

Validation of an Executive Function Screener in a Sample of Adolescents with
Neurological Disorders

by

Esther Direnfeld
B.Sc., Queen's University, 2007
M.Sc., University of Victoria, 2011

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of

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in the Department of Psychology

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Supervisory Committee

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Abstract

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Objective: It is thought that executive functions (EF) emerge as outcomes of interactions between cognitive and emotional processes. They are an integral component of the growing regulatory abilities of children and adolescents and are important for academic success, attainment of social competence, and psychological development, among others. It is essential to evaluate them during neuropsychological assessment. However, they are difficult to capture with performance-based, neuropsychological assessment tools. These were once considered 'gold standard' measurements of EF but have been critiqued for a number of reasons. As such, rating scales have been useful as a complementary, perhaps eventual alternative, to performance-based tests. Behavioural screeners have high replicability, making them practical for use across various populations, and to evaluate everyday behaviours. A four-factor executive function screener derived from the Behavior Assessment System for Children (BASC) was previously developed and validated in a variety of age ranges and groups (Garcia-Barrera et al., 2011). However, with the exception of children with ADHD, the effectiveness of the screener has not been examined in individuals with neurologic disorder. In this population, EF are often

impaired, due to delays or disruptions in normal brain development. Given these challenges in this population, this study 1) derived a similar screener for use in adolescents with neurologic disorder, using the second edition of the BASC, and 2) evaluated it against a commonly used EF rating scale [i.e., the Behavior Rating Inventory of Executive Function (BRIEF)] as well as performance-based executive function measures. Thirdly, this study characterized the nature of EFs in this clinical population, given that EF deficits are often central characteristics in many neurological disorders.

Participants and Methods: An archival analysis was conducted with 107 neurologically-affected adolescents seen for neuropsychological assessment at Queen Alexandra Centre for Children's Health. Patients were included in the study if they gave consent, had at least low average intellectual functioning, had a BASC-2 completed by a parent, and were between the ages of 12-18 years. Confirmatory factor analysis was used to evaluate the derived screener. Bivariate correlation analyses were used to evaluate convergent validity. To characterize the nature of this sample's EF profiles, differences among groups were measured in a profile analysis via multivariate analysis of variance.

Results: The four-factor model, as measured by the BASC-2 EF screener, fit the data most optimally, indicating that the structure of EF reflects the four-factor model observed in other studies. Consistent with other studies, convergent validity was observed with the BRIEF but not the performance-based tasks. Profile analysis indicated that there were some overall differences among the neurological groups and their BASC-2 scores as well as individual differences on the various factor scores. **Conclusions:** These findings support the four factor model measured by the screener in adolescents with neurological disorders. Given the consistency between the factor structure in this population and

previous studies measuring this screener in healthy populations, and the convergence of the screener and the BRIEF, these findings contribute to the body of literature supporting this executive functioning screener as a complement to performance-based tasks.

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Dedication

To my family

Chapter 1

Introduction

It has been proposed that executive functions emerge as outcomes of multiple interactions between cognitive and emotional control processes and that they are essential for self-regulation and efficiently achieving goal-directed behaviours (Garcia-Barrera, Karr, & Kamphaus, 2013).

Jurado and Rosselli (2007) define executive functions as:

Abilities which allow us to shift our mind set quickly and adapt to diverse situations while at the same time inhibiting inappropriate behaviours. They enable us to create a plan, initiate its execution, and persevere on the task at hand until its completion. Further, they mediate the ability to organize our thoughts in a goal directed way and are therefore essential for success in school and work situations, as well as everyday living. (p. 214).

Executive functioning has also been defined as the way in which people problem solve and accomplish goal-directed actions (Lezak, 1982), as well as the ability to maintain an appropriate problem solving set for attainment of a future goal (Welsh & Pennington, 1988). Given the myriad of terms, definitions, and explanations for executive functions, the term 'executive functions' remains somewhat controversial (see Barkley, 1997; Diamond, 2013; Garcia-Barrera, Kamphaus, & Bandalos, 2011; Miyake et al., 2000; Müller & Kerns, 2015). Despite the lack of agreement in the constitution and definition of executive functions, they are unique in that they are associated with context-specific action selection. Overall, they are necessary in circumstances that are novel, particularly those that require planning and decision-making (e.g., Duggan & Garcia-Barrera, 2015; Hughes & Graham, 2002; Zelazo, Carter, Reznick, & Frye, 1997).

