UNIVERSIDADE FEDERAL DE MINAS GERAIS

HEATHER KIM-ANN BAYLEY

USEFULNESS OF THE FIVE DIGIT TEST IN ATTENTION DEFICIT AND HYPERACTIVITY DISORDER AS A PREDICTOR OF READING AND ARITHMETIC DIFFICULTIES

BELO HORIZONTE

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Heather Kim-ann Bayley

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PROGRAMA DE PÓS-GRADUAÇÃO EM MEDICINA MOLECULAR

FOLHA DE APROVAÇÃO

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HEATHER KIM-ANN BAYLEY

Dissertação submetida à Banca Examinadora designada pelo Colegiado do Programa de Pós-Graduação em MEDICINA MOLECULAR, como requisito para obtenção do grau de Mestre em MEDICINA MOLECULAR, área de concentração MEDICINA MOLECULAR.

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Resumo

A avaliação neuropsicológica é uma ferramenta importante na identificação de comprometimentos cognitivos. Dito isso, o Teste dos Cinco Dígitos pode ser uma medida útil das funções executivas e ajuda a prever dificuldades de leitura e aritmética em crianças com Transtorno de Déficit de Atenção e Hiperatividade (TDAH). O TDAH é um transtorno do desenvolvimento neurológico caracterizado por dificuldade em regular a atenção e controlar impulsos e hiperatividade. As deficiências mencionadas complicam o processo de aquisição de habilidades complexas, como escrita, leitura e aritmética. Objetivo: Analisar o FDT como uma ferramenta para prever dificuldades de leitura e aritmética em crianças com TDAH. Método: A amostra foi composta por 105 participantes do Núcleo de Investigação da Impulsividade e Atenção (NITIDA) que foram diagnosticados com TDAH. Foram excluídos os participantes cujos sintomas se deviam a outros fatores, como síndromes, doenças neurodegenerativas (epilepsia, convulsões, tumores cerebrais, hidrocefalia e agenesia do corpo caloso) e incapacidade intelectual. Foram utilizados os seguintes instrumentos: MTA-SNAP-IV para medir sintomas de TDAH, K-SADS-PL - como questionário para pais / responsáveis, *The Child Behavior Checklist* (CBCL) para medidas psicossociais, Matrizes Progressivas de Raven e Escala Especial para medir a inteligência, Teste de Desempenho Escolar (TDE) para medir o desempenho acadêmico e O Teste dos Cinco Dígitos (FDT) para medir as funções executivas. Os dados foram analisados por modelos de regressão logística binária, utilizando o procedimento *Forward Wald*. Resultados: a etapa de leitura do FDT, que foi associada à tarefa de escrita, envolve a velocidade geral de processamento e o reconhecimento automático de estímulos, neste caso, números de 1 a 5. Em outras palavras, a nomeação automatizada atua como uma condição prévia para a aquisição de habilidades de leitura, fundamentais para a escrita, explicando essa associação. Houve também uma associação entre o desempenho em tarefas aritméticas no TDE e no FDT, contando o tempo e a inteligência fluida.

Palavras-chave: Processos Cognitivos; Teste dos Cinco Dígitos; Desempenho Escolar; Transtorno de Déficit de Atenção e Hiperatividade.

Abstract

Neuropsychological assessment is an important tool in identifying cognitive impairments. In the same breath, the Five Digit Test is a useful measure of executive functions and can help predict reading and arithmetic difficulties in children with Attention Deficit and Hyperactivity Disorder (ADHD). ADHD is a neurodevelopmental disorder characterized by having difficulty with regulating attention and controlling impulses and hyperactivity. Aforementioned impairments complicate the process of acquiring complex skills such as writing, reading, and arithmetic. **Aim:** Analyze the FDT as a tool in foreseeing reading and arithmetic difficulties in children with ADHD. **Method:** The cohort included 105 participants from the Research Centre of Impulsivity and Attention (NITIDA) who were diagnosed with ADHD. Participants whose symptoms were due to other factors, such as syndromes, neurodegenerative diseases (epilepsy, seizures, brain tumors, hydrocephalus, agenesis of the corpus callosum, etc.) and intellectual disability were excluded. The following instruments were used: MTA-SNAP-IV for measuring ADHD symptoms, K-SADS-PL - as parent / guardian questionnaire, The Child Behavior Checklist (CBCL) for psychosocial measures, Raven's Progressive Matrices and Special Scale to measure intelligence, School Achievement Test (TDE) to measure academic achievement and The Five Digit Test (FDT) to measure executive functions. Data was analyzed by binary logistic regression models, utilizing the *Forward Wald* procedure. **Results:** The FDT reading step, which was associated with the writing task, involves overall processing speed and the automatic recognition of stimuli, in this case numbers from 1 to 5. In other words, Rapid Automatized Naming acts as a precondition for the acquisition of reading skills, which are fundamental to writing, thus explaining this association. There was also an association between performance in arithmetic tasks in TDE and FDT counting time and fluid intelligence.

Keywords: Cognitive Processes; Five Digit Test; School Achievement; Attention Deficit Hyperactivity Disorder.

List of Tables

List of Abbreviations and Initials

ADHD: Attention Deficit and Hyperactivity Disorder

APA: American Psychological Association

CBCL: Child Behavior Checklist

COEP: (Comitê de Ética em Pesquisa) Research Ethics Committee

DDH: Double Deficit Hypothesis

DSM-5: Diagnostic and Statistical Manual of Mental Disorders

EFs: Executive Functions

FDT: Five-Digit Test

FMRI: Functional Magnetic Resonance Imaging

IQ: Intelligence Quotient

K-SADS-PL: Kiddie-SADS-Present and Lifetime Version

LD: Learning Difficulties

MD: Mathematical Difficulties

MTA SNAP-IV: Swanson, Nolan, and Pelham– version IV

NITIDA: (Núcleo de Investigação da Impulsividade e Atenção) Research Centre of Impulsivity and Attention

NPA: Neuropsychological Assessment

ODD: Oppositional Defiant Disorder

PA: Phonological Awareness

RAN: Rapid Automatized Naming

RD: Reading Difficulties

TDE: (Teste de Desempenho Escolar) School Achievement Test

UFMG: Universidade Federal de Minas Gerais

WM: Working Memory

CONTENTS

1. Introduction

Executive Functions (EFs) refer to higher cognitive processes that regulate emotion and behavior (Barkley, 2002). These abilities involve mental skills that include attention, inhibitory control, interference control, working memory, flexibility, and self-regulation. The aforementioned skills are essential to everyday tasks, learning, work, and managing daily life. Trouble with executive functions can make it hard to focus, follow directions, and handle emotions, among other things (Best & Miller, 2010).

Furthermore, cognitive processes have to operate in harmony in order to adequately adapt to the environment. Executive functions are responsible for such demands and coordinating these processes. Ingrained in cognitive capacities is attention, which can be both voluntary and involuntary, and greatly impacts many other cognitive functions (Lodge & Harrison, 2019). Even though it is a restricted capacity because of the limited neural resources to process the complexity of the stimuli, the cognitive ability to allocate our attention selectively allows us to prioritize only some elements of the environment while filtering out others (Hasher et al, 2007). This is also known as inhibitory attentional control. Inhibitory control involves not only being able to control one's attention, but also ignoring unwanted or unnecessary stimuli.

Moreover, along with inhibitory control being an essential part of attentional processes, working memory (WM) is also fundamental in selective, focused attention. As a matter of fact, WM and attention are similar considering when one focuses attention on information and is able to hold that information in the mind for a period of time. They work hand in hand, even on a neural basis (Fisk & Schneider, 1984). While the prefrontal parietal structure is the pillar for WM, selectively focusing on information while blocking out unwanted stimuli also relies on the prefrontal parietal structure. Studies have proven that training WM can also improve selective attention (Capodieci et al., 2018).

While inhibitory control and WM involve attention, cognitive flexibility involves the ability to change perspective. Cognitive flexibility depends on the skill of inhibiting or inactivating one's previous mindset and activating a different one. This process is done in WM. In other words, cognitive flexibility depends on inhibitory control and WM (Collins & Koechlin, 2012). Developing cognitive flexibility is essential for problem solving skills.

Henceforth, it is indisputably clear that cognitive processes work conjointly in the learning process. Studies also show that mathematical ability, for example, is related to executive functions in school-age children (Capano et al., 2008). Both working memory and inhibition control are predictors for early arithmetic competency, including child age, maternal education, and child vocabulary (Loe & Feldman, 2007) and with evidence from Miyake et al. (2000).

In the same breath, literacy skills, which include reading and writing, are preconditions for academic and social success (Borella, Carretti & Pelegrina, 2010; Duncan et al., 2007; Gathercole, Pickering, Knight & Stegmann, 2004). Identifying early predictors of literacy skills may help prevent academic failure, loss of self-confidence, and weakening children's incentives in primary school age (Capano et al., 2008).

Evidently, typically developing cognitive functions are preconditions for positive learning outcomes (Amber et al., 2019). However, when cognitive processes are impaired, it interrupts the learning process, as in the case of Attention Deficit and Hyperactivity Disorder (ADHD), in which executive functions are primarily debilitated (Barry, Lyman & Klinger, 2002). ADHD is a neurodevelopmental disorder. The main characteristics involve difficulty with regulating attention and controlling impulses and hyperactivity. Consequently, ADHD affects all aspects of life, including school performance, work, relationships, health, and finances. Impairments in executive functions can have a major impact on the ability to perform tasks such as planning, prioritizing, organizing, paying attention to, and remembering details, and controlling emotional reactions (Barkley, 2002). Furthermore, such impairments complicate the process of acquiring complex skills such as writing, reading, and arithmetic (Czamara et al., 2013). Acquiring reading, writing, and arithmetic skills involve primary automatic cognitive processes, which include the aforementioned rapid automatized naming (Lervåg & Hulme, 2009) in reading and writing skills and Subitizing (Haase, 2011) in arithmetic skills. Nonetheless, the good news is that ADHD can be successfully treated and managed.

With proper neuropsychological evaluation, tests, such as the Five Digit Test (FDT), while investigating executive function impairment, may also play the role of predicting arithmetic and literacy skills in children with ADHD, since both demand EFs. The FDT measures executive functions based on five quantities as simple recurrent cognitive units within tasks of increasing difficulty (Sedó, de Paula & Malloy-Diniz, 2015). The FDT also allows one to measure the speed and efficiency of cognitive processing, the consistency of focused attention, the progressive automatization of the task, and the ability to mobilize additional mental effort and inhibitory resources when sets are increasingly difficult and require much greater concentration.

Understanding these processes and being better able to assess them can be beneficial in predicting and later treating reading and mathematical difficulties since the connection between executive functions have a direct connection to learning outcomes. Studies indicate that problems in literacy skills, including inhibitory functions, are related to difficulties in comprehension abilities (Marini et al., 2020). The inhibitory inefficiency of children with difficulties in comprehension, however, is most commonly measured by WMs ability to ignore off-goal task information. This indicates that inhibitory control problems are related to reading problems in children with reading difficulties. Moreover, studies also show that there is a relationship between working memory skills and performance in mathematics, in particular with performance on complex span tasks (Borella et al., 2010).

