = intrinsic academic motivation.

3.5. Discussion

This study aimed to investigate the structural and psychometric properties of the Turkish language translation of the RST-PQ-C and to provide evidence that it can be used reliably. For this purpose, factor structure was assessed with the CFA and predictive utility was investigated with the hierarchical multiple regression analysis and the structural equation modelling. The hypothesized the three-factor structure was confirmed. There was a good fit between the hypothesized model and the data. Furthermore, it was shown that the BIS, BAS, and FFFS scales can predict intrinsic and extrinsic academic motivation. It was demonstrated that the Turkish version of the RST-PQ-C can be used reliably within Turkish speaking child population.

In the present study, the FFFS factor had the lowest Omega value. In the original study, the FFFS also had the lowest factor loadings when compared to the other scales. The FFFS was described as a general-purpose punishment sensitivity system that is responsible for mediating reactions to all aversive stimuli (Corr & McNaughton, 2008). The FFFS is fragmented and it contains elements of fighting, freezing, and fleeing. In the original validation study for the RST-PQ-C, the authors argued that writing straightforward FFFS items was challenging because even the best items would have a certain degree of goal conflict and relate to the BIS (Cooper et al., 2017). The lower Omega value for this scale can be attributed to the fragmented nature of the FFFS construct.

Another important issue was the separation of the FFFS and the BIS factors when the rRST's assumptions are considered (Krupić et al., 2016; McNaughton & Corr, 2004). The BIS and the FFFS were moderately correlated ($r = .55$). This value was very close to the value that was obtained in the original study of the RST-PQ-C, where it was reported that the FFFS and the BIS were positively and moderately correlated ($r = .53$; Cooper et al., 2017). This moderate relationship and convergence of these two constructs are in line with the assumption of the rRST that these systems can be coactivated. Corr and Cooper (2016) argued that the FFFS activation can result in the activation of the BIS, particularly in situations that include incompatible goals. On the other hand, these systems have been proposed to be separate and independently functioning constructs (Heym et al., 2008), which may be true at the factor analytical level but not necessarily at the level of functional behaviour. In the present study, obtaining independent BIS and FFFS factors supports this distinction. Overall, these findings provided further support for the notion of the separate but interacting FFFS and BIS.

The BAS and the BIS were found to be moderately and positively correlated. A moderate level of correlation between the BIS and the BAS suggests greater connectivity between these constructs in childhood. In the literature, there are some differences in terms of the values that were obtained from adult and children samples. Studies that included children (Blair et al., 2004; Luman et al., 2012; Vervoort et al., 2015) showed substantially larger correlations between the BIS and the BAS (the highest value obtained to be, $r = .51$; Amiri et al., 2019) than the studies that based on adults (the highest value obtained to be $r = .32$; Berkman et al., 2009; Jackson, 2009; Johnson et al., 2003). The higher sensitivity of these systems in childhood could be explained when approached from a nurture perspective. It can be speculated that particular experiences would change the sensitivity of reinforcement systems. For example, higher BAS activity and a higher frequency of reward-related approach behaviour would increase the possibility of more frequently facing aversive stimuli that trigger the FFFS. Moreover, the frequent need for conflict resolution can result in the frequent activation of the BIS. The repeated experience of such situations could result in the sensitized FFFS and the BIS. Hence, a higher BAS level and frequent approach behaviour could be related to the higher BIS level through the higher amount of irritating stimuli that have been faced. This could explain the obtained moderate positive correlation between the BAS and the BIS. Although this argument is speculative, the notion of a change in the sensitivity of a system is worthy of further attention.

Consideration of traditional variations and tendencies can be important in explaining this positive relationship as well. It could be speculated that if the probability of being punished is high in a certain tradition, then children will need to be even more cautious when they have the opportunity to be rewarded. Turkish tradition and the educational system can be criticised for being more punishing than rewarding. This could be a factor that increases the sensitivity of the FFFS and the BIS eventually resulting in a higher correlation value between the BAS and the BIS among Turkish children – these cultural differences might also be a target for future empirical scrutiny.

Alternatively, it can also be argued that because children are still in the early stages of the socialization process, they can be more impulsive than adults and they can take higher pleasure from the rewarding things when compared to an adult. On the other hand, they can get more scared or irritated from the aversive things because they have less ability to protect themselves and punishment would carry a bigger intensity for them when compared to adults.

A similar pattern appears in the relationship between the BIS and the FFFS. The highest value being $r = .54$ in children (Colder et al., 2011; De Pascalis et al., 2018; Luman et al., 2012) and $r = .46$ in adults (Franken & Muris, 2006; Hannan & Orcutt, 2013; Jackson, 2009; Perkins et al., 2007). Moreover, interestingly, the relationship between the BAS and the FFFS appears to have a higher correlation value among children ($r = .29$; Colder et al., 2011; Slobodskaya & Kuznetsova, 2013; Vervoort et al., 2010) than adults ($r = .26$; Franken & Muris, 2006; Jackson, 2009; Pugnaghi et al., 2018). Taking it all together, it can be argued that correlation values among reinforcement systems appear to be higher in childhood when compared to adulthood.

The correlations between the RST-PQ-C and the AMS were investigated. The moderate positive correlation between the BAS and the intrinsic academic motivation reflects that children with more sensitive BAS had higher levels of intrinsic academic motivation. According to the rRST, individuals with a higher BAS activity have higher motivation for approach (McNaughton & Corr, 2014) when a situation entails a reward. School tasks can be very rewarding when they are handled efficiently. Academic success is a valuable reward.

Present results could be interpreted to mean that the children with higher BAS activity perceive school tasks as rewarding and they are keen to obtain them.

As expected, the BIS and intrinsic academic motivation had a modest positive correlation. BIS activity can be related to worry (McNaughton & Corr, 2009). School tasks present a challenge. For any children that desire success, a cautious approach to school work is necessary. According to rRST, the possibility of a failure in the process of reaching the desired goal should activate the BIS. Higher BIS activity and frequent worry about failure would produce higher intrinsic motivation for avoiding it. It can be argued that the BIS sensitivity is positively related to intrinsic academic motivation because children with higher BIS activity could have a higher rate of worry about academic underachievement and genuinely want to avoid failure.

It can be concluded that both hope and worry are related to intrinsic academic motivation. However, children with the higher BAS sensitivity are motivated by hope and the children with the higher BIS sensitivity are motivated by worry. The first group try to obtain a reward, while the second group try to avoid failure. It can be argued that although both groups strive for success, they do it for different reasons.

The present study findings also demonstrate the predictive utility of the RST-PQ-C for academic motivation. Hierarchical regression analysis results show that the BAS was the strongest predictor of intrinsic motivation. The BIS appeared as a weaker predictor of intrinsic academic motivation. On the other hand, the BIS appeared to be a significant but weak predictor of extrinsic motivation. These results are in line with the findings of previous studies and the predictions of this thesis, in terms of the BIS, BAS, and the academic motivation relationships.

The predictive utility of the RST-PQ-C scales for academic motivation was also investigated via structural equation modelling. When the results were compared to the commonly accepted fit indices, it appeared that the model had a good fit with the data. The results were in agreement with the multiple regression analysis and the previous study findings where the BAS was the strongest predictor of intrinsic academic motivation while it did not significantly predict extrinsic academic motivation. The BIS was the relatively weaker predictor of both intrinsic and extrinsic academic motivation when compared to the BAS. Moreover, the FFFS was the weakest predictor of intrinsic academic motivation and it did not predict the extrinsic academic motivation. The SEM results provided further evidence for the predictive strength of the RST-PQ-C scales for academic motivation.

Present results suggest that the BIS and the BAS are two factors with the potential to influence school achievement through intrinsic motivation among primary school children. The link between reinforcement systems and school achievement is needed to be further investigated. For example, future studies can look into the mediating effect of intrinsic motivation in the relationship between the rRST behavioural systems and school achievement.

One limitation of the present study comes from the fact that there was no previously developed or translated tool for assessing reinforcement sensitivity among children in the Turkish language. For this reason, it was not possible to use another questionnaire for providing any convergent validity evidence. In the future, it would be worthwhile translating one of the other children's reinforcement sensitivity questionnaires into Turkish for this purpose. Moreover, in the present study, electrophysiological correlates of the FFFS and the BIS were not measured. Not having such equipment hindered the possibility of presenting physiological evidence for the distinction between these constructs.

3.6. Conclusion

The results of study one, provide evidence that the psychometric properties of the Turkish version of the RST-PQ-C are comparable to the original version and it can be used as a reliable assessment tool among Turkish speaking children. Results of the regression analysis and structural equation modelling show that the RST-PQ-C carries predictive utility for intrinsic academic motivation. This opens up whole new revenue for investigating the role of the RST behavioural systems in academic achievement.

In the present thesis, chapter one and chapter two provided a general theoretical ground and helped to define the critical variables for the three investigations to take place in this thesis. Chapter three presented evidence that the Turkish version of the RST-PQ-C can be reliably used in Turkish speaking child population. For the purposes of this thesis, it was critical to obtain a reliable questionnaire because the translated instrument was planned to be used in the two investigations that took place in Study 2.

Study 2 included two investigations and that is why it was divided into two separate parts. Two different problems were addressed: in Study 2a, frequently avoiding mental effort and in Study 2b impaired executive functioning was investigated. One important issue in Study 2a was the quantification of the avoidance behaviour. A measurement tool (i.e., Cognitive Effort Avoidance Measure) that included nine cognitive tests was produced. This tool provided an opportunity for recording the frequency of avoidance behaviour. A detailed description of the Cognitive Effort Avoidance Measure is given in the method section of Study 2a. In the following chapter, an investigation of the factors that are related to avoiding mental effort among children with ADHD is presented. It is important to note that the same data set was used in both investigations that took place in Study 2.

CHAPTER FOUR: STUDY 2a

Neuropsychological Mechanism of Avoiding Sustained Mental Effort Among Children with ADHD

4.1. Background

Children diagnosed as having Attention Deficit Hyperactivity Disorder (ADHD) have been observed to have a tendency for avoiding sustained mental effort. This chapter examines the potential roles of the underactive behavioural inhibition system (BIS) and impaired prepotent motor response inhibition performance in explaining the higher frequency of avoiding mental effort among children with ADHD.

Patzelt et al. (2019) stated that many people tend to choose the tasks with less cognitive demand because cognitive control is effortful. It can be often observed that avoiding mental effort leads to uncompleted tasks and it is often related to occupational or academic conflict, hence, it poses a problem. On the other hand, not all people tend to avoid mental effort. For instance, Coelho et al. (2020) argued that the need for cognition is a stable personality trait and people high in need for cognition seek out and engage with the tasks that require problem-solving. Coelho et al.'s (2020) study shows that although mental effort is costly, some individuals choose to engage with effortful cognitive tasks and do not tend to avoid it. It can be reasoned that individuals with a lower rate of effort avoidance, experience less occupational and interpersonal conflict and they can be more reliable in terms of completing assigned tasks when compared to avoiders.

Avoiding mental effort can be defined as being reluctant to use cognitive capacities (e.g., reasoning, inhibiting prepotent responses, and planning) to engage and solve effortful problems. Individuals with ADHD have been reported to avoid mental effort more frequently than non-patient individuals. Poulton (2015) argued that because of the impaired executive functioning, children with ADHD are required to exert a higher rate of mental effort for achieving optimal performance in a cognitive task. Previous research has linked exerting higher mental effort to larger pupil dilation (Tapper et al., 2021) and one recent study that investigated mental effort among children with ADHD has reported larger pupil dilation rates in a working memory task when compared to controls (Mies et al., 2019).

Studies in the literature suggest that response inhibition performance and avoiding mental effort are related. For example, Nador et al. (2020) found that inhibition performance (i.e., screening for irrelevant stimuli) was related to avoiding mental effort among non-patient adults. Moreover, Jennings et al. (1997) used the Stop signal Paradigm for investigating the inhibition process in a child ADHD sample. Although there were no group differences in the inhibition performance, they found longer inhibition latencies and argued that children with ADHD exert greater inhibitory effort to achieve performance equal to their peers.

Previous studies demonstrated that different types of inhibitory processes exist (Nigg, 2000). The prepotent motor response inhibition and the revised reinforcement sensitivity theory (rRST) - BIS are two different inhibitory processes and both of them have been linked to the inattentive symptoms of ADHD (Sadeghi et al., 2019). Importantly, both constructs have been reported to be positively related to the efficiency of cognitive control and self-regulation (Aichert et al., 2012; Aron, 2007; Bunford et al., 2017; Chambers et al., 2009). Hence, reports in the literature suggest that the impairment in the prepotent motor response inhibition and the BIS can be two factors that contribute to a higher rate of avoiding mental effort among children with ADHD. However, their potential role in avoiding mental effort has not been investigated. Based on the reports, the main question asked in the present study was whether the prepotent motor response inhibition and the BIS are related to each other and whether lower levels of these constructs contribute to higher rate of avoiding mental effort among children with ADHD.

4.1.1. BIS Activity and Avoiding Mental Effort

Accordıng to the rRST the BIS is a comparator mechanism that is involved in the detection and resolution of goal conflict (Amodio et al., 2008; Corr, 2008; Leue et al., 2012). When it detects a goal-conflict it switches to control mode and regulates motivation for adaptive behaviour. The BIS inhibits the activity of the BAS and the FFFS as it tries to resolve the conflict which is often likely to result in cautious approach behaviour.
fMRI study results support the notion that a common neural mechanism (i.e., BIS) plays a role in inhibiting both avoidance and approach related behaviours (Gable et al., 2018; Kelley, 2015).

The activity level of the BIS has been proposed to be critical in the management of both the BAS-related approach and the FFFS-related avoidance behaviour (Corr, 2008). Gable et al. (2018) argued that the BIS activity is related to management of the BAS and the FFFS related motivational processes. Results in the literature shown that lower BIS and higher BAS are implicated in higher rate of substance abuse (Fowles, 2001) and can predict psychopathy (Heym & Lawrence., 2010). Fowles (2001) further argued that "A dominance of the BAS over the BIS would produce both an impulsive temperament and a bias toward the positively reinforcing effects of drugs" p.94. These results suggest that weakness in the BIS activation could be related to a difficulty in regulating the BAS related motivation. Therefore, individual could experience impairment in controlling the BAS- related behaviours although inappropriate or harmful.

Majority of the studies have focused on the link between the BIS and the BAS and only few reports exist about the possible inhibitory effect of the BIS on the FFFS activity. For example, Findley (2014) argued that when weak BIS cannot inhibit the FFFS induced avoidance motivation then this could result in self-control failure. Moreover, in a review article, Gable et al. (2018) argued that hypoactivity of the BIS could account for unregulated withdrawal behaviours. Reports suggest that the BIS could play a role in inhibiting avoidance motivation and hence, low BIS activity could be related to the difficulty to resist fleeing.

Not being willing to engage or leaving a task uncompleted often results in negative consequences. In many instances, an individual is needed to endure an aversive situation until a desired goal is reached. In such circumstances, the BIS could play a critical role by initiating cautious behaviour and helping an individual to resist the temptation of fleeing. Exerting mental effort is costly and experiencing irritation in a cognitive task could activate the FFFS. Activation of the FFFS could increase avoidance motivation and result in fleeing if not properly regulated by the BIS. For this reason, in the present study, lower BIS activation is expected to be related to a higher rate of avoiding mental effort.

4.1.2. Prepotent Motor Response Inhibition Performance and Avoiding Mental Effort

Prepotent motor response inhibition can be described as the ability to stop a habitual motor response. The Go/no-go Task is a neuropsychological test that is widely used in the literature for the assessment of the prepotent motor response inhibition ability. Wright et al. (2014) carried out a meta-analysis where they covered over 300 studies that used the Go/no-go Task. It was found that the prepotent motor response inhibition performance was critical in various mental disorders. Study results showed a medium effect size for the prepotent response inhibition in 11 different psychiatric disorders including ADHD.

It has been proposed that prepotent response inhibition is a crucial part of cognitive control because habitual behaviours have to be inhibited before any higher-level executive control operation can be initiated. As previously described in the literature review section of the present thesis (p. 39), this process is named transcending the default mode (Mesulam, 2002) and it facilitates the engagement of higher-level control mechanisms, namely the executive functions. Study results suggest that the prepotent response inhibition is an integral part of the efficient cognitive control (Aron, 2007; Chambers et al., 2009) and it can be argued that a weakness in the inhibition of habitual responses can decrease the quality of cognitive processing. Hence, impaired prepotent motor response inhibition can contribute to a lower executive functioning performance (Berlin et al., 2003), experiencing higher task difficulty and eventually it could result in a higher frequency of avoiding mental effort.

Torgrimson et al. (2021) investigated the inhibition ability (i.e., prepotent response inhibition) and motivation (i.e., interest and perceived competence) in relation to task persistence and demonstrated that the prepotent motor response inhibition was a positive predictor of the task-persistence among elementary school children. This study's results show that children with lower prepotent motor response inhibition performance are less persistent on a cognitively challenging task. Based on the results, the authors concluded that the prepotent motor response inhibition is critical for children to engage and persist on a cognitively challenging task. Moreover, they argued that cognition and motivation should be investigated together for a better explanation of task-persistence.

Lower prepotent motor response inhibition performance could be related to experiencing higher difficulty in cognitive tasks and hence, result in an increase in avoidance motivation. However, a child is often expected to engage and persist until the desired outcome is obtained. On the other hand, the BIS can be critical in resisting avoidance motivation for achieving longer on-task behaviour in the face of a challenging cognitive task. For this reason, when the impaired prepotent motor response inhibition results in an increase in the level of difficulty of a task and produce avoidance motivation then an intact BIS could be critical in inhibiting avoidance motivation and help a child to have longer on-task behaviour.

Importantly, both the prepotent motor response inhibition and the BIS levels were found to be lower in the child ADHD population when compared to TD controls (Iaboni et al., 1997; Sadeghi et al., 2019; Wright et al., 2014). Moreover, reports in the literature suggest that the prepotent motor response inhibition and the BIS could be uniquely related among children with ADHD (Wiersema & Roeyers, 2009). To date, no study investigated the relationship between the prepotent motor response inhibition, the BIS, and avoiding mental effort among children with ADHD. Considering the above-mentioned findings, within the first hypothesis, it is expected that the prepotent motor response inhibition performance should influence the frequency of avoiding mental effort through the BIS activation level. In other words, the BIS should be a mediator in the relationship between the prepotent motor response inhibition performance and the frequency of avoiding mental effort (see Figure 8 for the proposed mediation model).

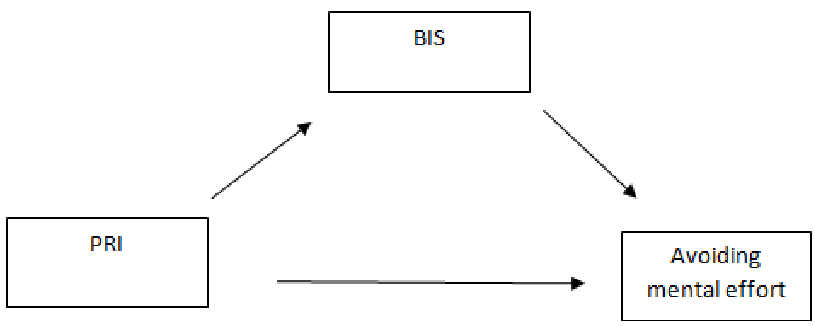

Figure 8. A simple mediation model proposed for showing the indirect effect of the PRI on avoiding mental effort through the BIS. PRI = prepotent motor response inhibition; BIS = behavioural inhibition system.

4.1.3. Rationale for a Moderation Effect: The Unique Relationship Between the Prepotent Motor Response Inhibition and the BIS

In the present section, initially, the studies that used electrophysiological methods for capturing the activity level of the BIS will be presented. Later, the existing evidence in terms of the relationship between the prepotent motor response inhibition and the rRST - BIS will be discussed.

Nigg (2000) described two broad categories of inhibition (i.e., executive inhibition and motivational inhibition) and further argued that these constructs could interact. This proposed distinction is supported by the neuro-anatomical data showing that they occupy distinct neuronal locations in the brain. Executive inhibition includes prepotent motor response inhibition and imaging data suggest that it is related to the lateral orbital pre-frontal cortex (Casey et al., 1997). On the other hand, motivational inhibition is related to the BIS and it is associated with the subcortical septal-hippocampal formation (Gray, 1982).

Several studies in the literature used EEG for investigating the neural signature of the BIS activation. For instance, Moore et al. (2012) investigated the relationship between the EEG measures and the BIS activity level. The authors reported that EEG variables discriminated between low/high BIS participants during primary goal conflict and concluded that the data support Gray and McNaughton's (2000) view that EEG theta oscillations reflect the BIS activity. In the same vein, Leue et al. (2012) investigated EEG patterns of low and high BIS adult participants. Their results showed that there was a more pronounced conflict monitoring in individuals with higher BIS activation levels. Results of EEG studies in literature suggest that the P300 amplitude can be used as the neural signature of the BIS activity level (Lange et al., 2012; Sadeghi et al., 2019).

In the child ADHD population, the P300 amplitude of the EEG measure was often found to be lower when compared to TD children. For example, Sadeghi et al. (2019)

compared the levels of goal-conflict-specific rhythmicity, among children with and without ADHD. The control group had normal EEG activity but the clinical group had lower EEG signatures reflecting lower BIS activation. This study's results show that when investigated with EEG, the BIS activation appears to be lower among children with ADHD.

No study has investigated the relationship between the behavioural outputs of the BIS and the prepotent motor response inhibition among TD children. However, this link has been investigated in healthy adults. Amodio et al. (2008) used the Go/no-go Task for measuring the prepotent motor response inhibition performance and also used the BIS/BAS questionnaire (Carver & White, 1994) for measuring the self-reported BIS activity level, along with the EEG recordings, among healthy adults. Results of this study showed that there was no significant correlation between the neural signature of the BIS and the prepotent motor response inhibition performance ($r = .08$, $p > .05$). Furthermore, importantly, behavioural analyses presented that the self-reported BIS activity scores and the prepotent motor response inhibition scores were not significantly related either ($r = -.14$; $p > .05$). These results suggest that behavioural output of the prepotent motor response inhibition and the self reported BIS are not related among healthy adults.

On the other hand, Wiersema and Roeyers (2009) used the Go/no-go Task and also employed the EEG measures for investigating the relationship between effortful control and ADHD. Results showed that when compared to controls, children with ADHD obtained lower prepotent motor response inhibition scores and had smaller P300 amplitude. These results implicate a positive correlation between the neural signature of the BIS and the behavioural measure of the prepotent motor response inhibition. It is important to note that such a relationship has not been reported among TD children or adults and seems unique to the child ADHD population. Wiersema and Roeyers's (2009) results demonstrate a positive correlation between prepotent motor response inhibition performance and the EEG signature of BIS but a curious question that remains to be answered at this point is whether a relationship exists between the behavioural measures of the prepotent motor response inhibition performance and the self-reported BIS activity level, among children with ADHD.