There is a rich and compelling history of research investigating executive functions, beginning over a century ago with the story of Phineas Gage. Gage was a construction foreman who had a tamping iron blast through the left frontal region of his brain and skull. Following a recovery period, Gage reportedly experienced no changes in his cognitive abilities, but his personality changed dramatically: he did not follow social conventions, he acted irrationally, he had difficulty processing emotion, and he was behaviourally disinhibited (Harlow, 1868). Due to the nature of Gage's deficits, Damasio, Grabowski, Frank, Galaburda, & Damasio (1994) speculate that Gage's injuries are likely consistent with damage to the ventromedial prefrontal regions rather than the traditionally suspected left dorsolateral region. Damasio and colleagues noted that these brain regions are associated with rational decision-making in personal and social matters, emotion processing and functions such as planning and organization. Early investigations relied on examining brain functions via brain injury, more recently we have examined executive functions through other methods such as clinical studies and statistical methods.

Recent literature has implicated the development of executive functions as important in many aspects of every day life. They are integral components of young children's growing regulatory abilities and are important for academic success, attainment of social competence, psychological development, behaviour, adaptive functioning, and quality of life, among others (Best, Miller, & Jones, 2009; Blair & Peters, 2003; Diamond, 2013; Schlagmüller & Schneider, 2002; St. Clair-Thompson & Gathercole, 2006). Executive functions also have an intricate relationship with intelligence that is not fully understood at this point in time (Duggan & Garcia-Barrera, 2015). As we have not come to a complete understanding regarding the nature of executive functions, it remains relevant to examine executive functions and its development to

determine how this important component of people's lives develops and how it may be affected in various contexts.

Development of executive functions. The abilities that comprise executive functions are important for the production of novel, goal-directed behaviours, and these abilities develop in a gradual fashion throughout life. Executive functioning abilities first emerge during early infancy, and continue to mature throughout early childhood and into adolescence, sometimes reaching their peak in young adulthood (Best et al., 2009; Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2013; Garon, Bryson, & Smith, 2008; Zelazo & Müller, 2010), potentially paralleling the growth of the prefrontal lobes and their circuitry (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Otero & Barker, 2014; Tsujimoto, 2008).

When examining executive functions, several researchers have used the “foundational” components of executive functions put forth by Miyake and colleagues (2000) to investigate executive functioning since the publication of their seminal study (e.g., Best & Miller, 2010; Brocki & Bohlin, 2004; Davidson et al., 2006; Garon et al., 2008; Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003). These foundational components consist of updating working memory, inhibition, and shifting (see Miyake et al., 2000).

Working memory can be thought of as a capacity-limited system that holds information “on line” (i.e., in mind) for short periods of time and monitors the information as needed. Updating working memory is related to holding and monitoring information in mind, but also involves actively revising information so that new and relevant information replaces older, irrelevant materials (Miyake et al., 2000). Inhibition is the inability to withhold automatic, or prepotent responses. Shifting is one's ability to switch between tasks (Monsell, 1996) and generally refers to the ability to shift between responses, sets, strategies, or tasks in an adaptive

manner, requiring the understanding that there are at minimum two possible ways of acting in any situation or context (Diamond, 2013). Miyake and colleagues (2000) describe the most important part of this cognitive concept as being able to disengage from something unimportant to subsequently actively engaging in a more relevant task. Updating working memory, inhibition, and shifting have all been functionally associated with the frontal lobes and its networks (Collette et al., 2005).

However, Miyake's taxonomy was derived using computerized tasks, essentially using performance based tests assessing time and accuracy. There remains debate as to the underlying components of executive functioning (Packwood, Hodgetts, & Tremblay, 2011), and how to best assess executive functions at different levels. Garcia-Barrera et al. (2011) have suggested an alternative approach for the estimation of *executive behaviour*, based on a four-factor model of executive functioning, that has shown longitudinal stability (Garcia-Barrera et al., 2013) and that will be discussed in detail below. Given that the foundational components of executive functions are separable, it is logical that the different components have unique and dissociable developmental trajectories as well. While emergent aspects of abilities such as working memory, inhibition, and set shifting begin to develop during infancy, significant maturational progression can be seen for some components as early as the preschool years (e.g., Garon et al., 2008), with differential improvement in the various components as children grow older. Adult levels for some complex executive functions (e.g., planning) are not achieved until late adolescence or even early adulthood (e.g., Best & Miller, 2010; Müller & Kerns, 2015; Davidson et al., 2006; Luna & Sweeney, 2001).