2. Literature Review:

2.1 Attention deficit and hyperactive disorder

Attention deficit and hyperactivity disorder (ADHD) is a common and challenging neuropsychological disorder characterized by persistent and age-inappropriate patterns of inattention, hyperactivity-impulsivity, or both (APA, 2014). It is well known that ADHD has a negative impact in different areas of life, such as social, societal, familial, vocational, and academic (Brown & Landgraf, 2010; Borella et al., 2010). The latter will be the focus of this dissertation.

It is important to note that the vast majority of children, particularly boys, who are diagnosed with ADHD, in order to counter the negative effects, stimulant medication is used (Schmidt, 2009). However, research confirms that the essence of ADHD symptoms, which include inattention, hyperactivity and impulsivity are not exclusive to ADHD. The comorbidity of mental and learning issues, including depression and anxiety, which highly overlap with ADHD (APA 2014), pose difficulties in diagnosis and treatment that do not include medication.

2.1.1 ADHD from a neurobiological and neuropsychological perspective

In an effort to understand, effectively diagnose, treat, and increase the effectiveness of medication and intervention in young children with ADHD, looking at it from a neural standpoint may be beneficial. It is crucial to understand how the ADHD brain works. This includes the wiring, the circuits, and the networks. Neuroimaging studies present evidence of structural and functional brain differences in children with ADHD (Albajara Sáenz, Villemonteix, & Massat, 2019). Such evidence indicates a neural basis for the cognitive and behavioral impairments. Research shows that ADHD brains have a smaller prefrontal cortex and basal ganglia, and decreased volume of the posterior inferior vermis of the cerebellum (Sowell et al. 2003). These areas are responsible for executive functions (EFs), focus and attention (Nakao, Radua, Rubia & Mataix-Cols, 2011). What this means is that the behavioral difference in ADHD is partially due to the neuroanatomic anomalies observed in children with ADHD. What may look like behavioral choices, for instance fidgeting, is likely due to said neuroanatomical differences in brain structure. Research has shown reduced gray matter in the caudate nucleus, the brain region that is responsible for integrating information across different parts of the brain and supports cognitive processes, including memory (Almeida Montes et al., 2010).

The underlying neurotransmitter responsible for the balance of the basal ganglia is dopamine (Emson, Waldvogel & Faull, 2010). Evidence from pioneering studies found that the higher hyperactivity symptomatology in boys was positively correlated with higher levels of dopamine metabolite in cerebrospinal fluid (Zametkin et al., 1990). Moreover, dopamine dysfunction in ADHD can be found in a functional magnetic resonance imaging (FMRI) study that proved children with ADHD had reduced activity in the frontal-striatal regions and showed impaired performance on response inhibition tasks (Teicher et al., 2000). Additionally, methylphenidate, which acts on the dopamine transporter, increased both frontal-striatal activity and performance on response inhibition tasks (Singh, Yeh, Verna & Das, 2015).

Research shows that ADHD can also be defined on the basis of cognitive dysregulation, a top-down dysfunctional regulation of cognitive capacities unrelated to emotional information processing (Petrovic & Castellanos, 2016). These include inattention, hyperactivity, and impulsivity. Evidence suggests that the relationship between biology and behavior in children with ADHD was mediated by a cool executive – inhibitory – dysfunction (Sonuga-Barke, 2002).

ADHD was presented on a neural level, pinpointing the relationship neuroanatomy has with cognitive processes, specifically attention, working memory (WM) and executive functions. A comprehensive neuropsychological assessment should evaluate all of these functional domains and generate recommendations for treatment of ADHD that consider any co-occurring conditions, in this case reading difficulties (RD) and mathematical difficulties (MD). Understanding reading and arithmetical difficulties also involve understanding the cognitive processes (Silver et al., 2006).

Cognition involves acquiring and understanding knowledge through perception, and learning, conjointly related to cognition, involves acquiring knowledge through experience. Note importantly that both are inexorably linked - learning requires cognition and cognition involves learning (Greeno, Collins & Resnick, 1996). Whenever one perceives by means of seeing or hearing something new, a series of cognitive processes take place and essentially result in learning.

It is widely known that attention affects one's perception and experience of the environment (Tong, 2018). Studies have also demonstrated that attention is limited both in capacity and in duration. It is also selective (Zanto & Gazzaley, 2016). Since attention is a limited resource, one has to be selective about what one decides to focus on, otherwise known as the top-down attentional process (Hopfinger, Buonocore & Magnun, 2000; Gazzaley & Nobre, 2012). Not only must one focus their attention on specific stimuli, but one must also filter out and ignore an enormous number of stimuli.

After stimulus is perceived, the information being paid attention to has to be put into memory in a process called storage (Frankland, Josselyn & Kohler, 2019). The memory system requires three characteristics: the ability to encode, or enter information into the system, to store it and later find and retrieve that information. However, while these three stages serve different functions, they interact: the encoding or coding method determines what and how information is stored, which in turn will limit what can be recalled or retrieved thereafter. If one pays attention to stimuli, that information will be registered into short-term memory. This part of one's memory retains the knowledge for a limited period (Baddeley, 1992). If one continuously repeats that information, it has the chance to move to long-term memory. This region has infinite storage capacity and can retain details indefinitely. The challenge, however, can be in retrieving that information.

Along with attention and memory, executive functions (EFs) are another set of cognitive processes that impact the learning outcome. EFs are responsible for one's cognitive ability to control and inhibit behavior. In other words, it is the ability of shifting, selecting and successfully monitoring behaviors that facilitate learning and contribute to a successful life (Lehto, Juujärvi, Kooistra & Pulkkinen, 2003). Characteristics of EFs include behavior inhibition, interference control, working memory and cognitive flexibility (Diamond, 2013). Studies show that these skills are not only vital to overall health, social and psychological development, but also predictors of success in school and in life (Gathercole et al., 2004).

It is safe to say that unimpaired EFs lead to a better quality of life. They are certainly more important for school success than intelligence quotient (IQ) since they work hand in hand with math and reading acquisition (Brown & Landgraf, 2010). The ability of controlling one's attention, behavior, thoughts, and emotions so as to overturn a tendency and alternatively do what's necessary without giving in to impulses or habits is known as inhibitory control, which allows for change and choice (Hasher, Lustig & Zacks, 2007). Inhibitory control of attention, also considered as interference control at the act of perception, allows one to focus on specific stimuli while ignoring distractors in the environment (Theeuwes, 1994; Wixted & Serences, 2018). When one unexpectedly hears a knock at the door that attracts one's attention while reading a book, it is known as bottom-up, automatic, or involuntary attention (Katsuki & Constantinidis, 2014). On the other hand, one can choose to ignore the knock at the door or inhibit attention to the stimuli and revert to the book is known as attentional control or attentional inhibition, top-down attention (Serences et al., 2005; Theeuwes, 1994).

Also, inhibitory control supports working memory (Raver & Blair, 2016). In order to connect a set of ideas, one should withstand focusing solely on just one and recognize that combining separate ideas creates new patterns. Resisting distractions is essential to such a combination. If one's inhibitory control fails, one's mind may wander (Hasher, Zacks & May, 1999). In reading a passage, for instance, conducive to understanding what was read, one must pay attention to the words combined and not the meaning of each word independently.

Based on an academic outcome standpoint, well developed reading, and mathematical abilities, as mentioned before, are preconditions for social and academic success (Borella et al., 2010; Duncan et al., 2007). In avoiding academic failure, it is important to determine early predictors of reading and arithmetic skills. One of the baseline predictors of typical reading skills, for example, is phonological awareness.

Phonological awareness (PA) plays an important role in learning to read (Melby-Lervåg, Lyster & Hulme, 2012). Poor phonological awareness is usually present in children with ADHD + Reading Difficulties (RD) and RD alone. It is evident, then, that PA is an important predictor of their poor reading abilities (Boets et al., 2012). It is additionally conceivable that children with RD show impairment in their working memory, and word reading proficiency (Swanson, Zheng, & Jerman, 2009). In such cases, working memory foresees not only phonological awareness but also word reading efficiency (Christopher et al., 2012).

The fact that children with RD show problems on the more difficult phonological tasks, difficulties in Rapid Automatized Naming (RAN) could be caused by the higher demand these tasks put on working memory (Wolf & Bowers, 1999). Unlike short-term memory, which is the capacity to retain limited amounts of information in mind for a short time, making it readily available for use, working memory is concerned with the processing of new information by coding and updating the information stored in the working memory (Miyake et al., 2000). Adequate working memory functions are directly related to the typical development of phonological awareness and word-reading capacity, and as such, working memory has an influence on reading efficiency thanks to phonological awareness (Michel et al., 2019). In typically developing children, working memory has also been shown to predict phonological acquisition (de Abreu et al., 2011) and word reading abilities (Christopher et al., 2012). Children with ADHD + RD generally show deficits in working memory and having phonological awareness and word reading efficiency problems (Swanson, Zheng & Jerman, 2009).

From the abovementioned, it can be concluded that impaired working memory plays a role in lower achievements on phonological awareness tasks. This succeedingly, lowers reading efficiency (Koop-van Campen, Segers & Verhoeven, 2018). As a matter of fact, harder phonological awareness tasks lean on working memory and its ability to constantly update and renew information. In this light, verbal working memory acts as a mediator between phonological awareness and reading efficiency. According to Loucas, Baird, Simonoff and Slonims (2016), it was argued that children with RDs access to phonological representations were impaired, but the phonological representations were unscathed. Needless to say, in agreement with Berninger (2008), working memory is attributed to phonological awareness, word reading efficiency and consequently reading abilities. Reiterating, it was also found that RD in adults is correlated to phonological awareness and working memory, and that the difficulties were mainly characterized by working memory deficits (Gathercole, Alloway, Willis & Adams, 2006).

On a similar note, in keeping with Lopes-Silva, Moura, Júlio-Costa, Geraldi Haase, and Wood's (2014) research on numerical cognition, it was proposed that phonetic awareness mediated the influence of verbal working memory, which can be compared to the previous argument that successful phonological awareness is dependent on unimpaired verbal working memory and its role in number transcoding.

Research supports that typically developing cognitive processes are preconditions for acquiring more complex abilities. Needless to say, when cognitive processes are impaired, this disrupts successful learning outcomes, as in the case of ADHD, in which executive functions are primarily dysfunctional (Barry, Lyman & Klinger, 2002).

2.1.2 Executive functions and ADHD

Studies have shown that neurodevelopmental disorders, akin to Attention deficit and hyperactivity disorder (ADHD) and learning difficulties (LD), often co-exist (Schuchardt et al., 2015). The predominance rates of ADHD without LD and LD without ADHD are both about 5%, with a comorbid rate of 20–60% (Huang et al., 2016). A cohort study has shown that children with ADHD symptoms had a higher risk of comorbid LD in their future life (Czamara et al., 2013).

For children with ADHD and children with LD, including reading and mathematical difficulties, impairments in executive functions (EFs), encompassing inhibiting one's reaction to distraction, task-switching, planning, decision making and working memory were found to be affected (Huang et al., 2016). Predictive of mathematical abilities and the capacity to read and comprehend are executive functions, specifically inhibition, shifting, and working memory. These are more often than not associated with inhibition dysfunction (Borella et al., 2010). Through neuropsychological assessments and research studies, children with ADHD + LD are found to have underprivileged executive functions than if the child had only one of the two disorders (Mattison & Mayes, 2012). Conceivably, children having both ADHD and LD may put a strain on executive function impairments, including working memory, inhibition control and task switching.