In sum, study results provide evidence that behavioural measures of the prepotent motor response inhibition performance and the BIS activity level are not related among healthy adults. Although further research is needed it can be expected that similar results could be obtained from TD children. On the other hand, Wiersema and Roeyers's (2009) study presents a positive correlation between the neural signature of the BIS and the prepotent motor response inhibition scores among children with ADHD. This finding raises the possibility that behavioural outputs of the prepotent motor response inhibition and the BIS can be related among children with ADHD, while they are not among TD children.

No studies have investigated the relationship between the prepotent motor response inhibition and the BIS using the behavioural measures in the child ADHD population although both variables have been reported to be lower in separate studies when compared to controls. The existing evidence in the literature suggests that behavioural measures of the prepotent motor response inhibition and the BIS should be positively correlated only among children with ADHD. Considering the reports, within the second hypothesis, it was predicted that the diagnosis status should be a moderator of the proposed relationships. In other words, the indirect effect of the prepotent motor response inhibition on the avoiding mental effort through the BIS should be contingent upon the ADHD diagnosis (see Figure 9 for the hypothesized moderated mediation model).

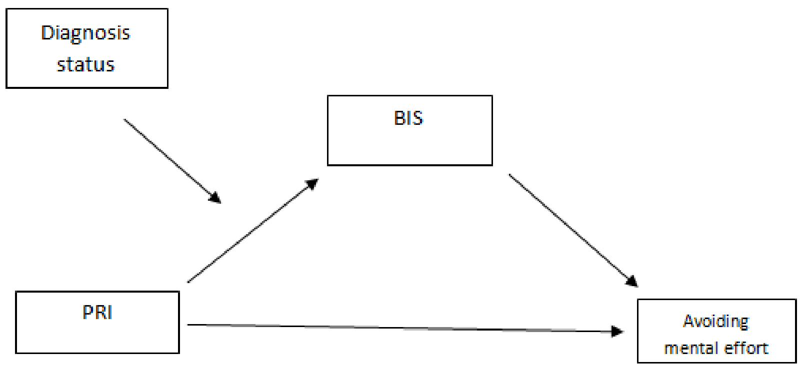

Figure 9. Conditional process model showing the diagnosis status as a moderator on the BIS mediated relationship between the prepotent response inhibition and the frequency of avoidance behaviour.PRI = prepotent motor response inhibition; BIS = behavioural inhibition system.

4.2. Possible Role of General Cognitive Performance in the Avoiding Mental Effort Among Children with ADHD

An important question that appears at this point is: how critical is the prepotent motor response inhibition impairment in the avoidance process? Is it possible that avoidance behaviour is driven by a general weakness in cognitive functioning rather than prepotent response inhibition? Do the results remain the same if the prepotent motor response inhibition score is replaced with a general cognitive composite score? Obtaining a cognitive composite is particularly common for detecting subtle cognitive changes in the pathologies that result in cognitive decline. For example, it has been used as a measure for detecting longitudinal cognitive changes in Alzheimer's disease (Malek-Ahmadi et al., 2018) and among patients with mild cognitive impairment (Jacobs et al., 2020).

Some scientists have argued that prepotent motor response inhibition is a primary function and an individual need to inhibit a response efficiently before a new behaviour can be produced (Barkley, 1997; Wodka et al., 2007). Furthermore, study results suggest that inhibition constitutes a network in the brain and some inhibitory skills are related to each other (e.g., prepotent motor response inhibition and inhibition of irrelevant stimuli; Verbruggen et al., 2004). That is why it is plausible to propose that the prepotent motor response inhibition (i.e., executive inhibition) can have a link with the BIS (i.e., motivational inhibition) while other cognitive functions do not.

The possibility of a general cognitive weakness resulting in the avoiding mental effort can be checked if a general cognitive composite score is obtained and replaced with the prepotent motor response inhibition performance in the analyses. For this inquiry a general cognitive factor (i.e., latent variable) can be obtained by calculating the common variance of nine tests (i.e., indicators). If the mediation analysis results show that the cognitive composite score cannot predict the frequency of avoiding mental effort through the BIS but the prepotent motor response inhibition performance does, then it can be concluded that only the prepotent motor response inhibition in its interaction with the BIS can explain the avoidance of mental effort among children with ADHD.

4.3. Method

The method section of Study 2a presents information about the design, participants, instruments, procedure, and the planned data analyses. It includes a description of the techniques that were used in the data collection and hypothesis testing. This section includes information about the actions taken to provide evidence for the proposed critical role of the prepotent motor response inhibition. Moreover, the present section also explains the employed strategy for providing the concurrent validity evidence for the Cognitive Effort Avoidance Measure. The Cognitive Effort Avoidance Measure was produced for the present study's purposes and used for quantifying avoidance behaviour. The rationale and the detailed description of this tool are presented in the instruments section.

4.3.1. Study Design and Variables of Interest

The present study was quasi-experimental in its nature and it had a between-subjects design. The clinical group included children diagnosed with ADHD. The control group included age and gender-matched TD children. Matching children for age and gender helped to minimize confounding effects. The same instruments were used for collecting data in both groups. Having such a design provided an opportunity to compare the performance of children with and without ADHD. In the moderated mediation analysis, the independent variable was the prepotent motor response inhibition and the dependent variable was the frequency of avoiding mental effort. The mediator variable was the BIS score and the moderator was the diagnostic status.

4.3.2. Participants

The clinical group comprised forty children (30 males, 10 females, $M_{age} = 8.92$ years, age range: 7-11 years), who were living in urban or rural areas in Cyprus. All children were Turkish language speakers and primary school students. They were recruited in the Burhan Nalbantoglu Hospital's child-psychiatry outpatient unit and all were drug naïve. The consecutive sampling method was used for recruiting children into the clinical group. Children who applied to the hospital and met the inclusion criteria were included in the group until the required number (N = 40) of participants was obtained. Inclusion criteria comprised: ADHD diagnosis, being a Turkish language speaker, and having at least one parent available for filling the parent consent form (see Appendix 3). Exclusion criteria: estimated IQ less than 80 and a known diagnosis of a neurological condition such as seizures as these could affect the test results. Children were paid 50 Turkish liras (10 Euros) at the end of the session for their participation. Informed consent was obtained from the children before the data collection started (see Appendix 4).

For the control group, 40 children (30 males; 10 females; $M_{\text{age}} = 9.05$ years, age range: 7-11 years) were recruited from a primary school (Near East Junior College) in Nicosia, Cyprus. The mean ages of children in the clinical and the control groups were not significantly different from each other, $t(78) = -0.48$, $p > .05$ (see Table 5). All the children were born and raised in Cyprus and they were Turkish language speakers. They were all living in or around Nicosia, Cyprus. Permission forms were sent to parents for allowing their children to participate in the study (see Appendix 5). The filled forms were brought back to school by students. The selection was carried out using an anonymous list. The list included only student number, age, and gender and it was comprised of the students for whom parents permitted participation. Children were recruited based on the age and gender distribution of the children in the clinical group. The aim of having such a strategy was to make the groups equal in terms of age and gender. The Inclusion criteria were having the parent's consent and being a Turkish language speaker. Exclusion criteria were having an estimated IQ below 80 and having a neurological or psychiatric diagnosis as these could affect the test results.

Ethical approval was obtained from the Near University's and the City University of London's institutional review boards (see Appendix 6). The data collection part of the study was completed in six months. In total, five children's data were discarded. The data collected from four children were discarded because their estimated IQ was below 80 and moreover, one child informed the experimenter during the testing that she did not want to continue to the session. Eventually, each group included 40 children.

Table 5

Means and standard deviations of ages and estimated intelligence in clinical and control groups

	Clinical (N= 40)		Control (N= 40)		t(df)
	M	SD	M	SD	
Children's age	8.92	1.37	9.05	1.43	-0.48(78)[a]
Father's age	41.1	6.18	41.5	3.64	-0.35(78)
Mother's age	37.4	5.34	39.4	3.08	-2.05(78)
Estimated intelligence	98.4	10.1	103.5	11.8	-3.54(78)[a]

Note. [a]Equal variances assumed, because Levene's test for equality > 0.05.

4.3.3. Measures

4.3.3.1. Cognitive effort avoidance measure

In the present thesis, the Cognitive Effort Avoidance Measure was produced for being able to quantify the amount of avoidance behaviour. A novel method was employed and the rationale was provided. In this procedure, nine previously validated, well known cognitive tests were used with the addition of two novel forms to obtain an avoidance score. The reason for this effort was the lack of such an instrument in the literature. Avoiding mental effort can be described as disliking or not willing to tackle the tasks that put weight on the cognitive capacities. Based on this definition, the Cognitive Effort Avoidance Measure employed several cognitive tests and with the addition of two forms (i.e., the display and the face form) it provided the participant with an opportunity to avoid a specific cognitive domain. Hence, it allowed the test administrator to observe the instances when a participant expressed avoidance behaviour after experiencing difficulty in a particular cognitive domain.

The Cognitive Effort Avoidance Measure includes nine neuropsychological tests and two forms. The first one of the forms is an A4 size display and it includes nine removable cards on it (i.e., the display; see Figure 10).

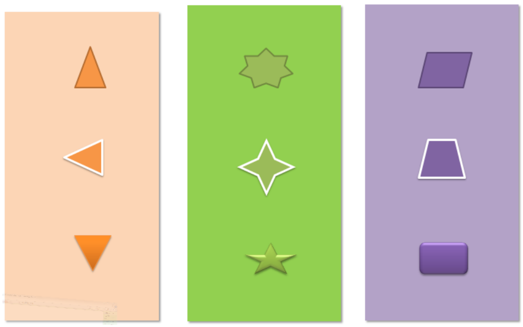

Figure 10. Cognitive Effort Avoidance Measure: the display

The second form is an A4 size paper that includes nine rows of faces. Each row includes five faces that vary from very sad to very happy, neutral face being in the middle (i.e., the face form; see Figure 11).

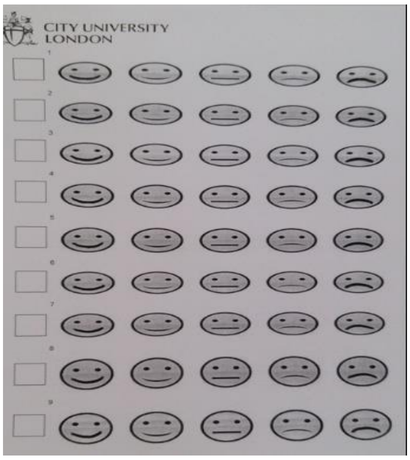

Figure 11. Cognitive Effort Avoidance Measure: the face form

The aim of adding the first form (i.e., the display) was to present the cards in the categories and allow children to pick a card of their own choice. The display is a laminated A4 size paper (297 x 420 mm) and throughout the session, it remains on the table, in a fixed position. It has three columns with different colours where three cards are placed in vertical order. Each card has a code at the back that is composed of a number and a letter for showing the corresponding test (e.g., 1A). Names and the order of the tests are presented in Table 6, and this is how they are presented at the beginning of a session. As the session progress, the cards are removed from the display and moved out of the sight of the participant. Using the Cognitive Effort Avoidance Measure is a three-step process. First, a participant takes a card from the display. Second, he or she completes a test, and third, circles out a face in the face form.

Instructions were as follows, you can take any one of the cards you want. Depending on the card you picked, you will receive a test. After completing the test you will circle a face in the face form. You should choose a face that best reflects how much difficulty you experienced in the test you completed. If it was easy for you then you should circle out one of the smiling faces but if you had difficulty then you should circle out one of the frowning faces. Please note that the tests in the same column are more similar to each other when compared to the tests in the other columns.

Informing participants about the similarity of the tests in the same column is critical. The rationale for this measure is as follows: if a child experiences difficulty with a test then he or she is going to avoid the section to which it belongs and will pick a less similar test from a different section. On the other hand, if a participant experiences no difficulty then he or she should not hesitate to choose a test from the same section. Based on this rationale, experiencing some difficulty with a test and then choosing the next test from a different domain was identified as the avoidance behaviour.

Table 6

Names and the order of the tests in the Cognitive Effort Avoidance Measure

	1	2	3
A	Auditory Continuous Performance Test	Working Memory- Switch Task	Wisconsin Card Sorting Test
B	Bourdon-Vos Test	Corsi Block Tapping Test	WISC-4 Matrix Reasoning subtest
C	WISC-4 Vocabulary subtest	Go-no/go Test	Choice Delay Task

Detailed descriptions of the cognitive tests that were used within the Cognitive Effort Avoidance Measure and the instructions for scoring are presented in Appendix 9.

The cycle of taking a card, completing a test and circling out a face was repeated until no more cards remained to be chosen. There were nine trials in each session. Unique codes of the cards they picked and the faces they circled were recorded on the face form. Scoring was performed as follows: if a child chooses a sad or very sad face and then picks the next card from a different section, this action was scored as the avoidance behaviour (see Figure 12, section a). On the other hand, choosing a neutral, happy or very happy face then picking a card from a different column was not scored as the avoidance behaviour (see Figure 12, section b). Furthermore, choosing a sad or very sad face and picking a card from the same category did not count as avoidance behaviour as well (see Figure 12, section c). The scoring continued until one or more cards were left in the same section (see Figure 13). There was no possibility of taking a card from another section and exhibiting avoidance when all the remaining cards were in the same section. The obtained output score was the frequency of avoidance behaviour. Each observed avoidance behaviour was recorded as 1 point and these were summed up at the end. The score that can be obtained varied between 0 and 7.

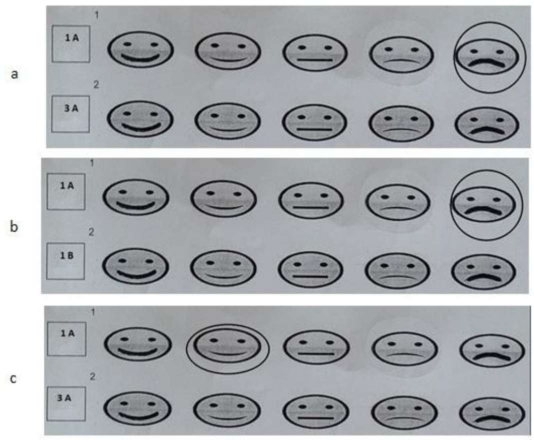

Figure 12. Some examples of scoring the Cognitive Effort Avoidance Measure. Section a shows the instance where a participant takes the first card of the section 1 and receives the corresponding test (i.e., Auditory Continuous Performance Test). When the test is completed, he or she circles out a frowning face and then takes the next card from a different section (i.e., 3A). Hence, this behaviour is identified as the avoidance behaviour. The section b shows the instance that a participant takes the first card of the section 1 and experiences some difficulty with the test-circles a frowning face. However, the participant takes the next card from the same section. Hence, he or she does not express avoidance behaviour. Section c shows the instance that a participant receives the test that corresponds to 1A (i.e., the first card of the first section) and he or she does not experience any difficulty- the smiling face was circled. He or she takes the next card from another category but this behaviour is not recorded as the avoidance because there was no difficulty preceding it.

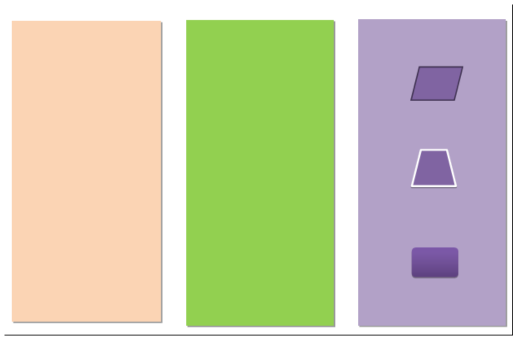

Figure 13. Showing the situation that all the remaining cards are in the same section hence, no possibility of avoidance behaviour.

4.3.3.1.1. Concurrent validity for the cognitive effort avoidance measure

The APA dictionary of psychology describes concurrent validity as follows, "The extent to which one measurement is backed up by a related measurement obtained at about the same point in time. In testing, the validity of results obtained from one test can often be assessed by comparison with a separate but related measurement collected at the same point in time" (VandenBos, 2017, p.229). Based on this definition, the output of the Cognitive Effort Avoidance Measure, the preference for easy academic work and the preference for challenge subscales of the Academic Motivation Scale (AMS; Harter, 1981) can be argued to be related and tap to the same construct.

The AMS was described in the previous chapter (the third chapter, on pages 75 and 76). However, it is important to reiterate some of its subscales (i.e., easy work and challenge subscales), for showing that the Cognitive Effort Avoidance Measure and the mentioned subscales assess the same concept: mental effort avoidance. The Cognitive Effort Avoidance Measure assesses the level of mental effort avoidance by exposing an individual to several cognitively demanding tasks and allowing the observation of avoidance behaviour after experiencing difficulty with a test. As a result, it produces a score that represents the level of mental effort avoidance.

On the other hand, the easy work subscale of the AMS is a self-report measure of the preference for easier academic tasks. It includes six statements: some example items are as follows, "I don't like to figure out difficult problems", "I don't like difficult schoolwork because I have to work too hard", "I like easy work that I am sure I can do", and "I like to stick to the assignments which are pretty easy to do". A higher score represents a higher preference for easier academic tasks. In other words, a higher score on this scale represents a higher preference for avoiding effortful cognitive tasks. Similarly, a higher score in the Cognitive Effort Avoidance Measure also represents the level of the tendency to avoid mentally effortful tasks. Hence, it appears that both the easy work subscale and the Cognitive Effort Avoidance Measure are aimed at measuring how much of an individual prefers to avoid mentally effortful tasks. Hence, if the Cognitive Effort Avoidance Measure assesses what it intends to measure then a positive correlation between the Cognitive Effort Avoidance Measure score and the easy work subscale score of the AMS can be expected.

When the easy work score is assigned as the reference variable then obtaining a significant, positive correlation coefficient can be presented as the evidence of concurrent validity for the Cognitive Effort Avoidance Measure.

On the other hand, the challenge subscale of the AMS, measures the level of preference for challenging academic tasks and it includes six statements. Some examples are as follows, “I like hard work because it's a challenge", "I like those school subjects that make me think pretty hard and figure things out", "I like difficult problems because I enjoy trying to figure them out", and "I like difficult schoolwork because I find it more interesting". The challenge subscale of the AMS measures the level of willingness for undertaking mentally demanding academic tasks and a higher score indicates a higher preference for challenging cognitive tasks. On the other hand, having a higher score on the Cognitive Effort Avoidance Measure means a higher level of effort avoidance. That is why a higher score on the challenge subscale of the AMS can be expected to be related to a lower score on the Cognitive Effort Avoidance Measure. When the challenge subscale is assigned as the reference variable, then obtaining a negative significant correlation coefficient between the scores of these instruments can be presented as the evidence of concurrent validity for the Cognitive Effort Avoidance Measure.

4.3.3.2. Turkish version of the reinforcement sensitivity theory–personality questionnaire –children

Turkish version of the Reinforcement Sensitivity Theory–Personality Questionnaire-Children (RST-PQ-C) was used to assess reinforcement sensitivity. Three separate scores were obtained from the BAS, the FFFS, and the BIS scales. The McDonalds’ Omega values for these scales were found to be .85, .65, and .73, respectively. The responses were given on a 4-point Likert scale and the score can be obtained on each scale varied between 0 and 21. A detailed description of the properties of this questionnaire can be found in chapter two, on page 74 and the items of this questionnaire are presented in the Appendices section (i.e., Appendix 2) of the present thesis.

4.3.3.3. Go/no-go task

The Go/no-go Task was a variation of the Sternberg Memory Task (Sternberg, 1975). The version modified by Hester and Garavan (2005) was used in this study. This task was developed to assess the inhibition ability of the prepotent motor responses with and without working memory (WM) load. In the present study, some modifications were made to the task in terms of the number of runs and the number of trials for making this measure appropriate for children.

E-Prime Version 2.0 computer program was used to present the stimuli in 50-point Arial font on a computer that running Windows XP with a 17-inch colour monitor (see Figure 14). There were four runs and each run included fifty trials. First, participants received a short practice session. Then the first run followed which was a go/no-go run without any cognitive load. Participants were instructed to press the keyboard key 'space bar' for the letters that appeared on the screen, but to withhold their response when the 'X' appeared. Each trial took 2,500 msec. and included the presentation of a single letter for 1,750 msec. and then a blank black screen for the concluding 750 msec. In the second run, the WM load was introduced. Participants were presented with two capital letters (D and H) that appeared in white on a black background. These letters constituted the cognitive load (memory list). The memory list was presented for 6 seconds and then immediately followed by a rehearsal period of 6 seconds. Participants were instructed to rehearse these letters and press the keyboard key 'space bar' for any letters that appeared on the screen but withhold their response if one of the letters from the memory list appears. Then the third run followed by three letters (C, T and S). Then the fourth run followed by four letters (L, U, A and N). Increasing the number of letters served to increase the load that was maintained in the working memory. The following score was recorded from the keyboard input: number of accurately inhibited responses (i.e., total correct). The scores that obtained in each condition (i.e., four conditions) were transformed to z-scores and a prepotent motor response inhibition composite was produced by summing up the scores of each condition. The obtained composite score was used in the analyses.

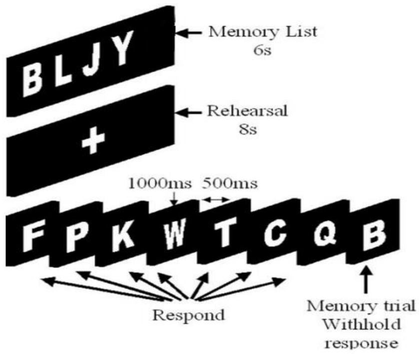

Figure 14. Go/no-go Task with working memory load

4.3.4. Procedure

Data from the clinical group were collected in the Burhan Nalbantoğlu Hospital's child-psychiatry outpatient clinic. This is the biggest government hospital in Cyprus. The permission for the data collection was obtained from the ministry of health (see Appendix 7). The proposed study was presented to the paediatric psychiatrists in a meeting who agreed to refer families for the assessment. Families applied to the hospital for the evaluation of their children. The children were brought to the hospital during one of the weekdays, between 8 am - 1 pm. The diagnostic process involved a multi-step approach. In the first session, the child psychiatrist interviewed parents and a child for ruling out autism spectrum disorder, intellectual disability, traumatic brain injury, and seizure disorders. Then an ADHD symptom checklist was completed (DuPaul et al., 2001). The information about medical history was recorded and a general medical examination was conducted. If ADHD was suspected then the Revised Conner's Parent Rating Scale- Long Form (Conners, 2000) and Revised Conner's Teacher Rating Scale-Long Form (Conners & Sitarenios, 1998) were given to be returned in the following meeting. In the second session, all the collected information was considered together. If there was clear evidence for six or more symptoms from any one of the inattention or hyperactivity-impulsivity domains, symptoms were present in two or more settings, symptoms reduced the quality of practical functioning, and if symptoms could not be better explained by another mental disorder then the diagnosis of ADHD was made. When the ADHD diagnosis was confirmed, then the parents and the children were informed about the present study and they were offered a chance to take place. The opt-in sampling strategy was used. Participation was voluntary and if the family and the child were willing to participate they either proceeded to the testing room immediately after the doctor's visit or took an appointment from the present study's investigator by phone for a later time.

