Assessment of Executive Function in Children and Adolescents with acquired brain injury

- A Systematic Literature Review

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10. Semester, Psykologi

Speciale Projekt

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Part A's samlede antal tegn/normalsider: 59.983 tegn/16,5 sider

Part B's samlede antal tegn/normalsider: 39.677 tegn/16,5 sider

Specialets samlede antal tegn/normalsider: 99.660 tegn/41,5 sider

AALBORG UNIVERSITET

Abstract

This particular Master's Thesis aims to investigate how executive functions are assessed in children and adolescents with acquired brain injury. To fulfill this objective the thesis is split into two a Part A and a Part B, where Part A is presented and written independently, while Part B is outlined around Part A as a framework and written to compliment Part A and support the thesis as a whole.

The independent Part A is a review article or more specifically, it is a systematic literature review. Part A aims to investigate a research question that goes '*What methods are used for the assessment of executive functions in children and adolescents with ABI, and how do they compare to each other?*', using the existing literature on the subject. Literature was gathered from PsycNET and PubMed before thoroughly screened and then synthesized into the article itself. Part A emphasizes the importance of assessment tools and methods during the synthesis and discusses several topics concerning assessment in general when dealing with executive function in a pediatric population.

Meanwhile Part B introduces the thesis itself by presenting the problem definition and subsequently rationalizing the choices behind it. Later in the thesis Part B also covers theory on traumatic brain injuries, stroke and brain tumors, but in relation to the pediatric population and executive functions, as well as examining how secondary ADHD might relate to the assessment of executive functions in children and adolescents with acquired brain injury.

Finally the thesis concludes that clinicians should attempt to include some ecologically valid measures as well as complementary measures when assessing the executive function of children and adolescents with acquired brain injury. The assessment tools BRIEF and CKTA are highlighted as well-recommended measures of executive functions for such a purpose. It is also reported that all the most common types of acquired brain injuries are associated with executive dysfunction, and that if secondary ADHD should appear post-injury, a greater amount of executive impairment is to be expected.

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Introduction

Problem definition

For this Master's Thesis the overall goal is the investigation of the existing research that is available on the subject of *'assessment of executive functions in children and adolescents with acquired brain injuries'*. Now there is actually a lot to take from this subject I just presented, so there are some things to address about it. In a way it can be considered a combination of four separate "themes" that have come together to further pin-point an area of interest. The first of these themes is that of 'assessment', and its inclusion in the subject of the thesis, makes the problem centered on assessment and diagnosis rather than another common theme like treatment. In other words, the thesis is interested in *how* to spot and evaluate the problem in question. The next theme is that of 'executive function', which defines *what* the psychological problem is that I want to assess. If this theme is put together with the first theme, we have the combined theme of 'assessment of executive function'. This opens up the thesis to investigate the various methods, tools and considerations required to assess executive functions.

The two remaining themes can both be regarded as the ones which help pin-point the sample or population of interest for the subject. 'Children and adolescents' make up the third theme. This theme is obviously pin-pointing *who* the population in question is regarding the subject. The fourth and final theme 'acquired brain injuries' is a disorder and could thus be interpreted as defining a problem in the subject, however, in the context of this thesis, it is instead a descriptive requirement accompanying the theme regarding the population of interest. To sum up, I define the problem by *how* the problem in the population is assessed, *what* the problem is, and *who* the population is. And this creates the subject that comes out as 'assessment of executive functions in children and adolescents'.

The exact definitions and ramifications of the terms 'executive functions', 'acquired brain injuries' and 'children and adolescents' are left somewhat ambiguous for now on purpose, since that already in their nature within psychological literature and research. Within the confines of the systematic literature review article of Part A, some of these terms will be defined as to what they entail and handled accordingly.

Rationale for thesis subject choice

Assessment of executive functions (EFs) is worthwhile to investigate because executive functions consist of a wide array of cognitive functions that are required for independent and self-directed behavior (Lezak, Howieson, Bigler & Tranel, 2012, p. 37). When EFs are significantly impaired, individuals might lose their ability to respond in an adaptive manner, fail to regulate or inhibit their emotion and behavior, lose their social skills, or other problems might arise (Capilla et al., 2004, p. 379; Lezak, Howieson, Bigler & Tranel, 2012, p. 666). One big issue working with EFs is that, the term ‘executive function’ can cover a lot of cognitive abilities, and the scope of how much it covers in its definition has met very little to no agreement (Capilla et al., 2004, p. 379). In other words, it is an umbrella-term that is conceptualized differently depending on the researcher. What is agreed upon is that impairment of executive functions often leads to problems that can affect all aspects of behavior (Capilla et al., 2004, pp. 379-380; Lezak, Howieson, Bigler & Tranel, 2012, p. 37). It is a very complex topic to deal with for those reasons, but also an interesting one.

The reason why the pediatric population consisting of children and adolescents are of special interest is because of their relation to EF. Not only are the EFs still developing throughout the entirety of both childhood and adolescence, but EFs are also important functions for learning and future development both at home, in school and social situations (Capilla et al., 2004, pp. 380-384; Gilboa et al., 2019, p. 1360; Lezak, Howieson, Bigler & Tranel, 2012, p. 37; Slomine et al., 2005, p. 651). Therefore impairment in EFs could have grave consequences for children since they are still developing, and because those very executive skills are being used for development themselves. Additionally, working with a pediatric population was also to satisfy a personal motivation to prepare myself for a potential future working in PPR.

As for the interest in acquired brain injuries (ABIs), the first reason is similar to that of EF. ABI is likewise an umbrella-term covering a wide array of different types of brain damage, and is also used differently in various studies and research papers (Teasell et al., 2007, p. 180). ABI also brings another relevant aspect to the subject regarding not only the population in question, but also to the aspect of EFs as they are also known as “frontal lobe functions”, and since ABI may implicate related brain regions or the frontal lobe (Capilla et al., 2004, p. 377). Finally the more personal reasons for focusing on ABI were to be more specific with my problem definition and also to better integrate my own field of expertise, which comes from a more medicinal and neuropsychological background established throughout my educational history.

In the systematic literature review of Part A, the subject of interest is generally the same as the rest of the thesis, but it is changed slightly to be directed more at investigating methods and assessment tools specifically. This slight change in the expression of the thesis subject is to reflect the aspect of gathering existing literature through the means of a systematic literature review. The rationale for focusing even more on methods and assessment tools in the article was both out of self-interest in neuropsychological testing and to gain better insight into various existing tools and their development.

Research question

The following research question is primarily directed at the systematic review article in Part A. Meanwhile, Part B mostly takes a step away from being directly concerned with the tools of assessment and instead explores topics more in line with the subject mentioned in the problem definition, which is still relevant for the majority of the research question.

> *What methods are used for the assessment of executive functions in children and adolescents with ABI, and how do they compare to each other?*

Structure and method of thesis

This Master’s Thesis consists of a two-part with Part A relating to a central systematic literature review article and a Part B relating the remaining framework around the thesis. Part A is only made up of the systematic literature review article itself. This part of the thesis was also the first part to be written, so that Part B could be written subsequently and support the article. In other words, the article in Part A is the central piece of the thesis, while Part B acts as a sort of supporting framework. To make the article in Part A, a systematic literature search was performed, while using the free browser version of EndNote to manually manage and screen citations before synthesizing the final selection of studies. This process is explained in much greater detail in the systematic literature review itself to maintain as much transparency possible. However, one thing that is not mentioned in that explanation is that during the screening process, articles with potential for Part B were also identified and put into a separate group in the citation manager. Part B of the thesis consists of this introductory section before the review article, and the following sections, about common types of ABI and secondary ADHD, that appear after the review article. While plenty of notes were written throughout the process, it wasn't until after finishing the systematic literature review of Part A that I began writing the sections of Part B. During the writing of Part B, plenty of literature was manually looked up, but the majority of it was not used as references. These un-referenced articles were not included in the curriculum.

Part A – Systematic Literature Review on the Assessment of Executive Function in Children and Adolescents with ABI

Abstract

Objective: This systematic literature review aims to investigate and discuss existing literature on methods and tools about the assessment of executive functions (EF) in children and adolescents with acquired brain injury (ABI). This review was done as part of a 10th semester Master's thesis in psychology.
Methods: Literature on the assessment of EF in children and adolescents with ABI was gathered from PsycNET and PubMed. This literature subsequently went through a thorough screening process to select and synthesize the articles most relevant to the objective.
Results: Out of a total 1338 references, 43 articles were selected for the review. Several questionnaires, performance-based measures, virtual reality (VR) measures and other measures were identified and information regarding each tool was compiled.
Conclusion: Currently available literature suggests that measures with good ecological validity are preferred in the assessment of EF in children and adolescents with ABI. Recommended measures include the Behavior Rating Inventory of Executive Function (BRIEF) and the Children's Kitchen Task Assessment (CKTA). Other promising EF measures are reported warranting more studies regarding pediatric ABI.

Introduction

Whether it is physical trauma from a car-crash, intoxication from dangerous substances or something else entirely, modern medicine and technology has greatly increased the survival rate of those involved in such events. As mortality rates decrease, it is quite natural to increase our awareness of any residual injuries or deficits that may follow any sort of injury (Horton, Soper & Reynolds, 2010). This line of thought especially holds true when considering acquired brain injuries or 'ABI' for short.

One aspect to this lies in the epidemiology of ABI, as it is one of the leading causes of mortalities and long term disabilities among children and adolescents (Gilboa et al., 2015; Teasell et al., 2007), as well as among young adults (Gilboa et al., 2015; Tibæk et al., 2017). As a leading cause of death and disability, the magnitude of ABI's burden on society is undeniably a serious issue. To give us an idea of its magnitude, one study, by Mar et al. (2011), investigated the economics behind ABI treatment in two regions of Spain (which were the Basque Country and Navarra) and estimated that the costs for treating ABI patients were equivalent to around 10.4 and 11.7% of the total public health expenditures in the two regions. Cost per individual patients were also estimated to be around a mean of €21.040, which in comparison is less than the average cost for Alzheimer patients, but more than the average cost for AIDS or degenerative ataxia patients (Mar et al., 2011).