2.1.3 Importance of neuropsychological assessment

Due to coexisting disorders in ADHD, its diagnosis is greatly impacted. Accurate assessment of ADHD is affected by a wide range of factors, not the least of which is the psychosocial view of the symptoms of ADHD. ADHD is often not diagnosed or under-diagnosed which, of course, leads to the mistreatment of the disorder. Evidence shows that misdiagnosis of ADHD is a tremendous obstacle for children and their families achieving their full potential academically and psychosocially (Alderman, 2011).

Clinical treatments demand scientific evidence of their effectiveness to be considered reasonable options as treatment for ADHD. The importance of evidence - based treatment and intervention has grown considerably within the clinical and academic communities; and it is this evidence being sought after to assist practitioners in their decision-making processes (Levant and Hasan, 2008).

There are numerous studies regarding the aetiology of ADHD, the long-term consequences of ADHD, the co-existing disorders of ADHD and treatment of ADHD. However, studies that explain the necessity of neuropsychological assessment (NPA) of ADHD (Pritchard, Nigro, Jacobson & Mahone, 2012) specifically the instruments used in predicting comorbidity, need to be increased. Questions to consider include the extent to which NPA can guide treatment of ADHD. NPA also contributes to accurate diagnosis of ADHD, treatment of symptoms and consequently helps improve the lives of those affected. The lack of support from notable researchers regarding the effectiveness of NPA for ADHD augur against the need for such evaluations (Alderman, 2011), and questioned the practicality of NPA in empirically supported treatment. The question still remains: Can NPA improve the accuracy of the diagnoses of ADHD and lead to better treatments than the diagnoses made from clinical observations, rating scales, and/or unstructured interviews alone?

Firstly, consider examining what a neuropsychological assessment means. It is an evaluation performed by a trained neuropsychologist (Barth, Kanwisher & Spelke, 2003) to test the following skills: general intelligence, academic achievement, executive functions, attention, memory, visual processing, language processing, adaptive skills, sensory and perceptual skills, behavioral, emotional, and social functioning. Said assessments are carried out by the following methods: anamnesis / interviews, a battery of standardized instruments, observation, behavior ratings completed by the patient, their family, and their teachers (Mahone & Slomine, 2008).

NPAs perform holistic evaluations of children's psyche; a 'deep-dive' of their functional neurobehavioral domains and co-occurring conditions to provide wide-ranging and specific recommendations for treatment. It is this that leads practicing child neuropsychologists to believe that NPAs provide better improvement in symptoms of ADHD and positively impact the lives of children and families of ADHD. NPAs employing a wider variety of tools than 'surface-level' observations (e.g., teacher/ parent ratings) give great focus to both cognitive and emotional factors influencing the child's attention and behavior (Pritchard et al, 2012). Although it has been shown that NPAs have assisted beyond MRIs and CTs in the medical treatment of ADHD, there is still little data collected showing how NPAs support the management of childhood ADHD.

Many symptoms of ADHD are common to other emotional and behavioral disorders and conditions. Symptoms such as difficulty concentrating and restlessness can be confused with learning disorders such as anxiety, depression (American Psychiatric Association, 2014), as well as medical conditions of thyroid dysfunction (Schmidt, 2009). This confusion adds complexity to the diagnosis of ADHD, which is even more so in girls due to later age of onset, subtler clinical manifestations, and limitations associated with the DSM-V diagnostic (O'Brien, Dowell, Mostofsky, Denckla & Mahone, 2010). Without eliminating the other causes for the symptoms of ADHD, its diagnosis would be doubtful, and a misdiagnosis would lead to less effective and more expensive treatment in the long term. For instance, ADHD can be treated effectively with stimulant medication, but, as mentioned a while ago, ADHD symptoms overlap with those of anxiety and depression which do not respond well to stimulant treatment (Gillberg et al., 2004). A child's functioning may remain essentially impaired even in the case of accurate diagnosis and appropriate treatment of ADHD because co-occurring conditions were not recognized and treated.

A complete neuropsychological assessment, as described earlier, provides a holistic evaluation of all functional domains, and recommends the appropriate treatment of ADHD and any co-occurring conditions if diagnosed. NPAs evaluate for ADHD and other explanations for symptoms accurately diagnosing for and differentiating all co-occurring disorders and conditions (Silver et al., 2006).

Of critical importance of an NPA is its multi-domain recommendations of treatment of the disorders diagnosed, including academic, social, and special skills interventions. Recommendations may be a spectrum of behavioral therapy, family counselling, occupational therapy, speech language treatment, medical/pharmacological treatments, etc., as, and when appropriate. NPAs are designed to be comprehensive in order to ensure that no relevant factor is missed or overlooked so that recommendations target symptoms and affect the critical agents of change in the child's life.

2.1.4 ADHD treatment can improve outcomes

While there is no cure for ADHD, finding the right treatment is crucial to managing it. There are several different treatments available in managing the symptoms of ADHD and in regulating cognitive function impairments. The most prevalent form of treatment is stimulant medication, including amphetamine and methylphenidate (Capp, Pearl and Conlon, 2005). Along with medication, treatment is often coupled with psychotherapeutic intervention and academic support (Caye et al., 2019). Research has shown that ADHD treatments can significantly decrease symptomatology. However, even with ADHD treatment, in some cases, individuals continue to show both functional impairment and symptoms remain present. (Langley et al., 2010).

Furthermore, as mentioned on several occasions throughout this review, even though medication can reduce ADHD symptoms, it doesn't regulate co-existing impairments, as in reading and mathematical difficulties, familial relationships, sociocultural deficits or even oppositional-defiant behavior (Loe & Feldman, 2007).

Although evidence suggests that behavioral intervention is effective in minimizing symptoms in ADHD symptoms and managing comorbid deficits, such as social impairments, research findings show that treatment and intervention are not always effective for individuals (Fabiano et al., 2009). In other words, individuals might experience some reduction in symptoms. However, if the treatment or intervention is not specifically targeting comorbid impairments, the overall success of intervention will not be accomplished, and consequently, quality of life and life satisfaction will still be impacted (Colvin & Stern, 2015).

2.2 Academic outcomes in ADHD

As aforementioned, when ADHD is undiagnosed, ignored or inappropriately treated with lacking or insufficient intervention, it poses indicative social, employment, relationship deficits, and academic difficulties (Colvin & Stern, 2015). Regarding the latter, children with ADHD are at greater risk of many adverse learning difficulties and are more likely to have low school performance (Barkley, 2006). Children with ADHD are more likely to receive special education services, be enrolled at lower levels, drop out of school, have a lower grade point average, and experience more suspensions and expulsions compared to typically developing children (Fletcher & Wolfe, 2008).

2.2.1 Reading difficulties

On a broad scope, it is understood that ADHD affects academic achievement. More specifically, ADHD walks hand in hand with reading and arithmetic difficulties (Gillberg et al., 2004). On the one hand, comorbidity between RD and ADHD typically ranges from 25 to 40% (Willcutt, Doyle, Nigg, Faraone & Pennington, 2005). Children with co-existing ADHD and RD vary from children with only one of these conditions (Tamm et al., 2017). Both conditions pose serious challenges to tasks that demand executive functions. ADHD + RD comorbidity also pose greater academic difficulty and more pervasive and extreme adverse social and occupational consequences than on children with either condition alone (Willcutt et al., 2010). Additionally, comorbid ADHD+RD is associated with more serious reading difficulties (Lyon & Krasnegor, 1996) and lower grades than RD alone (McNamara, 2005), and serious attention dysfunction than ADHD alone (Mayes & Calhoun, 2007).

Evidence-based treatments exist for both ADHD and RD. Both pharmacological and behavioral treatments, to an extent, are beneficial in reducing the effects of ADHD symptoms and some ADHD-related impairment (Sibley, Kuriyan, Evans, Waxmonsky & Smith, 2014). Due to the uniqueness of cognitive profiles of children with ADHD without RD, for example, it is important to treat the disorders with relevant disorder-specific interventions (Tamm et al., 2017). For instance, characteristics of RD but not ADHD include shortfalls in phonological processing, especially phonological awareness (Fletcher et al., 2009), whereas characteristics of ADHD include an assortment of executive function deficits (Barkley, 1997). While it is true that children with ADHD + RD show traits of both disorders, they do not appear to have a unique cognitive profile (Fletcher et al., 2009).

Note that strengthening phonological awareness does not seem sufficient in improving reading and writing skills (Hogan, Catts & Little, 2005). Researchers Wolf and Bower suggested deficits in rapid automatized naming (RAN), or reading efficiency and reading speed, as the second factor in reading deficit (Wolf & Bowers, 1999). The association between RAN and RD was explained in the double-deficit hypothesis (DDH), in which RAN is assumed to contribute independently to RD along with phonological awareness (Heikkilä, 2015; Norton, Black, Stanley, Tanaka, Gabrieli, Sawyer, & Hoeft, 2014). Therefore, it is vital to investigate RAN for effective diagnosis, prediction, and treatment of developmental reading disorders (Langer et al., 2019). RAN tasks measure speedy recognition of stimuli. Fundamentally, it is understood that RAN tasks assess two components of phonological processing: awareness of individual speech sounds (PA), phonological loop function (verbal short-term memory), and efficient retrieval of lexical phonology (RAN) (Peterson et al., 2018). Children with RD show dysfunctions in at least one of these skills (Peterson & Pennington, 2012). While the competence to quickly recover information from long-term memory may reflect rapid naming, its association with reading disorders may be primarily in the capacity of quickly retrieving phonological codes (Åvall et al., 2019).

2.2.2 Mathematical difficulties

Furthermore, children with comorbid ADHD and mathematical difficulties (MD) also differ from those with only one of these disorders (Enns et al., 2017). Children with MD have a marked difficulty in establishing reliable associations between problems and solutions, and consequently fail to make a successful transition from using procedural counting strategies to using retrieval-based resolutions (Ferrigno & Cantlon, 2017). Especially since MD are frequently associated with RD, children with ADHD + MD + RD are more severely impaired (De Smedt & Boets, 2010). Studies show that mathematical ability is related to executive functions in school-age children (Mattison & Mayes, 2012). Both working memory and inhibition control are predictors for early arithmetic competency (Miyake et al, 2000). It is proposed that the particular difficulties for children of underdeveloped mathematical skills are lack of inhibition control and poor working memory, which results in problems with switching and evaluation of new strategies for dealing with a particular task (Bull, Espy & Wiebe, 2008).

According to Formoso et al., (2017), subitizing, for instance, is a fundamental mathematical skill in early childhood and support for mathematics achievement. It is a fast, automatic, small-number enumeration process different from counting and provides a strong foundation for number sense acquisition (Fritz et al., 2019). Number sense and arithmetic acquisition is dependent on symbolic and non-symbolic processes (Gomides et al., 2018). The former is represented by “verbal code” (e.g. “two”) and the latter by analogue. Arithmetic acquisition, in the initial stages, requires non-symbolic processes given that the same is key to successful mathematical performance (Halberda, Mazzocco & Feigenson, 2008).

The Triple Code Model (TCM) of numerical cognition argues for the existence of three primary representational codes for number (Skagenholt, 2018), which include the visual Arabic number form (e.g. “13”), the auditory verbal word frame (e.g. “thirteen”), and analog nonsymbolic magnitude representations (e.g. •••••••••••••). The most basic of the three forms is analogue nonsymbolic representation, which includes numerosity.