The protracted developmental trajectory of the foundational components is particularly noticeable with working memory. The ability to simply hold information in mind is relatively

stable and develops early; infants in their first year of life and young children can hold one or two things in mind for quite some time (Diamond, 2013; Garon et al., 2008). However, the ability to manipulate the contents of working memory shows a more extended developmental progression (Davidson et al., 2006) with significant improvement observed in some cases at approximately seven years (Logie & Pearson, 1997; Gathercole, Pickering, Ambridge, & Wearing, 2004). For instance, children achieve success on the two subtests of Digit Span, which is a commonly administered test of working memory that measures an individual's ability to both hold information in mind and manipulate the information, at different rates. Children's performance on backward digit span (i.e., the manipulation condition) is more successful at a later age relative to forward digit span (i.e., the maintenance of information condition). While some researchers have noted that working memory has been sufficiently developed to be utilized during complex tasks by age seven (e.g., Gathercole et al., 2004), the same researchers have noted that working memory continues to develop linearly between the ages of 4 to 14 years, with flat performance between 14 and 15 years. Other researchers have also found linear increases in working memory in adolescence (Anderson et al., 2001). Similarly, other components of working memory have been found to reach adult levels only in adolescence (e.g., Huizinga et al., 2006). Müller and Kerns (2015) noted that working memory tasks that "involve a high level of executive control display a particularly protracted development" (p. 1090).

Like working memory, inhibition is another foundational component of executive functioning that demonstrates a protracted developmental course, with aspects of each first emerging during early life (e.g., Williams, Ponesse, Schachar, Logan, & Tannock, 1999). Davidson et al. (2006) reported that that young children can do very well on tasks measuring inhibitory control, with other cognitive demands minimized; they found that four-year-olds were

able to perform significantly better than chance on an inhibitory control task (i.e., the Pictures Test); however, inhibiting responses remained more difficult for the four-year-olds than for older children (i.e., those between 6 to 13 years). Similarly, Williams and colleagues (1999) found that 6 to 8 year olds were slower in inhibiting responses on a stop-signal task than 9 to 12 year olds, and Brocki and Bohlin (2004) reported significant improvements on inhibition between 7 to 9 and 9 to 11 years old. Although others have found increasingly better performance on inhibitory tasks as individuals mature, Romine & Reynolds (2005) conducted a meta-analysis in which they found that the greatest improvements in inhibitory tasks occurred in children ages 5 to 8 years old. A review of the developmental literature by Best and Miller (2010) noted improvements in inhibitory processes through to young adulthood, with rapid improvements in childhood followed by more gradual improvements in inhibition in adolescence.

Set shifting also follows a protracted developmental course. Diamond (2013) as well as Garon and colleagues (2008) have noted that shifting itself is an executive function that emerges relatively late, as it depends on a certain level of working memory and inhibition. However, it should be mentioned that studies of infants' abilities to shift between two types of objects indicate that this ability is at least emerging in infancy (Müller & Kerns, 2015). Further, Zelazo and Müller (2010) reported that while 2.5 year olds cannot integrate two rules into a one rule system (necessary for shifting), 3-year-olds can. Hughes (1998) also reported that preschoolers (i.e., 3 and 4 year olds) have the ability to shift between two response sets. Davidson and colleagues (2006) noted that while children between the ages of 6 and 13 can shift between tasks, they are slower and less accurate relative to adults, indicating that adult levels of shifting have not been reached by early adolescence. Like the other foundational components, these skills are emergent in infancy, with significant development in the preschool period, paralleling the

development of the prefrontal circuitry and likely, its increasing efficiency. Although the foundational components of executive functions begin their developmental trajectory in infancy, other more complex skills such as planning and problem solving remain largely undeveloped until later adolescence (Best & Miller, 2010; Hughes, 2011).