The other aspect as to why residual deficits caused by ABI are so important to be aware of is the potential impairments in future development for the patient, especially in the pediatric population. Childhood ABI have been shown to disrupt later development of various cognitive and linguistic functions, as well as impeding long-term academic achievement and social success (MacDonald, 2016; Gilboa et al., 2019). One of the reasons for this is that childhood ABI can often be associated with residual deficits in executive function, which is typically a result of damage to the frontal regions of the brain, such as the dorsolateral prefrontal cortex (Gilboa et al., 2019; McAllister, 2011). Executive functions, or EFs for short, can be considered a wide range of higher-order cognitive processes, involving core abilities important for performing complex tasks, learning and self-control, such as; planning, inhibition, attention, working memory and flexible thinking (Gilboa et al., 2019; Lezak, Howieson, Bigler & Tranel, 2012; McAllister, 2011). It is easy to understand why the impairment of such skills will significantly decrease the future development and quality of life when sustained during childhood. The ability to understand, perform and plan complex tasks is essential to properly follow instruction during everyday life and lessons during school. Likewise, if a child has trouble with attention or working memory, it will be a lot more difficult to retain the presented knowledge, thus diminishing the child's ability to learn properly. Meanwhile, if the child is impaired in terms of self-control, the lack of emotional and/or behavioral inhibition can lead to inappropriate behavior that disrupts that particular environment. Such disruptions can cause disturbances in both academic and social settings that can be auxiliary in causing the long-term impediments in both academic and social success, as mentioned earlier in this paragraph.

Besides the many problems that may arise due to the many potential residual deficits of executive dysfunction, these deficits are also not considered rare in the context of brain injuries, but are in fact among some of the cognitive domains typically impaired (McAllister, 2011). According to a study by Sesma, Slomine, Ding & McCarthy (2008) it was found that, somewhere between 18% to 38% of children with traumatic brain injury (TBI) and aged between 5 to 15 years, had reported significant executive dysfunction within the first year after injury. When combining both the occurrence and the implications for future development and everyday interactions that pediatric ABI represents, it becomes increasingly apparent that the assessment of EFs is a vital part of neuropsychological assessment when dealing with the pediatric ABI population (Gilboa et al., 2019; Johnson, Dematt & Salorio, 2009; MacDonald, 2016; Teasell et al., 2006). Additionally, the development of measures specifically targeted at assessing pediatric ABI, can be considered a relatively new area of research (MacDonald, 2016).

The objective of this study is to systematically review the existing literature involving the assessment of EFs in both children and adolescents that have sustained an ABI. A heavy emphasis is laid upon the assessment part of this objective. While interventions and rehabilitation is definitely a crucial aspect when it comes to EFs in pediatric ABI, this study has been focused on the initial phase of assessment. The research question that this study aims to answer instead, can be summarized as being concerned with the methods and tools that are used for the assessment of EFs in children and adolescents with ABI, and how those methods compare to each other. An important distinction of this research question is that it is specifically concerned with "assessment of children and adolescents" and not simply ABI sustained within childhood, which otherwise would have included assessment of adults who sustained pediatric ABI long ago. By reviewing what methods and tools have been studied for the assessment of EFs in children and adolescents with ABI, it will provide us with a platform that can act as the basis for a discussion of several topics and questions. What are the preferred methods and tools used for assessing EFs in the pediatric ABI population? What are the advantages and disadvantages of questionnaires and performance-based measures respectively? How does the assessment of EFs in pediatric

ABI translate to the environment of everyday life and school? These questions are among some of the topics that this study aims to investigate based on the existing literature. The study also aims to explore the disposition of existing literature, to see if there are some areas where research might show promise or is in need of more future research.

Definition for ABI in this article

For the sake of transparency, I will be providing a definition for the term ABI and its use in this research paper. The explanation for why this is necessary, is because the term ABI is a loosely defined umbrella term, which means that it is a term that encompasses a wide array of different types of injuries to the brain, but the exact spectrum that it covers is not universally used in a consistent manner (Chiavaroli et al., 2016; Teasell et al., 2007). In some instances ABI is also referred to as acquired brain damage or ABD for short (Mar et al., 2011). For the sake of consistency, this article will stick to using ‘ABI’, since it is the more commonly used term encountered during the process of making this review, and also because it better falls in line with similar terms like that of TBI.

The definition of acquired brain injury used in this paper boils down to encompassing any injuries to the brain that aren’t hereditary, congenital or degenerative. This definition means that ABI only includes injuries that are ‘acquired’, therefore inferring a previous state of being neurologically intact (Teasell et al., 2007). Additionally, since this definition needs the brain injury to be non-congenital, that implies that the brain injury has to occur after birth (Gilboa et al., 2015; Teasell et al., 2007). There are many types of injuries to the brain which fit this description, but they can generally be split into two types of origins (Chiavaroli et al., 2016).

The first type of origin consists of injuries of the traumatic types, which are the ones commonly referred to as TBIs. Injuries of the TBI type are by far the most common among the pediatric population (Johnson, DeMatt & Salorio, 2009). Common causes for TBI include car accidents, sports accidents, falls and physical violence (Chiavaroli et al., 2016; Nolin et al., 2012), which all can fall into the definition of ‘an acute, external force acting on the head, leading to alteration of consciousness’ (Wilson, Donders & Nguyen, 2011). TBIs are also classified in terms of severity. The severity can be classified as either mild, moderate or severe, which is usually done using the

Glasgow Coma Scale (GCS) as it is the most widely used global measure for this classification (Johnson, DeMatt & Salorio, 2009; Teasell et al., 2007).

The second type of origin consists of the non-traumatic brain injuries, which can be caused by a plethora of different diseases or issues as long as it falls within the definition. Some examples of causes for non-traumatic brain injuries are intoxication, infection, tumors, focal brain lesions, cerebrovascular diseases, metabolic diseases, anoxia or stroke (Chiavaroli et al., 2016; Gilboa et al., 2015; Johnson, DeMatt & Salorio, 2009; Mar et al., 2011; Teasell et al., 2007; Tibæk et al., 2017), of which stroke is the most common cause (Mar et al., 2011). However, while stroke is a very common cause for non-traumatic ABI in adults, it is considerably rarer in the pediatric population (Tsze & Valente, 2011).

Methods

This systematic literature review was conducted in accordance with some of the recommendations provided by the 'PRISMA 2009 Checklist' (Moher, Liberati, Tetzlaff, Altman & PRISMA Group, 2009). This checklist was used more as an inspiration or a guideline rather than a literal step-by-step instruction. So for the sake of transparency, the conducted procedure will be described thoroughly in this section.

Literature Search Strategy

For this review, only two databases were used for the systematic literature search, which were PsycNET and PubMed. Both searches were limited to only include articles with a publication date between January 1990 and February 2021, with the last search and citation retrieved on February 22, 2021. The search was limited with filters to only show 'Peer-Reviewed' results on PsycNET, while the PubMed search was limited to only show 'Free full text' articles. As for the search words used, they can be grouped into five separate search strings that together make up the full search query. These groupings have been named Function, Sample, Cause, Relevance and Exclude to highlight each search string's intended filtering purpose for the search query. The first string, 'Function', was ["Executive function*" OR attention OR focus OR "problem solving" OR planning OR "theory of mind" OR "working memory" OR inhibition OR "emotional regulation" OR self-regulation OR "decision making" OR decision-making OR "emotional control" OR self-restraint OR "social skills" OR "short term memory" OR flexibility OR "flexible thinking"] to ensure that articles in the search query involved either EF or closely related functions. The second string, 'Sample', was [AND child* OR kids OR adolescen* OR toddler* OR juvenile OR teen* OR infant OR youth*] so that mostly articles involving the appropriate age group would appear in the search query. The third search string, 'Cause', was [AND ABI OR "acquired brain injur*" OR TBI OR "traumatic brain injur*" OR concussion OR "brain injur*" OR "cranial injur*" OR "intracranial injur*" OR "brain damage"] on PubMed, but on PsycNET, additional search words were added to this search string, which were [OR stroke OR "brain tumor" OR "oxygen deprivation" OR drowning OR "anoxic episode*" OR poisoning OR "alcohol abuse" OR "substance abuse" OR "drug abuse"]. The purpose of the third search string was for the search query to primarily find articles related to ABI. The fourth search string, 'Relevance', was [AND assess* OR evaluat* OR test* OR exam*] to help filter out articles not involving anything relevant to assessment or testing. The last search string, 'Exclude', was [NOT congenital OR neurodegenerati*] to help exclude articles involving the types of brain injuries that do not fit the same definition of ABI as used in this review.

All five search strings were set to search through 'Title/Abstract' on PubMed and through 'Keywords' on PsycNET with the exception of the Relevance search string for PsycNET, which was set to search through 'Any Field'. Overall both the Cause and Relevance search strings were stricter when used on PubMed. The reason behind using a stricter search strategy for the PubMed database, in comparison to the PsycNET database, was because PubMed as a database contains many articles that aren't directly related to the more psychological themes like EF and cognitive assessment tools.

The full search query generated a total of 1.339 results of which 880 results were generated by PsycNET, and 459 results were generated by PubMed. A few variations of the above-mentioned search query were also done initially before making a final choice for the search query used for this review. The current search query was chosen primarily because the amount of generated results were deemed neither too strict and also still manageable for a single person to manually screen during the amount of available time, considering this review article is part of a Master's thesis. After completing the database search, all citations were exported from each database to a folder and subsequently imported to a reference manager. The reference manager used was a free browser version of EndNote. One citation from PubMed could not be imported to EndNote due to technical difficulties, which was presumably because the citation in question had hundreds of authors attached to it. Therefore, the final amount of obtainable references gathered before the screening process was 1.338 citations.

Literature Screening Process

When performing the screening of the gathered literature, the process was divided into four different stages to both structuralize the process and maintain clarity over previous steps taken during the entire screening process. These stages were made into groupings on EndNote and consisted of the initial unscreened literature, literature after initial screening, literature after abstract screening and lastly literature after a full text screening. As such each group signified the remaining literature before and after each phase of the screening process.

In the first initial screening phase of the screening process, the purpose was first of all to look through the literature and remove any duplicate articles that were retrieved from both databases. This was done by going through the entire list first sorted by author and then manually removing any duplicates encountered. Afterwards the same procedure was then repeated, but sorted by titles in alphabetical order, while noting down and being aware of any titles that started with some kind of symbol (e.g. “ or *[*), to check if they would appear again later without a symbol during the screening. In cases where one of the duplicated articles was an updated version of the original article, only the more up-to-date version was kept. Besides duplicates, erratum, corrigendum and reply articles were also removed during the initial screening. However, these were kept in another separate folder, just in case their respective article was selected later on. During this initial screening phase, 71 records were removed leaving 1.267 articles for the next screening phase.