Numerosity involves the ability to recognise the quantity of objects in a particular set (Chick, 2014). In numerosity, there is a process called subitizing (Revkin, Piazza, Izard, Cohen & Dehaene, 2008; Cappelletti et al., 2013). Improvements in numerosity have been proven to extend on a broad scope, including judgements about quantity comparisons, for example, are there more black dots or green dots; judgments about time, for example, which time interval was longer, and space, for example, which line is longer? (Chick, 2014; Haist et al., 2015). Deficits in these areas may have implications for diagnostic classification, treatment, and interventions.

Along with the development of nonsymbolic magnitude representations, i.e., numerosity, a phonological code for the non-symbolic arithmetic representations is essential to acquiring complex mathematical skills. The phonological code is stored in memory, where a verbal route is organized in a network to be retrieved thereafter (Dehaene & Cohen, 1997). Over time, non-symbolic representations are less relied upon and symbolic representations hold the key to more complex mathematical acquisitions. Therefore, knowing that the phonological code for non-symbolic representations is stored in long-term memory, it is understood that deficits in these symbolic representations interrupt their retrieval (Menon, 2016; Manor, Shalev, Joseph & Gross-Tsur, 2001).

In accordance with the triple code model, cognitive neuroimaging, and behavioral observations, research shows that there is a strong connection between phonological processing and retrieval of arithmetical information (Barrouillet, 2018). Subsequently, people with phonological processing disorders, such as those with comprehension problems or developmental dyslexia exhibit numerical information retrieval problems (De Smedt, Taylor, Archibald & Ansari, 2010). Evidence indicates that retrieval of arithmetic information was lower in individuals with reading disabilities and are less effective in doing so (De Smedt, 2018). Phonological processing, particularly phonological awareness, was related to the arithmetic information storage (Lopes-Silva, Moura, Júlio-Costa, Geraldi Haase & Wood, 2014).

2.2.3 Learning difficulties in ADHD

On the whole, research shows that children with ADHD suffer from an academic disadvantage upon entering school (Barry, Lyman & Klinger, 2002). According to DuPaul & Stoner (2014), it was proven that pre-school children with ADHD showed deficits in academic skills prior to formal school entry. They are more likely to have difficulties with basic arithmetic and pre-reading skills in their first year of school than their typically developing peers (Simmons & Singleton, 2008). Furthermore, knowing that executive functions are the core deficits specific to ADHD, studies show that there is a positive correlation between deficits in these cognitive processes and underdeveloped reading and mathematical difficulties (Gilmore & Cragg, 2018). Studies also show that there are gender differences in ADHD. On the one hand, girls with ADHD were found to be less impaired than boys with ADHD (Devine, Soltész, Nobes, Goswami & Szűcs, 2013). Not only are deficits in executive functions the main reason behind academic failure in ADHD and reading and mathematical difficulties, but also inattention. The main reason for poor academic achievement has much to do with inattention.

As previously stated, executive functions are the primary deficits in ADHD and reading and mathematical acquisition relies heavily on said cognitive processes. Moreover, there is also a specific relationship between reading skills and mathematical skills acquisition, namely phonological processing, and arithmetic fact retrieval (Gomides et al., 2018). The triple-code model can explain this relationship. According to Dehaene, Piazza, Pinel, and Cohen (2003), the Triple-code model postulates that non-symbolic processes are represented by a verbal code, that is, a phonological code. Having created a phonological code, verbally dependent arithmetic tasks will in turn rely on said phonological code for the retrieval of arithmetic facts. This is also proven in cognitive neuroimaging research, which suggests a neural overlap between phonological processing and arithmetic fact retrieval (De Smedt & Boets, 2010). Evidence shows that the overlap can be found in the left-temporo-parietal region, specifically in the left angular and supramarginal gyri (Dehaene et al., 2003; Grabner et al., 2009; Schlaggar & McCandliss, 2007). Evidence in developmental research also suggests that there is a relationship between phonological awareness and arithmetic fact retrieval (De Smedt, Taylor, Archibald, & Ansari, 2010). As a result of this relationship, it is expected that children with reading difficulties, specifically in phonological processing, will also have difficulties with arithmetic fact retrieval (Vellutino, Fletcher, Snowling & Scanlon, 2004). Knowing the importance of neuropsychological evaluation in accurately diagnosing ADHD and knowing that there is a great chance of comorbidity with learning difficulties, the present study, therefore, aimed to examine the usefulness of the Five Digit Test in neuropsychological evaluation as a predictor of reading and mathematical difficulties. Such data might further shed light on the general associations between phonological processing and arithmetic fact retrieval and their underlying neural correlates.

2.3 Five - digit test

Neuropsychological assessment has proven to be an important tool in the mental health clinic. This procedure usually involves the use of standardized tests to assess specific mental functions and their relationships with the learning process (Hale, Wilcox & Reddy, 2016). Considering the importance of neuropsychological assessment and the importance in identifying impairments in executive functions, the Five Digit Test can be a useful predictor of Reading and Mathematical Difficulties in ADHD.

The Five Digit Test's main intention is to assess the individual's processing speed and mental efficiency in any language, in addition to identifying the decrease in said speed and efficiency, characteristic of individuals with neurological and / or psychiatric disorders.

The Five Digit Test (FDT) is an instrument that provides measures related to attention and executive functions. It is a multilingual, numeric-Stroop paradigm test of cognitive functions that is based on minimal linguistic knowledge. Part 1, reading, presents digits in quantities that correspond exactly to their values (e.g., one 1, two 2, etc.). Part 2, counting, shows groups of one to five asterisks (e.g., *** and respond 3) of which the individual has to recognize the set and say the number of existing asterisks. In reading and counting, the answers represent automatic processes. Reading and counting does not require much effort from the individual. In choosing, which is part 3 (e.g., "1,1" and answer 2) and shifting, part 4, (set-shifting rules of part 1 and part 3), on the contrary, the individual has to perform controlled actions that require a higher level of mental resources. The measure to evaluate participants' performance was the time spent to complete the tasks in each part. The faster the time, the better the performance in each part.

The FDT is divided into four parts. Each of the four test situations is presented visually as a 50-item page within small squares that form a matrix of ten successive lines. The individual has to read or count these groups of signs and provide a series of answers. The results allow easy discrimination of neurological problems, characterized by low speed and efficiency, as well as the difficulty in initiating an increasing mental effort whenever the difficulty of the task demands it. The first two parts of reading and counting measure simple and automatic cognitive processes (digit reading and asterisk counting) while the parts of choosing (intervention of inhibiting a response) and shifting (inhibiting a habit and activating another) measure more complex processes that require active cognitive control. The latter two require a higher level of mental resources (Sedó, de Paula & Malloy-Diniz, 2015). These four test situations provide information about specific mental processes, including overall speed of cognitive processing, verbal fluidity, focused attention of the individual and their reaction to ongoing effort and the individual's ability to mobilize the additional cognitive effort and resources needed to inhibit involuntary responses and deliberately alternate between two mental operations.

Studies show that difficulties in inhibitory processes are linked to poorer performance, for example, literacy skills are linked to poor comprehension skills (Arnold et al., 2017). Be that as it may, the inhibitory inefficiency of children with difficulties in comprehension is measured by the ability to inhibit off-goal task content from WM. Supposedly, children with difficulties in reading comprehension have specific inhibitory problems. Moreover, studies also show that there is a connection between working memory and performance in mathematics, in particular with performance on complex span tasks (Borella et al., 2010).

As with span tasks, the FDT uses the five quantities as simple recurring cognitive units within tasks of increasing difficulty; and this allows us to measure, in any language, the speed and mental efficiency of the individual and immediately identify the decrease in speed and efficiency that characterizes the individual with neurological difficulties (Sedó et al, 2015).

A test like the FDT can much more easily examine cognitive functions in a wide range of individuals: not only in the usual cases, but also in those with a very different level of education (including illiterate individuals) and in cases with minimum knowledge of the language. The FDT allows for describing the speed and efficiency of cognitive processing, the constancy of focused attention, the progressive automation of the task and the ability to mobilize additional mental effort when the stages present increasing difficulty and require much greater concentration.

The four test steps provide information about some mental processes. Four of them can be particularly relevant for neuropsychological diagnosis: 1) general speed of cognitive processing; 2) verbal fluidity, that is, the facility of identifying words; 3) the individual’s focused attention and his reaction to the continued effort; and finally, 4) the individual’s ability to mobilize and the additional cognitive effort required to inhibit involuntary responses and deliberately switch between two different mental operations (Sedó et al, 2015). These four processes are discussed below:

- Processing speed is a mental capacity that can be measured. It is the time required to respond to and/or process information/stimuli in the environment (Diamond, 2002).
- Access to verbal concepts. The second aspect is the ease of identifying the words. Each of the FDT’s tasks involves naming a series of fifty numerals; and it is known that access to verbal concepts occurs much more slowly and with more

difficulty in individuals who have neurological dysfunction (Rohrer, Knight, Warren, Fox, Rossor, & Warren, 2008). In FDT, the serial presentation of responses multiplies this individual latency by 50, thus widening the differences. The responses in the first two parts provide information on two different ways of accessing words: first (Reading) from a phonological clue (reading) when the individual evokes the verbal code of the recognized number (Heilman, Voeller & Rupley, 1996); and then (in counting) without using any phonological evidence.

- The rapid and efficient production of a series of 50 elements reveals not only the presence of focused/sustained attention, but also the ability to automate and learn; and the resistance of the individual's neuronal system to fatigue. The scoring technique allows to compare the speed of the individual in each of the two halves and to observe the presence of a progressive acceleration or, in contrast, the presence of delay and progressive overload.
- Voluntary mobilization of additional resources. There is a difference between the simple reaction time (the time it takes to respond to a stimulus upon identifying it) and the choice reaction time (the time it takes to identify two or more stimuli, each requiring a different response). The latter is linked to a voluntary decision. Shiffrin and Schneider (1977) considered simple reaction time as an automatic process and choice reaction time as a controlled process (Schneider & Chein, 2003).

The FDT was thought of in order to amend the limitations of the classic Stroop Test (ST) of naming colors: a classic neuropsychological test that measures the verbal fluidity and the selective attention of the individual. The ST, based on the reading of words like "red", "blue" and "green", have some practical inconveniences solved by the FDT.

Firstly, the Stroop Test cannot be applied to illiterate or dyslexic individuals, or to those who have a deficit in color perception, in addition to the fact that the test has to undergo translation and adaptation to be applied in intercultural situations (Lang, Rexler, Riley, De Cristoforo & Sedó, 2002).

The FDT replaces written words with visual symbols that are easily recognizable and verbalizable in all languages: groups of digits, which can be counted with "one", "two", "three", "four", and "five". In addition, the FDT replaces the naming of colors by counting these groups of digits, in which the individual has to count the digits without reading the values. For this reason, it is possible to apply the FDT to new groups of individuals and to those who have minimum knowledge of the examiner's language or who speak a different language. It is important to highlight that the FDT uses not only the three traditional situations of the ST, but adds a fourth situation, developed later by Bohnen, Jolles and Twijnstgra (1992), and that gives the test an additional validity. The individual has to alternate between two different mental tasks and use a higher level of voluntary mental effort.

2.4 Neuropsychological assessment, FDT and ADHD

In order for neuropsychological assessment to be extensive, it has to include a comprehensive interview or anamnesis with the child's caregivers; a mental status examination of the child; a medical examination to understand the well-being and neurological issues of the child; a cognitive assessment; use of ADHD-focused, parent and teacher rating scales; and school reports and other additional evaluations if necessary (speech, language assessment and mathematical assessments) (Nikolas, Marshall, Hoelzle, 2019).