Data collection took place in a quiet room, next to the doctor's office in the paediatric-psychiatry unit of the hospital. At the beginning of a session, both the parents and the children filled and signed an informed consent form. Then the parents were given a demographic information form (see Table 7 for percentages of demographic variables) and the children were given the Turkish version of the RST-PQ-C and the AMS to complete. The child was seated in front of a table. On the table, there was a computer, a mouse, a pen and the Cognitive Effort Avoidance Measure. Some of the tests were in pen and paper format but some other tests were computerized and they were administered using a Windows-based colour computer.

The participant was told that he or she will pick a card from the Cognitive Effort Avoidance Measure's display and then read the number and the letter at the back of the card. Afterwards, he or she will be given the corresponding test and will complete the test according to the instructions. Afterwards, he or she will circle out a face in the face form and this process will continue until he or she circled out the last face in the form.

Initially, a child took one of the nine cards which were placed on the laminated A4 size display of the Cognitive Effort Avoidance Measure and then he or she read out loud the letter and the number at the back of the card (1A, 3C, etc.). The number and the letter of the first task were recorded in the first box of the face form of the Cognitive Effort Avoidance Measure. Then, the experimenter gave the corresponding test and the instructions. Depending on the card selected, the experimenter either gave a paper and pencil test and recorded the responses in the appropriate response form, manually or clicked the designated shortcut on the desktop for opening the test on the computer. In such cases, the computer recorded the responses. When the test was completed, the child was prompted to look at the face form of the Cognitive Effort Avoidance Measure and was asked to circle out one of the five faces in the row that represented the level of difficulty he or she experienced in the completed test. Faces varied from very happy (the first face on the left-hand side) to very sad (the last face on the right-hand side), neutral face being in the middle. After marking the face form of Cognitive Effort Avoidance Measure, the display board of the Cognitive Effort Avoidance Measure was pointed out and the child was prompted to take another card. This process was continued until the child circled out the last face in the last row of the face form of the Cognitive Effort Avoidance Measure. Each child had only one session during the data collection and each testing session took one and a half hours.

Data from the control group were collected in the Near East Junior College. This was one of the primary schools in Nicosia/Cyprus. Permission for the data collection was obtained from the headmaster of the school (see Appendix 8). 500 Informed consent forms were sent out to parents. 220 of these forms were returned. 194 children were allowed to participate in the study. These children's student numbers, age, and gender were recorded on paper and a list was prepared for recruiting 40 participants for the control group.

The sessions were held in a quiet room which was provided by the school administration. The student who was chosen from the list was called to the testing room. The process of data collection was entirely similar to the way the data collected in the clinical group. The same computer, mouse, test materials, and questionnaires were used. The sessions were carried out by the investigator of the present study. Data collection with each child took one and a half hours. Each child went through only one session.

Table 7

Descriptive statistics: percentages of demographic variables

	Clinical	Control	χ^2
	%	%	
Father graduated from university	35	80	21.07*
Mother graduated from university	25	50	9.30*
Living in the city	77.5	75	.06
Only one sister or brother	35	17.5	3.19
Parents divorced	20	15	.34
High income (i.e., over 2000 €)	20	35	5.51

*$p < .05$

4.3.5. Data Analytic Strategy

Initially, the data were analyzed using IBM SPSS Statistics 24 for Windows. Descriptive statistics were computed. An independent samples t-test was performed for comparing groups with and without ADHD in terms of their prepotent motor response inhibition performance, the BIS activation level, and the frequency of avoiding mental effort.

Then, the Pearson correlation coefficients were computed for investigating the relationships between the prepotent motor response inhibition, the BIS, and the frequency of avoiding mental effort.

A simple mediation model of the relationships between the prepotent motor response inhibition and the frequency of avoiding mental effort through the BIS (H1) was tested separately in both groups with the PROCESS model 4 (Hayes, 2013). A moderated mediation analysis was run using the PROCESS model 7 to assess if the diagnosis status was a moderator for the proposed mediation model. This analysis was employed for testing the second hypothesis which stated that the indirect effect of the prepotent motor response inhibition on the frequency of avoidance through the BIS should be a function of ADHD diagnosis (see Figure 15 for statistical model).

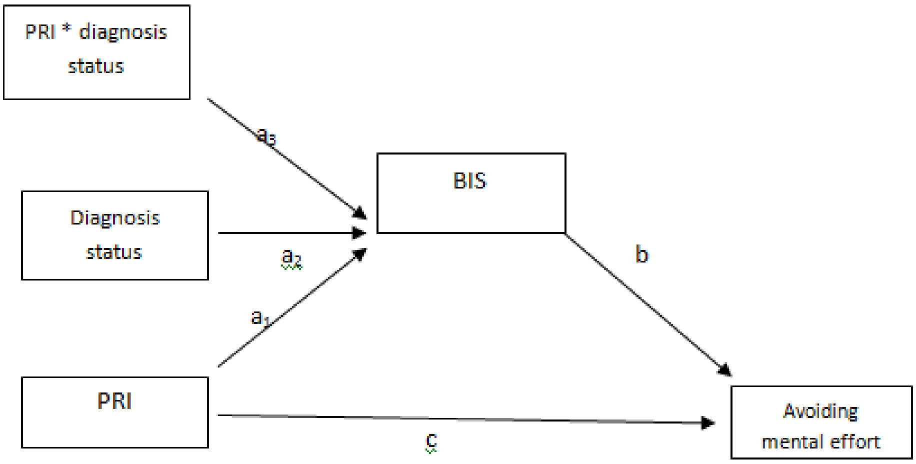

Figure 15. Statistical model showing the conditional indirect effect of the prepotent response inhibition on the frequency of avoidance behaviour through the BIS. PRI = prepotent motor response inhibition; BIS = behavioural inhibition system.

The cognitive composite score (i.e., latent variable) that is made of the common variance of the nine manifest variables was calculated using the confirmatory factor analysis with the data imputation option in the AMOS (Arbuckle, 2009). Maximum likelihood estimates were calculated from the covariance matrix and several fit indexes were computed. Model fit was investigated using chi-square goodness-of-fit test (lower chi-square value indicates better fit; Loehlin, 1998), the root mean square error of approximation (RMSEA; better fit when ≤ .06; Steiger, 1990), standardized root mean square residual (SRMR; better fit when ≤ .08; Chen et al., 2008), Tucker–Lewis index (TLI; excellent fit when obtained value is greater than .95; Tucker & Lewis, 1973), and comparative fit index (CFI; better fit when ≥ .95; Bentler, 1990).

Concurrent validity was assessed using the Pearson correlation coefficient by examining correlations between the Cognitive Effort Avoidance Measure, easy work and challenge subscales of the AMS.

4.4. Results

A statistical power analysis using G*Power 3.1 (Faul et al., 2007) was performed to estimate the adequacy of the sample size for detecting a large effect. The estimated effect size for this study was $f^2 = .35$ which is considered a large effect size according to Cohen (1992). With $\alpha = .05$ and power $(1-\beta) = .80$, the required sample size for having enough power to reliably detect a large effect size in a moderated mediation analysis with three predictors was 33. The present study includes 80 participants; hence, it has sufficient power to detect a large effect.

4.4.1. Concurrent Validity of Cognitive Effort Avoidance Measure

The concurrent validity of the Cognitive Effort Avoidance Measure was assessed by the Pearson product-moment correlation coefficient. Significance, direction and the strength of the relationships between the Cognitive Effort Avoidance Measure, the easy work and the challenge subscales of the AMS were investigated. A modest significant positive correlation was obtained between the Cognitive Effort Avoidance Measure and the preference for easy work (r = .34, p = .006). This result shows that children who more frequently avoid mental effort in the Cognitive Effort Avoidance Measure also prefer easier academic work. Furthermore, a strong negative correlation was obtained between the Cognitive Effort Avoidance Measure score and the challenge subscale score (r = -.71, p < .001). This result demonstrates that children, who less frequently avoid mental effort, prefer to undertake challenging academic tasks.

4.4.2. Group Differences and Zero-Order Correlations

In the first set of analyses, independent samples t-test was used for comparing the group differences in terms of the prepotent motor response inhibition, the BIS, and avoiding mental effort. Two groups statistically significantly differed in the prepotent motor response inhibition performance, the BIS activity level, and the frequency of avoidance behaviour. Children with ADHD obtained lower prepotent motor response inhibition and BIS scores. However, their rate of avoiding mental effort was higher when compared to the control group (see Table 8 for a comparison of values).

Table 8

Descriptive and inferential statistics of prepotent response inhibition scores, BIS scores and Cognitive Effort Avoidance Measure scores in ADHD and control groups

Measure	ADHD (N = 40)		Control (N = 40)		t (df)	d
	M	SD	M	SD		
PRI	7.08	2.42	10.18	3.14	-4.95(78)*[a]	0.11
BIS	10.13	5.17	13.75	3.83	-3.56(78)*	0.80
Avoidance	2.78	1.46	0.60	0.95	7.89(78)*	1.84

Note. * p < .01; [a] Equal variances assumed because Levene's test for equality > .05; d = Cohen's d; PRI = Prepotent motor response inhibition; BIS = Behavioural inhibition system.

In the second set of analyses, Pearson correlation coefficients were computed for investigating the relationships between the variables of interest (see Table 9). In the clinical group, statistically significant relationships were obtained between the variables. There was a modest positive correlation between the prepotent motor response inhibition performance and the BIS activation level. Furthermore, prepotent motor response inhibition performance had a modest negative correlation with avoiding mental effort. The BIS activation level was also negatively and moderately correlated with avoiding mental effort. On the other hand, in the control group, relationships between the prepotent motor response inhibition scores, the BIS scores, and the avoidance scores did not reach the level of statistical significance.

Table 9

Zero-order correlations between variables in the whole sample, ADHD group and control group

	The whole sample			ADHD group			Control group		
Measures	1	2	3	1	2	3	1	2	3
1.PRI	-	$.25^{*}$	$-.50^{**}$	-	$.36^{*}$	$-.33^{*}$	-	-.19	-.25
2. BIS		-	$-.52^{**}$		-	$-.54^{**}$		-	-.09
3. Avoiding mental effort			-			-			-

Note. $^{*}p < .05$; $^{**}p < .01$; PRI = Prepotent motor response inhibition; BIS = Behavioural inhibition system

4.4.3. Mediation Analyses

Results of the mediation analyses were summarized in Table 10 for the clinical group and Table 11 for the control group. In the clinical group, the path a, b, and c (i.e., total effect) were significant. The confidence interval for the indirect effect did not contain zero, showing that the effect of the prepotent motor response inhibition on avoiding mental effort was mediated by the BIS. Obtaining a significant mediation effect for the BIS, supported the first hypothesis. Furthermore, when controlling for mediator, the prepotent motor response inhibition performance was no longer a significant predictor of the frequency of avoidance (direct effect: path c|), β = -.09, t (37) = -1, 06, p = .29. This indicated a complete mediation of the BIS, in the relationship between the prepotent motor response inhibition performance and the frequency of avoiding mental effort.

Table 10

Standardized results of the regression-based mediation model showing the indirect effect of the PRI on avoiding mental effort through the BIS in the clinical group

	BIS			AME	
PRI	**.36****			**-.33***	
BIS				**-.49****	
R^2	.12			.32	
F(df1, df2)	5.57**(1, 38)			45.21**(2, 37)	
Standardized inderect effect					
Predictor	**mediator**	**criterion**	**Effect**	**BootLLCI**	**BootULCI**
PRI	BIS	Avoiding mental effort	-0.17(17%)	-.3777	-.0200
Direct effect of PRI on AME			-0.09	-.2706	.0847
Total effect of PRI on AME			-0.20	-.3849	-.0114

Note. PRI = prepotent motor response inhibition; BIS = behavioural inhibition system; AME = avoiding mental effort.
$^{*}p < .05$; $^{**}p < .01$

On the other hand, as can be observed in Table 11, in the control group, none of the paths were significant. The prepotent motor response inhibition did not predict the BIS or the frequency of avoiding mental effort. Moreover, the BIS was not a mediator.

Table 11

Standardized results of the regression-based mediation model showing the indirect effect of the PRI on avoiding mental effort through the BIS in the control group

	BIS			AME	
PRI	-.19			-.24	
BIS				-.15	
R^2	.03			.08	
F(df1, df2)	1.46 (1, 38)			1.70 (2, 37)	
Standardized inderect effect					
Predictor	**mediator**	**criterion**	**Effect**	**BootLLCI**	**BootULCI**
PRI	BIS	Avoiding mental effort	.02	-.0431	.1145
Direct effect of PRI on AME			-.08	.0139	-.2790
Total effect of PRI on AME			-.07	.0208	-2498

Note. PRI = prepotent response inhibition; BIS = behavioural inhibition system; AME = avoiding mental effort.

4.4.4. Moderated Mediation Analysis

The conditional indirect effect of the prepotent motor response inhibition was tested using the moderated mediation analysis with 5000 bootstrapped samples. Table 12 shows the results of the model, using diagnosis status as a moderator. All the paths were significant along with the a_3 which indicated the existence of an interaction between the diagnosis status and the prepotent motor response inhibition performance. This provided evidence that the diagnostic status moderated the path between the prepotent motor response inhibition and the BIS. In other words, the first stage of the mediation model (prepotent motor response inhibition performance →BIS activation) was moderated by the diagnosis status.

Table 12

Ordinary least squares regression coefficients for the conditional indirect effect of the PRI on avoiding mental effort through the BIS, with group membership as moderator

Outcome→	**BIS**			**Avoiding mental effort**		
Predictor	**Path**	**Coeff**	**SE**	**Path**	**Coeff**	**SE**
intercept		-6.69	4.94		5.16*	0.48
PRI	a_1	1.76*	0.62	c	-0.21*	0.05
BIS	-	-	-	b	-0.14*	0.03
Group	a_2	11.42*	3.22	-	-	-
PRI x Group	a_3	-0.99*	0.37	-	-	-
	$R^2 = .22$			$R^2 = .42$		
	$F\ (3,76) = 7.23^*$			$F\ (2,77) = 28.29^*$		

Note: Coeff = unstandardized regression coefficients; SE = standard error; PRI = prepotent response inhibition; BIS = behavioural inhibition system; coefficients with asterisks are significant 95% confidence level.

Results revealed that the prepotent response inhibition had an indirect effect on the frequency of avoidance through the BIS in the clinical group (effect = -0.11, SE = 0.05, Boot LLCI = -0.22, Boot ULCI = -0.01), but there was no such effect in the control group (effect = 0.03, SE = 0.03, Boot LLCI = -0.02, Boot ULCI = 0.08). A visual representation of the interaction between the prepotent motor response inhibition performance and the diagnostic status, in predicting the BIS activity level is presented in Figure 16. The figure plots that a lower level of the prepotent motor response inhibition performance predicts a lower level of the BIS activity only in the presence of an ADHD diagnosis. On the other hand, when the ADHD diagnosis is not present, even at the lower levels of the prepotent motor response inhibition performance the BIS appear to be at an optimal level. This suggests an independent functioning of the prepotent motor response inhibition and the BIS among TD controls.

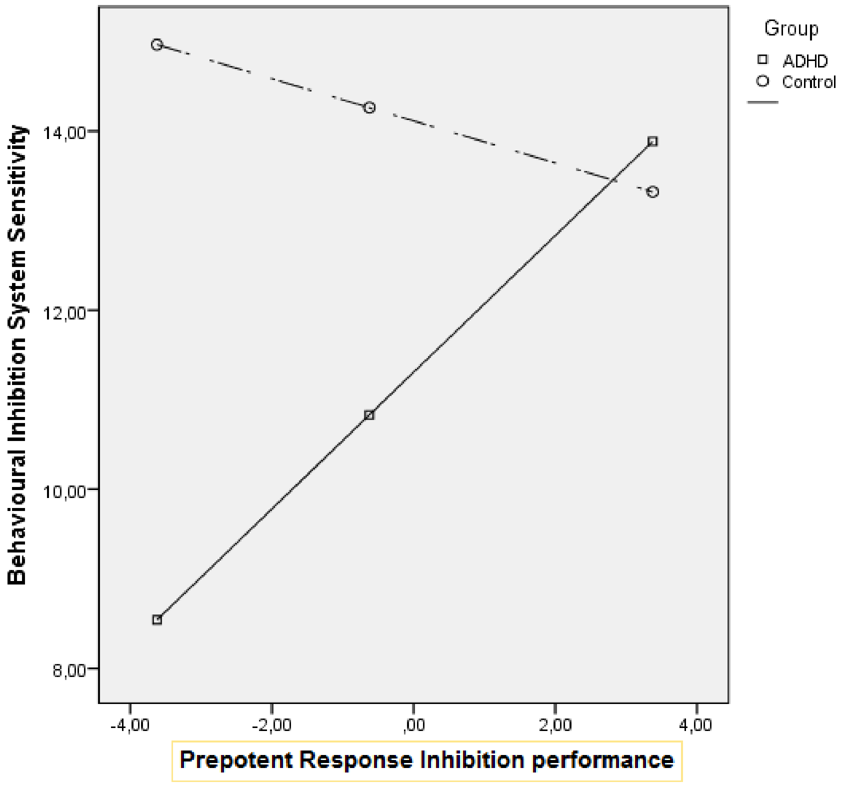

Figure 16. Interaction between the prepotent response inhibition and the diagnosis status in predicting the behavioural inhibition system activity.

4.4.5. Cognitive Composite

The a priori model (see Figure 17) that tested with the confirmatory factor analysis consisted of one latent variable (i.e., cognitive composite score) and eight manifest variables (Continuous Performance Test, Bourdon Test, Vocabulary Test, Task-switching Test, Memory Span Test, WCST, Matrix Reasoning Test, and Go/no-go Test). The Choice delay Task was excluded from the figure because its loading value appeared to be zero. The model fit was investigated with the commonly used indices and obtained values were X^2 (20, N = 40) = 23.07, $p < .05$; RMSEA = .044; SRMR = .056; TLI = .975 and CFI = .982. Taken together, these values indicated a good fit.

When the mediation analyses were rerun after replacing the prepotent motor response inhibition with the cognitive composite score in the clinical group, the path a was not significant (the cognitive composite score did not predict the BIS; $\beta = -1.66$, $t(38) = -1.53$, p

= .13). But, path b (the BIS → avoidance) and path c (cognitive composite → avoidance) were significant. Importantly, the indirect effect of the cognitive composite score was not significant. Meaning that cognitive composite score did not have an indirect effect on the frequency of avoidance through the BIS (Indirect effect: β = .19, Boot SE = .14, $CI_{95\%}$ = -.057 to .510). When mediation analysis was rerun in the control group with the cognitive composite score as a predictor variable, none of the paths appeared to be significant.

Afterwards, the prepotent response inhibition score was replaced with the cognitive composite score in the moderated mediation analysis which involved both groups. Results showed that there was no interaction between the composite score and group, ΔR^2 = .019, b = 1.91, p = 0.18, 95% CI: [-.9259, 4.7366]. There was no moderating effect of diagnosis status.

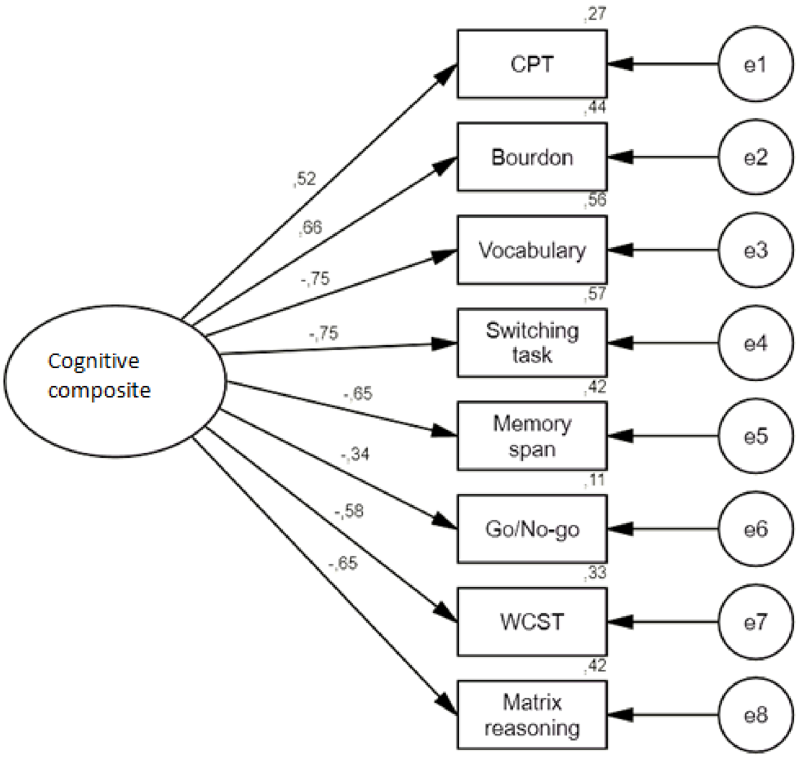

Figure 17. One factor model of general cognitive ability that based on the eight cognitive tests. CPT = Continuous Performance Test, Bourdon = Bourdon-Vos Test, Vocabulary = vocabulary Subtest of WASI-2, Switching task = Working memory-switch Task, Memory span = Corsi block tapping Test, Go/No-go = Go/No-go Task, WCST = Wisconsin card sorting Test, Matrix reasoning = Matrix reasoning Subtest of WASI-2.

4.5. Discussion

DSM-5 states that children with ADHD strongly dislike and try to avoid tasks that require sustained mental effort. In the present study, the role of the prepotent motor response inhibition and the BIS in the frequently avoiding mental effort was investigated. The first aim was testing a moderated mediation model for showing the conditional indirect effect of the prepotent motor response inhibition on avoiding mental effort through the BIS. The second aim was to demonstrate the critical relationship between the prepotent motor response inhibition and the BIS, in the proposed mediation model, using a general cognitive composite score. The third aim was providing concurrent validity evidence for the Cognitive Effort Avoidance Measure. Findings supported the hypotheses. The conditional indirect effect of the prepotent motor response inhibition on the avoidance through the BIS was moderated by the diagnosis status. Furthermore, the cognitive composite score did not have a significant indirect effect on the avoidance through the BIS, as expected. Finally, obtained correlation values provided concurrent validity evidence for the Cognitive Effort Avoidance Measure.