The next screening phase was the abstract screening phase. As the name suggests, all 1.267 abstracts were manually screened one by one to determine eligibility for inclusion. Eligibility for inclusion was judged according to several inclusion and exclusion criteria, which were decided upon before the abstract screening began. The first inclusion criterion was that the article had to involve children or adolescents aged somewhere between 0 and 18 years. That being said, if the age-range of a sample was something like 5 to 20 years, it was still accepted as long as the majority of the sample wasn't over 18 years old. If an article also involved adults on top of children and adolescents in their sample, the article would only still be included if the pediatric population of the sample were a part of the main objective of the study and if they were analytically separable from the adult population of the sample. It is important to once again note, that this age-of-sample criterion is referring to the sample's age-at-testing or age-of-assessment and not their age-at-injury, since the assessment of children and adolescents itself is an important part of the research question for this review. Along the first inclusion criterion regarding article samples, an exclusion criterion was also made. This exclusion criterion regarding article samples said to exclude any non-human samples like rats, monkeys or etc. Since the review is working with the assessment of a complicated construct like EF, there is no need to add further complexion. Besides, in my opinion it seems doubtful that many inferences could be made between the assessment itself of humans and animals when involving higher-order cognitive functions life EFs.

Another essential inclusion criterion is that the article needs to involve children or adolescents with ABI according to the definition used for this review. As such, it was likewise an exclusion criterion if the article was about ABI caused by hereditary, congenital or degenerative issues. Additionally, merely being exposed to the typical causes of ABI was not sufficient for this inclusion criterion. To qualify for inclusion, children or adolescents had to have been diagnosed as having ABI in some way, whether that involved deterioration of cognitive, physical, social or regulatory skills, evidence through imaging technology or something else, didn't matter. This meant that something like an article involving substance abuse, which can lead to ABI, wouldn't be included unless ABI was documented or part of the main focus.

The last inclusion criterion was that the article had to involve assessment of EFs as a topic or aim. Simply performing an assessment was not sufficient to qualify for this criterion. Assessment had to be discussed, evaluated or tested in some fashion, meaning that the assessment itself was part of a primary or secondary objective, and not just a tool to reach a different objective. The assessment method or tool in question also had to be used for the purpose of saying something about EFs specifically. While skills like problem solving are closely related to EFs (Drigas & Karyotaki, 2019), unless the article properly addresses EFs in relation to the objective, articles about such skills or function were not included. This criterion of assessment was applied in a very strict fashion during the screening process and this led to a lot of articles from PubMed about sports- and substance-induced ABI to be excluded.

From just the abstracts it was sometimes hard to judge whether articles actually fit these inclusion and exclusion criteria. In these cases where I wasn't sure whether to include an article or not, the general rule was to include it for the next screening phase. Since this review was part of an independent Master's thesis, the screening was done by a single person, which meant there was no need for any strategies to reach a consensus when judging eligibility. During the abstract screening phase 1.169 articles were excluded leaving 98 articles for the next and final screening phase.

The last screening phase was the full text screening phase. In this screening phase the intention was to read all 98 articles to once again judge their eligibility for being included in this review. Unfortunately 2 articles from PsycNET, which were promising according to their abstracts and titles, didn't have any available access to an online full text or PDF. The other 96 articles were retrieved without issue. The screening of the 96 remaining articles started with a skim reading. In this skim reading, articles were judged by the same inclusion and exclusion criteria as in the abstract screening phase. Articles were also judged slightly in terms of their quality during the skim reading, like for example if their relevant sample size was way too small in relation to the type of study it was, though the vast majority of exclusions were made based on the inclusion and exclusion criteria. After the skim reading 48 of 96 articles were excluded leaving another 48 articles. These 48 articles were then read once more but thoroughly this time, while also taking notes to pin-point anything relevant to the research question during the reading. During this thorough reading, where reading to comprehend and take proper notes were the primary focus, articles were still being judged for eligibility, and so 5 more articles were excluded during this part of the full text screening phase. With the conclusion of the thorough reading the entire literature screening process was over and 43 articles remained in the final literature selection.

Synthesis of Literature

By making thorough notes during the reading of the full text screening phase, getting an overview of relevant information and topics for each article aided greatly in the process of synthesizing literature afterwards. The notes for each of the 43 articles were labeled to indicate the type of study and what relevancy they had to the research question. These notes generally consisted of writing down a description of the article and its aim, along with notes on background information, methods & results, discussion & conclusion, and lastly what the key points to take away were. The resulting compilation of notes took up over 39 pages, and was often referred to during the synthesis of the gathered literature and when navigating through the selected articles for more information. The synthesis itself didn't adhere to any particular guidelines or checklists. Instead relevant information was manually synthesized and grouped in accordance to the respective method, tool or topic.

Results

The performed screening of literature resulted in the PRISMA flow diagram, which can be seen below in *Fig. 1*. Of these 43 selected articles, the vast majority of articles were concerned with one or more specific measurements to assess EFs or specific

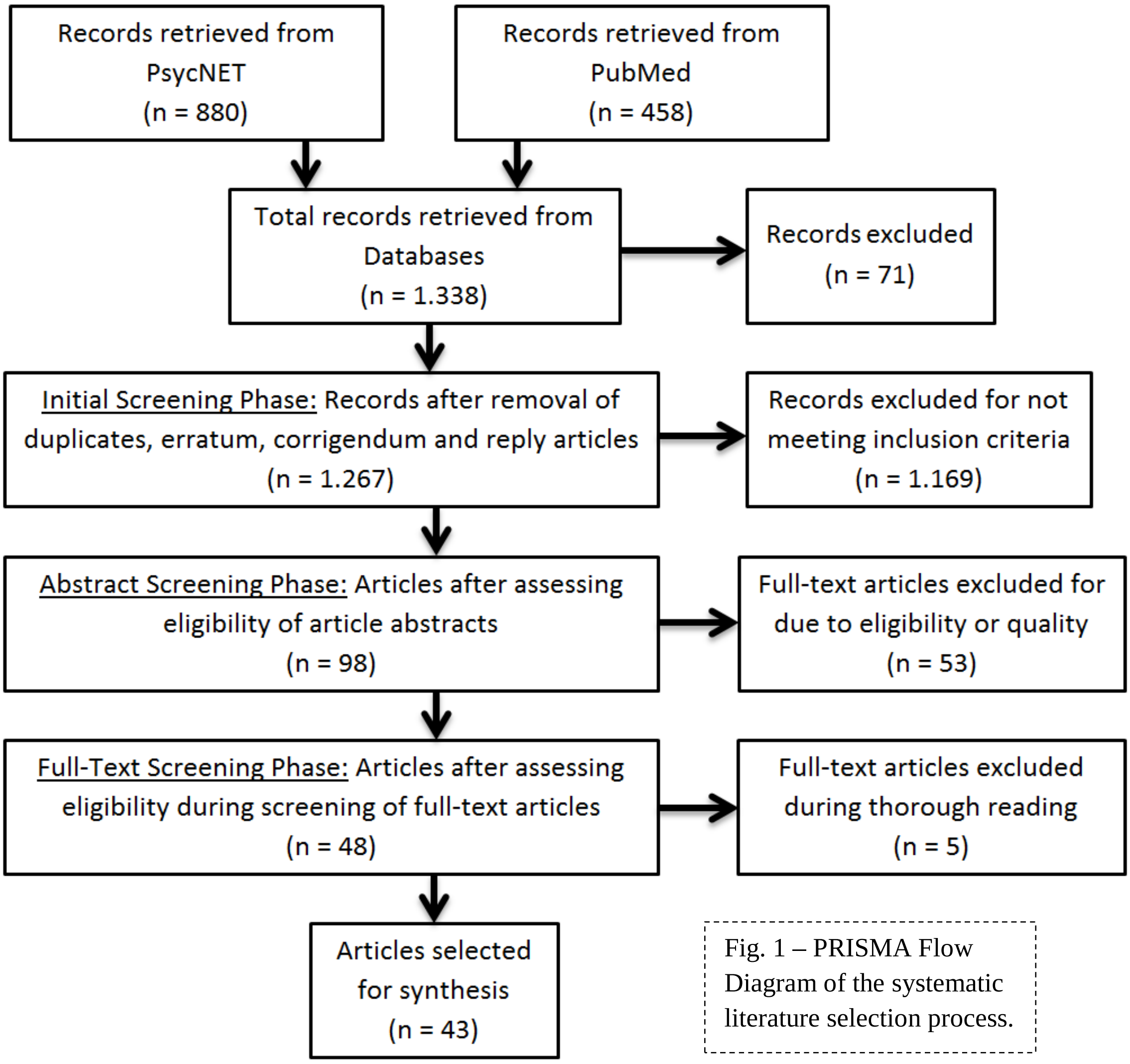

Fig. 1 – PRISMA Flow Diagram of the systematic literature selection process.

executive constructs, while 10 articles were labeled as being concerned with assessment in general, rather than specific tools. Between the many articles on measures of EF, the Behavior Rating Inventory of Executive Function (BRIEF) was the most common measure of interest, being part of the primary objective in 12 different articles, whereas the next most common measure of interest was the Children's Kitchen Task Assessment (CKTA), which was part of the primary objective in 4 different articles. Besides these tools, other questionnaires, performance-based measures, neuropsychological test batteries and even virtual reality tasks were also among the selected articles included in this review.

In this results section, key points relevant to the research question are presented for each of the assessment tools that were actively studied within the selected literature. The results will be presented in the following order: Questionnaires and Rating Scales → various performance-based measures → VR Tasks → Test Batteries. Common or interesting topics from the selected literature that are relevant to the research question will be brought up and discussed in the discussion section.

BRIEF is a widely used questionnaire when assessing executive function in children, and especially when dealing with conditions of a developmental or congenital nature, and of course also when dealing with acquired brain conditions (Chevignard et al., 2017), and generally in the context of TBI (Howarth et al., 2013). In general, BRIEF is a 'rating scale' measure that requires the answering of many questions or items by a certain individual, where both the items, number of items and even the individual who answers, depends on which version of BRIEF is used. Among the 12 articles which have BRIEF as part of their main objective 11 of them included the standard parental rating version BRIEF-Parent, where the parent of the child or adolescent completes the questionnaire (Chevignard et al., 2017; Conklin, Salorio & Slomine, 2008; de Vries et al., 2018; Di Lorenzo, Desrocher & Westmacott, 2021; Donders, DenBraber & Vos, 2010; Donders & DeWit, 2017; Howarth et al., 2013; Roche et al., 2020; Wilson, Donders & Nguyen, 2011). The construct validity of the BRIEF-Parent version is strongly supported by Donders, DenBraber & Vos (2010) using a two-factorial model, while several of the articles support BRIEF-Parent's sensitivity to EF impairments in children and adolescents with TBI, either through statistical analysis (Mangeot et al., 2002; Roche et al., 2020; Vriezen & Pigott, 2002) or through referencing previous studies (Conklin, Salorio & Slomine, 2008; Di Lorenzo, Desrocher & Westmacott, 2021; Donders & DeWit, 2017; Howarth et al., 2013; Roche et al., 2020; Vriezen & Pigott, 2002). Meanwhile, when the rating scale measure BRIEF was investigated for association with performance-based EF tasks, mixed results were found between studies. Mangeot et al. (2002) found a modest relationship between BRIEF and performance-based EF tasks for pediatric TBI patients, Di Lorenzo, Desrocher & Westmacott (2021) and Vriezen & Pigott (2002) found low-moderate correlations, while de Vries et al. (2018) reported no significant correlations at all between BRIEF-Parent and EF tasks. Conklin Solorio & Slomine (2008) looked at the association between the working memory index (WM-index) of BRIEF-Parent and working memory tasks specifically but also found no associations. Despite the lack of association Conklin Solorio & Slomine (2008), Di Lorenzo, Desrocher & Westmacott (2021), and Howarth et al. (2013) report that the WM-index of BRIEF-Parent might be sensitive to working memory deficits in TBI and pediatric brain tumor survivor (PBTS) patients.