Therefore, neuropsychological assessment has the potential to offer a better understanding of ADHD-specific symptomatology, co-existing disorders, and the individual's particular strengths and weaknesses in order to make recommendations for optimizing treatment to address all of these factors (Gualtieri & Johnson, 2005). In addition to specific behavioral and pharmacologic interventions for children with ADHD, other measures are taken to offer equity for children with ADHD (Enns et al., 2017).

Furthermore, knowing the relationship ADHD has with learning difficulties, using the FDT as an essential instrument would be beneficial. Applying an integrative model of executive function to the investigation of executive function in young children presents advantages over considering executive function components in isolation among children with ADHD (Garon et al., 2008). Furthermore, testing specific impairments in executive function components allows one to consider how they are related in children with ADHD in order to identify areas of overlap versus separation and, consequently, being one step closer to adequate treatment and intervention for children with ADHD and learning difficulties, specifically reading and arithmetic difficulties.

In Garon et al.'s 2008 model, attention underlies all executive function abilities, then working memory and inhibition (Kapa & Doubleday, 2017). Proposed by the model is the theory that cognitive efficiency develops as a consequence of maturation from infancy into early preschool. It is important for basic functions to be sufficiently developed in order to acquire more complex abilities, as in executive function abilities such as attention shifting, planning, and problem solving. According to Garon et al.'s model, the hierarchical association between executive function components predicts that a child with deficits in basic, lower-level components would show difficulty in more complex, higher-level components due to the possibility of cascading effects of lower-level deficits (Garon, Bryson & Smith, 2008).

Neuropsychological evaluation can indeed capture the elements of executive function impairments that characterize patients with ADHD and learning difficulties (Rabinovici et al., 2015). Neuropsychological assessment is also suitable for identifying cognitive impairments that may complicate management of ADHD. One of the major problems of ADHD is not being effectively diagnosed, which poses a lack of treatment, or if inadequately diagnosed, intervention is ineffective. Underdiagnosed ADHD can pose psychological, financial, academic, and social burdens both on the individual and the community. Many mechanisms may be at work linking undiagnosed ADHD to vulnerabilities.

The impacts of disorder-specific ADHD treatment (i.e., carefully monitored medication and behavioral parent training) or reading intervention (i.e. systematic, phonologically-based reading instruction) on word reading/decoding outcomes and ADHD symptoms among children with comorbid ADHD+RD, and the impacts of mathematical intervention (i.e., the systematic numeracy strategy, such as the Springboard and Spiral mathematics program (Dowker, 2004)) on the approximate numerical system, verbal memory and hypersensitivity of individuals with MD to memory interference among children with comorbid ADHD+MD can increase the effectiveness of the treatment by specifically targeting where the problem lies (Tamm et al., 2017). It is possible that attentional outcomes would be significantly better in students who received ADHD treatment compared to students who received only reading treatment and the incremental benefit of providing a combined ADHD and reading intervention or ADHD and arithmetic intervention compared to either of these disorder-specific interventions alone (Huang et al., 2015; McGrath et al., 2011). It was similarly hypothesized that reading outcomes would be significantly higher in students who received reading interventions compared to students who received only ADHD treatment. It was also hypothesized that children who received the combined treatment would achieve significantly higher attentional and word reading outcomes than children who received either disorder-specific treatment (Butterworth & Kovas, 2013).

Based on overlapping executive function impairments in ADHD, reading and mathematical difficulties, and with the detailed assessment offered by the Five Digit Test, the purpose of this study was to comprehensively address questions regarding appropriate neuropsychological assessments, specifically the use of the FDT in predicting RD and/or MD in children with ADHD.

3. Objectives

3.1 General objectives

Analyze how the FDT helps in predicting reading and arithmetic difficulties in children with ADHD.

3.2 Specific objectives

a) Analyze the association between cognitive functions in ADHD and reading and mathematical difficulties

b) Verify the speed of cognitive processing and its association with reading and mathematical difficulties.

c) Verify attention processes and its association with reading and mathematical difficulties.

d) Verify the role of interference control and its association with reading and mathematical difficulties.

4. Methods

4.1 Ethical considerations

The Research Ethics Committee of UFMG - COEP approved the research project (CAAE-02899412.9.0000.5149) entitled “Multidimensional assessment of individuals with Attention Deficit Hyperactivity Disorder” (**Attachment A**).

4.2 Participants

In the present study, 105 children diagnosed with ADHD were evaluated. Participants whose symptoms were due to other factors, such as syndromes, neurodegenerative diseases (epilepsy, seizures, brain tumors, hydrocephalus, agenesis of the corpus callosum, etc.) and intellectual disability were excluded. The study was conducted at the outpatient clinic, (Research Centre of Impulsivity and Attention - NITIDA, at the Federal University of Minas Gerais). The clinic evaluates children between the ages of 6 and 10 years old for the assessment and treatment of ADHD and other associated disorders. Potential patients, first, register online and join the waiting list. Subsequently, contact is made, and an anamnesis is done. All participants sign a Free and Informed Consent Form (**Appendix**). NITIDA contributes to advances in the area of Impulse control and Inattention (**Attachment B**). The evaluation of the children took place in an interdisciplinary way, with a medical professional (pediatrician or psychiatrist) and a psychologist (psychologist or neuropsychologist) conducting or supervising the procedures. The child’s diagnosis, as well as possible comorbidities, was carried out through the standardized interview Kiddie-SADS-Present and Lifetime Version (K-SADS-PL/Brazil, 2003), conducted with the person responsible for the patient and later with the child. The diagnoses are discussed by the professionals involved and the children are referred for treatment or follow-up depending on the results. Patients are generally followed into adolescence and are generally referred by the public health or education system. The description of the participants can be found in Table 1.

Table 1

Participant characteristics

Variables		N	%
Sex	Male	82	78%
	Female	23	22%
Age (years)	7	11	10%
	8	17	16%
	9	16	15%
	10	22	21%
	11	15	14%
	12	15	14%
	13	5	5%
	14	2	2%
	15	2	2%
Psychostimulant	No	86	82%
	Yes	19	18%
Socioeconomic background (n=56)	A	1	2%
	B1	5	9%
	B2	20	36%
	C1	21	37%
	C2	7	12%
	DE	2	4%
ADHD Subtypes	Inattentive	38	36%
	Hyperactive	3	3%
	Combined	61	58%
	Not specified	3	3%

The screening process usually takes two days. On day one, the parent or guardian, after filling out the SNAP, K-SADS-PL and CBCL forms, goes in for an anamnesis, while the child undergoes a neuropsychological evaluation. The neuropsychological evaluation includes the School Achievement Test (TDE), the FDT, and Raven's Progressive Matrices and Special Scale. ADHD diagnosis is made in agreement with at least two examiners and is also based on the K-SADS-PL interview. If a child is diagnosed with ADHD, then a consultation form is filled out and the consent form signed. Results are then put into the research database. On day two, the child undergoes research protocol, including blood collection after which the sample is then checked. Possible child and parent code for blood collection is registered in the genetic bank database: multidimensional ADHD - NITIDA Genetic Bank. Along with genetic samples, the child performs computerized tests lasting 50 to 70 minutes. Feedback is subsequently given. For this research, a retrospective study was done where the medical records of patients who had already performed the procedures in question were analyzed and selected according to the variables of interest. Table 2 shows the comorbidities found in the sample.

Table 2

Comorbidities found in patients with ADHD

Comorbidities (disorders diagnosed by K-SADS-PL)	**N**	**%**	**Comorbidities** (disorders diagnosed by K-SADS-PL)	**N**	**%**
Enuresis	10	10%	Tics	2	2%
Encopresis	3	3%	Depression	5	5%
Oppositional and Defiant	40	38%	Mania	3	3%
Conduct	6	6%	Psychosis	0	0%
Panic	0	0%	Post-traumatic Stress	0	0%
Separation anxiety	12	11%	Anorexia	0	0%
Social Phobia	8	8%	Bulimia	0	0%
Agoraphobia-Specific Phobia	10	10%	Cigarette use	1	1%

Generalized anxiety	10	10%	Use of Alcohol	1	1%
Obsessive-Compulsive	0	0%	Autism	10	10%

4.3 Instruments

Swanson, Nolan, and Pelham– version IV MTA-SNAP-IV (Scale for evaluation of ADHD symptoms)

Instrument composed of 26 items developed to screen for ADHD symptoms and Oppositional Defiant Disorder in children and adolescents. It can be completed by parents or teachers and employs the symptoms listed in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) for attention deficit hyperactivity disorder (criterion A) and oppositional defiant disorder (ODD). The parent/guardian or teacher assesses inattentive (items 1–9), hyperactive-impulsive (items 10–18) and challenging (items 19–26) behaviors using a 4-point Likert scale ranging from 0 (not at all) to 3 (too many). The score of each category is calculated by the average and considers the number of items (sum / 9 for inattention and hyperactivity-impulsivity and sum / 8 for ODD symptoms).

Kiddie-SADS-Present and Lifetime Version / K-SADS-PL

Parents underwent a semi-structured psychiatric diagnostic interview with the Brazilian version of the Kiddie-SADS-Present and Lifetime Version (K-SADS-PL) and current symptoms of inattention and hyperactivity-impulsivity were recorded. All questions from the screening and supplementary sections were investigated and the summary evidence checklist for ADHD (DSM-IV) was completed. The sum of inattention and hyperactivity-impulsivity symptoms from the summary diagnostic checklist can range from 0 to 9 for each ADHD dimension.

Child Behavior Checklist (CBCL)

Parent questionnaire that aims to assess psychopathology in children from 4 to 18 years old. This scale consists of 2 parts: the first one with 120 items that correspond to behaviors that the child may have, where parents should mark on a scale from 0 (not true), 1 (sometimes or partly true) or 2 (often true), items that constitute mostly affirmations and, in the end, giving the caregiver room to present 2 statements of his choice. The second part concerns the skills of children in their participation in hobbies, sports, and social interactions. This instrument is validated for the Brazilian population and consists of 8 subscales: Isolation, Somatic Complaints, Anxiety / Depression, Social Problems, Attention Problems, Thinking Problems, Aggressive Behavior and Delinquent Behavior.

Raven's Progressive Matrices and Special Scale

Raven's Progressive Matrices and Special Scale is a fluid intelligence test used in the evaluation of children and adolescents. It is a multiple-choice intelligence test of abstract reasoning. In each test item, the individual is asked to identify the missing item that completes a pattern. Many patterns are presented in the form of a 4x4, 3x3, or 2x2 matrix, hence its name.

School Achievement Test (TDE)

An instrument that seeks to offer an objective assessment of the fundamental abilities for academic achievement (writing, arithmetic and reading). The sample was divided into low achievement (25th percentile or lower) and typical achievement (>25th percentile), based on a normative study from Minas Gerais involving writing and arithmetic subtests.

The Five-Digit Test (FDT)

Instrument that provides measures related to attention and executive functions (Attachment C). FDT is a multilingual test of cognitive functions that is based on minimal linguistic knowledge. It is a numeric-Stroop paradigm. Part 1 (reading) presents digits in quantities that correspond exactly to their values (one 1, two 2, etc.). Part 2, counting, shows groups of one to five asterisks (*** and respond 3) of which the individual has to recognize the set and say the number of existing asterisks. In reading and counting, the answers represent automatic processes. Reading and counting does not require much effort from the individual. In choosing, which is part 3 ("1,1" and answer 2) and shifting (set-shifting rules of part 1 and part 3), on the contrary, the individual has to perform controlled actions that require a higher level of mental resources.