4.5.1. Children with ADHD Avoid Mental Effort More Frequently than Their Typically Developing Peers

Initially, the levels of the prepotent motor response inhibition, the BIS, and frequency of avoidance were compared between the groups. The DSM-5's proposition which states that the children with ADHD avoid sustained mental effort more often than their TD peers was evaluated. No previous study that investigated mental effort has used multiple cognitive tests in such an evaluation. Instead, they used different levels of the same test and relied on the subjective self-report of participants (e.g., Mies et al., 2019). Hence it was important to evaluate the rate of avoidance with an objective measure.

Findings supported the clinical-observation based proposition of the DSM-5 that children with ADHD avoid tasks that require mental effort more frequently than TD children. Empirical evidence for this proposition was provided using an objective tool that includes multiple tests that tax various mental capacities. On the other hand, the prepotent motor response inhibition performance was found to be lower in the clinical group as expected. This finding was in line with the previous study results in the literature (Scheres et al., 2004; Slusarek et al., 2001). Moreover, the BIS activity level was also lower among children with ADHD and this was in line with the suggestions of the previous studies (Iaboni et al., 1997; Quay, 1997; Sadeghi et al., 2019).

Obtained correlations were in the expected directions. In the clinical group, the prepotent motor response inhibition performance and the BIS activation level were negatively related to avoiding mental effort. This finding showed that lower scores in the prepotent motor response inhibition and the BIS were related to more frequently avoiding mental effort. The largest correlation value was obtained between the BIS activity level and frequency of avoiding mental effort ($r = -.54$, $p = .001$), demonstrating the critical role of the BIS in the avoidance process. On the other hand, none of these variables was significantly correlated in the control group. Obtaining significant correlations in the clinical group but not in the control group suggests the presence of mental processes that are unique to the child ADHD population.

4.5.2. Mediating Role of the BIS

Mediation analyses results showed that in the clinical group, all the paths were significant. The BIS appeared as a mediator between the prepotent motor response inhibition performance and the frequency of avoiding mental effort. In other words, the prepotent motor response inhibition predicted the BIS and then the BIS also predicted the frequency of avoidance. Findings supported the first hypothesis.

The prepotent motor response inhibition has been proposed to be crucial in stopping a habitual motor response and study results show that it is correlated with other types of inhibition as well. For example, Friedman and Miyake (2004) reported that resisting attentional distraction and prepotent motor response inhibition performance are strongly correlated. The present results show that the prepotent motor response inhibition performance is also related to the inhibition ability that is managed by the BIS. The BIS has been proposed to inhibit motivated behaviours. Previously, Nigg (2000) speculated that the executive and the motivational inhibition should be related. The present findings demonstrate that the efficiency of inhibiting motor responses is related to inhibiting motivated behaviour. One unit change in the prepotent motor response inhibition performance relates to a 0.36 point change in the BIS activity.

Prepotent motor response inhibition performance also predicted the frequency of avoiding mental effort (path c), but when the BIS activity level was controlled, this relationship was no longer significant. This indicated that the BIS fully mediated the relationship between the prepotent motor response inhibition efficiency and amount of avoidance. The effect of the prepotent motor response inhibition was primarily dependent on the BIS activation level rather than directly affecting the amount of avoidance. Finding a complete mediation emphasizes the critical role of the relationship between the prepotent motor response inhibition and the BIS in the appearance of avoidance behaviour. The estimated proportion of the total effect of the prepotent motor response inhibition due to the mediator, BIS, (ratio of total effect to indirect effect, a x b /c) was 0.90 (i.e., percentage of the total effect that mediated). This shows that 90% of the total effect operates through the BIS.

The rRST proposes that the BIS regulate motivated behaviour when a conflict arises between the BAS and the FFFS (Amodio et al., 2008). Its activation enables a cautious approach (Corr, 2004). According to the rRST the BIS can inhibit avoidance behaviour until the best course of action is selected. This implies that the BIS help to resist avoidance motivation in the presence of aversive stimuli and facilitate a longer on-task span. Hence, it can be argued that a lower level of the BIS can be related to a lower ability to resist avoidance motivation.

The present study's results show that children with ADHD have lower prepotent motor response inhibition scores, lower BIS scores, and a higher rate of mental effort avoidance. Engaging with cognitive tasks is effortful and impaired prepotent motor response inhibition could significantly increase experienced difficulty (Wodka et al., 2007; Berlin et al., 2003). According to rRST, such a difficulty can cause irritation, activate the FFFS and produce avoidance motivation. The BIS is the construct that enables an individual resisting avoidance motivation and hypoactivity of BIS implies diminished ability to resist fleeing. Taking it all together, the present results can be interpreted to mean that impaired prepotent motor response inhibition results in a higher task difficulty and hypoactive BIS fails to inhibit avoidance motivation hence a higher rate of avoiding mental effort appears.

4.5.3. Moderating Role of the Diagnostic Status

Moderated mediation analysis results showed that the indirect effect of the prepotent motor response inhibition on the avoiding mental effort through the BIS was moderated by the diagnosis status. Moderated mediation hypothesis was confirmed (hypothesis two). Specifically, the path a (prepotent motor response inhibition → BIS) was moderated with the diagnosis status. This finding shows that the proposed mediation mechanism exists only among children with ADHD but not among TD children. In other words, none of the paths were significant in the control group and only in the clinical group the BIS serves as a mediator between the prepotent motor response inhibition performance and avoidance.

An important question here is why the proposed mechanism exists in the ADHD group but it does not among TD children? There is evidence in the literature showing that the prepotent motor response inhibition and the BIS are not related among healthy adults (Amodio et al., 2008). The present study further adds to the literature that behavioural measures of the prepotent motor response inhibition and the BIS are not significantly related in TD children, as well. On the other hand, Sadeghi et al.'s (2019) study shows that children with ADHD have lower P300 amplitude which indicates less BIS activation level when compared to TD children. Additionally, Wiersema et al.'s (2009) study demonstrates that there is a positive correlation between the P300 amplitude (i.e., EEG output) and the behavioural output of the prepotent motor response inhibition, only among children with ADHD. The present study further adds to the literature that the behavioural outputs of the BIS and the prepotent motor response inhibition are positively related, only among children with ADHD. This relationship does not exist among TD children and seems to be a unique feature of ADHD.

All in all, these results can be interpreted to mean that the prepotent motor response inhibition and the BIS are not related among non-patient individuals because intact prepotent motor response inhibition supports and facilitates optimal cognitive performance and do not contribute to a higher perceived difficulty of cognitive tasks. Moreover, intact prepotent motor response inhibition could be enough for inhibiting effort avoidance to a sufficient degree. Hence, it can function independently and does not correlate with the BIS activation level. On the other hand, it seems that impaired prepotent motor response inhibition performance requires the involvement of the BIS as an auxiliary construct among children with ADHD. In other words, the inefficiency of the prepotent motor response inhibition requires the BIS to compensate for its weakness. Hence, a correlation between these constructs appears. However, the prepotent motor response inhibition and the BIS seem to be the components of a less efficient inhibition network in ADHD and this global weakness appear to result in a BIS hypoactivity as well. Eventually, despite the involvement of the BIS, the total strength of inhibition ability cannot reach to an adequate level to reduce the rate of avoidance behaviour and hence, frequently avoiding mental effort appears among children with ADHD.

4.5.4. The General Cognitive Composite Score and Avoiding Mental Effort

The obtained cognitive composite score replaced the prepotent motor response inhibition score in the mediation and moderated mediation analyses. The question of this inquiry was whether the level of general cognitive ability affects the frequency of avoidance through the BIS. In other words, can we replace the prepotent response inhibition with the cognitive composite score and obtain similar results?

It appeared that cognitive composite did not have an indirect effect on the frequency of avoidance through the BIS. This result shows that, specifically, the prepotent motor response inhibition performance can predict the activity level of the BIS but the general cognitive capacity cannot. The present results suggest that inhibition could constitute an interactive network in the brain. The PRI and the BIS can be two components of this network that play a critical role in the management and inhibition of inappropriate behaviours.

4.5.5. Concurrent Validity Evidence for the Cognitive Effort Avoidance Measure

Finally, concurrent validity of the Cognitive Effort Avoidance Measure was evaluated using the easy-work and the challenge subscales of the AMS. The directions of the correlations were as expected. Children that more frequently avoided mental effort in the Cognitive Effort Avoidance Measure were also reported to prefer easier tasks in the easy work subscale of the AMS. Based on this result it can be argued that children that obtained a higher avoidance score on the Cognitive Effort Avoidance Measure dislike exerting mental effort and try to avoid it.

Furthermore, children who avoid mental effort less in the Cognitive Effort Avoidance Measure were also reported to prefer challenging academic tasks in the challenge subscale of the AMS. It was notable that there was a strong negative correlation between the Cognitive Effort Avoidance Measure score and the challenge subscale score (i.e., $r = -.71$). These findings provide evidence for the similarity of the construct that the Cognitive Effort Avoidance Measure, the easy work subscale, and the challenge subscale intent to assess. Findings provide some evidence that the Cognitive Effort Avoidance Measure is an efficient and valid measure of how much of a child tends to avoid mental effort. In other words, how much he or she dislikes engaging with the effortful cognitive tasks. When the obtained evidence is considered, it can be concluded that the Cognitive Effort Avoidance Measure assesses what it intends to assess.

4.6. Theoretical Implications

The present study advances our knowledge about the role of prepotent motor response inhibition and the BIS in childhood psychopathology. Initially, it informs the ADHD theory by providing evidence for an underlying neuropsychological mechanism that explains the higher rate of avoiding sustained mental effort among children with ADHD.

The inhibition theory of ADHD proposes that the inhibition impairment underlies symptoms of ADHD (Hwang et al., 2019). The present study provides evidence that impaired prepotent motor response inhibition contributes to frequently avoiding mental effort in ADHD, however, this happens through the rRST - BIS. The present findings further, suggests that different kinds of inhibition (executive and motivational inhibition) could be related to each other as a part of a general inhibition system. A curious question that remains to be answered is whether the efficiency of the other inhibition processes other than prepotent motor response inhibition (e.g., inhibiting irrelevant distracters) are related to the BIS activity level.

Another finding that concerns the theory of ADHD is that the prepotent motor response inhibition and the BIS are not related among TD children. However, these variables are positively correlated among children with ADHD. This finding presents a rare connection between these two constructs that is unique to ADHD pathology. However, the exact reason for this connection is not clear at the present. One possible explanation might be that among TD children, the efficiency of the prepotent motor response inhibition is enough for stopping the avoidance behaviour and there is not a need for the engagement of the BIS as a secondary supportive inhibition mechanism. Hence, no significant correlation appears between the PRI performance and the BIS activity level.

The emergence of this relationship could be better pictured with an analogy. In a car with some powerful main brakes, only these brakes will be used for stopping the car when slowing down is needed and there will be no need to use the hand brake for support. Hence, there will be no correlation between using the main brakes and the hand brake. On the other hand, if the main brakes are not powerful enough then the hand brake will be used and they will be used together for having enough power to stop the car. Hence, a correlation between the use of the main brakes and the use of the hand brake will appear.

4.7. Clinical Implications

Parents of children with ADHD often complain that their children do not want to do homework, experience difficulty in engaging with the tasks that require mental effort, and leave the tasks uncompleted. Avoiding mental effort has been demonstrated to be an impairing behaviour in terms of academic achievement (Zoromski et al., 2021) and self-confidence (Harpin et al., 2013) among children with ADHD. The present study provides empirical support about its frequent expression in ADHD and shows that the prepotent motor response inhibition and the BIS play a crucial role in its appearance. Findings suggest that children with ADHD have less capacity to resist to avoidance motivation that is produced by irritating stimuli. A question can be asked, what can be done about changing the BIS activity level among these children? This would require pharmacological intervention. However, the effect of the popular ADHD medication on the BIS activity levels is unknown.

The findings also point to the prepotent motor response inhibition performance as a potential target for reducing the amount of avoidance. Cognitive training which is targeted at enhancing the prepotent motor response inhibition ability can be effective in reducing the frequency of avoidance.

4.8. Limitations and Future Directions

One limitation of the present study is that its cross-sectional design does not allow concluding that the prepotent motor response inhibition performance affects the level of the BIS. A future study, with an experimental design, can test if any change in the prepotent motor response inhibition efficiency is the cause of the change in the BIS activity level.

In the present study, it was found that a unique link exists between the prepotent motor response inhibition and the BIS among children with ADHD. An fMRI study can be designed to investigate the neural correlates of this link. Furthermore, it can be interesting to see if the same mechanism exists among adults with ADHD. It has been reported that procrastination is more often encountered among adults with ADHD than non-patient individuals. It can be interesting to investigate if the lower levels of the prepotent motor response inhibition and the BIS remain into adulthood and contribute to procrastination.

In the present study, it was not possible to collect information about the comorbidity of oppositional defiant disorder. Hence, its possible effect in the avoidance process was not investigated and could not be partial out. Future studies could consider collecting information about the comorbid oppositional defiant disorder and include this in the analyses to partial out any influence that it may exert in the processes.

Finally, The PRI and the BIS together accounted for 32% of the variance hence, some other factors would seem to play a role in the process of avoiding mental effort. Future studies can include instruments for measuring levels of some factors that could influence avoiding mental effort such as self-confidence, personality traits, and impulsivity. This can help underpin some other factors that contribute to this problem.

4.9. Conclusion

Avoiding mental effort is a symptom of ADHD that results in academic underachievement. The present study is important in terms of linking the impaired prepotent motor response inhibition and the hypoactive BIS to the observed higher rate of mental effort avoidance among these children. Obtained findings provide support for the proposed neuropsychological mechanism in explaining frequently avoiding mental effort.

Moderated mediation analysis results demonstrate that lower levels of the prepotent motor response inhibition and the BIS results in a higher rate of mental effort avoidance among children with ADHD. The findings suggest that the prepotent motor response inhibition can function independently among TD children but it acts in collaboration with the BIS among children with ADHD. The weak prepotent motor response inhibition requires a higher support of the BIS for better management of the avoidance motivation among children with ADHD. The findings support the notion of a unitary inhibition network where separate inhibitory functions support each other in the service of producing context-appropriate behaviour.

The present study also provides evidence for the concurrent validity of the Cognitive Effort Avoidance Measure and it shows that such an approach can be employed for the assessment of the level of mental effort avoidance. Finally, the present study informs the clinical practice that interventions that aimed at improving the prepotent motor response inhibition and the BIS level could be useful in reducing the rate of mental effort avoidance among children with ADHD.

The present chapter shows that impaired executive functioning (i.e., prepotent motor response inhibition) plays a role in an observed difficulty (i.e., mental effort avoidance) of children with ADHD. There is a recent interest in the role of WM in terms of the observed executive functioning impairments. In the next chapter, the reason for executive functioning impairment among children with ADHD is investigated.

CHAPTER FIVE: STUDY 2b

Effect of Increased Working Memory load and Reinforcement Sensitivity on the Executive Functioning Performance Among Children with ADHD

5.1. Background

ADHD is a disorder of self-regulation and executive functioning. Executive functioning can be described as using higher-level brain functions (e.g., inhibiting prepotent responses, task-switching, and planning) and organizing behaviours for attaining specific goals (a detailed description has been provided in the literature review section, between pages 39 and 44). Children with ADHD cannot manage their behaviour as efficient as their typically developing (TD) peers (Barkley, 2011). They experience difficulty in getting started, remembering important things such as bringing homework home, completing long projects, analysing, and problem-solving. Executive dysfunction has been proposed to play role in the observed functional impairments and it has been reported that all children with ADHD express some impairment at least in one of the executive functioning domains (Kofler et al., 2019).

The prepotent motor response inhibition that measured with the Go-no/go Task was found to be impaired among these children; however, whether the inhibitory problem is primary or secondary in causing executive functioning impairment is a question that remains to be answered (Nigg, 2001). For example, Castellanos et al. (2006) argued that the primary deficit in ADHD is not due to inhibition but due to the working memory (WM). In support of this argument, meta-analyses showed that children with ADHD exhibit impairment in all the WM components (Martinussen et al., 2005) and the largest impairment was found to be in the central executive (CE) part (Kasper et al., 2012). In the present chapter, the problem tackled was the lack of information regarding the factors that play a role in the executive functioning impairment among children with ADHD. The aim was to show the effect of maintaining WM load and the level of reinforcement sensitivity on the impaired executive functioning performance.

WM is the system where maintenance and manipulation of information takes place (Baddeley & Hitch, 1974; a detailed description of the WM has been provided, between pages 52-54). Maintenance ability has been proposed to keep the information active while it is being manipulated and it is critical for efficient executive functioning among healthy adults (Gruszka & Necka, 2017). Accumulating evidence suggests that the CE component of WM is a common but limited resource pool for cognitive control (Van De Voorde et al., 2011). Simultaneously maintaining and manipulating information can trigger competition and dispersion of the available resources (Hester & Garavan, 2005).

Studies showed that increased WM load results in decreased reading comprehension (Kofler et al., 2018) and decreased recall ability (Alderson et al., 2013) in the ADHD population. On the contrary, Kim et al. (2005) showed that increased WM load can result in better resistance to distractor interference among non-patient adults. This finding indicates that cognitive load can function as a facilitator of better cognitive performance among healthy adults. However, this result has not been replicated in the typically developing (TD) child samples and awaits further investigation.

Inhibitory control and task-switching performances are impaired among children with ADHD (Hung et al., 2016; Wodka et al., 2007). These are critical executive functions and the reason for their weakness is not clear. Some studies reported that efficient maintenance is crucial for optimal performance in inhibitory control (Hester & Garavan, 2005) and task-switching (Liefooghe et al., 2008) among healthy adults. The effect of maintaining gradually increased WM load, on executive functioning performance has not been investigated among children with ADHD. For this reason, the main question of Study 2b is whether maintaining WM load plays a role in the executive functioning impairment among children with ADHD.

5.1.1. WM load, Prepotent Motor Response Inhibition, and ADHD

Prepotent motor response inhibition has been described as the intentional suppression of prepotent motor responses (Rucker et al., 2012). There are mixed results in the literature in terms of the prepotent motor response inhibition performance in the ADHD population (Holmes et al., 2014). An intriguing debate about the centrality of inhibition in ADHD continues amongst scientists. Barkley's inhibition account (Barkley, 1997) advocates for the notion that inhibition is the primary impairment in ADHD. On the other hand, the WM model of ADHD proposes that the WM impairment is central in the appearance of ADHD symptoms (Kasper et al., 2012; Kofler et al., 2011; Rapport et al., 2001).

It can be proposed that this conflict can be resolved if the WM load is taken into the account. For example, Kane et al. (2001) divided healthy adult participants into low WM capacity and high WM capacity groups. The participants were given the Go/no-go Task with and without increased WM load. Results showed that there was no difference between low and high capacity individuals in terms of their prepotent motor response inhibition performance when there was no WM load. However, it appeared that the lower capacity individuals had the worst prepotent motor response inhibition performance when the task was made more difficult by adding maintenance demand. This study's results demonstrate that the amount of the load in the WM affects the inhibition performance among non-patient adults with a lower WM capacity.

Seymour et al. (2016) carried out a study for investigating the effect of increased cognitive demand on prepotent motor response inhibition performance. Children between 8-

12 years of age, with and without ADHD, completed a simple Go/no-go Task and then a complex Go/no-go Task with increased cognitive load. In the simple task, the children pressed the space bar for the green ships but withheld their responses for the red ships that appeared on the computer screen. In the complex Go/no-go Task, they needed to press the spacebar for green ships and for the red ships that were preceded by an even number of green ships. Furthermore, they were to withhold their responses when a red ship was preceded by an odd number of green ships. Results of this study showed that boys with ADHD were more impaired in both tasks when compared to TD boys. On the other hand, girls with ADHD were impaired only in the complex Go/no-go Task when compared to TD girls. Results of this study show that there was no performance difference between the girls with and without ADHD in the first level when there was no WM load, but increased maintenance demand impaired the prepotent response inhibition performance of girls with ADHD. These findings provide partial evidence that children with ADHD can perform at the normal level but their inhibition performance gets impaired when WM demand increases. Importantly, this study was not able to demonstrate how the prepotent response inhibition performance would be affected if the WM load was increased gradually.

In the above-mentioned study, there were only two levels: the first level was with no load and the second level was with a very complex rule to remember which also comprised the WM load. In this study, the WM load was not gradually increased. That is why it was not possible to observe how the groups would respond to gradually increased WM load. On the other hand, the Go/no-go Task used in the present thesis had four different levels. There was no load in the first level and the load was gradually increased in the remaining three levels. The aim of using such a task was to increase the sensitivity to a level that allows detecting even the slightest change in the prepotent motor response inhibition performance.

Currently, we do not know how much load is too much to lift for children with ADHD. Gradually increased WM load can allow a comparison of the groups' performance and provide information about the point where children with ADHD experience the greatest difficulty. On the other hand, there are findings in the literature to suggest that increased WM load can increase the resistance to interference. If this is the case, employing different levels of WM load can allow observing the point of a performance increase among TD children.

To date, no study has investigated the effect of maintenance demand on the prepotent motor response inhibition performance using a dual-task paradigm that enables a gradual increase of WM load in four different levels among children with ADHD. That is why the first specific question of Study 2b was whether maintaining systematically increased WM load results in a gradual decrease in the prepotent motor response inhibition performance among children with ADHD. It was reasoned that if the maintenance process is abnormal then this can result in the use of too many resources due to compensatory struggle among children with ADHD. If this struggle causes a drain then the remaining controlled attention resources may not be enough for supporting simultaneously activated executive functions and result in impairment.

Considering the existing evidence, in the present study, it was hypothesized that a) the prepotent motor response inhibition scores in the clinical and control group should not be significantly different from each other when there is no WM demand, b) overall prepotent motor response inhibition scores in the clinical group should be lower than the control group in the presence of MW demand, and c) gradual increase of WM load should result in a gradual decrease in the prepotent motor response inhibition performance of the clinical group. However, it can be expected that a higher load could increase the performance of TD controls.

5.1.2. WM load, Task-switching, and ADHD

Task-switching can be described as the transfer of attention, back and forth, between different tasks (Rucker et al., 2012). For example, a student in a class will often have to switch between listening and taking notes. For optimal task-switching performance, the rule and the cue that govern the switch have to be maintained in the WM. Literature includes mixed results in terms of task-switching performance among children with ADHD. Wu et al. (2006) investigated task switching in low and high WM load conditions. Children with and without ADHD completed a Stroop Task and they needed to switch between colour naming and word reading. Results of this study showed that reaction times of the ADHD group were not consistently slower in the high WM load condition when compared to TD controls. The authors concluded that the findings do not support a WM related task-switching deficit. However, in this study, a cue was used to inform the participants about the switching trials and the absence of this cue served as the increased WM load. It can be argued that the amount of WM load used was very low for detecting any reaction time differences.