In summary, executive functions develop over an extended period of time, with more basic aspects of executive functions emerging in infancy and others only reaching peak levels in late adolescence or early adulthood. In their meta-analysis, Romine and Reynolds (2005) found that the greatest development of executive functions such as planning, verbal and design fluency, and inhibition of perseveration occurred between 5 to 8 years old, with continued gains in these abilities across childhood and adolescence and some abilities (e.g., planning and verbal fluency) developing into adulthood. While the majority of theorists agree that executive function development occurs across many years, there is still discussion as to the exact developmental mechanism. Garon et al. (2008) summarize the development of executive functioning across the preschool years and posit that development of executive functioning corresponds to the development of attention and subsequent integration of the executive functioning components, with the development of attention enabling increased ability to overcome prepotent (dominant) thoughts and acts. Diamond (2013), however, posits that the development of inhibition explains children's ability to regulate and control their thoughts and actions, thereby modulating their executive functioning and resolving conflict.

Executive functions in neurologic populations. Cumulative evidence has shown that those with developmental and acquired disorders often have tremendous difficulties with executive functioning. Indeed, one of the strongest pieces of evidence comes from findings demonstrating that executive dysfunction plays a key role in attention deficit hyperactivity

disorder (ADHD) and autism (Denckla, 1996; Gioia, Isquith, Kenworthy, & Barton, 2002; Pennington & Ozonoff, 1996); similarly, other studies have demonstrated that significant cognitive effects are associated with other neurological disorders, including traumatic brain injury (TBI), conduct disorder, and others (Hughes & Graham, 2002; Levin, Fletcher, Kufera, & Harward, 1996; Royall et al., 2002; Zelazo & Müller, 2010). Nevertheless, it should be emphasized that different components of executive functioning (e.g., working memory vs. inhibitory control vs. shifting, etc.) may be affected differentially in the various groups (Zelazo & Müller, 2010). For instance, deficits in executive functions are often observed following TBI, with specific dysfunction in inhibition, problem solving, shifting, planning, initiation, and organization (Chapman et al., 2010; Dennis, Guger, Roncadin, Barnes, & Schachar, 2001; Slomine et al., 2002). Similar deficits are also seen in children who survived various types of pediatric brain tumor; these individuals are often left with difficulties in self-monitoring, initiation, inhibition, working memory, cognitive flexibility, and planning (Wolfe et al., 2013). Gioia and colleagues (2002) found that children with developmental disorders had significantly worse executive functions than typically developing controls. Using Garcia-Barrera et al.'s (2011) assessment approach, children with ADHD have also been found to have worse executive behaviour than healthy controls (Garcia-Barrera, Karr, Duran, Direnfeld, & Pineda, 2015). There have also been inconsistent findings of executive dysfunction in people with other neurologic disorders; for instance, children with Tourette's Syndrome have been found to have comparable (Pennington & Ozonoff, 1996) as well as poorer (Baron-Cohen, Cross, Crowson, & Robertson, 1994) executive function performance than typically developing children.

Differential executive deficit profiles characterize a range of clinical syndromes. These variations on clinical presentation may be attributable to a combination of factors, including age

of onset, state of brain development, severity and localization of insult, among others. Therefore, it is beneficial to characterize the nature of executive function deficits in this study's clinical sample. In fact, this idea of unique executive functioning patterns for those with different clinical disorders has previously been examined in a number of studies (e.g., Gioia et al., 2002; Ozonoff & Jensen, 1999), and it would be valuable to further extend these characterizations.

It is not unexpected that executive dysfunction is prevalent in individuals with these disorders as abnormalities in the brain circuitries involved in executive functions are often present in many neurological disorders (see Best & Miller, 2010; Valera, Faraone, Biederman, Poldrack, & Seidman, 2005). The question however remains whether executive functions are fundamentally different in these groups relative to typically developing children or whether they are simply weaker.

Gerrard-Morris and colleagues (2010) noted that following TBI, disruptions in executive functions were seen even after 18 months. Given that TBI often affects frontal and temporal regions involved in executive function circuitry, this is not surprising. It is probable that in acquired disorders, executive functions are fundamentally disrupted by insult, and in developmental disorders, neural circuitry may simply be more inefficient. However, the resulting effects are similar, with weaker executive functions present in these populations. The lack of even short-term recovery for young children with TBI over a period of 6 to 18 months may be due to the "greater vulnerability of the younger brain to diffuse insult, the potential for early insults to result in greater alterations in neural development, and a greater effect of cognitive deficits acquired at an earlier age on subsequent developmental progress" (Gerrard-Morris et al., 2010, p. 10). Supporting these assertions, neuroimaging research in those who have had brain tumours, TBI, ADHD, and other neurologic disorders have begun to link deficits to reduced or

abnormal white matter volume in circuitry associated with executive functions (see Gerrard-Morris et al.; Wolfe et al., 2013; and Bush, 2009 for a review of ADHD).