5. Results

5.1 Data analysis

The classification of school difficulties was analyzed based on achievement in the TDE test. The raw score of the patients were compared with the classification elaborated by Oliveira-Ferreira et al. (2012) based on a population study of elementary school students in Minas Gerais. Based on this study, school achievement was stratified into deficit or normal, both for writing and arithmetic, based on the classification divided by school grade.

For the cognitive variables, all the results obtained in the Raven's Progressive Matrices and Special Scale and in the FDT were transformed into Z-scores, based on the population norms stratified by age, contained in the manuals of the tests (Sedó et al., 2015; Raven, 2003). This allows cognitive data to be used respecting the participant's age, since in this age group expressive cognitive changes are expected in short intervals of time.

Regarding the SNAP-IV variables, the raw score reported by the parents was used in the dimensions inattention, hyperactivity and oppositional/defiant. The score was adopted since a clinical study with the questionnaire, also conducted by our research group, found no association between age and intensity of symptoms reported in the questionnaire (Costa, Paula, Malloy-Diniz, Romano-Silva & Miranda, 2019).

To analyze the association between cognitive variables, symptoms of inattention, hyperactivity and oppositional defiant disorder, a correlation analysis was initially adopted and later logistic regression models. The correlation analysis was performed in an exploratory way, aiming to analyze more generally how the variables behave in this study. Binary logistic regression models, on the other hand, evaluate the role of multiple predictors for the classification of a binary outcome (Field, 2009). Two models were used, one for the evaluation of writing difficulties and the other for the evaluation of mathematical difficulties.

In the logistic regression models, the TDE was classified as the dependent variable (Deficit x Normal) and the variables FDT - Reading, FDT - Counting, FDT - Inhibition, FDT - Flexibility, Raven's Colored Progressive Matrices, SNAP-IV Inattention, SNAP-IV Hyperactivity and SNAP-IV OD as independent variables. As there is multicollinearity in the model (cognitive variables are expected to be correlated, as well as ADHD symptoms), a step entry model (Wald's Forward method) was opted for. In this case, each variable is added to the model individually, and maintained in the final model if it generates a significant change in the results. All analyses were performed in The SPSS 25.0 Software.

5.2 Classification of the students' school achievement

The classification of the students' school achievement suggests that 8% of the sample presented impairment only in writing and 30% only in arithmetic. Altogether, 17% of the children studied presented impairment in both academic skills, totaling 55% of the sample with some school deficit (Figure 1).

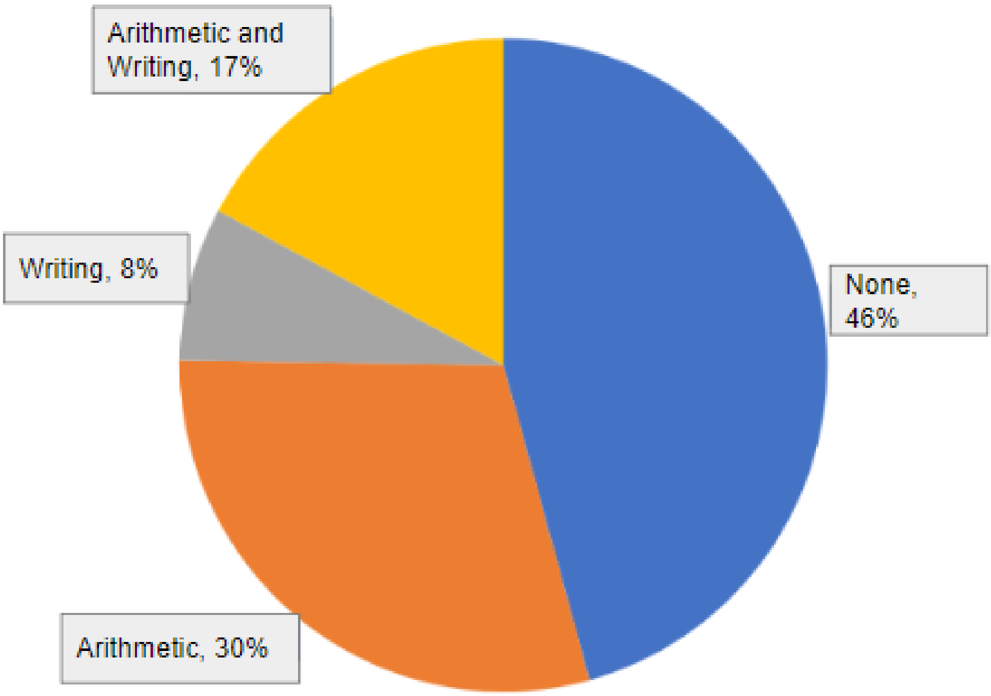

Figure 1: Distribution of academic difficulties from the sample.

Along with the results of the cognitive assessment, the population parameters were also added to better understand the data. In terms of intelligence, a great difference between the sample and the general population was not observed. However, in terms of attention (measured by the FDT test) and ADHD symptoms (measured by SNAP-IV) important mean differences were observed, in addition to a large range of results.

Table 3

Five Digit Test: Assessment for ADHD Symptoms

Assessment	Mean	SD	Minimum	Maximum	Parameter*
Raven	-0.16	1.16	-3,30	2.41	0.00 ± 1.00
FDT - Reading	-0.60	1.31	-5.12	-1,81	0.00 ± 1.00
FDT - Counting	-0.90	1.92	-5.32	-1,75	0.00 ± 1.00
FDT - Inhibition	-0.87	1.30	-4.90	-1,26	0.00 ± 1.00
FDT - Flexibility	-0.63	1.14	-4.67	-1,55	0.00 ± 1.00
SNAP-IV - Inattention	19.03	5.71	0	27	9.00 ± 7.00
SNAP-IV - Hyperactivity	15.94	7.85	0	27	8.00 ± 7.00
SNAP-IV - OD	10.58	6.66	0	24	6.00 ± 6.00

Note: * Assessment Manual - Raven e FDT – e Costa et al. (2018) – SNAP-IV. FDT: Five Digit Test, SNAP-IV: Assessment Scale for Symptoms of ADHD, OD: Oppositional/Defiant

5.3 Correlation analysis

The correlation matrix between school achievement measures, cognitive variables and ADHD symptoms is shown in Table 4. Significant and, in general, weak or moderate correlations between reading achievement with the intelligence test (Raven) and the steps of reading, counting and flexibility of the FDT were found. The directions of the correlations suggest that the better the performance in the tests, the better the school achievement. Regarding arithmetic, only the FDT counting variable presented a significant and moderate correlation with school achievement. Again, the better the test performance, the better the school achievement. ADHD symptoms showed no significant correlation with school achievement. There was still a weak but significant correlation between writing achievement and arithmetic achievement.

Table 4

Correlation Analysis

Instruments	TDE - Writing		TDE - Arithmetic	
	r	p	r	p
TDE - Writing	1	.	,259**	0,008
TDE - Arithmetic	,259**	0,008	1	.
Raven	,198*	0,043	0,166	0,09
FDT - Reading	-,314**	0,001	-0,155	0,115
FDT - Counting	-,347**	0	-,310**	0,001
FDT - Inhibition	-0,151	0,125	-0,163	0,098
FDT - Flexibility	-,281**	0,004	-0,154	0,116
SNAP-IV - Inattention	0,013	0,891	0,015	0,876
SNAP-IV - Hyperactivity	-0,071	0,469	0,163	0,097
SNAP-IV - OD	-0,009	0,927	0,131	0,184

Note: *p<.05; **p<.01. FDT: Five Digit Test, SNAP-IV: Assessment Scale for Symptoms of ADHD, OD: Oppositional/Defiant

5.4 Logistic regression

Logistic regression models were significant, both for writing achievement (Table 5) and for arithmetic (Table 6). The predictive model for writing presented a moderate effect size (R^2=0.13) and had only the FDT Reading subtest as a predictor. The predictive model of arithmetic achievement presented an effect size between weak and moderate (R^2=0.07) and had only the FDT Counting subtest as a predictor.

Table 5

Results of the logistic regression model predictive of achievement in writing

χ^2	df	p	Predictors	Wald	Exp(B)	p
5.77	1	0.016	FDT – Reading	0.35	0.57	0.004
			Excluded - Raven	-	-	0.104
			Excluded - FDT Counting	-	-	0.777
			Excluded - FDT Inhibition	-	-	0.310
			Excluded - FDT - Flexibility	-	-	0.059
			Excluded - SNAP-IV - Inattention	-	-	0.906
			Excluded - SNAP-IV - Hyperactivity	-	-	0.440
			Excluded - SNAP-IV - OD	-	-	0.652

FDT: Five Digit Test, SNAP-IV: Assessment Scale for Symptoms of ADHD, OD: Oppositional/Defiant

Table 6

Results of the logistic regression model predictive of achievement in arithmetic

χ^2	df	p	Predictors	Wald	Exp(B)	p
5.77	1	0.016	FDT - Counting	4.10	0.73	0.043
			Excluded - Raven	-	-	0.243
			Excluded - FDT Reading	-	-	0.221
			Excluded - FDT Inhibition	-	-	0.671
			Excluded - FDT - Flexibility	-	-	0.821
			Excluded - SNAP-IV - Inattention	-	-	0.706

			Excluded - SNAP-IV - Hyperactivity	-	-	0.113
			Excluded - SNAP-IV - OD	-	-	0.245

FDT: Five Digit Test, SNAP-IV: Assessment Scale for Symptoms of ADHD, OD: Oppositional/Defiant

6. Discussion

In this study, cognitive processes including attention, working memory, executive functions (inhibition control and cognitive flexibility) were measured by the Stroop paradigms FDT. The FDT reading step, which was associated with the writing task, involves overall processing speed and the automatic recognition of stimuli, in this case numbers from 1 to 5. In other words, Rapid Automatized Naming acts as a precondition for the acquisition of reading skills, which are fundamental to writing, thus explaining this association. There was also an association between performance in arithmetic tasks in TDE and FDT counting time and fluid intelligence. According to the model of the triple code, described by Dehaene and Cohen (1997), there are three representations necessary for numerical processing: the verbal representations, the Arabic numerals, and the symbolic representation of magnitude. The first two are cultural constructions developed from the latter, which is considered more primitive. Thus, the counting step of the FDT involves the representation of magnitudes (subitizing), being an important step for the more complex arithmetic processing and was associated with the frequency of cognitive failures in everyday life.

Under these circumstances, it is evident that executive functions play a larger role than intelligence in the acquisition of reading, writing and arithmetic skills. The FDT is a suitable instrument for detecting these impairments. EFs are critical not only for academic achievement, but also for a successful work and social life, especially since they involve creativity, flexibility, self-control, and discipline. Several studies describe impairments in academic achievement of children with ADHD in general (Loe & Feldman, 2007; Czamara et al., 2013). Consequently, executive functions seem to be good predictors of school performance in early childhood. Neuropsychological evaluation is, therefore, a fundamental tool for a prognostic analysis in ADHD (Nikolas et al., 2019).