On the other hand, Cepeda et al. (2000) compared children with and without ADHD in terms of their task-switching performance. Participants were administered a task-switching paradigm comprised of two simple tasks. They needed to switch between the tasks depending on a given cue. Results of this study showed that children with ADHD had lower switching performance than TD controls. Furthermore, Hung et al. (2016) investigated the effect of exercise on task-switching ability. Children with and without ADHD went through a task-shifting paradigm and they were needed to switch between two different conditions. Results showed that children with ADHD had larger switch costs, longer reaction times, and less accuracy.

These results suggest a task-switching impairment among children with ADHD when compared to TD controls. To date, no study investigated the effect of the maintenance demand on task-switching performance using a task that employs a gradual increase of WM load among children with ADHD. The second specific question asked in Study 2b was whether systematically increased WM load results in the gradual decrease in the task-switching performance among children with ADHD. Moreover, it was also asked whether maintaining an increased WM load would trigger an increase in the task-switching performance among TD children. In the present study, it was further hypothesized that d) overall task-switching performance of children with ADHD should be lower than TD children; e) gradual increase of WM load should result in a gradual decrease in the task-switching performance of the children with ADHD. However, an increased switching performance due to the higher load can be expected among TD controls.

5.1.3. WM load; the Fight, Flight, Freeze System and ADHD

Evidence in the literature suggests that reinforcement sensitivity is related to executive functioning and WM. Scientists have argued that in the face of a threat, particularly the behavioural inhibition system (BIS) and the fight, flight, freeze system (FFFS) activation can be associated with the engagement of the prefrontal cortex and the WM resources (Blair et al., 2004; Corr, 2011). Threat detection and fear can activate WM and influence what an individual attends to and the level of processing (LeDoux, 2003).

Jackson et al. (2014) investigated the relationship between the FFFS and executive functioning and reported that the FFFS activity was found to be negatively correlated with executive functioning among healthy adults. The authors concluded that fear has a limiting influence on cognitive functioning. The FFFS has been postulated to mediate the reactions to the conditioned and unconditioned aversive stimuli. It is responsible for producing responses in threatening or punishing circumstances (Gray & McNaughton, 2000). Underlying neural structures of the FFFS has proposed to be periaqueductal gray, hypothalamus, and amygdala

(DeYoung, 2010). These brain regions also have been reported to project to the frontal lobes and influence executive functioning (Scott & Schoenberg, 2011).

Further evidence supporting this notion is provided by Walker and Jackson (2014) where authors reported that the FFFS activation was found to be related negatively both to fluency and originality of thought. Importantly, Clark and Loxton (2012) found that the FFFS activity predicted lower work engagement only if the job to be accomplished was considered cognitively demanding. This study's results suggest that the effect of the FFFS on cognition can be more pronounced in circumstances that involve a higher WM load.

Studies which investigated the FFFS activity in ADHD are scarce. Only a few studies looked at the relationship between the FFFS activation and the abnormal functioning in ADHD. However, there are study reports linking the FFFS to the inattentiveness and hyperactivity symptoms (Gomez et al., 2012; Heym et al., 2015). To date, no study investigated the effect of the FFFS activity on the executive functioning performance in the presence of WM demand among children with ADHD. Considering the previous reports, in the current study, it was further hypothesized that f) the FFFS activation should be a covariate and have an impairing impact on the prepotent response inhibition performance, and g) the FFFS activation should covary with the WM load and it should have a negative influence on the task-switching performance. Furthermore, based on the reports that the FFFS affect cognitive ability adversely, it can be reasoned that because children with ADHD generally obtain lower scores in the neuropsychological tests, then the higher FFFS level can be expected to have a more pronounced effect in the clinical group.

In sum, the main question of this study was whether higher WM load and the FFFS sensitivity levels affect executive functioning performance adversely among children with ADHD. In this population, the most consistent impairment has been found to be in the WM. The CE part of this system has been postulated to be the attention controller. Resource allocation theory of attention proposes that controlled attention is a limited source that can be directed to multiple activities but resulting in fewer resources that can be directed elsewhere. If maintenance is compromised and it consumes excessive resources in a compensatory attempt for optimal performance then this over activity can result in impaired performance when competing executive functions are activated simultaneously.

To date, the effect of maintaining systematically increased WM load on executive functioning performance has not been investigated among children with ADHD. Moreover, scientists argued that reinforcement sensitivity and WM processes can be related. However, the nature of this relationship remains unclear. No previous study investigated the effect of the FFFS on the cognitive functioning performance in the presence of WM load among children or adult populations. In the present study, the effect of higher WM load and FFFS activity on executive functioning performance was sought to be investigated.

5.2. Method

The same data set was used in both investigations of Study 2. In the present chapter, the data collected by the Go/no-go Task and the Working memory-switch Task were further analysed for investigating the effect of the WM load on the executive functioning performance. Moreover, Turkish version of the Reinforcement Sensitivity-Personality Questionnaire-Children (RST-PQ-C) subscale scores was added to investigate the possible interaction of the reinforcement sensitivity and WM load conditions.

5.2.1. Participants

The same children's data were used in both investigations of Study 2. Hence, a detailed description of the participants was provided in the method section of Study 2a (see pages 103 and 104). For this reason, in this section, only a very brief summary is provided.

Data from clinical group was collected in a hospital and data from control group was collected in a primary school in Nicosia, Cyprus. There were 40 children in each group and their age ranged between 7 and 11 years. Children in clinical group were recruited using the consecutive sampling technique after the ADHD diagnosis that confirmed by a paediatric psychiatrist. On the other hand, children in the control group were recruited using the convenient sampling technique and a particular attention was paid for matching age and gender to the clinical group.

5.2.2. Measures

Data collected by the Go/no-go Task, the Working memory-switch Task, and Turkish version of the RST-PQ-C was analyzed for testing the hypotheses of the present study. Information about these tasks is presented below.

5.2.2.1. Go/no-go task

The prepotent motor response inhibition performance was critical in the previous investigation that took place in chapter four of the present thesis. Hence, this task was described in detail in the method section of chapter four, on pages 112 and 113. However, reiteration of the important aspects of this task can help to remind reader about structure of the task and obtained scores.

The Go/no-go Task used in the present thesis was the version modified by Hester and Garavan (2005). This task was developed to assess the prepotent motor response inhibition ability. The Go/no-go Task included four runs with four different load conditions. In each run, participants were presented with the changing letters of the Latin alphabet on a computer screen and instructed to press the space bar for all the presented letters but withhold responding when a target item appears. In the first run, there was no WM load and participants were instructed to inhibit their response when the letter X appears. In the second run, participants were given two letters (i.e., memory list) to rehearse. Maintaining these letters constituted WM load and they were instructed to withhold their response when one of these letters appears on the screen. In the third run, participants were given three letters to maintain and they were instructed to inhibit their response when one of these items appears. In the fourth run, participants were given four letters to maintain and they were instructed to withhold responding when one of the maintained letters appears on the screen. In each load condition, the obtained output score was the total number of correctly inhibited responses (i.e., total correct). Eventually, four different runs with four different load conditions yielded four different raw scores. Higher score indicated a better prepotent motor response inhibition performance and the obtained raw scores in each run were used in the analyses.

5.2.2.2. Working memory - switch task

The Working memory-switch Task (Hester & Garavan, 2005) used in this study was a variation of the Sternberg Memory Task (Sternberg, 1975). This task was developed for the assessment of the task-switching ability among adults. In the present study, some changes were made to this task in terms of the number of trials and the number of letters, to make this measure appropriate for children.

The stimuli were presented by using E-prime 2 professional on a Windows-based computer with a 17-inch colour monitor (see Figure 18). Each participant went through a three-step practice session. In the first step, they saw two letters on the screen as the memory list and then the letters disappeared. Right after this, they watched some randomly changing letters. They were instructed to use their left hand and press the keyboard key 1, if a letter is from the memory list but press 2 if it is not. In the second step of the practice session, there was no memory list. They were presented with the changing letters which were either in red or blue colour. They were instructed to use the right hand and press keyboard key 0 for the red letters and press o for the blue letters. In the third step, they were presented with two letters as the memory list and then watched the changing letters on the screen. They were told to use both hands simultaneously for responding. They were instructed to use the left hand for indicating if a letter was from the memory list or not and use the right hand for indicating if a letter was blue or red. After the practice session, the first run of the main task began. The same instructions were used in the main task. Ignoring the memory list rule and switching to the colour rule was recorded as the correct task-switching response.

In each run, a participant had a different number of letters of the Latin alphabet to remember as the memory list (memory list letters in the first run were B-S, in the second run were D-H-G, and the third run were N-Y-L-D). Each run included 50 trials and only 12 of these trials involved switching stimuli. Initially, the memory list was presented for 6 seconds and then immediately followed by a rehearsal period of 6 seconds. Then, each time, only one letter was presented on the screen. Each letter appeared for 1.750 msec. on a black background followed by a black screen for 750 msec. The letters presented were in 50-point Arial font. Participants were told to rehearse the memory items in their minds during the test runs. They were asked to recall the letters before the first trial began and also after the last trial ended to make sure that the letters were remembered and maintained at all times during the test runs. Participants had a chance to rest for 20 seconds between the runs. The following score was recorded: number of correct task-switching responses (i.e., task-switching accuracy).

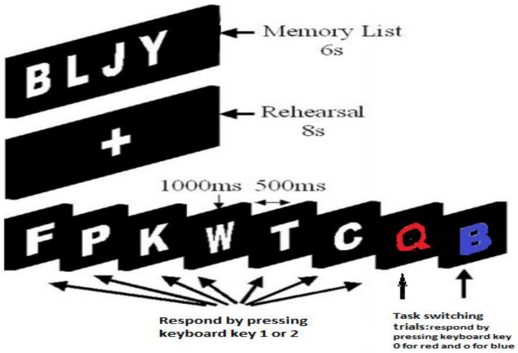

Figure 18. Working Memory - Switch Task

5.2.2.3. Turkish version of the RST-PQ-C

A detailed description of the properties of this questionnaire can be found in chapter two, on page 74, and the items of this questionnaire are presented in the Appendices section (i.e., Appendix 2) of the present thesis. In the present investigation, the outputs that entered in the analyses were the total scores that obtained from each scale.

5.2.3. Procedure

A detailed description of the procedure was presented in the method part of Study 2a, in the previous chapter (see pages 113-116). For this reason, only a brief summary is presented in the present section.

All the children completed Turkish version of the RST-PQ-C, the Academic Motivation Scale, and nine neuropsychological tests: Continuous performance Test, Bourdon Test, Vocabulary Test, Memory span Test, Choice-delay Task, WCST, Matrix reasoning Test, Go/no-go Task, and Working memory-switch Task. Cognitive Effort Avoidance

Measure (see page 105) allowed children to choose the tests freely. For this reason some children had the Go/no-go Task first and then they received the Task-switch Test, later. On the other hand, some other children had the Task-switching Test first and then they received the Go/no-go Task. Each child went through only one session and a session was approximately one and a half hour long.

There was a difference between Study 2a and Study 2b in terms of the way that output scores of the Go/no-go Task were used. In the previous study, raw scores were transformed to z-scores and an inhibition composite was obtained and used in the regression analysis. However, in the present investigation, the obtained raw scores were directly entered in the ANOVA and ANCOVA without any transformation.

5.2.4. Data Analytic Strategy for Study 2b

In this study, the prepotent motor response inhibition performance that was measured with the Go/no-go Task and the task-switching performance that was measured with the Working memory-switch Task were dependent variables. The groups and the conditions were the independent variables. The BAS, the FFFS, and the BIS were covariates. Statistical analyses included mixed repeated measures ANOVA for investigating the effect of the increased load, on the executive functioning performance of two groups. Later, separate ANCOVAs were computed for investigating if the BAS, the BIS, and the FFFS were covariates. Furthermore, moderation analysis was conducted using the Hayes' PROCESS, model 1, for evaluating the moderating role of the diagnosis status in the relationship between the FFFS activity level and the task-switching performance.

5.3. Results

G*Power software (v. 3.1.9.2; Faul et al., 2007) was used to determine the needed sample size for 0.25 (medium effect size) with power set to 0.80 as recommended by Cohen (1992). For an effect size of 0.25, $\alpha = 0.05$, power $(1-\beta) = 0.80$, 2 groups, and four repetitions, 24 total subjects are needed for a repeated-measures ANOVA to detect a statistically significant difference of medium effect size. The present study included 80 participants.

5.3.1. WM Load and Prepotent Motor Response Inhibition Performance

For investigating the effect of the WM demand on the prepotent motor response inhibition performance, the effect of maintaining varying levels of WM load was compared between two groups, using mixed repeated-measures ANOVA with the group (clinical and control) as the between-subjects factor and the WM load condition (zero, low, medium, and high) as the within-subjects factor. The dependent variable was the prepotent motor response inhibition performance. Bonferroni *post hoc* tests were conducted.

Assumptions of the repeated measures ANOVA were tested. Mauchly's test of sphericity was marginally significant ($p = 0.04$). That is why the Greenhouse-Geisser estimate of the F statistic was used. Homogeneity of variance was tested by Levene's test. Levene's test was significant for the third load condition but the number of subjects in each group was equal. Box's test of equality of covariance matrices was not significant ($p = .36$). All the assumptions of the test were met.

Mixed repeated measures ANOVA results showed that there was a main effect of group, $F(1, 78) = 16.12$, $p < .001$, $\eta_p^2 = 0.17$, meaning that the average prepotent motor response inhibition scores were significantly different between the groups. The control group's mean prepotent motor response inhibition scores were higher in each load condition. However, between-group pairwise comparisons showed that the two groups' prepotent response inhibition scores were not significantly different from each other in the first load condition when there was no WM load, $p = .36$. Group differences in average prepotent response inhibition scores can be observed in Table 13.

Table 13

Means, mean differences and standard deviations of the prepotent response inhibition scores across the load conditions in the clinical and control group

	Clinical (N = 40)		Control (N = 40)		Mean difference	Cohen's d
	M	SD	M	SD		
Condition 1	12.05	1.99	12.45	1.89	0.4	0.21
Condition 2	9.70	2.13	10.88	2.37	1.17	0.52
Condition 3	8.0	2.16	9.68	3.17	1.67	0.62
Condition 4	7.08	2.42	10.18	3.14	3.10	1.11

Note. Condition 1 included no letters to maintain. Condition 2 included two letters (D, H), condition 3 included three letters (C, T and M) and condition 4 included four letters (L, U, A and N) to maintain as the WM load.

There was a significant main effect of load on the prepotent motor response inhibition scores, $F (2.75, 214.18) = 57.86$, $p < .001$, $\eta_p^2 = 0.42$. Meaning that amount of load maintained in the WM affected the prepotent motor response inhibition scores. Furthermore, there was a significant interaction effect between the load and the group, $F (2.75, 214.18) = 6.68$, $p < .001$ $\eta_p^2 = 0.08$. This showed that the prepotent motor response inhibition scores differed across the load conditions depending on being in the clinical or the control group. In other words, increased load affected the two groups differently. In the clinical group, there was a gradual decrease in the mean prepotent motor response inhibition scores from condition one to condition four. The lowest score was obtained in the fourth condition where the amount of WM load was the highest. Furthermore, when the mean differences were investigated using the pairwise comparisons, it appeared that the prepotent response inhibition scores were significantly different from each other in each load condition, $p < .05$. This finding showed that increased load resulted in decreased prepotent motor response inhibition scores and the scores among the conditions were significantly different from each other in the clinical group.

On the other hand, in the control group, increased WM load resulted in a decrease in the prepotent motor response inhibition performance from condition 1 to condition 3. However, in the fourth load condition, the prepotent motor response inhibition performance increased where the amount of WM load was the highest. The prepotent motor response inhibition scores of load conditions 1-2, and 2-3 were significantly different from each other but conditions 3 and 4 were not ($p = .26$).

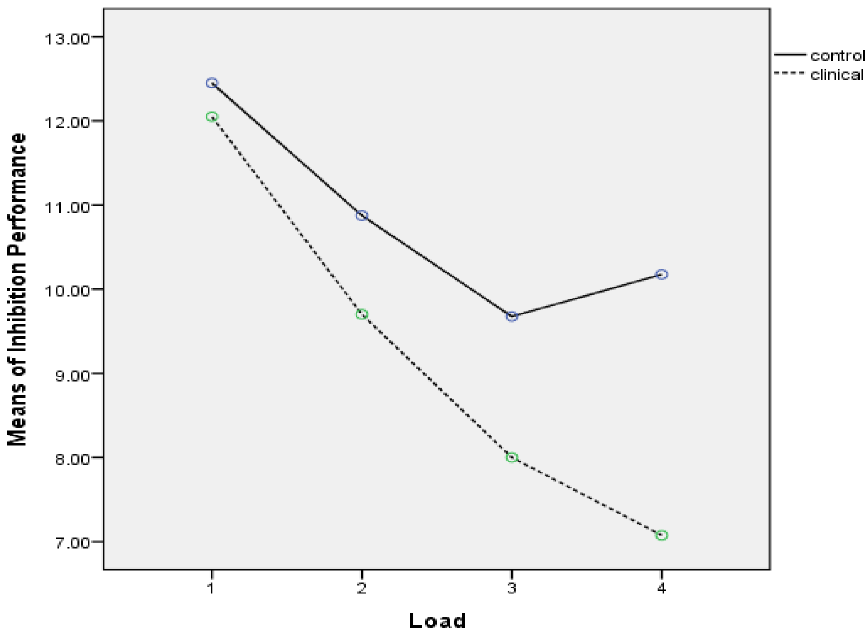

Figure 19. Mean scores of the prepotent response inhibition across the four load conditions for the clinical and control group. The main effect of load and group was observed, with controls outperforming the ADHD group.

The estimated marginal means and interaction graph are presented in Figure 19. The graph shows that in the first load condition, the group performances were similar and there was no significant difference between the prepotent motor response inhibition scores. The second and third load condition resulted in decreased prepotent motor response inhibition performance in both groups. However, in the fourth load condition, heavier load resulted in a decreased performance in the clinical group but it increased the prepotent motor response inhibition performance of the control group. When the slope of lines is investigated, it can be seen that the clinical group's slope is steeper than the control group, implying that increased load had a large negative impact on the prepotent motor response inhibition performance of the clinical group but not on the prepotent motor response inhibition performance of the control group.

Three separate mixed repeated measures ANCOVAs were computed for investigating the effects of the BIS, BAS, and FFFS in the model. First, the BIS scale scores were added as a covariate. Analysis results showed that the BIS scale scores were not related to any of the load conditions and did not have an effect on the prepotent response inhibition scores, $F(2.73, 201.20) = 2.46$, $p = .06$. When the BAS scores were added as a covariate, the analysis results showed that the BAS scale average scores also did not relate to any of the load conditions and did not affect the prepotent motor response inhibition scores, $F(2.73, 201.30) = 2.21$, $p = .08$. Finally, the FFFS scores were added as a covariate. Results showed that the FFFS scale scores did not covary with any of the load conditions and it did not affect the prepotent motor response inhibition scores, $F(2.74, 211.23) = 0.39$, $p = .76$.

5.3.2. WM Load and Task-Switching Performance

Hypothesis d stated that increased working memory load should result in a gradual impairment in the task-switching performance among children with ADHD. For testing this hypothesis, the effect of three different levels of working memory load was compared between two groups using mixed repeated measures ANOVA with group (clinical and control) as the between-subjects factor and WM load condition (low, medium, and high) as the within-subjects factor. The dependent variable was the task-switching performance. Bonferroni *post hoc* tests were conducted.

Assumptions of the repeated measures ANOVA were tested. Mauchly's test of sphericity was not significant ($p > 0.05$). Homogeneity of variance was tested by Levene's test. Levene's test was significant for the third load condition but the number of subjects in each group was equal. Box's test of equality of covariance matrices was not significant ($p = .34$). All the assumptions of the test were met.

Mixed repeated measures ANOVA results showed that there was main effect of group, $F (1, 78) = 14.45$, $p < .001$, $\eta_p^2 = 0.15$. The control group outperformed the clinical group in each load condition. Furthermore, between-group pairwise comparisons showed that the scores of the two groups were significantly different from each other in each load condition. Average task-switching scores in each load condition can be observed in Table 14.

Table 14

Means, mean differences and standard deviations of task-switching scores across the load conditions in the clinical and control group

	Clinical (N = 40)		Control (N = 40)		Mean difference	Cohen's d
	M	SD	M	SD		
Condition 1	6.40	2.77	7.90	2.47	1.50	0.57
Condition 2	6.07	2.97	7.78	3.03	1.70	0.57
Condition 3	4.9	3.17	7.95	2.29	2.97	1.10

Note. Condition 1 included two letters (B, S), condition 2 included three letters (D, H, and G) and condition 3 included four letters (N, Y, L and D) to maintain as the WM load.

There was a significant main effect of load, $F(2, 156) = 3.30$, $p = .03$, $\eta_p^2 = 0.04$. Meaning, the amount of load maintained in the WM affected the task-switching scores. There was a significant interaction effect between the load and the group, $F(2, 156) = 4.30$, $p < .01$, $\eta_p^2 = 0.05$. This showed that the children's task-switching scores differed across the load conditions, depending on being in the clinical or in the control group. In the clinical group, there was a gradual decrease in the average task-switching scores from condition one to condition three. The lowest score was obtained in the third condition where the amount of WM load was the highest. When the mean differences were investigated using the pairwise comparisons, it appeared that the task-switching scores were not significantly different in the load conditions 1 and 2, $p = .40$, but there were significant differences between load conditions 1-3 and 2-3, $p < .05$. On the other hand, in the control group, increased WM load resulted in a decrease from condition 1 to condition 2. However, task-switching scores increased in the third load condition where the amount of WM load was the highest. Furthermore, the average task-switching scores were not significantly different from each other in any of the load conditions, $F(2, 77) = 0.11$, $p = .89$.