The teacher rating form, BRIEF-Teacher, was included in addition to BRIEF-Parent in 3 of the 12 BRIEF articles. All 3 of these studies compared BRIEF-Teach ratings to BRIEF-Parent ratings as part of their objectives and they all found that, while not significantly different statistically, BRIEF-Teacher rating scores tended to be slightly higher than BRIEF-Parent ratings (Chevignard et al., 2017; de Vries et al., 2018; Di Lorenzo, Desrocher & Westmacott, 2021). BRIEF-Teacher was also compared with EF tasks in 2 of these studies, with de Vries et al. (2018) reporting significant correlations between the BRIEF-Teacher WM-index and several EF tasks, while Di Lorenzo, Desrocher & Westmacott (2021) reported significant correlations for several BRIEF-Teacher indexes, including the WM-index.

The last version of BRIEF present in the selected literature was the self-rating form BRIEF-SR. BRIEF-SR was included in 2 of the 12 BRIEF articles. In Byerly & Donders (2013), adolescents with TBI were in general found to provide less severe self-ratings when compared relatively to their performance on a neuropsychological laboratory test called ‘Tower of London’ (TOL), thus indicating deficits in self-awareness. Byerly & Donders (2013) concluded that BRIEF-SR is questionable to use for the assessment of EF, but may be clinically useful in giving insights into adolescents’ level of self-awareness. Level of agreement between BRIEF-Parent and BRIEF-SR was examined in Wilson, Donders & Nguyen (2011) and found that parental ratings of executive dysfunction were overall higher than self-ratings, with higher injury severity being associated to larger differences in metacognitive abilities between the two rating forms.

The Child Behavior Checklist (CBCL) is a widely used parental rating questionnaire for assessing children and adolescents' emotional and psychosocial adjustment, and includes scales about social and attentional problems (Donders & DeWit, 2017). According to Vriezen & Pigott (2000) performance on the Attention Problems scale of CBCL is not indicative of the greater attentional problems in children with moderate to severe brain injuries, due to performance being within one standard deviation of the normative mean. This may stand as evidence against at least the sensitivity of the Attention Problems scale of CBCL. Meanwhile, in Donders & DeWit (2017), the CBCL was compared to the BRIEF-Parent questionnaire to investigate the agreement and possible overlap/distinction between the two questionnaires. The study found that CBCL and BRIEF were in agreement in around 3 out of every 4 cases when completed by parents of children with mild TBI, which suggests a complementary relationship between the two measures according (Donders & DeWit, 2017).

The Questionaire of Executive Functioning (QEF) is another questionnaire studied among the selected articles. In Geurten et al. (2016) children with moderate to severe TBI were administered a self-rating form of QEF while one of their parents completed a parental rating form of QEF, for the purpose of evaluating the self-awareness of executive dysfunction in these children and to evaluate convergent validity of QEF. The study found mixed results for convergent validity, but overall the results suggested that QEF is a valid tool for both assessing executive function and self-awareness, as its ability to distinguish between children with TBI and controls showed significant differences in both self-rating and parental rating forms, but mostly the parental rating (Geurten et al., 2016).

The Children's Category Test (CCT) is an individually administered neuropsychological test in a booklet format that consists of two levels, where level one (CCT-1) is used on children aged 5 to 8 years and level two (CCT-2) is used on children aged 9 to 16 years (Allen, Knatz & Mayfield, 2006; Bello, Allen & Mayfield, 2008). In the study by Allen, Knatz & Mayfield (2006) the CCT-1 is reported to be a valid instrument that is significantly sensitive to severe TBI in children, but not particularly sensitive in mild to moderate cases. Meanwhile in Bello, Allen & Mayfield (2008) the CCT-2 is reported to also be a valid tool, however, it was not found to be significantly sensitive to any severity of TBI, and the reason for this was unclear.

The Comprehensive Trail Making Test (CTMT) was adapted from the classic Trail Making Test (TMT) to include children into standardization by making 1-5 levels of trails rather than just A and B (Bauman Johnson et al., 2010). The validity of CTMT as an assessment tool of EFs on children with moderate to severe TBI is supported because Bauman Johnson et al. (2010) demonstrated strong sensitivity and good overall utility. The study worked with children aged between 11 to 19 years, but suggests future research repeating the objective on those younger than 11 years (Bauman Johnson et al., 2010).

The Children's Color Trails Test (CCTT) is another adaptation of TMT, but the CCTT was designed to specifically measure sustained visual attention, sequencing, psychomotor speed and cognitive flexibility (Llorente et al., 2009). In the second study of the article Llorente et al. (2009), the authors study the factorial validity of CCTT in a large sample of children with TBI and report supporting evidence for CCTT as a measure of attention and emerging executive skills like cognitive flexibility and inhibition.

Digit Span is another classic EF measure like TMT, and its sensitivity to pediatric TBI was examined in two of the selected literature articles (Vriezen & Pigott, 2000; Warschausky, Kewman & Selim, 1996). In Vriezen & Pigott (2000), several attentional measures including Digit Span were examined for sensitivity to moderate to severe TBI in children, but results did not support sensitivity of Digit Span to the sample. Likewise in Warschausky, Kewman & Selim (1996), which investigated sensitivity to pediatric TBI in Digit Span, performance of children with TBI did not significantly differ from performance of the control group. While non-significant the TBI group did perform poorer overall and made more errors (Warschausky, Kewman & Selim, 1996).

The Children's Kitchen Task Assessment (CKTA) is more commonly referred to as the Children's Cooking Task or CCT for short. To avoid confusing this measure with the Children's Category Task, which is also abbreviated as CCT, the alternate name and abbreviation of CKTA will be used instead. This measure was specifically developed as an open-ended naturalistic task meant to be useful for assessing EF in children with TBI (Chevignard et al., 2009). Chevignard et al. (2010) shows evidence for CCT as a sensitive tool for the assessment of EF in children capable of distinguishing TBI patients. It is also a sensitive measure to self-awareness and prospective memory in children with ABI (Krasny-Pacini et al., 2015; Krasny-Pacini et al., 2017).

The Tinker Toy Test is another measure of EF sensitive to pediatric TBI, and it involves instructing a patient to independently construct something specific from toy-like parts and pieces (Roberts et al., 1995). Performance on the Tinker Toy Test was significantly correlated with intelligence scores (Roberts et al., 1995).

In the article Shanahan, McAllister & Curtin (2011), two case studies were presented to illustrate the clinical utility of the Party Planning Task (PPT) on individuals with severe pediatric TBI. PPT is a non-standard EF assessment tool where the individual has to organize an imaginary party under several constraints. PPT was shown to be useful for assessing the EFs of the two cases studied and detecting even subtle EF changes (Shanahan, McAllister & Curtin, 2011).

Porteus Maze Test (PMT) is a visually guided maze-learning task developed to evaluate planning ability (Levin, Song, Ewing-Cobbs & Roberson, 2001). Results from Levin, Song, Ewing-Cobbs & Roberson (2001) support the use of PMT as a measure of planning, because it was sensitive to severity of TBI and volume of lesions in the children who participated. The authors also suggest future studies to investigate if inhibition displayed during PMT can be associated with self-regulatory inhibition of behavior, which as previously stated in this review is part of EF (Levin, Song, Ewing-Cobbs & Roberson, 2001).

In Timmermans & Christensen (1991) attentional deficits in pediatric TBI were studied using Gordon Diagnostic System (GDS), which is an atypical measure of attention performed on a small device or computer, consisting of a CPT and Direct-Reinforcement-of-Latency task. The majority of the sample with pediatric TBI scored within normal limits on the GDS, and only the CPT part of the measure showed concurrent validity with other attentional measures (Timmermans & Christensen, 1991). Because of the supportive evidence for the validity of the CPT part of the measure, GDS may still be of some use in clinical test batteries concerning sustained attention or vigilance (Timmermans & Christensen, 1991).

The Student version of Functional Assessment of Verbal Reasoning and Executive Strategies (S-FAVRES) is a measure of higher level cognitive-communication functions specifically designed for adolescents with ABI and consists of four verbal reasoning tasks about novel and ecologically valid situations (MacDonald, 2016). S-FAVRES is sensitive to ABI in adolescents in all four scores just as designed, however when MacDonald (2016) compared the concurrent validity of S-FAVRES to relevant indexes of BRIEF, no significant correlations were found.

Among the selected literature articles for this review were four different studies that deal with various virtual reality (VR) assessment tools. The first of these studies involved the only non-immersive VR assessment tool among the four VR measures called Jansari Assessment of Executive Functions (JEF-C©), which as the name implies is used to assess EFs (Gilboa et al., 2019). When tested for validity and feasibility in children with ABI, JEF-C© was shown to be a cheap and feasible tool because it was playful and easy to administer, but also had good discriminant validity since children with ABI performed significantly worse than controls (Gilboa et al., 2019). Additionally, the JEF-C© wasn't significantly correlated with various other measures of EF, including BRIEF (Gilboa et al., 2019).

The second VR measure is the Virtual Shopping Task (VMall) and is the only semi-immersive VR assessment tool among the four VR measures (Erez et al., 2013). VMall is sensitive to severe TBI in children as this group has a poorer performance than controls (Erez et al., 2013). In Erez et al. (2013) children also reported through a feedback questionnaire that the VMall task was enjoyable and motivating, which makes the authors conclude that VMall might have potential for use for repeated assessment or intervention in children with TBI.

The last two VR measures are fully-immersive VR assessment tools. The first one of these two is the Virtual Classroom (VC) which was developed as an ecological measure of attentional skills in children (Gilboa et al., 2015). Gilboa et al. (2015) studied the validity and utility of VC on children with ABI, and their results indicate that VC works as an ecologically valid and sensitive measure of attentional skills in pediatric ABI. Concurrent validity was also supported since VC had significant correlations with other measures of attention, and VC was also correlated with injury severity and age (Gilboa et al., 2015).