Having undergone neuropsychological evaluation with the possibility of detecting neurological impairment, one is able to undergo adequate treatment and necessary training. Studies show that training and practice can improve executive functions, thereby improving reading and arithmetic skills (Tamm et al., 2017). EFs gain from training in task switching. For example, training task switching in the FDT requires inhibitory control, cognitive flexibility and working memory. EF demands need to be continually, and incrementally increased or few gains are seen. There is no question that practice leads to expertise. In other words, repeated practice is key.

7. Conclusion and Limitations

Enhancement of cognitive performance predicts better adaptation to changes in the environment and favors the development of effective strategies for the individual's success. Having an efficient neural network that spends less and less energy in acquiring new skills and completing simple tasks is synonymous to adaptive success. Research in neuropsychological assessment is committed to finding different means of improving cognitive efficiency and counteracting biological, economical, and socio-cultural costs.

Executive functions are observed through neuropsychological assessment as important parameters for the verification of cognitive efficiency in ADHD and in learning difficulties, including reading and mathematical difficulties. Currently, the evaluation and diagnosis of ADHD is based on behavioral observations and regular diagnostic procedures carried out by psychiatrists, neurologists, pediatricians, and specialized practitioners are based largely on subjective assessments of perceived behavior. Practitioners often lack adequate time and training to follow the recommended diagnostic guidelines and elaborate effective treatment. Consequently, ADHD has been misdiagnosed or confused with co-occurring disorders (mild forms of autism, anxiety, and depression, for example) leading to inaccurate or ineffective treatment in affected children.

Compounding this issue, interventions based on behavior and/or drug therapies for ADHD can address the symptoms of the disorder; however, the results may be temporary, not all symptoms show marked improvements, their effectiveness on individuals vary widely, and ADHD often co-occurs with learning difficulties and disorders. The cost of assessments, diagnosis and treatment is always a factor in dealing with ADHD. Despite the financial costs of neuropsychological assessments being used to deny its use, the potential savings economically, societally, and personally justifies its application in the early stages of a child's development. Evidence provided by studies give clear indication of neuropsychological assessments' more accurate diagnoses leading to more effective treatment of ADHD; consequently, more effective treatment results in reduced costs in the long term to the individual and to the society. It must be said, however, that more studies to specifically address the question of cost savings need to be conducted.

Objective means should also contribute to the clinical diagnosis of ADHD. A more reliable method of diagnosis is therefore required that can accurately differentiate children with ADHD from those who don't, and also help in predicting learning difficulties, one of the common co-occurrences in ADHD, while helping to determine the most effective treatment to address the disorder and additional difficulties. Hence, the need for a specific measure to assess executive functions since it is impaired both in ADHD and reading and mathematical difficulties.

Studies show that neuropsychological assessments can provide the reliable diagnosis of children with ADHD and give the following benefits: i) multiple determinants or measures, instead of only an inadequate report from a parent or teacher, testing a child's neurobehavioral, cognitive, emotional, and social strengths and needs; ii) heavy focus would be placed on co-occurring conditions such as academic, psychological and cognitive with consideration given to known behaviors associated with ADHD; iii) a range of recommendations for treatments aimed not just at the symptoms of ADHD but also co-occurring disorders (such as reading and mathematical difficulties and disorders, among others) that can span multiple domains; and iv) establishing a functional baseline determined by psychometrics against which the effects of the treatment and development can be measured.

With neuropsychological assessments including the use of the Five Digit Test for ADHD, customized treatments can be formulated for children whose diagnosis identifies one's strengths and weaknesses and whose treatment and intervention is based on targeting specific symptoms, in the case of this study, symptoms related to executive function impairment related to reading and mathematical difficulties.

The use of the Five Digit Test in neuropsychological assessments can offer more accurate and thorough diagnosis. In addition, knowing whether the results are coupled with intelligence are noticeable components that should be well studied. However, this is not the case in Brazil, where data on these phenomena are scarce and, therefore, justifies the need for the theme to be explored. It was proposed to check the cognitive performance of a group of students diagnosed with ADHD from the NITIDA database in Belo Horizonte, Minas Gerais. Even though the database includes students from all over Minas Gerais, with majority from Belo Horizonte, knowing that due to the huge extent of the national territory, it is recommended to do further studies that can represent the Brazilian population. Based on the evidence provided from multiple studies that executive functions are impaired in ADHD and in reading and mathematical difficulties, the question is: Is the Five Digit Test a useful predictor in reading and mathematical difficulties in ADHD? This was also positively proven in the study.

There were several advantages of using the Five Digit Test as an accurate predictor of reading and mathematical difficulties presented during this research. Firstly, it is cost effective. Secondly, it is easily translated and adapted to the culture and population. It is intercultural. Thirdly, it effectively tests executive functions, domains that are impaired in ADHD and reading and mathematical difficulties. Lastly, the FDTs main intention is to assess the individual's mental speed and efficiency, in addition to identifying the decrease in speed and efficiency, characteristic of individuals with neurological and / or psychiatric disorders.

Furthermore, throughout this dissertation, three points were addressed: 1) ADHD is one of the most common neurodevelopmental disorders; 2) ADHD is associated with considerable deficits in academic success; and, 3) detailed ADHD assessment and treatments are and should continue being studied. With careful deliberation, it goes without saying that attention needs to be given to the understanding and treating of ADHD + LD, including reading and mathematical difficulties, more effectively.

In order to determine how effective neuropsychological assessments can be, comparisons between the effects of the treatment derived from neuropsychological assessment to treatment based on routine assessments for children with ADHD need to be explored. Both groups would have to be compared over short and long-term intervals looking at symptom severity, quality of life, academic, emotional, and behavioral functioning. The impact on family-life and changes to the quality of life should also be compared between the groups to gain further understanding about living with ADHD. Further research comparing the two groups should highlight how much the effective individualized treatment of ADHD has on economic savings and healthcare, which ultimately resulted from accurate diagnosis from the neuropsychological assessments.

The etiology of Attention Deficit Hyperactivity Disorder is probably due to a combination of small environmental and genetic anomalies, in other words, changes in the biological, psychological, and social domains. Arising from this, ADHD manifests to varying degrees in vulnerable people causing the diagnosis of the disorder to be more complicated. Cognitive training in ADHD can take two approaches. The first approach is based on the hypothesis that the disorder stems from neuropsychological deficiencies and therefore strengthening those deficiencies should reduce ADHD symptoms and related conditions. This type of cognitive training treats the core symptoms of ADHD directly. The second approach seeks to treat ADHD indirectly by reducing the related conditions to the neuropsychological deficiencies, independent of the core ADHD symptoms.

Additional research is necessary in order to understand how language and executive function are related in children with reading difficulties (RD). Poorer attention skills may make it more difficult for children with RD to recognize underlying grammatical rules in language input or working memory deficits may disrupt word learning. Last, it may be the case that, as with typical populations, language and executive functions are bidirectionally related in RD with deficits in one area potentially compounding problems in the other.

Research into the effects of executive function training on the outcome of language abilities with children with RD would be quite beneficial. Earlier research points to improvement in non-linguistic cognitive skills relating to improving children's expressive language abilities who have RD. Future studies are necessary for identifying which types of cognitive training are most effective for improving language abilities in children with RD.

Last, future research addressing similar questions regarding the underlying nature of executive function components both within samples of children with RD and between children with RD and typical language development will benefit from advanced modelling techniques. Individuals with RD and dyslexia retrieve fewer facts from memory. Phonological processing deficits coincide with fact retrieval deficits in dyscalculia. Multiplication but not subtraction fact retrieval is mediated by phonology. Future work should address the neural overlap between phonology and mathematical fact retrieval.

More research about neuropsychological assessment is needed. Questions regarding its specific impact on the psychological, social, academic, and functional well-being of ADHD children and their families requires investigation. The usefulness of psychometric tests being applied individually or in conjunction with other tests should also be explored to diagnose ADHD. However, the use of psychometric tests in formulating treatment for ADHD affected children is insufficient as the disorder affects the supporting family and community as well. The role of the family and community as part of the treatment of ADHD sufferers needs thorough research as well and included in the neuropsychological assessment. In the future, research that compares the effect of the treatment derived from neuropsychological assessment on the lives of children affected by ADHD and their families versus the treatment derived from traditional tests administered routinely should be conducted. Several other questions can be considered and studied in detail in the future: is) given that executive functions are impaired in ADHD and in reading and mathematical difficulties, should treatment and intervention be done separately for each disorder? ii) Should treatment and intervention be conjoined? iii) What would the results be for separate and conjoined intervention?

Some of the limitations of the study include the sample size. Research is done to find a solution to a particular medical problem (formulated as a research question which in turn is) based on statistics. In an ideal situation, the entire population should be studied but this is almost impossible. Whatever the aim of the research, one can draw a precise and accurate conclusion only with an appropriate sample size. A smaller sample can decrease the statistical power. Note, having an exceptionally large sample size is also not recommended as it has its own consequences. Having a small sample size does not diminish the value of this work, but it does cause interest in new research that can reaffirm the findings. Another limitation included research that had to be purchased. The study depended on papers whose access was limited by cost. Several important chapters from books had to be purchased in order to view the data. This was overcome by extensive research into other simple topics. Being denied or having limited access did not prevent the research from following through. This was countered by multiple evidence-based research that was readily available.

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Zanto, T. P., & Gazzaley, A. (2016). The term attention is multifaceted and often refers to a set of cognitive processes that transcends a single definition or overarching theory (Parasuraman, 1998). The goal of this chapter is to review aspects of selective attention and its neural substrates in the context of changes that occur with normal aging. Selective attention refers to goal-directed focus on task-relevant information while ignoring other irrelevant information. This chapter is subdivided according to the type of information that .... Cognitive Neuroscience of Aging: Linking Cognitive and Cerebral Aging, 207.

Appendix - Informed Concent Form.

Termo de Consentimento Livre e Esclarecido (>18 anos))

Título da Pesquisa:

Avaliação Multidimensional de Indivíduos com Transtorno de Déficit de Atenção e Hiperatividade (TDAH)

Prezado (a),

Gostaríamos de convidá-lo (a) para participar de uma pesquisa cujo objetivo é conhecer as habilidades e limitações de indivíduos com Transtorno de Déficit de Atenção e Hiperatividade (TDAH) em relação ao seu comportamento, ao seu modo de aprender e de se relacionar com as pessoas. Além disso, nesta pesquisa estudaremos como estas habilidades estão relacionadas e podem ser influenciadas por características biológicas como o código genético de cada um. Acreditamos que isso nos ajudará a entender melhor as pessoas com TDAH facilitando o planejamento de intervenções que sejam mais adequadas às suas características.

Nosso convite é para que participe desta pesquisa no grupo:

( )1. Portador de TDAH; ( ) 2. Parente de primeiro grau de portador de TDAH; ( ) 3.Grupo controle.

Leia as informações abaixo antes de autorizar ou não sua participação na pesquisa.

Indivíduos com alto nível de desatenção, hiperatividade e impulsividade podem apresentar dificuldades de aprendizagem, no trabalho e de relacionamento social. Neste estudo, buscamos entender como as características de pessoas com TDAH podem afetar suas atividades do dia-a-dia para que futuramente possamos identificar precocemente o transtorno a fim de diminuir a probabilidade de prejuízos acumulados.