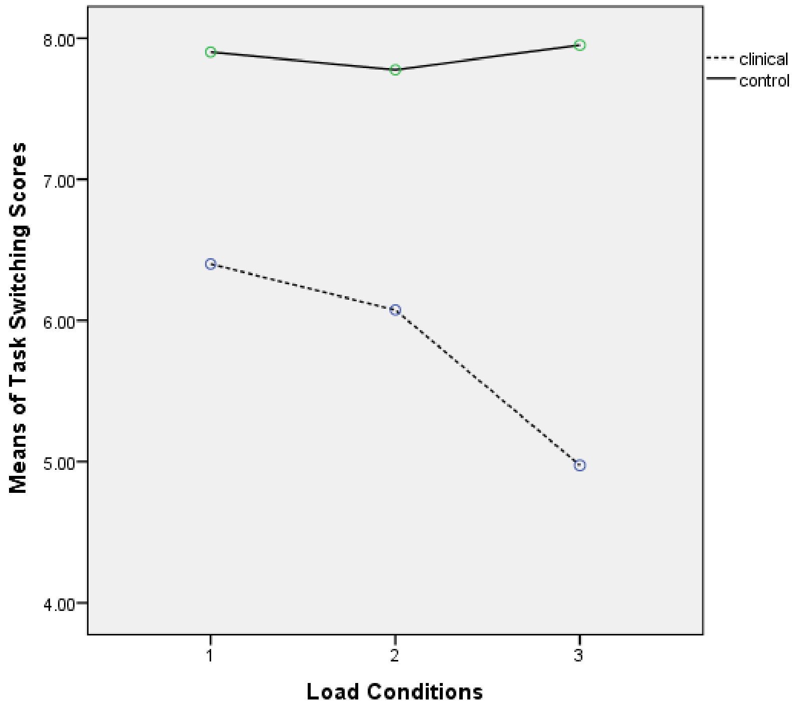

Figure 20. Mean scores for the Working memory-switch Task across the three load conditions for the clinical and control group. The main effect of load and group was observed, with the controls outperforming the ADHD group.

The estimated marginal means and interaction graph can be observed in Figure 20. The graph shows that the average task-switching scores were significantly different from each other in the first load condition and the control group scored higher than the clinical group. There was a decrease in the task-switching scores of both groups in the second load condition. Finally, in the highest load condition, the clinical group's scores continued to decrease but the control group's scores increased. When the slope of lines is investigated it can be seen that the clinical group’s slope is much steeper than the control group in the third load condition. This shows that high WM demand had a large negative impact on the task-switching scores of the clinical group but it had a positive impact on the scores of the control group.

Three separate mixed repeated measure ANCOVAs were computed for investigating the covariation of the BIS, BAS, and FFFS. First, the BIS scale scores were added as a covariate. Analysis results showed that the BIS scale scores did not covary with the task-switching scores, F (2, 153.76) = 0.44, p = .64. When the BAS scale scores were added as a covariate, the analysis results showed that it also did not interact with the load conditions and did not covary with the task-switching scores, F (2, 153.84) = 1.21, p = .30. Finally, the FFFS scale scores were added as a covariate. Results showed that there was a significant interaction between the FFFS scale scores and the load, F (2, 154) = 3.16, p = .04, $\eta_p^2 = 0.04$. Meaning that the increased FFFS sensitivity was significantly related to the decreased task-switching scores in the highest WM load condition, r = -.44, p < .001. Hence, based on the obtained results, the PROCESS macro for SPSS was employed (Hayes, 2013) for further investigating the possible moderating role of diagnosis status in the relationship between the FFFS sensitivity and the task-switching performance (see Figure 21).

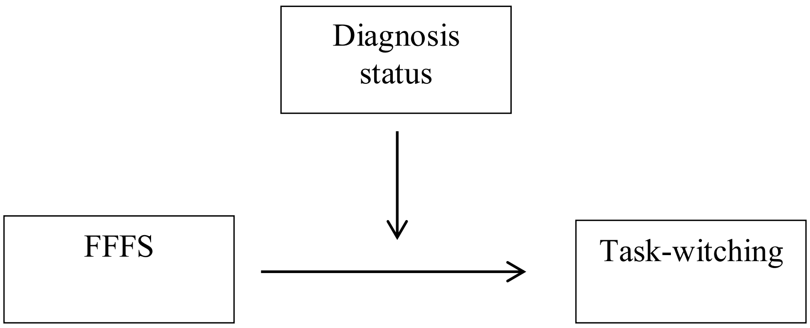

Figure 21. The proposed model for testing the moderating role of the group membership in the relationship between the fight-flight-freeze system (FFFS) and the task-switching performance.

The overall model was significant, F (3, 76) = 19.89, p < .001, R^2 = .34. The FFFS was a predictor of the task-switching performance, *b* = -.21, t(76) = -2.57, p = .01. Diagnosis status also predicted the task-switching performance, *b* = 2.91, t(76) = 5.01, p < .001. There was a significant FFFS and diagnosis status interaction, *b* = 0.43, t(76) = 2.63, p < .001, showing that the diagnosis status was a moderator of the relationship of the FFFS and the task-switching performance. In other words, only in the presence of ADHD diagnosis, the

FFFS was related to the task-switching performance, at the highest WM load condition. When simple slopes were investigated (see Figure 22) it appeared that in the clinical group, the higher FFFS scores were related to the lower task-switching scores. In other words, in the clinical group, children who had higher FFFS activation exhibited lower task-switching performance.

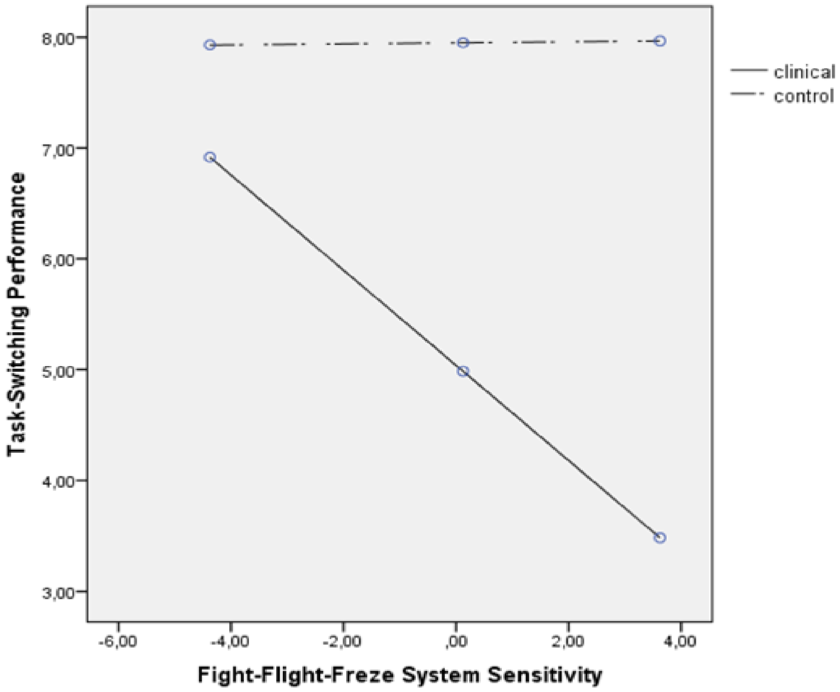

Figure 22. Simple slopes showing the interaction between the fight, flight, freeze system activity level and the group in predicting task-switching performance.

5.4. Discussion

In the present chapter, the reason for executive functioning impairment among children with ADHD was investigated. The first aim was to show that the prepotent motor response inhibition performance of the children with ADHD was the same as their TD peers when there was no WM demand. The second, and the main aim was to demonstrate the roles of the maintenance demand and the level of the FFFS activity in the executive functioning impairment (i.e., prepotent motor response inhibition and task-switching) among children with ADHD. Results supported the hypotheses. First, no significant difference was found between the prepotent motor response inhibition scores of the two groups when there was no WM load. Second, gradually increased WM demand resulted in the decreased prepotent motor response inhibition and task-switching performance in the clinical group. On the other hand, an opposite pattern appeared in the control group. WM load stimulated better prepotent motor response inhibition and task-switching performance when the demand was highest. Furthermore, it was found that the higher sensitivity of the FFFS impaired the task-switching performance in the presence of high maintenance demand and this was only observed among children with ADHD.

5.4.1. WM Load and Prepotent Motor Response Inhibition

In the present study, it was found that there was no significant difference in the prepotent motor response inhibition performance between the groups when there was no WM demand. This finding is in line with the studies in the literature which used the Go/no-go Task without any WM load and reported no prepotent motor response inhibition weakness among children with ADHD (Castellanos et al., 2006; Engelhardt et al., 2008; Geurts et al., 2005; Kofler et al., 2019; Scheres et al., 2004; Van De Voorde et al., 2010; Wright et al., 2014). On the other hand, studies that included increased WM load within the Go/no-go Task reported impaired prepotent motor response inhibition performance (Seymour et al., 2016; Wodka et al., 2007). Similar scores among groups demonstrate that children in the clinical group were able to meet the controlled attention demand of the Go/no-go Task, as well as the children in the control group when there was no WM load.

Results showed that in the clinical group, increased load resulted in a gradual decrease in the prepotent motor response inhibition performance throughout the conditions. Furthermore, the scores were lower in each condition when compared to controls.

Importantly, in the Go/no-go Task, the amount of load that had to be maintained was increased gradually along with the conditions but the level of the demand for the controlled attention (i.e., the prepotent response inhibition) was held constant - the number of the stimuli that called for inhibition was the same in each load condition. That is why the load was the only factor that could affect the prepotent motor response inhibition performance. Children remembered the maintained letters when they were asked at the end of the task. This shows that the lower prepotent motor response inhibition score in the clinical group was not due to an inability to hold the load in the WM. Rather, it can be inferred that lower prepotent motor response inhibition scores were due to the extent of resources consumed for maintaining the load.

Impairing effect of increased WM load can be explained with the resource allocation theory of attention. According to this theory, simultaneous cognitive processes must share the available limited resources. Performance can decrease if one process fails to leave enough resources for other processes to be performed (Wickens et al., 1980). Scientists argued that WM's CE is a limited executive attention resource and it is related to executive functioning performance (Brocki et al., 2008; Kane et al., 2007). There are reports in the literature that support the assumptions of the resource allocation theory of attention. For instance, Hester and Garavan (2005) used the Go/no-go Task where non-patient adult participants were given increasing amounts of letters while trying to inhibit their prepotent responses. Study results showed that increased WM load reduced the inhibition control. The authors of the study argued that both functions should rely on a common attentional source. Reports suggest that both maintenance and inhibition abilities tap into the CE component of WM (Pennington & Ozonoff, 1996; Roberts et al., 1994). That is why the present study's results can be interpreted to mean that when maintaining WM load consumed most of the controlled attention resources then the remaining resources were not enough for supporting an optimal prepotent motor response inhibition performance among children with ADHD.

An important question is why maintaining WM load consume most of the CE resources among children with ADHD? In both groups, increased load resulted in the decreased prepotent response inhibition performance until the third condition. However, in the fourth condition, the control groups' performance increased whereas the clinical group's performance continued decreasing. The largest mean difference among the two groups was recorded in the fourth load condition. This finding suggests that children with ADHD had the greatest difficulty in the fourth condition where the load was the heaviest. On the contrary, the control group's increased prepotent motor response inhibition scores in the fourth condition indicate that they were oriented to the task and were able to allocate enough resources to meet the task demand. On the other hand, children with ADHD were not able to allocate enough resources and meet the task demand for an optimal inhibition performance.

It can be argued that overconsumption of CE resources could be due to a compensatory effort of a weak and vulnerable maintenance ability trying to hold on to the information. Literature includes evidence about the compensatory effort while maintaining WM load among children with ADHD. For instance, Lenartowicz et al. (2014) sought to dissociate component processes of WM (i.e., vigilance, encoding, and maintenance), based on the notion that they can be differentially impaired in ADHD. Based on the obtained EEG results the authors argued that alpha power increase during the maintenance period (relative to baseline), suggested a compensatory effort.

Based on the present study's findings, it can be concluded that a weakness in the maintenance function makes holding WM load more effortful and costly. Such a compensatory effort results in the use of too many CE resources and the remaining resources cannot be enough for supporting an optimal prepotent motor response inhibition performance.

All in all, results support the notion that weak maintenance ability underlies impaired prepotent motor response inhibition among children with ADHD.

5.4.2. WM Load and Task-switching

Obtained results from the Working memory-switch Task showed that in the clinical group increased WM demand resulted in a gradual decrease in the task-switching performance throughout the conditions. Moreover, scores were lower when compared to controls. The task that was used allowed observing the effect of the increased WM load because the amount of load was increased without changing the executive demand. This was made possible by presenting an equal number of shifting trials in each load condition. When they were asked, the children remembered the letters at the end of the runs, which shows that the lower performance was not caused by forgetting but can be attributed to a problem in the consumption of executive attention resources.

Present findings are in line with the studies which demonstrated that increasing WM load resulted in decreased task-switching performance among non-patient adults (Baddeley et al., 2001; Smith et al., 2001). No previous study has investigated the effect of the gradual increase of WM load on task-switching performance among children with ADHD.
Studies that investigated task-switching have used two simple tasks for measuring the switching performance (e.g., Cepeda et al., 2000) but they did not consider the role of WM. Hence, the present results are important in terms of demonstrating the WM's role in the impaired task-switching performance among children with ADHD.

In the present study, both groups' performance decreased until the second condition. In the third condition, the clinical group's performance continued declining and the worst task-switching performance was recorded. On the other hand, there was an increase in the control group's performance and the best task-switching performance was exhibited when the

WM load was the heaviest. These findings show that TD children can devote more resources and increase their performance when the maintenance demand increases. On the other hand, children with ADHD are not able to allocate enough resources for supporting an optimal task-switching performance. Present results suggest that children with ADHD consume more CE resources for maintaining information when compared to their TD peers.

Maintenance and task-switching have been proposed to tap into the same CE source (Hester & Garavan, 2005). Moreover, reports in the literature suggest an abnormality in the maintenance process among children with ADHD (Ko et al., 2013; Kobel et al., 2009). When the findings of the present study and the resource allocation paradigm is considered together then it can be concluded that maintaining information in the WM consumes too many resources and the remaining resources cannot be enough for supporting an optimal task-switching performance among children with ADHD.

5.4.3. The FFFS and Executive functioning

One of the purposes of the present study was to investigate the reinforcement sensitivity's effect on executive functioning. That is why three separate mixed repeated measures ANCOVAs were run where the BIS, BAS and FFFS scores were entered as covariates and the prepotent motor response inhibition scores and the task-switching scores were entered as the dependent variables in the separate models. Results showed that none of the revised reinforcement sensitivity theory (rRST) brain-behavioural systems affected the prepotent response inhibition performance in any load conditions.

On the other hand, one significant result was obtained when the reinforcement sensitivity's effect on the interaction between the WM load and the task-switching performance was investigated. Results showed that the BAS and the BIS did not influence the task-switching performance. However, when the FFFS was entered as a covariate it appeared that the FFFS level was a factor that affected the task-switching performance. Importantly, FFFS did not have any effect in the first two conditions. However, a higher FFFS level impaired the task-switching performance at the third load condition where the WM load was the heaviest.

These results suggest that the FFFS activation level is related to the CE processes. This is in line with the studies which reported that the reinforcement sensitivity is related to the WM (Blair, 2003; Dovis et al., 2015). Results can be interpreted by considering the resource allocation paradigm and the rRST together (Kanfer & Ackerman, 1989; Norman & Bobrow, 1975). Resource allocation theory argues that attention resources comprise a limited set of cognitive processes which can be directed towards various activities. As the resources are directed toward an activity, there should be fewer remaining resources to be directed elsewhere.

On the other hand, the rRST proposes that the FFFS react to aversive stimuli. Hence, children with higher FFFS levels can be argued to have a greater sensitivity to aversive situations. Kennis et al. (2013) argued that individuals with a highly reactive FFFS can be characterized as irritable, tense, and sensitive to threat cues. In a similar vein, Morton and White (2013) investigated the relationship between the FFFS level and driving ability and found a significant correlation between higher FFFS sensitivity and poorer driving performance among young individuals. Authors argued that individuals with heightened sensitivity to aversive cues could allocate more attention resources to the stressful aspect of a task and this would reduce the driving performance.

Working memory- switch Task was the most difficult task among all the other tests that have been used in the present thesis. Children used both hands to respond: in each trial they continuously needed to decide and respond if a letter was from memory list or not by using their left hand. Moreover, they needed to switch between tasks when the switching-cue appeared by using their right hand. There was a demand for being vigilant at all times. Furthermore, the difficulty of the task had its peak when WM load was the highest in the last load condition. Difficulty in a cognitive task can be perceived as an aversive cue (Kennis et al., 2013). Hence, it is possible that children with higher FFFS activity were more irritated with the high difficulty level of the Working memory-switch task. It can be argued that due to an increased attentional focus on the aversive aspect of the task, they had a reduced attention capacity and fewer resources to devote to task-switching. Moreover, when this was combined with the maintenance related overconsumption then it can be argued that children with a higher FFFS activity experienced a greater scarcity in the controlled attention resources and were not able to allocate enough resources to have optimal task-switching performance.

Furthermore, the moderation analysis results showed that diagnosis status was a moderator of the relationship between the FFFS activity and the task-switching performance. This was the case only in the third load condition. The FFFS activity level predicts the task-switching performance when WM demand gets higher only among children with ADHD. Investigating simple slopes showed that children with ADHD with lower FFFS activity obtained better task-switching scores. In the control group, the FFFS sensitivity and the task-shifting performance was not related in the any of load conditions. This can be attributed to the intact maintenance ability and having enough resources for supporting an optimal task-switching performance.

5.5. Clinical Implications

WM can be argued to be involved in most of the academic tasks and problems that children face in a school setting. Some of these tasks would be particularly similar to the ones that are presented in the Go/no-go Task and the Working memory-switch Task. In the present study, increasing the load by one letter at a time allowed pinpointing the breaking point in the performance among children with ADHD. In an educational setting, the number of words or the number of instructional steps which can be maintained by a child with ADHD can be discovered. If their WM is not loaded beyond what they can maintain, then a better executive functioning performance can be achieved. Findings demonstrate that WM load is a factor that has to be considered in the tasks that optimal executive functioning performance is expected among children with ADHD.

Present study results suggest that cognitive training targeted at remediating the maintenance ability can help improve executive functioning. If the amount of load that a child with ADHD can maintain is pinpointed, then specifically tailored material can be given to this child along with a second task (i.e., a dual-task paradigm). In this way, a child can practice and improve his or her maintenance ability by maintaining information while try reaching a specified goal.

In the present study, it was also found that higher FFFS sensitivity was related to lower executive functioning performance (i.e., task-switching). This indicates that a higher sensitivity of the FFFS can be related to increased irritation which could result in additional consumption of CE's resources. That is why it can be proposed that if a way of reducing the activation level of the FFFS is found, then more resources can be reserved for controlled attention.

Rapport et al. (2009) reported that increased WM load results in an increased amount of hyperactivity. In the present study, it was found that increased WM load results in impaired prepotent motor response inhibition performance. It is reasonable to suggest that increased WM load would result in more hyperactivity through impaired inhibition performance. It can be speculated that increased WM load impairs inhibition and then impaired inhibition results in more frequent hyperactivity and impulsivity. That is why it can be suggested that decreasing the WM load for a child with ADHD could increase the prepotent motor response inhibition efficiency and help reduce the amount of hyperactivity.

5.6. Theoretical Implications

In the present study, increasing WM load impaired the executive functioning performance among children with ADHD. According to the attentional resource allocation theory, attention is a limited source that can be allocated to multiple tasks and simultaneous cognitive processes must share the available resources. Performance can decrease if one of the processes fails to leave enough resources for other processes to be performed (Kahneman, 1973; Merrill, 1990). For example, in a reading task, there can be a trade-off between decoding the words and comprehension of the text (Vipond, 1980). This can result in a less efficient understanding of the text if the majority of resources have been allocated to word decoding. The results of the present study support the resource allocation theory of attention, showing that when maintenance and manipulation of information are activated simultaneously they compete for the existing attention resources. The present study results provide further evidence that the CE is a common controlled attention pool and there is a trade-off between controlled functions. This challenges the independent resources of the attention hypothesis (Wickens et al., 1980) and gives support to the notion of a singular, common source for controlled attention.

Present results suggest that active maintenance of WM load can be closely related to concentration ability. However, there is a need for a clear definition of concentration ability in the literature. Based on the findings, it can be speculated that when a certain amount of load is too much to maintain, then the concentration may break. This could be related to ADHD symptoms such as having difficulty sustaining attention in tasks, not being able to follow through instructions or conversations, and having difficulty in organizing tasks and activities.

5.7. Limitations and Future Directions

The main aim was to investigate the effect of WM demand on executive functioning performance. Although it was demonstrated that a higher load affects the prepotent motor response inhibition and task-switching, adversely, it cannot be claimed that the rest of the executive functions will be affected in the same way. That is why the effect of maintenance demand on the performance of the rest of the executive functions can be investigated in a future study. Furthermore, the present study was carried out with children aged between 7 and 11. That is why results cannot be generalized to adolescents and adults. A future study should attempt to replicate these findings in these age groups.

The present study results imply that maintenance ability and concentration are related. Maintenance performance can be related to appearance and the quality of concentration. However, concentration was not the primary focus of interest in the present investigation. That is why the present design does not allow conclusions about the dynamics of concentration. A future study should investigate the effect of WM load on the efficiency of concentration using an appropriate paradigm. Importantly, in the literature, the concepts of sustained attention and concentration have been used interchangeably. However, the present study findings suggest that they can be separate mental capacities. Therefore, there is a need for differentiating concentration from sustained attention. A more detailed discussion about this issue is presented in the general discussion section under the heading ‘resource allocation, concentration, and inattentive symptoms of ADHD’ (see page 180).

5.8. Conclusion

The present study investigated the role of the WM load and the rRST- FFFS's influence in the reported executive functioning impairment among children with ADHD. Findings provide substantial support for the notion that abnormal WM processes underlie impaired prepotent motor response inhibition and task-switching performance among children with ADHD. The obtained results consolidate that maintaining WM load results in impaired executive functioning performance in this population. Moreover, findings also imply a maintenance weakness that leads to a rapid drain of the controlled attention resources which eventually result in impaired prepotent motor response inhibition and impaired task-switching performance.

On the contrary to typically developing children, children with ADHD cannot allocate enough resources to increase their effort for meeting the task demand and have an optimal executive functioning performance. This finding has important implications in terms of the reported weak concentration ability among these children and findings suggest that the weakness in the maintenance ability can play a role in the concentration impairment among children with ADHD.

Finally, the present findings demonstrate a relationship between the rRST-FFFS and the efficiency of executive functioning among children with ADHD. This further supports the notion that the central executive component of the WM is a common but limited pool for controlled attention and the allocation of its resources can be influenced by the level of the FFFS.