The last VR measure is a fully-immersive VR assessment tool called ClinicaVR: Classroom-CPT developed as a continuous performance test (CPT) measure of attention and inhibition based on an identical non-VR version called VIGIL-CPT (Nolin et al., 2012). In Nolin et al. (2012) the ClinicaVR: Classroom-CPT and VIGIL-CPT were administered to adolescents with mild TBI from sport-related concussions to study validity and usability. Results found ClinicaVR: Classroom-CPT to be sensitive enough to even detect the subtle effects of sports concussions and also to be more ecologically valid than the original non-VR version (Nolin et al., 2012). Several participants did, however, report getting cybersickness, but there was no correlation between cybersickness and virtual test scores (Nolin et al., 2012).

A validity study of the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), a computerized test battery developed for assessing attention, memory and processing speed, was also present among the selected literature (Conklin et al., 2013). Sensitivity to cognitive late effects for PBTS patients was examined and supported through worse performance in PBTS group in comparison to two different control group (Conklin et al., 2013). Additionally some ImPACT subtests were significantly correlated with similar measures, indicating a degree of convergent validity behind the test battery (Conklin et al., 2013).

Discussion

Based on the selected literature in this review, it is difficult to properly compare the various assessment tools and measures of EF in relation to ABI. This is not just because of the skewed distribution of what measures each article investigates, but more of an issue rooted in the nature of ABI itself. As mentioned during the earlier section defining ABI, ABI is an umbrella term and can thus be the consequence of a wide variety of causes and impact different areas of the brain. Therefore it is quite natural that ABI can likewise produce a wide array of somewhat unpredictable impairments affecting the patient physically, psychologically or neurocognitively (Teasell et al., 2007). Since the injury profiles for each person can be very different in ABI, the following impairments or sequelae aren’t consistent and each individual ABI patient may display symptoms in completely different domains or constructs (McAllister, 2011; Teasell et al., 2007). This is also one of the reasons that the vast majority of the articles selected for this review involve TBI patients alone, rather than ABI patients (Teasell et al., 2007). Additionally, while TBI can be quite complex, it is at the same time rather predictable in many cases of assessment, since the injury profile often primarily depends on the location and trajectory of the brain damage involved (McAllister, 2011). However, this predictability is not as reliable as one might think, since pediatric TBI can commonly occur as diffuse brain injuries rather than just being located at a particular region of the brain (Vriezen & Pigott, 2002). Therefore one should be careful with their predictions based of brain imaging techniques since injuries and not exclude the possibility of impairments in other regions than the one noticeably damaged.

When considering these kinds of complexities it becomes apparent that we can't simply identify or attribute a patient's executive impairments following ABI by marking them off a checklist and call it a day, or follow the monotonous guideline for assessment. This predicament isn't really unique for ABI, since a lot of injuries and diseases also depend on identifying several common symptoms to properly diagnose, despite those symptoms not being universal for that particular patient group due to injuries and diseases having some degree of variety between patients. The difference here is that the amount of variety that the umbrella term ABI encompass is a lot larger than that of most other types of injuries and diseases. This is still the case when we're just looking at solely the EFs, where there're a lot of different executive abilities that could be impaired, and on top of that, it has also been seen many times that these impairments following ABI can sometimes appear immediately after injury, while others develop over time or instead hinder future growth (Horton Jr, Soper & Reynolds, 2010). Therefore every one of the assessment tools for measuring EFs present in the selected literature should not be judged based on their value as an independent measure, but rather their clinical potential as one of several measures, in the context of the assessment of suspected executive dysfunction in pediatric ABI.

When reviewing the selected literature, another important aspect regarding the quality and usability for assessment of EF in pediatric ABI became apparent. This aspect concerns both what types of measures there are for assessing EFs in pediatric ABI, and to what degree different types of assessment tools actually measure the same cognitive skills or if they rather measure similar constructs. When looking at the various assessment tools independently, the type of assessment tool will usually fall within one of three broad categories, which are; (1) the classic ‘pen-and-paper’ performance-based measures usually done in an office or laboratory setting, (2) rating scales and questionnaires that are completed by a proxy or sometimes the patient themselves, (3) observational performance-based measures usually set in a natural or simulated environment (Chevignard et al., 2012). These groupings should be quite helpful to fully understand the prominent topic of ecological validity which appeared relatively frequent among the reviewed articles. Ecological validity of assessment tools played an important part in some of these articles regarding whether measures of EF skills were also applicable to the context of everyday life settings, which is the primary context of concern during clinical practice (Chevignard et al., 2009; Chevignard, Catroppa, Galvin & Anderson, 2010; Chevignard et al., 2017; Krasny-Pacini, Servant, Alzieu & Chevignard, 2017; Gilboa et al., 2015; Nolin et al., 2012).

For the ‘pen-and-paper’ performance-based measures category we might look at something like Digit Span, Wisconsin Card Sorting Test (WCST), Verbal Fluency tests or TMT as examples of EF measures, which are usually performed in a clinical setting and administered in a highly standardized way (Krivitzky et al., 2019; Vriezen & Pigott, 2002). While assessment tools such as these have been proven valid in their ability to measure constructs of EF, those constructs might not be appropriate to generalize to an everyday life context (Chevignard et al., 2009; Chevignard et al., 2012; Gilboa et al., 2015; Krasny-Pacini et al., 2017). In fact there already exists prior evidence that indicates that children with frontal-lobe injuries can exhibit a good performance as if unimpaired on standardized performance-based measures of EF, despite showing major executive deficits in their everyday life and school environments (Chevignard, Catroppa, Galvin & Anderson, 2010; Vriezen & Pigott, 2002).

Meanwhile, the rating scales and questionnaire category is literally completed in accordance to the observations and judgements of a proxy or the individual themselves, based upon the child’s actual ‘real world’ functioning in their everyday life or/and school setting, without the structure provided by a clinical setting or standardized approach (Chevignard et al., 2012; Krivitzky et al., 2019). In other words, rating scales and questionnaires are expected to have high ecological validity. For this reason assessment tools of this category are also the main approach taken when assessing impairments that affect a child's everyday behavior, like that of executive deficits (Chevignard et al., 2017). The lack of structure and standardization certainly makes these kinds of measures more realistic and ecological. However, that lack of structure also means we aren't guaranteed to see the limits of the child's abilities.

Lastly there's the category of observational performance-based measures. These tasks will simulate a somewhat natural environment and then through direct observation the examiner will measure the child's abilities based upon their performance (Chevignard et al., 2012). As such the ecological validity of this type of measure will almost strictly hinge upon how well the simulated natural environment allows for the child to exhibit those same 'real-world' behaviors. If this simulated environment under controlled conditions is done well enough, the ecological validity can become good enough to allow generalizations to be made about the child's natural 'real-world' scenarios (Chevignard et al., 2012; Gilboa et al., 2015). In that sense, assessment tools belonging to the observational performance-based measure category, has the potential to be the most ecologically valid measures. Then again, developing such assessment tools capable of evoking and measuring the complexities of 'real-world' behaviors is no easy task, so measures in this category tend to be the most time-consuming and least feasible to clinically administer (Chevignard et al., 2012).

In the three articles Vriezen & Pigott (2002), de Vries et al. (2018) and Krivitzky et al. (2019), which are among the selected literature for this review, the main objective of these articles was to investigate the relationship between the BRIEF-Parent questionnaire and several performance-based measures of EFs. All three articles were consistent in their findings about the relationship between BRIEF-Parent and performance-based measures, since none of them found the two to be significantly correlated (de Vries et al., 2018; Krivitzky et al., 2019; Vriezen & Pigott, 2002). In other words, a child who is poorly rated on BRIEF isn't necessarily expected to perform poorly on performance-based EF tasks as well, as there is no significantly noticeable association between the two performances according to these results. One possible explanation given for the lack of significant correlations between the two is that while they may assess the same executive abilities, they probably don't assess the exact same underlying constructs related to that domain, in part due to the measuring of behavior manifesting in different contexts (Krivitzky et al., 2019). Another existing hypothesis on the relationship between the two is that performance-based EF tasks will measure the executive dysfunction present, while questionnaires and rating scales will instead be measuring how the executive dysfunction manifests as consequences in everyday life (de Vries et al., 2018). The problem I see with this interpretation is that, one would at the very least expect some modest correlations if that were the case, which is very much not in line with what is seen in the literature.

The lack of ecological validity for the 'pen-and-paper' performance-based measures, combined with the lack of correlation to rating scales and questionnaires, means that they could be considered ill-suited as the standard measure for assessing everyday difficulties in EFs associated with ABI (Chevignard et al., 2012; Gilboa et al., 2015). Despite this, studies still seem to agree that using a mix of both behavioral ratings and performance-based measures is the ideal method when assessing executive dysfunction in children with ABI, since the assessment tools of different categories provide different and therefore non-redundant information on the subject's EF skills (de Vries et al., 2018; Krivitzky et al., 2019; Vriezen & Pigott, 2002). Considering the uncertainties and complexities of ABI, it does indeed seem rational to make use of multiple different sources in assessment to gain a complete picture. Additionally, the classic 'pen-and-paper' performance-based measures have their advantages in being highly structured and also tend to be some of the most feasible and easy tasks to implement into clinical assessment in general (Chevignard et al., 2012). Another aspect to consider is that, while the 'pen-and-paper' tasks lack ecological validity for everyday life, their structuralized context often tests the limits of a child's cognitive skills and avoid ceiling effects. This could be said to be similar to an exam context in a school setting. Evidence that is potentially supportive to this small hypothesis can be found in de Vries et al. (2018), where the BRIEF-Teacher form was also included in the comparison between rating scales and performance-based EF tasks in pediatric ABI, but on the other hand, both Di Lorenzo, Desrocher & Westmacott (2021) and Krivitzky et al. (2019) report mixed results. Research on whether the relationship for teacher rating scales and performance-based EF tasks when assessing pediatric ABI seems to have potential as future research.