Caso você autorize sua participação na pesquisa, algumas informações sobre sua história serão solicitadas através do preenchimento de questionários quanto ao seu estado de saúde e educação, numa entrevista de aproximadamente 60 minutos de duração. Depois, alguns testes serão realizados em aproximadamente três sessões de 1 hora cada. Estes testes avaliam funções relacionadas à aprendizagem como atenção, percepção, memória, raciocínio, pensamento, motricidade e equilíbrio, linguagem e capacidade de planejar e cumprir seus objetivos. As tarefas serão propostas procurando-se promover e manter sua motivação. A avaliação será feita no Hospital das Clínicas da UFMG por uma equipe multidisciplinar. Adicionalmente, um profissional da saúde habilitado fará uma coleta de material biológico simples (raspagem com algodão das mucosas da boca ou coleta de 10 ml de sangue de uma veia do braço) para realização de análise genética.

O risco biológico envolvido na pesquisa é mínimo. A coleta de sangue pode doer um pouco e deixar uma mancha no local, mas, como numa escoriação rotineira, desaparece com o passar do tempo. Todo o material utilizado para coleta é estéril, descartável, e não existe nenhum risco de contrair doenças. Em relação à avaliação neuropsicológica, o risco máximo é de desconforto físico e ansiedade relacionada aos procedimentos de testagem. Todo esforço será feito no sentido de atentar para o bem-estar físico e psicológico dos participantes, interrompendo-se a testagem aos menores sinais de desconforto, além de se adotar procedimentos de relaxamento e esclarecimento.

A sua participação na pesquisa é voluntária e não implica em nenhum compromisso financeiro entre você e a equipe da UFMG. Dessa forma, você poderá negar o consentimento ou optar, em qualquer momento da pesquisa, pelo encerramento de sua participação sem sofrer nenhum tipo de prejuízo. Os resultados da pesquisa poderão ser utilizados em trabalhos científicos publicados ou apresentados oralmente em congressos e palestras sem revelar a identidade dos participantes.

Ao final, você obterá oralmente e por escrito, sob a forma de aconselhamento e de um relatório, os resultados da análise dos dados de seu (sua) filho (a) realizada por profissionais das áreas da pediatria, genética e psicologia. Caso seja identificado algum problema de saúde ou alguma necessidade educacional, sua família será orientada e lhe encaminharemos para os serviços disponíveis na comunidade com o objetivo de otimizar sua saúde , bem-estar e desempenho funcional.

Agradecemos sua atenção e valiosa colaboração.

Atenciosamente,

____

Prof. Dr. Marco Aurélio Romano Silva
CRM-23889
Prof. Titular do Departamento de Saúde Mental da UFMG
Telefone: (31) 3409 9650
Av. Prof. Alfredo Balena, 190 - sala 114 / Belo Horizonte - MG

Para maiores esclarecimentos: Comitê de Ética em Pesquisa (COEP-UFMG), na Av. Antônio Carlos, 6627 – Unidade administrativa II, 2º andar/ Campus Pampulha- UFMG Tel: (31)34094592/ E-mail: coep@prpq.ufmg.br

Participante

Eu,____, abaixo assinado (a), declaro ter sido informado (a) sobre os procedimentos e propostas da pesquisa 'Avaliação Multidimensional de Indivíduos com Transtorno de Déficit de Atenção e Hiperatividade (TDAH)'e concordo com minha participação voluntariamente.

Belo Horizonte, ________ de ______________________de _____________.

____
Assinatura

Attachment A - Research Approval

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Projeto: CAAE –02899412.9.0000.5149

Interessado(a): Profa. Débora Marques de Miranda
Departamento de Saúde Mental
Faculdade de Medicina - UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 03 de outubro de 2012, o projeto de pesquisa intitulado **"Avaliação multidimensional de indivíduos com transtorno de déficit de atenção e hiperatividade"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto.

Profa. Maria Teresa Marques Amaral
Coordenadora do COEP-UFMG

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Attachment B - NITIDA Research Centre

NITIDA - Research Center of Impulsivity and Attention
Externalizing Behaviors/Disorders (focus on ADHD)
*Children from **5-to-10 years** old*

INCT
Medicina Molecular

Entry strategies:
- Inscription at the University Hospital – HC (no inclusion criteria, except for age)
- Screening at schools

Maintenance at NITIDA: clinical interview and diagnosis indicative of an **externalizing disorder**
- Treatment (pharmacological and/or PMT)
- Blood Collection for Molecular studies

Instruments:

-**Clinical Interview and Diagnosis**: K-SADS-PL + CARS (ASD)
-**MPSA** (multi-dimensional scale for ASD (PDD) + ADHD)
-**Patient and family characterization** (parent report):

1. Sociodemographic data and medical history
2. MTA-SNAP-IV (ADHD and ODD symptoms)
3. CBCL 6/18 (problem behavior in children)
4. PSDQ 32-item (Parenting Styles and Dimensions)
5. BDI-II (depression), STAI (anxiety), ASRS-18 (adhd) (parent symptoms' characterization)

-**Children's cognitive measurement**

1. Raven's CPM (fluid intelligence)
2. WISC-III Vocabulary
3. Five Digits Test (automatic/controlled attentional processes)
4. TDE (school achievement test –spelling, readind and arithmetic)
5. Temporal Estimation + Temporal Discouting
6. CPT-II

Ongoing researches:

-Inheritance and Impact of ADHD symptoms on Telomere Length;
-Stress and ADHD (Trier Social Stress Test (TSST) and salivary and blood serum cortisol);
-Parenting Style influence on ADHD severity and Telomere Length depending on genetic sensitivity/risk ("dopaminergic genes");
-MPSA (multi-dimensional scale for PDD and ADHD) validation in Brazil;
-SNAP-IV psychometric properties in Brazil;
-ASD vs ADHD vs ASD+ADHD vs Typical developing performance on a Temporal Discounting Task and its hemodynamic correlates (potential for diagnostic differentiation; cognitive-affective specificities; dual process theory of decision-making).

Directors/Principal Investigators:
Débora Marques de Miranda, PhD – Department of Pediatrics/UFMG
Leandro Fernandes Malloy-Diniz, PhD - Department of Psychiatry/UFMG

Attachment C - Five Digit Test Normative Data

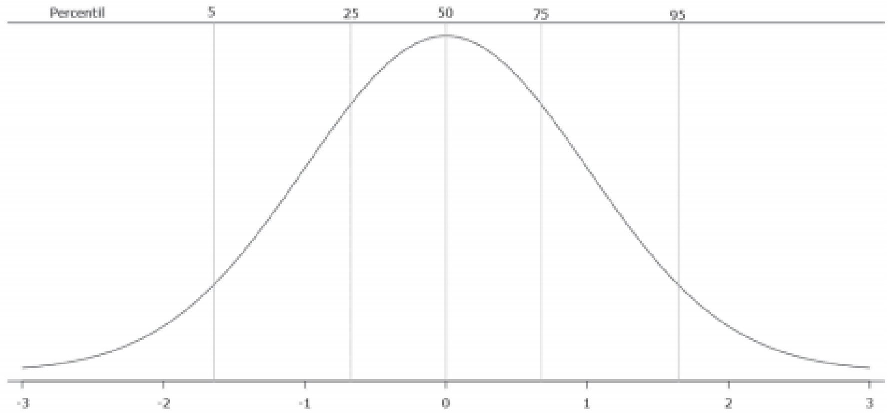

Figura 6.1 – *Correspondência entre a curva normal e os valores percentis*

Tabela 6.2 *Dados normativos do FDT para a população brasileira considerando a amostra de normatização como um todo (N=1033)*

		Média	*DP*	*Pc.95*	*Pc.75*	*Pc.50*	*Pc.25*	*Pc.5*
Tempos	Leitura	25,1	7,5	16	20	24	29	37
	Contagem	29,9	10,0	19	23	27	34	48
	Escolha	46,5	18,2	28	34	42	54	79
	Alternância	58,8	22,6	35	43	53	70	97
	Inibição	21,3	13,8	6	12	18	27	46
	Flexibilidade	33,7	18,3	14	21	29	43	65
Erros	Leitura	0	0,2	0	0	0	0	0
	Contagem	0,1	0,6	0	0	0	0	1
	Escolha	1,0	1,8	0	0	0	1	4
	Alternância	1,8	2,7	0	0	1	2	7

Tabela 6.3 *Dados normativos para crianças de 6 a 8 anos (N=44)*

		Média	*DP*	*Pc.95*	*Pc.75*	*Pc.50*	*Pc.25*	*Pc.5*
Tempos	Leitura	35,4	9,3	25	29	34	39	48
	Contagem	51,0	18,7	32	40	48	56	83
	Escolha	79,4	24,1	41	66	79	94	109
	Alternância	93,7	26,3	58	75	91	113	133
	Inibição	44,0	19,5	17	31	43	55	76
	Flexibilidade	58,3	20,8	26	41	55	75	92
Erros	Leitura	0	0,2	0	0	0	0	0
	Contagem	0,5	1,2	0	0	0	0	4
	Escolha	2,6	2,6	0	0	2	4	9
	Alternância	3,9	4,7	0	1	2	5	10

Tabela 6.4 *Dados normativos para crianças de 9 a 10 anos (N=129)*

		Média	*DP*	*Pc.95*	*Pc.75*	*Pc.50*	*Pc.25*	*Pc.5*
Tempos	Leitura	29,4	5,2	22	26	29	32	38
	Contagem	39,4	7,1	28	34	39	43	52
	Escolha	65,1	13,5	46	56	63	73	88
	Alternância	78,5	23,2	54	67	75	87	101
	Inibição	35,7	11,7	19	28	35	42	57
	Flexibilidade	49,1	21,8	28	39	46	57	73
Erros	Leitura	0	0,2	0	0	0	0	0
	Contagem	0,4	0,8	0	0	0	0	2
	Escolha	1,9	1,9	0	0	1	3	6
	Alternância	3,1	2,9	0	1	2	4	8

Tabela 6.5 *Dados normativos para crianças de 11 a 12 anos (N=59)*

		Média	*DP*	*Pc.95*	*Pc.75*	*Pc.50*	*Pc.25*	*Pc.5*
Tempos	Leitura	29,4	13,5	20	24	27	32	47
	Contagem	38,2	11,4	25	32	36	44	54
	Escolha	59,4	28,9	38	48	56	62	93
	Alternância	68,6	27,5	46	55	66	73	96
	Inibição	30,0	18,0	12	20	28	35	51
	Flexibilidade	39,2	17,7	16	30	39	44	68
Erros	Leitura	0,1	0,3	0	0	0	0	1
	Contagem	0,4	1,1	0	0	0	0	3
	Escolha	1,7	2,7	0	0	1	2	10
	Alternância	2,6	3,2	0	0	2	3	10

Tabela 6.6 *Dados normativos para adolescentes de 13 a 15 anos (N=46)*

		Média	*DP*	*Pc.95*	*Pc.75*	*Pc.50*	*Pc.25*	*Pc.5*
Tempos	Leitura	23,3	5,2	17	20	23	26	34
	Contagem	30,0	7,3	21	24	28	35	44
	Escolha	47,1	11,8	33	40	45	53	68
	Alternância	56,9	15,2	36	46	53	67	81
	Inibição	23,8	9,0	8	19	23,5	29	42
	Flexibilidade	33,6	12,5	14	25	32	43	53
Erros	Leitura	0	0	0	0	0	0	0
	Contagem	0,2	0,5	0	0	0	0	2
	Escolha	1,6	2,4	0	0	1	2	7
	Alternância	1,9	2,1	0	0	1	3	5