CHAPTER SIX: GENERAL DISCUSSION

This thesis examined the roles of controlled attention and reinforcement sensitivity in the avoidance of mental effort and the impaired executive functioning in children with a diagnosis of ADHD. There were three main aims. The first aim was to translate the Reinforcement Sensitivity Theory-Personality Questionnaire-Children version (RST-PQ-C) into the Turkish language and providing evidence for its reliability. The second aim was to test a moderated mediation model to explain the higher frequency of avoiding mental effort among children with ADHD. Finally, the third aim was to reveal the effects of the WM load and the reinforcement sensitivity on impaired executive functioning among these children. The final chapter opens with a summary of the main findings of this doctoral research. Then it continues with the discussion of implications for theories and clinical applications. Finally, strengths, limitations, and directions are presented to guide future research.

6.1. Main Findings

In Study one (chapter three), the hypothesized three-factor model of the translated RST-PQ-C had a good fit with the data when investigated with the most commonly used indices of model fit. Furthermore, adequate Omega values for each factor were obtained. Overall, evidence was provided for reliable use of the Turkish language translation of the RST-PQ-C among Turkish speaking children.

In Study 2a (chapter four), it was found that the prepotent motor response inhibition performance had an indirect effect on the frequency of avoiding mental effort through the behavioural inhibition system (BIS). Furthermore, results of the moderated mediation analysis showed that this effect was contingent upon ADHD clinical status. In other words, the prepotent motor response inhibition efficiency had a critical relationship with the BIS activation level and the lower levels of these variables resulted in a higher frequency of avoiding mental effort among children with ADHD.

In Study 2b, it was found that there were no group differences in the prepotent motor response inhibition performance when there was no WM load. However, when the WM load was added, the prepotent motor response inhibition and the task-switching scores were lower in the clinical group throughout the three load conditions. Especially, in the last load condition where the WM load was the highest, the clinical group obtained the worst scores. In contrast, there was an increase in the prepotent motor response inhibition and the task-switching scores of the control group. Furthermore, it was found that higher FFFS activity was a factor that reduced the task-switching scores in the highest WM load condition and this effect was observed only among children with ADHD.

6.2. Study One

6.2.1. Psychometric properties of the Turkish version of the Reinforcement Sensitivity-Personality Questionnaire-Children

The main question of study one was whether the Turkish translation of the RST-PQ-C had the structural integrity for being used reliably among Turkish speaking children. For answering this question, translated RST-PQ-C and the Academic Motivation Scale (AMS) were administered to 738 primary school students. Collected data were analysed using confirmatory factor analysis, hierarchical multiple regression, and structural equation modelling techniques. Obtained results confirmed hypothesized three-factor structure (i.e., one BAS factor, one FFFS factor, and one BIS factor).

Previously developed questionnaires for assessing reinforcement sensitivity among children can be argued to include some drawbacks. The most popular two instruments are the

Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia et al., 2001) and the BIS/BAS scales (Carver & White, 1994). These are an adaptation of adult questionnaires and initially did not have a separate FFFS scale. Later revisions of these instruments yielded a separate FFFS scale but the stability of this factor is still being discussed among scientists (Corr, 2016). On the other hand, the RST-PQ-C was developed specifically for children and particular attention was paid to separating the BIS from the FFFS.

Separating the BIS from the FFFS is important in the light of the rRST. According to the theory, although both are defensive systems they react to different stimuli and activate a different set of processes. In study one, obtaining separate factors for the BIS and the FFFS was in line with the rRST's proposition about these two systems and having them distinguished let investigating their unique roles in avoiding mental effort and impaired executive functioning, in Study 2. Importantly, in the present thesis, this instrument was used for the first time within a child ADHD sample. In the Study 2a (fourth chapter), it was demonstrated that the BIS plays a role in more frequently avoiding mental effort and in the Study 2b (fifth chapter), it was demonstrated that the FFFS plays role in the impaired executive functioning among children with ADHD.

Moreover, the results of the structural equation model provided evidence for the predictive utility of the translated RST-PQ-C scales (i.e., BAS, FFFS, and BIS) for the AMS scores (i.e., intrinsic and extrinsic academic motivation). Importantly, hierarchical multiple regression and the structural equation modelling analyses results were in agreement with each other and obtained results were in line with the previous study results that showed the BAS and the BIS are good predictors of intrinsic academic motivation. These results provide some evidence that the BAS and the BIS scales, in the translated questionnaire, measure what they intend to measure.

The results suggest that higher levels of both the BAS and the BIS can influence school achievement in a positive way among primary school children. The link between reinforcement sensitivity and school achievement is needed to be further investigated. For example, a study could investigate the mediating role of intrinsic motivation in the relationship between the BAS and the level of school achievement. Alternatively, looking at the mediating effect of the reinforcement systems on the relationship between IQ and the level of school achievement could further clarify the nature of the interaction between the BAS, FFFS, BIS, and academic achievement.

Overall, Study 1 demonstrates that the Turkish version of the RST-PQ-C is a reliable measure of reinforcement sensitivity for Turkish speaking children. It separates the BIS from the FFFS just like the original instrument and it carries a potential for stimulating further research about the role of reinforcement sensitivity in ADHD.

6.3. Study Two

6.3.1. Impaired inhibition underlies frequently avoiding mental effort among children with ADHD

Study one, provided an opportunity for evaluating the activation level of reinforcement systems and allowed the demonstration of the important roles they play in executive functioning impairment and in avoiding mental effort among children with ADHD. When taken together, results of Study 2a and Study 2b reveal that the over consumption of controlled attention resources leads to impaired executive functioning and this, in turn, results in a higher rate of avoiding mental effort. Moreover, rRST behavioural systems play critical roles in both impairments and a consideration of motivational and neurocognitive factors together can be argued to be a step forward in explaining symptoms of ADHD.

ADHD includes symptoms such as avoiding mental effort, difficulty remaining focused on tasks, being disorganized, and not being able to follow through on instructions (APA, 2013). Impaired executive functioning is a factor that has been demonstrated to play role in the appearance of ADHD symptoms (Wodka et al., 2007). On the other hand, one other factor with the potential to affect the process is the motivational regulation (van Goozen et al., 2004). Study 2a was undertaken to examine the roles of the prepotent motor response inhibition and the rRST - BIS in the observed higher rate of avoiding mental effort. Based on the present study's findings, it can be claimed that a lower level of prepotent motor response inhibition and the BIS, result in a higher rate of avoiding mental effort among children with ADHD.

Prepotent motor response inhibition is an executive skill and studies have demonstrated that it is negatively correlated with the number of ADHD symptoms (Brocki et al., 2007). Inhibiting a potent motor response is critical because it sets the occasion for self-regulation by providing a gap between stimulus and response. Previously, Karsdorp et al. (2014) showed that poor inhibitory control is related to difficulty in suppressing avoidance behaviour and this, in turn, results in a higher rate of avoidance. Non-patient adult participants completed the Stop-signal Task and the Cold-presser Task in which the participants had to keep their hands in a box filled with cold water. Results of this study show that poorer prepotent motor response inhibition is related to more frequent avoidance during pain.

The present study further adds to the literature that poorer prepotent motor response inhibition predicts a higher rate of mental effort avoidance. As previously discussed, there is clear evidence in the literature showing that impaired prepotent motor response inhibition is related to impaired executive functioning (Wodka et al., 2007) and to perceiving cognitive tasks as more effortful (Hsu et al., 2017). The relationship between prepotent motor response inhibition and avoiding mental effort may be straightforward. It could be argued that impaired prepotent motor response inhibition interferes with the efficiency of executive functioning and results in increased task difficulty hence, a higher rate of avoidance.

Cognitive tasks are aversive because they require effortful control (Vogel et al., 2020). Impaired inhibition can increase the experienced difficulty with cognitive tasks and contribute to stronger avoidance motivation. In such circumstances, resisting avoidance motivation may become more critical for longer on-task behaviour. Barkley, (1999) argued that deficient prepotent response inhibition could interfere with the regulation of motivation and result in diminished persistency in effortful tasks. The present results support this proposition by showing that in the child ADHD population, the prepotent motor response inhibition is linked with one of the rRST behavioural systems (i.e., BIS) that is responsible for the regulation of motivation.

The Study 2a presents that the BIS has a complete mediation effect between the prepotent motor response inhibition and the frequency of avoiding mental effort. Gray and McNaughton (2000) theorized that the BIS regulates the BAS and the FFFS-related motivation in the service of adaptive behaviour. Scientists argued that the BIS is superordinate to both approach and withdrawal systems and its activation can result in overriding motivational impulses and inhibition of a behavioural response (Aron et al., 2004; Gable et al., 2018; Amadio et al 2008).

Definition of the BIS includes inhibiting avoidance motivation that is induced with the activation of the FFFS. That is why hypoactivity of the BIS can result in difficulty to resist avoidance motivation that is induced by the FFFS in the presence of a challenging cognitive task. Literature includes evidence to favour this proposition. For instance, Findley (2014) demonstrated that when the weak BIS is not able to inhibit the FFFS-induced avoidance motivation efficiently, this results in self-control failure among non-patients adults.

Hence, the findings reported in this thesis suggest that hypoactivity of the BIS is related to a higher rate of mental effort avoidance through a reduced capacity to resist avoidance motivation. Taking it all together, it could be argued that lower prepotent motor response inhibition ability results in experiencing tasks as more difficult and hence produces a higher avoidance motivation. On the other hand, hypoactive BIS is not able to efficiently inhibit avoidance motivation hence, a higher rate of avoiding mental effort appears.

6.3.2. The relationship between inhibition of motor response and inhibition of motivated behaviour: an Inhibition network?

An important finding of study 2a is that prepotent motor response inhibition predicts the activation level of the BIS only among children with ADHD. Two important questions this connection raise is why the prepotent motor response inhibition and the BIS are related? And how the BIS inhibit avoidance motivation?

Ferrey et al. (2012) aimed to investigate whether prepotent motor response inhibition results in the devaluation of sexual stimuli. They presented participants with some sexual images in the Go/no-go Task. Sexually appealing stimuli (i.e., pictures) were used as the no-go cue and non-patient adult participants needed to withhold their response when a target image appeared. Results showed that inhibition applied during the Go/no-go Task resulted in a devaluation of sexual stimuli. This study demonstrates that motor inhibition of potent response can lead to a change in motivation.

Ferrey et al.'s (2012) study shows that inhibiting prepotent motor response can reduce the motivation that is attached to stimuli, to some extent. Based on this finding it can be reasoned that in some situations the relationship between the prepotent motor response inhibition and the motivation may or may not involve the BIS. If the prepotent motor response inhibition ability is intact and the magnitude of the motivation to be override is not high then any further inhibitory activity may not be necessary. In other words, the BIS involvement may not be needed and no correlation would appear between the prepotent motor response inhibition and the BIS activity level.

On the other hand, in some situations when a response is inhibited then some motivation that is attached to the stimuli would remain. If the remaining motivation is high then the BIS involvement would be necessary to regulate motivation. In particular, if prepotent motor response inhibition ability is not intact/strong enough then there might be a higher demand for the BIS involvement for regulating approach or avoidance-related motivation. In such cases, a correlation between the prepotent motor response inhibition and the BIS would emerge.

In Study 2, children engaged with demanding cognitive tasks. It can be argued that children with lower prepotent motor response inhibition performance were encountered with a higher difficulty hence they had a higher magnitude of avoidance motivation. In such a case the BIS can be critical for regulating motivation. It can be speculated that in doing so, it could stimulate the BAS through its cortical connections and increase the perceived value of stimuli in an attempt to keep the organism in the situation. Hence, the FFFS-induced avoidance motivation may be controlled by increasing the perceived value of stimuli. If weak BIS fail to stimulate the BAS through the cortical connections to increase the perceived value of the stimuli then the FFFS-induced avoidance motivation may not be managed and inhibited efficiently. In such cases a child may experience difficulty to endure aversive stimuli for a better outcome and eventually have a higher rate of avoidance behaviour.

Based on the present findings, it can be concluded that both the inhibition of prepotent motor response and the inhibition of motivated behaviour is differentially impaired among children with ADHD. Reports in the literature indicate a resource allocation problem in this population (Dörrenbächer & Kray, 2019a; Gualtieri & Johnson, 2006; Wu et al., 2006). Study

2b shows that maintaining WM load and not being able to allocate enough resources can impair the prepotent motor response inhibition performance. That is why it can be argued that scarcity of controlled attention resources could be a factor in the lower prepotent motor response inhibition performance which was related to the lower level of the BIS. Based on the present study findings it can be argued that if the inhibition ability constitutes a network in the brain then the prepotent motor response inhibition and the BIS levels can be influenced due to a global scarcity of resources.

6.3.3. WM load impairs executive functioning performance among children with ADHD

Some recent reports linked the working memory with the symptoms of ADHD and further suggested that the maintenance impairment could be related to lower executive functioning performance (Fosco et al., 2020; Kofler, Spiegel et al., 2019). The problem addressed in Study 2b was the gap in the literature about the effect of maintaining working memory load on executive functioning performance (i.e., the prepotent motor response inhibition and task-switching), among children with ADHD. The aim was to compare clinical and control groups by observing their performance in varying WM load conditions. Furthermore, the effect of the sensitivities of the rRST behavioural systems –the FFFS, in particular- on the executive functioning performance, in the presence of the WM load was sought to be investigated.

The core findings in this study were that maintaining WM load impairs executive functioning performance among children with ADHD, but it increases the performance among TD children. Furthermore, the two groups' prepotent motor response inhibition performance does not significantly differ when there is no WM load. Moreover, higher FFFS activation reduces task-switching performance in the presence of WM load only among children with ADHD. Overall results show that children with ADHD have a lower executive functioning performance because they cannot handle the maintenance demand.

In the tasks that were used in Study 2b, the maintenance demand was gradually increased but the controlled attention demand was kept constant throughout the conditions. Importantly, the pattern of the results that were obtained in both the Go/no-go Task and the Task-switching Paradigm were identical. Hence, the evidence is obtained to conclude that maintaining information impairs performance at least in two of the executive functions (i.e., prepotent motor response inhibition and task-switching) and that the effect of the load on the remaining executive functions should be further investigated.

Results indicate an abnormality within the maintenance process of WM. Maintenance is a critical function and Duncan (1996) showed that disorganization appears when information cannot be maintained efficiently. Hence, it is reasonable to suggest that the maintenance related problem could also play a role in some other difficulties that are observed in ADHD. For this reason, the possible adverse effect of maintaining information on the other symptoms of ADHD such as difficulty following instructions and lack of organization should be further investigated.

6.3.4. Resource allocation, concentration, and inattentive symptoms of ADHD

The findings of the present study show that both children with and without ADHD can maintain the WM load but the extent of the resources they use are different. Study 2b's findings can be explained within the framework of the resource allocation theory of attention. This theory proposes that controlled attention (i.e., executive control) is a limited source and simultaneously activated cognitive functions compete for available resources. If the majority of resources are allocated for a particular function then the remaining resources that can be devoted to another function could be fewer (Norman & Bobrow, 1975). In the light of this theory, and the present findings, it can be argued that maintaining WM load consumes more controlled attention resources among children with ADHD when compared to controls. When most of the resources are allocated for supporting the maintenance, then the remaining controlled attention resources are not enough for an optimal executive functioning performance.

Consumption of excessive extent of resources in the service of maintaining WM load could be related to other symptoms of ADHD such as difficulty remaining focused on tasks, being disorganized, and not being able to follow through on instructions. It can be argued that if the maintenance limit is exceeded then the children with ADHD may not be able to sustain their attention effectively. Moreover, being distracted could also be related to depleted resources and could result in daydreaming or not seeming to listen when spoken to.

The resource allocation hypothesis for ADHD offers an alternative explanation for the deficits observed in children with ADHD by centralizing the resource allocation as a core deficit (Sergeant et al., 1999). According to this model, attentional impairment in ADHD appears secondary to an abnormality in the resource allocation (Van der Meere, 1996). Researchers who have investigated resource allocation among children with ADHD used different cognitive tasks, recorded EEG outputs, and measured the heart rate changes. They found alterations in performance variability during task switching (Dörrenbächer & Kray, 2019), lower P300 amplitudes (Greenham, 1998), and slower reaction times (Cheung et al., 2017) when compared to TD controls. These authors univocally argued that their results indicate impairment in resource allocation.

Authors concluded that children with ADHD have impairment in allocating enough resources to meet the demand of the cognitive tasks (Cheung et al., 2017). The present study's findings are in line with these results. However, the above mentioned studies did not necessarily employ a dual-task paradigm with increased WM load. It can be argued that it is important to use a dual-task paradigm for investigating the role of resource allocation in executive functioning impairment. For instance, some studies employed multiple tasks for assessing task-switching, but the WM load was very low for detecting an interaction (e.g., Wu et al., 2006). On the other hand, some studies kept the controlled attention demand constant along the trials, but did not include WM load (e.g., Dörrenbächer & Kray, 2019). Hence, in terms of the resource allocation problem, the results in the literature remain indicative.

When investigating for the resource allocation impairment as an underlying factor for the executive dysfunction, it is advisable to use more than two levels of gradually increased WM load and, furthermore, it is critical to keep the demand of controlled attention constant throughout the conditions (e.g., keeping the number of target items equal across the levels). Using such a crafted task, the results of Study 2b demonstrated the role of the impaired resource allocation in the obtained group differences in terms of the executive functioning performance. Moreover, using such a task allowed adding to the literature that impaired resource allocation was due to a compensatory effort within the WM system for maintaining information.

The present study's findings also present that typically developing children do not experience resource depletion. According to the load theory, the amount of perceptual load is a factor that affects the efficiency of distractor processing (Lavie et al., 2004). There are studies in the literature showing that increased WM load can increase cognitive performance. In this regard, Forster and Lavie (2008) investigated the effect of load on the task-irrelevant distractors. Based on the study results the authors concluded that the interfering effects of task-irrelevant distractors can be eliminated with increased WM load. This study provides some support that increased WM load can enhance the efficiency of screening for extraneous stimuli among healthy adults. This result supports the argument that some WM load is necessary for achieving concentration. The findings of the present thesis extend the literature by revealing that the prepotent motor response inhibition and task-switching performance increase in the presence of a higher WM demand among TD children. Moreover, these findings suggest that impaired maintenance ability may be related to impaired screening of the extraneous stimuli and getting easily distracted and thus an inability to concentrate in children with a diagnosis of ADHD.

Furthermore, it may be speculated that the opposite patterns among groups in the last condition of the tasks in Study 2b - decreased performance in clinical group but increased performance in control group - demonstrate the importance of maintenance in the process of concentration. Children with ADHD have been reported to have difficulty sustaining their attention (APA, 2013). However, it should be noted that children with ADHD can play video games for long periods of time suggesting that it is easier for them to sustain attention on simple tasks where WM load is not high, and it is not perceived in an aversive manner. Hence, it could be argued that concentration would be different from monotonously sustaining attention in terms of the effort that is required.

The results reported in this thesis suggest that efficient maintenance of a certain level of WM load could be necessary for concentration to appear. For example, sustained attention engages when an individual watches the flight of balloons in the air for several minutes and does not initiate any controlled cognitive processes. On the other hand, concentration is necessary if he or she is asked to categorize these balloons depending on their colour, and then, tell the number of balloons in each category - this imposes a WM load. Achieving this task requires maintaining information (i.e., instructions, category names and number of the air balloons) until all the balloons are counted and categorized. This task requires keeping the information in an active WM state. If maintaining information is effortful, and also aversive, then a child with ADHD may be quick to disengage from the task due to the difficulty that he or she experiences while trying to concentrate.

Findings of Study 2a suggest that children with ADHD have a higher tendency to avoid tasks due to lower activation level of the BIS. For this reason, a child with ADHD may not endure an aversive situation and push himself or herself to concentrate. However, concentrating may need some endurance and effort and hence can be irritating. When the findings of the Study 2a are considered then it could be argued that children with ADHD are not able to inhibit the FFFS related avoidance motivation as efficient as TD children. Therefore, if maintaining concentration consumes excessive resources and results in the higher difficulty in the manipulation of information then this should be expected to lead to higher irritation and less willingness to continue engaging with task. This line of argument is supported by a finding in study 2b namely that children with ADHD with a higher levels of FFFS activation level obtains lower task-switching scores.

Present study findings suggest that the ability to concentrate and prolong concentration is related to the level of maintenance demand, and that maintaining information is a critical component in the concentration process. When there are not enough resources to allocate, concentration may not be achieved for very long. When the controlled attention resources are consumed, because of a struggle to maintain, fewer resources remain to be allocated for manipulation. That is why the distractibility and daydreaming that have often been observed among children with ADHD could appear due to an inability to spare enough resources to concentrate and manipulate.

6.4. Conclusion

Over many decades now, the search for the causal neuropsychological bases of ADHD has evolved from a single common deficit theory to one that emphasizes multiple causal pathways. Despite these theoretical advances, there has not been a corresponding distinct neuropsychological profile that can be utilised for diagnostic purposes (Roberts et al., 2017). Above all the other factors, the investigation of executive functioning and self-regulation impairment continues to occupy a central place in ADHD research. Theoretical knowledge advances in the expectation that it can help not only to explain ADHD symptoms but to contribute to the development of better diagnosis and treatment strategies. This doctoral thesis contributes to this important clinical literature by the examination of the interplay of reinforcement sensitivity, inhibition, and working memory processes. The findings make a novel and significant contribution to delineating neuropsychological bases of ADHD.

In this thesis, evidence was provided to support the claim that the Turkish version of the RST-PQ-C has good psychometric properties and can be reliably used among Turkish-speaking children, including those with a diagnosis of ADHD. The RST-PQ-C crucially separates the BIS from the FFFS. Although the validity of the concept of the FFFS scale has been questioned in the previous questionnaires, the RST-PQ-C provides substantive support for it – and is consistent with psychometric developments based closely on the rRST. A reliable scale can aid in the investigation of the role of this system in pathologies seen in childhood, and this role can be differentiated from BIS. In the present thesis, the RST-PQ-C is used for the first time within a child patient population. Present results consolidate the notion that reinforcement sensitivity plays an important role in ADHD. Findings of Study 2 reveal that a hypoactive BIS contributes to the frequency of avoiding mental effort; and, in contrast higher FFFS activity contributes to impaired executive functioning. This is an important differentiation and may be expected to stimulate new lines of research further to delineate the different effects of the FFFS and the BIS in the various dysfunctional processes implicated in ADHD. In general, these findings highlight that the RST-PQ-C has the potential to be used in future studies to examine the role of abnormal reinforcement sensitivity in the full range of ADHD-related impairments.

A consideration of motivational and neurocognitive factors together can be argued to be a step forward in explaining symptoms of ADHD. In Study 2a, it is concluded that impairment in prepotent motor response inhibition and hypoactivity in BIS result in a higher rate of mental effort avoidance in children with ADHD. This finding demonstrates a direct role for the BIS in the appearance of an ADHD symptom. According to the findings of this thesis, the BIS appears to be the main mechanism in the regulation of avoidance motivation. ADHD pathology involves motivational impairment and, therefore, it could be worthwhile further to investigate the role of the BIS in the observed motivational difficulties in ADHD, such as starting a task but leaving it when difficulty is encountered. Or, not start doing something because it has an irritating aspect, and leads to procrastination.