Out of all the measures of EF to discuss in this review, the BRIEF questionnaire was definitely the most well documented assessment tool in the context of pediatric ABI with plenty of supportive evidence. This same tendency was seen in a review by Chevignard et al. (2012) where BRIEF was also reported to be the preferred rating measure for children and adolescents with ABI. Considering the vast supportive evidence, high ecological validity and versatility of having multiple rating forms, the popularity of BRIEF for assessing EFs in pediatric ABI is understandable. While BRIEF-Parent was the most commonly used version, the BRIEF-Teacher rating seems to be the slightly more valid and accurate measure of the two based on the literature (Chevignard et al., 2017; de Vries et al., 2018; Di Lorenzo, Desrocher & Westmacott, 2021). Despite being slightly superior at measuring EFs in children the BRIEF-Teacher might not be better for clinical practice. This is because the BRIEF-Teacher seems to lack feasibility comparatively to BRIEF-Parent. As an example, in Chevignard et al. (2017) a sample of 194 children with severe TBI, 193 children had a caregiver complete the BRIEF-Parent, while only 28 children had a teacher complete the BRIEF-Teacher. Teachers seem to be a lot more likely to refuse completing questionnaires than the child's own caregiver, thus decreasing feasibility in clinical practice. Meanwhile BRIEF-SR is the least desirable of the forms for assessing EFs in pediatric ABI, unless the clinician wants to examine self-awareness specifically (Byerly & Donders, 2013). The other two questionnaires in this review, CBCL and QEF may also have their uses but with mixed results reported for these, BRIEF would be the preferred choice of questionnaires. Since CBCL was found to provide some distinct and complementary information to BRIEF it should be reasonable to also use both questionnaires during an assessment of EF in pediatric ABI (Donders & DeWit, 2017).

When reviewing the various performance-based assessment tools, the tools I initially found to be promising were CCT-1, CTMT, CCTT and PMT, because these EF measures were all reported valid measures in pediatric TBI but also because they are similar to traditional neuropsychological assessment tools in their clinical feasibility and standardized structure (Allen, Knatz & Mayfield, 2006; Bauman Johnson et al., 2010; Levin, Song, Ewing-Cobbs & Roberson, 2001; Llorente et al., 2009). Unexpectedly both CCT-2 and Digit Span were not found to be significantly sensitive to TBI at any injury severity in the literature, despite CCT-2 simply being a harder version of CCT-1 for older children and Digit Span being such a widely used and valid measure of EF (Bello, Allen & Mayfield, 2008; Vriezen & Pigott, 2000; Warschausky, Kewman & Selim, 1996). Children with pediatric TBI did perform worse on both CCT-2 and Digit Span compared to controls so they might still be worthwhile measures in the assessment of EFs in pediatric ABI.

Tinker Toy Test and S-FAVRES are also worth highlighting. S-FAVRES was highly sensitive to adolescents with ABI, was ecologically valid and as a verbal reasoning task, it should have relatively good feasibility in a clinical setting (MacDonald, 2016). Likewise the Tinker Toy Test received supportive evidence for sensitivity in pediatric TBI and good feasibility as it is a playful task, which only takes 10 minutes to administer (Roberts et al., 1995). One small practical problem for the Tinker Toy Test's clinical feasibility that e is that it will require carrying a container for the Tinker Toys, but such a problem can be circumvented in several ways.

For observational performance-based measures that simulate naturalistic environments without VR the CKTA seems to be the preferable choice. Its validity as a measure was well documented in this review with very supportive evidence in 4 articles, showing its utility for both pediatric TBI and ABI (Chevignard et al., 2009; Chevignard et al., 2010; Krasny-Pacini et al., 2015; Krasny-Pacini et al., 2017). PPT also showed promise as an observational performance-based measure of EF, but only an article with two case studies was among the selected literature in this review (Shanahan, McAllister & Curtin, 2011). Future research doing statistical analysis on PPT with a larger sample would be ideal. Both of these measures also have the weakness of being very time-consuming to administer and are therefore less clinically feasible.

All VR measures in this review were found to be sensitive to TBI or ABI (Erez et al., 2013; Gilboa et al., 2015; Gilboa et al., 2019; Nolin et al., 2012). Among these were the JEF-C© from Gilboa et al. (2019) and the ClinicaVR: Classroom-CPT from Nolin et al. (2012), which use a non-immersive and a fully-immersive VR environment respectively. A non-immersive VR environment like in the JEF-C© refers to when there is only a virtual or simulated environment inside the computer screen, which in essence is just like a simple computer game controlled by the mouse (Gilboa et al., 2019). Meanwhile a fully-immersive VR environment refers to when the subject is wearing a head mounted display (HMD) and is visually directing themselves within the virtual environment as if they were actually there. Both immersion types were reported as having good ecological validity (Gilboa et al., 2019; Nolin et al., 2012), however, one can't help but wonder if the fully-immersive VR measures are significantly better in this area and therefore be the preferred type despite occasional cybersickness. With 6-minute tests like ClinicaVR: Classroom-CPT, fully-immersive VR measures are clinically feasible and completed before cybersickness can become an issue (Nolin et al., 2012).

Measures of EF generally had more difficulty with sensitivity for mild TBI (mTBI) in this review (Landry-Roy et al., 2008; Malliard-Wermelinger, 2009). Considering the relationship between injury severity and EF deficits, it is no surprise. When assessing pediatric mTBI, it might be beneficial to include measures of other deficits like sleep problems (Landry-Roy et al., 2008) or subtle motor signs (Crasta, Slomine, Mahone & Suskauer, 2020), which have also been linked with EF deficits.

Conclusion

In conclusion, this systematic literature review found several articles that covered the methods and tools used for the assessment of EFs in children and adolescents with ABI. A common preference in the reviewed articles was to choose measures of EF that were developed with ecological validity in mind, as these measures tended to be sensitive to executive deficits following pediatric ABI. Of particular note was the BRIEF questionnaire as the preferred and most well-documented tool among the selected literature. When performing an assessment of EF on a child or adolescent with ABI, the use of the BRIEF-Parent (or BRIEF-Teacher if available) questionnaire is recommended. The use of multiple different and complementary EF measures is also recommended due to the nature of EF deficits following ABI being somewhat unpredictable. The observational performance-based CKTA was another noteworthy measure to recommend if it is clinically feasible given it is a time-consuming tool. Other promising tools included CCT-1, CTMT, CCTT, PMT, Tinker Toy Test S-FAVRES and PPT, but more studies on these measures would be preferred before stronger recommendations can be given for the assessment of EF in children and adolescents. Lastly the same can be said about the VR measures JEF-C©, VMall, VC and ClinicaVR: Classroom-CPT, showing promise for VR's role in the development of future ecologically valid measures.

Declaration of interest

While there is no conflict of interest that could invalidate or introduce bias, this article was made for the explicit purpose of a Masters' Thesis. This means the author's own learning was the primary motivation for this article, and that it was written with limited time and resources.

Part B - Framing piece (heading title TBD)

In this section of Part B in the Master's Thesis, I will cover theory relevant for understanding ABI in relation to the assessment of EF, but also cover a topic that caught my attention during the process of writing the systematic literature review for Part A. Technically the introductory section, which was before Part A, also belongs to Part B of the Master's Thesis, however it is the following sections of the thesis that will fulfil purpose of framing the research background attached to the subject or problem definition of the thesis.

Common types of ABI

As mentioned in Systematic Literature Review or Part A of the Master's Thesis, ABI is an umbrella term that encompasses many possible causes. While this article was centered on assessment of EF in children and adolescents with ABI, in clinical practice you probably wouldn't ever initiate an assessment with the perspective of ABI, since ABI isn't really a very precise term for causality. Instead it makes more sense to plan the assessment in accordance to a more precise cause like TBI, stroke, anoxia, intoxication or whatever the clinician assumes the cause of the injury was. This is important because different pediatric brain disorders will subsequently result in distinct patterns of EF deficits (Araujo et al., 2017, p. 529). In the following section, I will go more into depth with TBI and mention some other common types of ABI that are still in line with the criteria listed in the definition previously given in Part A of the Master's Thesis.

Traumatic Brain Injuries

As the most common cause of brain damage among children and adolescents (Lezak, Howieson, Bigler & Tranel, 2012, p. 180), as well as the most common cause of trauma fatality during childhood and young adulthood in industrialized societies (Cupi, Cordaro, Cuzzocrea & Impellizzeri, 2020, p. 1; Heather et al., 2013, p. 1), traumatic brain injury (TBI) can be considered the primary cause for ABI in the pediatric and young adult population. Brain injuries that fall within the category of TBI are defined as temporary or permanent structural damage sustained to the brain as a result of some source of external physical force causing an impact or sudden change in velocity due to acceleration or deceleration (Cupi, Cordaro, Cuzzocrea &

Impellizzeri, 2020, p. 1; Lezak, Howieson, Bigler & Tranel, 2012, p. 180). According to a study of TBI mortality among children and adolescents aged 0-19 years from the United States, the three leading causes of TBI mortality were unintentional transport crashes, suicide and homicide by firearms (Cheng et al., 2020, p. 95). The highest mortality rates were found among male adolescents aged between 15-19 years old (Cheng et al., 2020, p. 94).

TBIs are also sometimes referred to as 'head injuries' because clinical practice makes a distinction between two classifications regarding the state of the skull post trauma (Cupi, Cordaro, Cuzzocrea & Impellizzeri, 2020, p. 1; Lezak, Howieson, Bigler & Tranel, 2012, p. 180). The first classification is closed head injury (CHI), which is the more frequent of the two classifications in childhood and adolescence, and will usually result from cases of blunt trauma like transport accidents, assaults and falls (Cupi, Cordaro, Cuzzocrea & Impellizzeri, 2020, p. 1; Lezak, Howieson, Bigler & Tranel, 2012, p. 180; Yeates, 2000, p. 92). When TBI is classified as a CHI, the 'closed' refers to the state of skull being intact, and therefore not exposing the brain, but it does not necessarily mean the skull is un-damaged (Lezak, Howieson, Bigler & Tranel, 2012, pp. 180,193). So even if small fragments are broken off or the skull slightly fractures, it is still considered a CHI as long as the skull isn't breached. To properly understand how the brain is damaged under these circumstances there are some biomechanical forces to explain. First is the potential damage caused by 'contact force', which refers to the mechanical forces present upon impact that mold and push the skull inwards towards the brain causing potential tissue damage (Lezak, Howieson, Bigler & Tranel, 2012, p. 194). This kind of force requires the head to come into collision with something to create the impact. If someone were to hit you hard in the back of your head with a baseball bat, contact forces would be the predominant cause of any potential brain injuries. Another biomechanical force that can cause CHI is 'inertial forces', which refer to the mechanical forces present during sudden changes in accelerations or deceleration as your body resists the change in velocity, creating shock waves causing the brain to move violently and possibly collide with the inside of your skull (Lezak, Howieson, Bigler & Tranel, 2012, pp. 194-195). Probably the best example of this is when you're sitting in a car, when the driver suddenly kicks the brakes and you feel yourself getting thrown forward. These inertial forces can greatly strain the brain at a cellular level and brain damage (Lezak, Howieson, Bigler & Tranel, 2012, p. 195). As the previous example implies, inertial forces can cause CHI during a car crash when your head is flung forward which violently causes pressure on the brain through shock waves. Considering the biomechanics behind CHIs it becomes abundantly clear why CHI tend to produce more generalized or diffuse brain injuries (Lezak, Howieson, Bigler & Tranel, 2012, p. 193). Since shock waves are sent through the entire brain and causing strain wherever, it is hard to predict exactly which parts of the brain have sustained tissue damage. One last thing to note about the biomechanics of CHI is that these types of brain injuries are related to age, because of how the thickness of the skull varies with age (Lezak, Howieson, Bigler & Tranel, 2012, p. 194).

When dealing with CHIs the term ‘contusion’ is used to refer to the focal part of the brain injury (Lezak, Howieson, Bigler & Tranel, 2012, p. 195). Rather contusions can be thought of as referring to where the brain is essentially bruised due to being flung around in the cranium. The frontal lobe of the brain is a common site for contusions when they appear, due to the placement of the frontal region and the cranial shape surrounding the brain (Lezak, Howieson, Bigler & Tranel, 2012, pp. 195,201). Some other useful terms are ‘coup’ and ‘contrecoup’. Coup refers to the point of impact for the brain injury (Lezak, Howieson, Bigler & Tranel, 2012, p. 195). In the baseball bat example, the coup would be right where the bat struck the skull. Meanwhile a contrecoup refers to when the brain bounces to the opposite side of the coup and sustains a contusion upon impact (Lezak, Howieson, Bigler & Tranel, 2012, pp. 195,201).

The second classification is penetrating head injury (PHI), and is commonly caused by stabbing or gunfire piercing through the skull (Cupi, Cordaro, Cuzzocrea & Impellizzeri, 2020, p. 1; Lezak, Howieson, Bigler & Tranel, 2012, pp. 180,188). The PHI classification refers to head injuries that penetrate the skull and therefore exposes an entryway to the brain, which is why it is also sometimes referred to as ‘open head injuries’ (Lezak, Howieson, Bigler & Tranel, 2012, p. 180). Injuries belonging to the PHI classification are often associated with widespread damage in the brain caused by bone fragments (Lezak, Howieson, Bigler & Tranel, 2012, p. 188). Since the cranial structure of the skull is penetrated and breached in PHIs, the fragments of broken bone, which originated from the location where the skull was shattered, are scattered and driven further into the brain. Because PHI requires the skull to be breached as per its definition, it can generally be considered more violent than CHI in most cases, since it takes considerable force to achieve this. PHI also often involves a foreign object penetrating and mangling the tissue of the brain, but sometimes a tangential injury can occur, where the object hits the skull at an angle and glances off, leaving the skull fractured open (Lezak, Howieson, Bigler & Tranel, 2012, p. 188). Generally the damage that PHI inflicts on the brain primarily depends on the trajectory of the bone fragments and the object that penetrates the skull. These trajectories and what regions of the brain they pass through are heavily related to behavioral outcomes and should therefore be considered thoroughly when putting together a prediction of the neuropsychological outcome (Lezak, Howieson, Bigler & Tranel, 2012, p. 188). Such information can also greatly aid the clinician in choosing which measures are appropriate for screening and assessment. If the object-trajectories are going through the dorsolateral prefrontal cortex as an example, we would know to make sure to include EF measures in the diagnostic investigation (McAllister, 2011, pp. 291-292). But these object-trajectories aren’t the only thing that may damage the brain during PHI. When an object penetrates the skull and collides with the brain tissue, it not only mangles the area of collision, but also transfers momentum. If a significant amount of force is transferred to the brain upon collision this way, it will result in a shock waves and pressure effects strong enough to damage the brain (Lezak, Howieson, Bigler & Tranel, 2012, p. 191). Brain damage sustained in this fashion can be more widespread and unpredictable. Such diffuse damage is comparable to what happens during CHI (Lezak, Howieson, Bigler & Tranel, 2012, pp. 191,194-195). When considering all the characteristics of PHI, it should be no wonder that the mortality rate is much higher than with CHI (Lezak, Howieson, Bigler & Tranel, 2012, p. 188). Combining the lower occurrence and the much higher mortality rate of PHI, tells us that PHI patients will be relatively rarer than CHI patients.

When a person sustains and survives a TBI, there is also a risk that the patient can suffer a secondary or delayed injury to the brain (Lezak, Howieson, Bigler & Tranel, 2012, p. 180). As shock waves travel through the brain and jumble it around, plenty of things can go wrong and set up the right conditions for additional brain damage to develop. Torn brain tissue, high intercranial pressure, cerebral swelling or other issue can cause a variety of issues like hypoxia, ischemia or even infections, which can evolve over time and cascade out of control (Lezak, Howieson, Bigler & Tranel, 2012, p. 200; McAllister, 2011, pp. 290-291). These secondary or delayed injuries can in some instances be a bigger problem than the initial TBI itself, so it is very important to monitor and characterize the injury when dealing with TBI (Lezak, Howieson, Bigler & Tranel, 2012, pp. 180-181). This makes follow-ups crucial when dealing with TBI, as delayed secondary injuries could be overlooked otherwise, leaving them to possibly spiral out of control and cause myriad of issues or even death.

TBIs can come in three varying degrees of severity from mild to moderate to severe, which, as mentioned in Part A of the thesis, are usually defined using scores from the Glasgow Coma Scale (GCS) as a predictive measure (Lezak, Howieson, Bigler & Tranel, 2012, pp. 183,184; Teasell et al., 2007, p. 108). These degrees of severity are divided so that GCS scores from 13-15 are classified as mild, GCS scores from 9-12 are classified as moderate and lastly GCS scores from 3-8 are classified as severe (Heather et al., 2013, p. 2; Johnson, DeMatt & Salorio, 2009, p. 124). In the most severe cases of TBI, we’re looking at cases, where the majority of the brain has been injured beyond repair, leading to either prolonged coma or a vegetative state, if not death (Lezak, Howieson, Bigler & Tranel, 2012, p. 182). On the other end of the spectrum, involving the mildest cases of TBI, we’re instead looking at cases where temporary neurological changes like feeling dazed, disoriented or confused only last for a brief moment and the brain is left intact (Lezak, Howieson, Bigler & Tranel, 2012, p. 182; Prince & Bruhns, 2017, pp. 1-2). When TBI only fulfills around the minimal requirements for being considered a brain injury, it is sometimes classified as a concussion (Lezak, Howieson, Bigler & Tranel, 2012, p. 183). For that reason concussions can be considered a mild form of TBI, but determining the exact details about what qualifies as a concussion has been met with a substantial amount of controversy (Lezak, Howieson, Bigler & Tranel, 2012, pp. 180,183; Prince & Bruhns, 2017, p. 2).

Severity classification is also used to predict TBI outcomes as research have found it to be related to both behavioral and neuropsychological outcomes (Lezak, Howieson, Bigler & Tranel, 2012, p. 182; Johnson, DeMatt & Salorio, 2009, p. 124). As one might expect, a higher degree of severity will usually result in more cognitive deficits. When mild TBI (mTBI) results in cognitive dysfunction, it will most commonly be domains related to EFs like attention, memory, processing speed, and/or EFs themselves, of which attentional deficits are the most common (Lezak, Howieson, Bigler & Tranel, 2012, p. 209; Prince & Bruhns, 2017, p. 5). Meanwhile on the other end of the spectrum, a classification of severe TBI's will predict EF outcomes such as deficits in working & prospective memory, crippling deficits in self-awareness, impaired inhibition leading to inappropriate or impulsive behavior, and great difficulty with social context, as common outcomes of executive dysfunction (Lezak, Howieson, Bigler & Tranel, 2012, pp. 212-215; Johnson, DeMatt & Salorio, 2009, p. 125). But outcome predictions are only predictions, so these EF deficits may not appear, yet they can be useful in combination with injury type and other characteristics to assist the clinician in making the most appropriate neuropsychological assessment.

Ischemic and Hemorrhagic Stroke

Cerebrovascular disorders (CVD) are diseases or conditions that affect the cerebral circulation somehow, and the most common of these is apoplexy or commonly known by the term 'stroke' (Lezak, Howieson, Bigler & Tranel, 2012, p. 229). As mentioned in Part A of the Master's Thesis, stroke is considerably rarer among children and adolescents compared to adults. Despite that, stroke still has around the same incidence rate as brain tumors (BT) among children and is a leading cause of childhood mortalities, and this incidence rate increases exponentially with age beyond adolescence (Lezak, Howieson, Bigler & Tranel, 2012, p. 230; Long et al., 2011a, p. 279).

The way that stroke damages the brain tissue is through infarctions blocking the normal flow of blood to the brain, and therefore starving the brain tissue, since it cannot receive a sufficient amount of oxygen or nutrient (Lezak, Howieson, Bigler & Tranel, 2012, p. 230; Rivella & Viterbori, 2021, p. 209). If the blockade is not removed in time, the nervous tissue will quickly degrade and the damage will become irreversible, so time is of the essence when dealing with stroke. When someone has a stroke, it is generally either an ischemic stroke or a hemorrhagic stroke. Ischemic stroke is the more common of the two making up around 87% of all cases of stroke, and it is categorized by the something obstructing the blood vessel, typically caused by a 'thrombosis', which is the forming of a blood clot in the blood vessel (Lezak, Howieson, Bigler & Tranel, 2012, p. 231). Basically it is like the brains blood vessels are pipes that get clogged up with coagulated blood and more. An analogy could be made with military logistics of a supply line sending food to some troops. If the supply line is cut off, the troops will not receive enough food, just like the brain tissue won't get sufficient oxygen or nutrients without proper blood flow. And if the supply line cannot be reestablished in time, some people will start to starve and die, leading to an irreversible loss of troops. Reestablishing the supply line later, won't bring people back from the dead, just like how restoring normal blood flow won't regenerate dead brain tissue.

Hemorrhagic stroke is less common than ischemic stroke, but it is a lot more deadly in comparison, as it has a high mortality rate (Lezak, Howieson, Bigler & Tranel, 2012, pp. 231,234). What categorizes a stroke as hemorrhagic is the rupturing of a weakened blood vessel wall, which subsequently means that the blood will spill out into the surrounding area of the brain (Lezak, Howieson, Bigler & Tranel, 2012, p. 234). As the blood leaks out and fills up the area around the rupture, it starts occupying that space. As the leaking blood increases in volume, the pressure on the brain will keep increasing and eventually damage it.