The findings of this thesis support the argument that inhibition plays a critical role as an underlying neuropsychological variable in ADHD symptom presentation. Furthermore, based on the results, it can be concluded that maintaining WM load results in impairment in the prepotent motor response inhibition and the task-switching abilities among children with ADHD. In the present thesis, findings provide clear evidence that maintaining WM load consumes an excessive amount of controlled attention resources and produces a problem in allocating the required amount of resources for optimal executive functioning performance, among children with ADHD. These findings call attention to the impaired maintenance ability of the WM in the child ADHD population and should encourage researchers to investigate the effects of impaired maintenance in the inattentive symptoms of ADHD.

One important clinical implication of the present work is the demonstration that the constructs (i.e., the prepotent motor response inhibition and the BIS) that are critical in the self-regulation of longer on-task behaviour are impaired among children with ADHD. It is plausible to argue that this impairment is related to frequently avoiding cognitively demanding school tasks and not doing homework. Hence, a cognitive training intervention that targeted the improvement of the prepotent motor response inhibition ability seems feasible for reducing the rate of avoiding mental effort. Moreover, the present findings add new insight into the role of maintaining WM load in prepotent motor response inhibition and the task-switching impairment. Accordingly, it can be argued that any intervention with the potential to improve maintenance ability would result in improved prepotent motor response inhibition and task-switching performance. Such an improvement may be expected to translate to enhanced daily life practices, as well as increasing the success in solving cognitively demanding problems: this may make a very significant contribution to the quality of life of children with a diagnosis of ADHD.

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Appendices

Appendix 1: symptoms in DSM-5 for ADHD diagnosis

1. Inattention
   a. Often fails to give close attention to details or makes careless mistakes in schoolwork, at work, or during other activities (e.g., overlooks or misses details, work is inaccurate).
   b. Often has difficulty sustaining attention in tasks or play activities (e.g., has difficulty remaining focused during lectures, conversations, or lengthy reading).
   c. Often does not seem to listen when spoken to directly (e.g., mind seems elsewhere, even in the absence of any obvious distraction).
   d. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (e.g., starts tasks but quickly loses focus and is easily sidetracked).
   e. Often has difficulty organizing tasks and activities (e.g., difficulty managing sequential tasks; difficulty keeping materials and belongings in order; messy, disorganized work; has poor time management; fails to meet deadlines).
   f. Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (e.g., schoolwork or homework; for older adolescents and adults, preparing reports, completing forms, reviewing lengthy papers).
   g. Often loses things necessary for tasks or activities (e.g., school materials, pencils, books, tools, wallets, keys, paperwork, eyeglasses, mobile telephones).
   h. Is often easily distracted by extraneous stimuli (for older adolescents and adults, may include unrelated thoughts).

i. Is often forgetful in daily activities (e.g., doing chores, running errands; for older adolescents and adults, returning calls, paying bills, keeping appointments).

2. Hyperactivity and impulsivity
   a. Often fidgets with or taps hands or feet or squirms in seat.
   b. Often leaves seat in situations when remaining seated is expected (e.g., leaves his or her place in the classroom, in the office or other workplace, or in other situations that require remaining in place).
   c. Often runs about or climbs in situations where it is inappropriate. (Note: In adolescents or adults, may be limited to feeling restless.)
   d. Often unable to play or engage in leisure activities quietly.
   e. Is often "on the go," acting as if "driven by a motor" (e.g., is unable to be or uncomfortable being still for extended time, as in restaurants, meetings; may be experienced by others as being restless or difficult to keep up with).
   f. Often talks excessively.
   g. Often blurts out an answer before a question has been completed (e.g., completes people's sentences; cannot wait for turn in conversation).
   h. Often has difficulty waiting his or her turn (e.g., while waiting in line).
   i. Often interrupts or intrudes on others (e.g., butts into conversations, games, or activities; may start using other people's things without asking or receiving permission; for adolescents and adults, may intrude into or take over what others are doing).

Appendix 2: Reinforcement Sensitivity Theory-Personality Questionnaire-Children Version

Instructions: can you please, read each statement carefully and then thick the box that describes you?

	Never	Some times	Often	Always
I would be careful when playing a game or sport				
I would stop and think before going down a hill on a skateboard, rollerblades, bike etc.				
I like to do new and exciting things				
I would be frozen to the spot if I saw a large shadow when swimming in the ocean				
I want to keep on improving (getting better) at my favourite things				
I would stop what I was doing if I thought there was physical danger or I might hurt myself				
I would be frozen to the spot if there was a snake or spider in the bathroom with me				
I worry about what would happen if I was hurt				
I like to practise something I like doing so I can get better				
I would run away if I saw a spider or snake				
I would stop what I was doing if I thought it was too risky to keep going				
I would freeze if I heard strange noises when in bed at night time				
I am interested in exploring places				
I would think carefully about trying out for something (e.g. sports team, school captain etc.) in case I didn't make it in				
I would run back upstairs if there were no lights on downstairs				
I put in lots of effort to achieve a goal (get where I want)				
I would freeze if I thought a bird was going to attack me				
would run away from an animal if it was making me feel scared				
I am careful when doing something that might hurt me				
I am training to be better at sport/things I like doing				
I work hard to do well at the things I like doing				

Appendix 3: parent consent form for study 2

CITY UNIVERSITY LONDON

Information and the consent form for parent

Name of the study that we want to carry is 'Investigating the avoidance behaviour and the working memory impairment in the children with ADHD'. Purpose of the study is discovering the variables and their effects on the avoidance behaviour and the concentration in the children with Attention Deficit Hyperactivity Disorder (ADHD). We want to invite your child to be in the control group. You do not have to give your permission and may choose not to allow your child to participate in the study. During the study two questionairres will be given to your child to complete. Then, 10 cognitive tests will be given for assessing his/her cognitive performance. There will be one session. The whole study will not takemore than 60 minutes.

There are no foreseen disadvantages of taking part in the study for your child. However, if a child want to withdraw during the study he can do so without being have to produce an explanation. If you want to take more information about the study you can do so by contacting Ibrahim Orhan Bahtiyar by phone [redacted] or by e-mail [redacted]. If you want to contact the supervisor of the project you can send e-mail to [redacted] .This study is undertaken as a part of a PhD project and approved by City University of London and Near East University. If you want to complain about anything you can write to

Can you please tick the appropriate blank place below?

The study has been explained to me. I know what is involved and what my child need to do.

I give my consent for my child to participate in the study ……………………………….

I do not give my consent for my child to participate in the study …………………………..

Name of Parent:

Name of Children:

Signature:

Appendix 4: children informed consent form

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LONDON

Young Person Consent Form

	✓ Yes	X No
Has somebody explained what we will be doing today?		
Do you understand what you are asked to do?		
Do you have any questions?		
Have you understood the answers to your questions?		
Do you understand that you can stop working with us at any time?		
Are you happy to be part of this study?		

Your Name: ____

Signed: ____

Today's Date: ____

My Name: ____

Appendix 5: parent informed consent form for study 2 (clinical group)

CITY UNIVERSITY LONDON

Informed Consent Form for Parents/Guardians of Project Participants

Project Title: Investigating the avoidance behavior and the working memory impairment in the children with ADHD

I agree that my child ……………………………………(full name of child) for whom I am a guardian may take part in the above City University London research project. The project has been explained to

...............……….…….. and to me, and I have read the Participant Information Sheet, which I may keep for my records.

I understand that agreeing to take part means that I am willing to allow

…………………………………………………………………(Principal Investigator) to: give me or to my child to complete questionnaires asking me or my child about reward sensitivity and academic motivation. Use pen and paper or computerized cognitive test for assessing my child's cognitive abilities.

Data Protection

This information will be held and processed for the following purpose(s): investigating the interaction of the variables that causes the avoidance behavior and cognitive difficulty.

I understand that any information ……………………………………. (full name of child) provides is confidential, and that no information that could lead to the identification of any individual will be disclosed in any reports on the project, or to any other party. No identifiable personal data will be published. The identifiable data will not be shared with any other organisation.

I understand that ………………………’s (full name of child) participation is voluntary, that s/he can choose not to participate in part or all of the project, and that s/he or I can withdraw at any stage of the project without being penalised or disadvantaged in any way.

Participant’s Name: .... (please print)

Participant’s Age:......................

Your relationship to participant: ....

Signature of Parent/Guardian: ....Date:...............................

Appendix 6: ethics approvals from CUL and NEU

Psychology Research Ethics Committee

School of Arts and Social Sciences

City University London

London EC1R 0JD

20 October 2017

DearIbrahimBahtiyarOrhan and Professor Philip Corr:

Reference:PSYETH (R/F) 17/18 02

Project title:Effect of reinforcement sensitivity on the avoidance behavior and the role of working memory in the cognitive impairment in the ADHD

I am writing to confirm that the research proposal detailed above has been granted approval by the City University London Psychology Department Research Ethics Committee.

Period of approval

Approval is valid for a period of three years from the date of this letter. If data collection runs beyond this period you will need to apply for an extension using the Amendments Form.

Project amendments

You will also need to submit an Amendments Form if you want to make any of the following changes to your research:

(a) Recruit a new category of participants

(b) Change, or add to, the research method employed

(c) Collect additional types of data

(d) Change the researchers involved in the project

Adverse events

You will need to submit an Adverse Events Form, copied to the Secretary of the Senate Research Ethics Committee [redacted], in the event of any of the following:

(a) Adverse events

(b) Breaches of confidentiality

(c) Safeguarding issues relating to children and vulnerable adults

(d) Incidents that affect the personal safety of a participant or researcher

Issues (a) and (b) should be reported as soon as possible and no later than 5 days after the event. Issues (c) and (d) should be reported immediately. Where appropriate the researcher should also report adverse events to other relevant institutions such as the police or social services.

Should you have any further queries then please do not hesitate to get in touch.

Kind regards,

[redacted]

Ethics committee Secretary Chair

Email: [redacted]

YAKIN DOĞU ÜNİVERSİTESİ

BİLİMSEL ARAŞTIRMALAR ETİK KURULU

30.03.2017

Dear İbrahim Bahtiyar,

Your application titled "**Effect of reinforcement sensitivity on the avoidance behavior and the role of Working memory in the cognitive impairment in the ADHD**"with the application number YDÜ/SB/2017/10 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

[redacted]

Rapporteur of the Scientific Research Ethics Committee

[redacted]

Note: If you need to provide an official letter to an institution with the signature of the Head of NEU Scientific Research Ethics Committee, please apply to the secretariat of the ethics committee by showing this document.

Appendix 7: permission of data collection from Ministry of Health of TRNC, for study two

KUZEY KIBRIS TÜRK CUMHURİYETİ
SAĞLIK BAKANLIĞI
YATAKLI TEDAVİ KURUMLARI DAİRESİ

Sayı. YTK.0.00-1/2013-16/ 298 Lefkoşa : 20.01.2016

Barış Ruh ve Sinir Hastanesi . **Başhekimliği,**
Lefkoşa.

City Univercity London'da doktora eğtimi alan İbrahim Bahtiyar'ın, "Çocuklarda Dikkat Eksikliği-Hiperaktivite Bozukluğu" ile ilgili tez çalışmasını, Mart 2016 – Mart 2017 tarihleri arasında Hastaneniz polikliniğine başvuran Çocuklara uygulaması ve çalışmasının raporlarını Bakanlığımızla paylaşması kaydıyla Müdürlüğümüzce uygun görülmüştür.

Bilgilerinizi ve gereğini saygı ile rica ederim.

[redacted]

Dağıtım: Sn. İbrahim Bahtiyar,
City Univercity London

EI. 15/8U

Adres: Bedreddin Demirel Caddesi No: 142 Lefkoşa.
Tel: (+90 392) 228 3173, 228 4011, 228 4068 / Faks: (+90 392) 228 4247

TURKISH REPUBLIC OF NORTHERN CYPRUS

MINISTRY OF HEALTH

DEPARTMENT OF INPATIENT TREATMENT INSTITUTIONS

Number. YTK.0.00-1 / 2013 – 16/298 Lefkoşa: 20,01,2016

Barış Ruh ve Sinir Hastanesi , **Administration,**

Lsefkoşa.

Ibrahim Bahtiyar who studies for a PhD in the City University London has given the permission to carry his study which is about 'Attention Deficit Hyperactivity Disorder' between March 2016 and March 2017 in the children's psychiatry unit with the children who applies with the condition with the only condition that he will need to prepare a report about the study results when he complete his study.

[redacted]

Head of the inpatient treatment institution

Distribution to : Mr.Ibrahim Bahtiyar

City University London

Appendix 8: permission from the head master of the Near East Junior college for collecting data for control group

YAKIN DOĞU ÜNİVERSİTESİ

Friday, March 17, 2017

To the Chairman of the Near East University, Institutional Review Board,

The particular section(s) of the Study entitled 'Investigating the reasons of the cognitive weakness and the avoidance behavior in the Attention Deficit Hyperactivity Disorder (ADHD) will be conducted in the Near East Primary School under my supervision.

With respect,

[redacted]

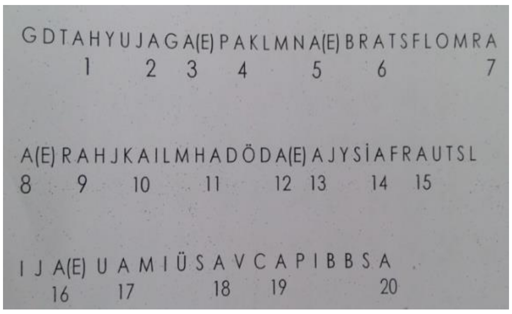
Head Master of the Primary school

THE NEAR EAST JUNIOR COLLEGE 1926

Appendix 9: description and instructions of neuropsychological tests that were used within the Cognitive Effort Avoidance Measure in the study 2a.

Auditory Continuous Performance Test

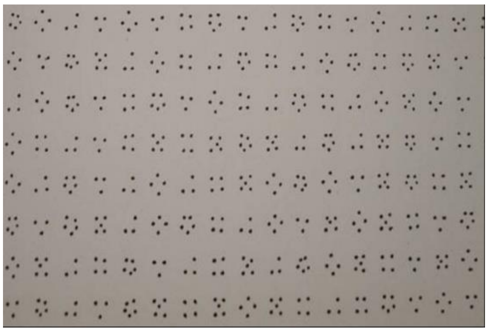
Auditory Continuous Performance Test (ACPT; Rosvold et al., 1956) was developed for the assessment of the sustained auditory-attention performance. Sustained auditory attention can be defined as maintaining attention on particular auditory stimuli in a given time interval. The task involved a presentation of constantly changing auditory stimuli (letters of Latin alphabet) with a clearly defined target (letter A). The participant was instructed to listen to the spoken letters and respond by hitting a pen on the table when he or she hears the sound of the target letter. Test administrator read the randomized letters by one letter per second. There were 20 target letters in a run. The accurate and inaccurate responses of the participant were recorded. The output measures for this test were omission (missed letters) and commission (responding to a non-target letter) errors. Test-retest reliability of ACPT was reported be .74 (Rosvold et al., 1956).



A snapshot of the Auditory Continuous Performance Test

Bourdon-Vos Test

Bourdon-Vos Test (Vos, 1998) was developed for measuring sustained visual attention. This is a cancellation test in which 10 rows of 25 small dot patterns are presented. Each pattern can include three, four or five dots. The pattern that composed of four dots is the target to be cancelled. The participant was instructed to circle out the targets as fast and as accurately as possible in normal reading order. The Bourdon-Vos Test was validated and the norms were established for the age groups 6 to 18 years old (Vos, 1998). Obtained output was the total number of the omission errors (i.e., missed targets).



A snapshot of the Bourdon-Vos Test

Vocabulary Test

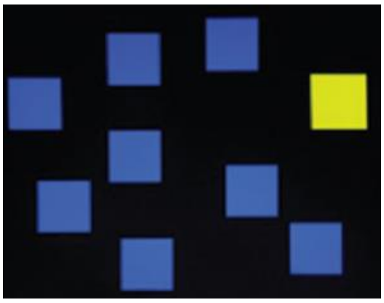
The vocabulary subtest of WISC-IV (Wechsler, 2011) was developed for measuring knowledge of word meanings and verbal concept formation. In this test, the participant is asked to give oral definitions of words. The participant can obtain 0, 1 or 2 depending on the quality of his or her answer. A participant can be given up to 30 words but the test is discontinued after three consecutive incorrect answers that scored 0. This subtest was translated into Turkish language and validity/reliability evidence was provided using a sample that included 2225 children (Uluç et al., 2011).

Working Memory - Switch Task

Working memory-switch Task (Hester & Garavan, 2005) used in this study was a variation of the Sternberg Memory Task (Sternberg, 1975). This task was developed for the assessment of the task-switching ability. The following score was recorded: number of correct task-switching responses (i.e., task-switching accuracy). The scores obtained from this instrument were also used in the investigation that took place in study 2b. Task-shifting performance was critical in the investigation of factors that affects executive functioning performance. Hence, detailed description of this test is presented in the method section of the study 2b, on pages 147-148 of the present thesis.

Corsi Block-Tapping Test

Corsi Block-Tapping Test (CBTT; Corsi, 1972) was developed for the assessment of visual working memory span. The visual working memory can be defined as the ability to maintain visual representations for a period of time. Windows based computer with a 17-inch coloured screen was used for the presentation of stimuli. Nine blue squares (3x3 grids) appeared on the screen and their locations were fixed throughout the runs. Blue squares lit up briefly one after another in a particular sequence. The participant was instructed to watch the glowing squares, on a computer screen, until the end of the presentation and produce the same sequence right after the end of each presentation by tapping on the squares using a computer mouse. The same stimuli sequences were administered to all children. Each participant had a practice run to make sure that he or she was understood what to do. The length was increased after every second trial, starting at two and ranging to nine squares lighting up in a sequence. Each level included two trials. The test was terminated when a participant failed in both trials at a given level. The output score was the length of the memory span where the last two consecutive correct responses were obtained.



A snapshot of the Corsi Block Tapping Test

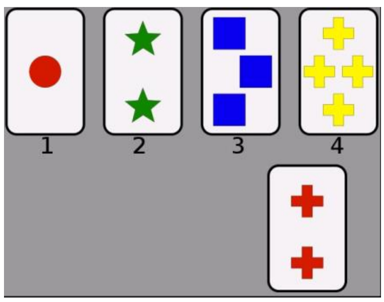
Go/no-go Task

Go/no-go Task with working memory load was a variation of the Sternberg memory task (Sternberg, 1975). The version modified by Hester and Garavan (2005) was used in this study. This task was developed to assess the prepotent response inhibition ability. The prepotent response inhibition performance was critical in the investigation of avoiding mental effort and this task was presented in detail in the method section of the chapter four, on pages 112- 113.

Wisconsin Card Sorting Test

Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948) was developed as a measure of executive functioning. An executive function can be defined as a consciously controllable brain function that can be used for problem-solving in challenging situations. WCST assesses the ability to establish a set, maintaining a set and adapting to a rule-change. The stimuli were presented using a Windows-based computer and 17-inch colour screen. There were two rows of cards. Four cards were located at the bottom row (stimulus cards) and one card was located at the top row (target stimulus card). Cards were in colour and presented on a grey background.

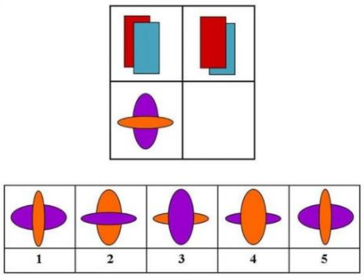
Each card contained geometrical symbols but the symbols varied in terms of shape, colour or number. The participant was given 64 cards that vary along the same dimensions and are asked to match the cards in the deck with one of the four stimulus cards. The participant was instructed to make a correct match by pressing one of the numeric keys between one and four on the computer keyboard. The participant received feedback on the computer screen for the correct match (O) or incorrect match (X) after each response. The sorting strategy was to be inferred from the feedback provided. Once 10 consecutive cards are categorized correctly, the sorting principle changed without warning or comments from the examiner, and all sorts, made according to the previous strategy received negative feedback. Obtained scores were total correct, perseverative responses, categories completed, and trials to complete the first category. Romine et al. (2004) carried a meta-analytic study for assessing the sensitivity and specificity of WCST in neurodevelopmental disorders and they reported that WCST had high sensitivity in detecting executive functioning impairments among children with ADHD.



A snapshot of the Wisconsin Card Sorting Test

Matrix Reasoning Test

Matrix reasoning subtest of Wechsler Intelligence Test for Children - IV (WISC-4; Wechsler, 2011) was used for assessing abstract reasoning ability. Participants were presented with a partially filled grid and instructed to select the item that properly completed the matrix. For example, participants saw two sets of shapes, such as stars and pentagons, with one set arranged in a certain colour sequence. The participant then had to determine the correct colour sequence of the second set of shapes to complete the grid. Banks and Franzen (2010) provided convergent validity evidence showing that the Matrix reasoning subtest had a high positive correlation with Test of Nonverbal Intelligence.



A snapshot of the Matrix Reasoning Test

Choice Delay Task

Choice Delay Task (CDT; Sonuga-Barke, Taylor, Sembi, & Smith, 1992) was developed for assessing preference for a small but immediate reward instead of a larger but later reward. A 17-inch colour monitor was used for presenting the stimuli. In this task, the participant made a fixed number of repeated choices between a smaller reward delivered immediately and a larger reward delivered after a delay. Participants were instructed to click on one of two squares presented on the computer screen. They were told that the first one earns less money but involves no waiting. On the other hand, the second one earns more money but has a 30 seconds delay before he or she can choose again. The number of choices of the smaller reward was recorded as the measure of delay aversion.

Estimated Intelligence

Wechsler Abbreviated Scale of Intelligence- Second Edition

Wechsler Abbreviated Scale of Intelligence-Second Edition (WASI-II; Wechsler, 2011) was developed to provide a short and reliable estimate of intelligence. WASI-II includes four subtests: Vocabulary, Similarities, Block Design, and Matrix Reasoning. An estimate of general intellectual ability can be obtained by using the Vocabulary subtest and Matrix reasoning subtest, together. These two subtests provide a good assessment of the full scale estimated intelligence. Obtained raw scores from two subtests were transformed into T scores. Then the sum of these T scores was used to produce the estimated full IQ. Research, provided evidence for adequate reliability for children between the ages of 7 to 11 years, with internal consistency coefficients for vocabulary ranging from .86 to .92 and for matrix reasoning ranging from .98 to .94 (Wechsler, 2011).