Children with a history of stroke tend to have some EF deficits in areas such as inhibition, cognitive flexibility and working memory, on top of exhibiting deficits in everyday aspects of EF (Long et al., 2011a, p. 286; Long et al., 2011b, p. 973; Rivella & Viterbori, 2021, p. 210). Childhood stroke displays a wide range of EF deficits comparatively to normative data, and the impairment will tend to be evident on both performance-based cognitive measures of EF and rating scales (Long et al., 2011b, p. 982). Specifically for the rating scales, Long et al. (2011b, pp. 974,983) used BRIEF-Parent and BRIEF-Teacher on children aged 10-15 years with a history of stroke, either ischemic or hemorrhagic, and they found that while both ratings revealed significant impairments in EF, the BRIEF-Teacher ratings were consistently higher than parental ratings. These findings on the relation between parent and teacher ratings for stroke are in agreement with the similar findings previously mentioned for TBI in Part A of the Master's Thesis.

Childhood stroke can be unpredictable regarding how it affects EF, since it can display a wide range of deficits. In Rivella & Viterbori (2021, p. 219), inhibition was found to be the most vulnerable domain of EF during childhood stroke. To somewhat predict the amount of EF deficits in childhood stroke, it is instead good to take both lesion location and lesion size into account. Diffuse lesions will often show some EF deficits and in cases of larger diffuse lesions they can often display the same deficits as smaller focal lesions in the frontal lobe (Long et al., 2011b, p. 984; Rivella & Viterbori, 2021, p. 223). Meanwhile more focal cases of childhood stroke are associated with significantly greater impairments of EF when located in the frontal regions, as well as the cortical and subcortical regions of the brain (Long et al., 2011a, p. 286; Rivella & Viterbori, 2021, pp. 222-224). Additionally, cases of combined cortical and subcortical lesions were worse, in terms of executive dysfunction, than if the lesion was only in one of the two areas (Rivella & Viterbori, 2021, p. 222). Then again, it isn't really a surprise that the more damage there is to regions connected to executive function, the worse the impairment of EF gets. On this same line of thought, lesion size have also been found to be significantly associated with the amount of EF deficits, with larger lesion size resulting in more severe executive dysfunction (Long et al., 2011b, p. 984; Rivella & Viterbori, 2021, p. 223). One important thing to note about the lesion location for predicting outcome in stroke is that non-frontal lesions can also contribute to executive dysfunction in children (Araujo et al., 2017, p. 535; Rivella & Viterbori, 2021, p. 224). Additionally, some functional neuroimaging studies have also found that when children perform tasks requiring EF skills, their brain activation during performance of the tasks is more diffuse when compared with the brain activation in adults (Long et al., 2011b, p. 973). These neuroimaging differences combined with the executive dysfunction following non-frontal lesions are possibly indicative that executive processes are more diffusely involved with the brain during childhood, making the prediction of executive impairments in stroke even more complex for the pediatric population (Long et al., 2011a, p. 286; Long et al., 2011b, p. 973). Araujo et al. (2017, p. 536) suggests that clinicians be careful and include a thorough assessment of EFs when dealing with non-frontal lesions in children.

Pediatric Brain Tumors

In the pediatric population, the most common location for solid tumors is in the brain in the form of brain tumors, which are the second most common type of childhood cancer (de Vries et al., 2018, p. 845; Desjardins et al., 2020, p. 83; Wolfe et al., 2013, p. 370). The survival rate for pediatric brain tumors have increased substantially in the past several decades, which in turn means we have a lot more pediatric brain tumor survivors (PBTSs), and increasing the awareness of the cognitive impairments that may follow (de Vries et al., 2018, pp. 844-845; Roche et al., 2020, p. 583; Wolfe et al., 2013, pp. 370-371). As for these cognitive impairments that are present in PBTSs, they frequently include various deficits in EF and have been shown to appear in all main tumor types (Desjardins et al., 2020, p. 83; Roche et al., 2020, p. 583; Wolfe et al., 2013, p. 371). Executive dysfunction is therefore important to assess in PBTS and not just once. Pediatric brain tumors are often followed by cognitive impairment developing later depending on variables such as location of the brain tumor or treatment received (de Vries et al., 2018, p. 845).

Secondary ADHD

Attention-deficit/hyperactivity disorder (ADHD) is a common disorder often studied in children because of how it affects development (Martel, Nikolas & Nigg, 2007, p. 1437). It is well known that ADHD causes impairments in domains such as attention and behavioral inhibition, which are EF deficits (Martel, Nikolas & Nigg, 2007, p. 1437; Ornstein et al., 2013, pp. 2, 8; Slomine et al., 2005, p. 645). Attention and behavioral inhibition are similarly common EF deficits seen in TBI (Ornstein et al., 2013, p. 8; Slomine et al., 2005, p. 645). However, ADHD is a neurodevelopmental disorder and does not fit with the ABI definition for several reasons. Despite this, secondary ADHD is still relevant to consider when assessing EF in children or adolescents with ABI. When children and adolescents sustain TBI, there is reportedly a risk of developing psychiatric disorders, of which ADHD is one of them that is of importance to the individual's future development and EFs (Ornstein et al., 2013, p. 1; Ornstein et al., 2014, p. 972). When ADHD is caused as a consequence of another issue, it is referred to as secondary ADHD (S-ADHD), to indicate that it did not exist prior to the cause and wasn't of a congenital or hereditary nature (Ornstein et al., 2013, p. 1; Ornstein et al., 2014, p. 972). It has been reported that S-ADHD is developed post-injury in around 15-20% of children who sustain pediatric TBI, but these findings are suspected to have been overrepresented (Ornstein et al., 2014, p. 972). Regardless of the exact percentages, since S-ADHD is a common occurrence post-injury to pediatric TBI, it will be something to keep in mind during the assessment of EF.

Now it has been presented that both TBI and stroke are associated with deficits in EF, as well as ADHD also being associated with deficits in EF. This leaves the interesting question of whether the post-injury addition of S-ADHD will further increase the impairments of EFs in pediatric TBI or if the EF impairments that they bring will overlap, showing no significant difference in executive dysfunction in pediatric TBI with or without S-ADHD. To begin with, children with the regular premorbid ADHD have been shown to exhibit more problems in some executive domains like emotional dysregulation, socials skills and aggression, than what is exhibited in those domains for pediatric TBI that is without the S-ADHD post-injury (Slomine et al., 2005, p. 646). When pediatric TBI accompanied by S-ADHD was compared in a study to both premorbid ADHD and TBI without S-ADHD, it was found that the group consisting of pediatric TBI with S-ADHD showed no significant differences to the premorbid ADHD group regarding the previously mentioned executive domains and general intellectual functioning (Ornstein et al., 2013, p. 3; Slomine et al., 2005, p. 646). In other words pediatric TBI accompanied by S-ADHD seems to result in worse EF outcomes than when pediatric TBI is without S-ADHD. Importantly for children’s development, memory and learning were also among the domains that were increasingly impaired when S-ADHD was present (Slomine et al., 2005, p. 651). With all these findings in mind, it becomes evident that the possibility of pediatric TBI being accompanied by S-ADHD is a crucial concern during assessment, since the presence of S-ADHD can lead to increased impairment in EFs that are essential for attention, learning and inhibition. Besides TBI, several studies have also investigated pediatric stroke and its relation to S-ADHD regarding EF outcomes, and found similar findings, where the presence of S-ADHD was associated with a significant increase of impairments in EFs for pediatric stroke (Rivella & Viterbori, 2021, p. 219). Therefore clinicians need to be wary of post-injury S-ADHD in pediatric stroke as well, since it will also affect the degree of EF impairment observed.

Conclusion

Before coming to any conclusions about the assessment of EF in children and adolescents with ABI, it is important to realize what part of the problem definition or objective is being referred to. Since EF and ABI both are umbrella terms that encompass a wide array of cognitive abilities and types of brain injuries respectively, most conclusions won’t be generalizable to the entire spectrum of EF or ABI. Frankly, the can be said about children and adolescents, because of how much EF develops over time in this the pediatric period and also because of how ABI can affect the individual differently due to the development and varying plasticity of the brain. In other words, you could say the there’s almost too many variables to make any generalized conclusions, so most conclusions must instead be specified as to which EF skills, which type of ABI and what age group are involved. In hindsight this seems extremely obvious, but it is an issue that hadn’t really crossed my mind prior to writing this Master’s Thesis.

There were two conclusions from this thesis that I found to be very generalizable, which came from the systematic literature review of Part A. In many of the reviewed articles there was an emphasis and preference for using measures of EF that had a high ecological validity. This most likely has to do with how most types of executive dysfunction will typically affect all aspects of behavior. Since ecologically valid tasks allow for more natural environments, behavioral aspects of impairments can be measured, regardless of the type of executive dysfunction, and therefore it can be somewhat generalized to ABI. So it seems fair to conclude that assessment of EF in pediatric ABI should include ecologically valid measures if possible. It was also concluded in the review that during assessment of EF in pediatric ABI, the use of multiple measures of EF that are complementary rather than redundant was highly recommended as well.

Part A also contained several more specific conclusions. First off the questionnaire BRIEF was preferred by many and was well-documented as a useful assessment tool sensitive to EF deficits in pediatric ABI. Additionally, the teacher rating form of BRIEF seems to be the most effective, but the parent form was by far the most feasible. The CKTA was also repeatedly reported as a useful and sensitive measure for assessing EF in pediatric ABI, but also time-consuming. Other measures were also shown to be promising in Part A, but without more studies supporting them, it seems too hasty to recommend them. So based on the gathered literature in the review, I can conclude that the inclusion of the BRIEF questionnaire and the CKTA are highly recommended for assessing EFs in children and adolescents with ABI. Lastly, Part A also reported several promising VR measures. As fully-immersive VR is becoming more commonplace in entertainment, education and assessment, I suggest future studies to further investigate the potential of using VR to measure EFs due to their high ecological validity.

Based on the theoretical background provided on the common types of ABI, I can conclude that all of the most common types of ABI will typically lead to executive dysfunction of some kind and especially in the pediatric population, where the regions that govern executive function aren’t yet as centralized to the frontal lobe as in adults. With how common EF deficits are in the various types of pediatric ABI, thorough assessment of EF seems to be almost mandatory. Taken into account with how EF deficits might impair children and adolescents future development, this statement only become more evident. Finally, Part B also covered the topic of ABI with secondary ADHD post-injury and its relation to EF deficits. Here I can conclude that the presence of S-ADHD is associated with worse executive outcomes in both pediatric TBI and pediatric stroke. Therefore it is recommended that clinician be wary of possible S-ADHD after ABI, and include these considerations during assessment.

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Total number of pages used for writing the rest of the Master's thesis: 1.409 pages

Combined total number of unique pages in the selected curriculum: 1.954 pages