Measurement issues. Given the importance of executive functions in individuals' everyday lives, particularly in behaviour, adaptive functioning, and academic achievement, executive functions are critical to examine during assessment. However, researchers and clinicians still face multiple concerns when researching this construct in their studies or when evaluating these processes during a clinical assessment.

One of the main challenges that makes it difficult to measure executive functions reliably and in a valid manner is the “task impurity” issue (Friedman et al., 2008), meaning that it is often challenging to extract “pure” measures of executive functioning from traditional neuropsychological measures. This issue highlights that performance on traditional neuropsychological measures, which are generally complex, multi-step tasks, typically relates to multiple underlying executive functions, such as behavioural inhibition, working memory, as well as non-executive functions such as language or visual-spatial processing (Romine & Reynolds, 2005). Depending on the task, and indeed even the experience of the individual performing the task, outcomes may be the result of these non-executive processes rather than executive ones, which makes it difficult to measure executive functioning within and across groups.

Adding to challenges in measuring executive functioning is the lack of correspondence between traditional executive functioning tasks and real-world behaviours. Anderson, Anderson, Northam, Jacobs, and Mikiewicz (2002) posit that there is likely a lack of sensitivity in traditional neuropsychological measures that is directly related to the multidimensional nature of situations experienced in everyday life. Compared to daily functioning, traditional testing

situations generally provide greater structure, organization, guidance, planning, cueing, and monitoring, in order to promote optimal performance by the individual. In effect, this reduces external executive functioning demands, as well as “artificially and ambiguously” fractionating an integrated, everyday system into specific processes (Burgess, 1997). However, these quantitative testing measures can be augmented by qualitative behavioural observations that are inherent in the practice of clinical neuropsychologists. For instance, executive dysfunction is often noted or marked during assessment by impulsivity, disinhibition, difficulties monitoring and regulating performance, poor planning and problem solving, perseveration, and/or cognitive inflexibility (Anderson et al., 2002). These qualitative observations generally correspond to difficulties observed during everyday functioning and reported by parents, teachers, and other individuals.

Construct validity issues. As mentioned previously, another significant concern is the lack of consensus in the definition of executive functions (Jurado & Rosselli, 2007). While executive functions were originally considered “frontal-lobe” functions (Friedman et al., 2008; Hughes, 2011), it is now evident that although the prefrontal cortex plays a significant role in executive functions, various neural circuitries are involved in their production and execution (Collette et al., 2005). In addition, there is not one agreed upon way of understanding executive function, which has resulted in different conceptual theories of the construct (Jurado & Rosselli, 2007). While there are different conceptual theories of the construct, given the body of literature concerning executive functions, it is evident that understanding the nature of executive functions is complex. As previously mentioned, Miyake and colleagues (2000) proposed a method to examine executive functioning. Using confirmatory factor analysis (CFA), they conceptualized executive functions as the product of three separate, yet related foundational components, which

combine to produce more complex executive tasks. They described executive functions as both unitary and diverse functions, demonstrating that working memory, set shifting, and inhibition are separate, yet related constructs. Specifically, in adults, these foundational components are causal in the production of more complex executive functioning performance.

The method described by Miyake and colleagues (2000) has been further utilized in the investigation of executive functioning across development to examine whether this foundational structure of executive functions is comparable in childhood and adolescence. Using CFA, Lehto et al. (2003) observed that the three-factor model of executive function comprising working memory, shifting, and inhibition demonstrated the most adequate fit for children aged 8-13 years old. Examining a wider age range and comparing the latent factors across developmental groups, Huizinga et al. (2006) found adequate fit for a model of executive functioning in which the three factors were separable. However, Huizinga and colleagues (2006) found that the three manifest inhibition factors did not load onto a single common factor, indicating some differences in the 3-factor model compared to the findings of Lehto and colleagues (2003).

Although some researchers have found support for the three-factor model, there is still disagreement regarding the fractionation of executive functions into its components. As previously mentioned, the components of executive functioning begin to emerge as early as infancy. Still, the exact nature of the fractionation of executive functions has remained unsettled.

Numerous research groups have investigated the fractionation of executive functions in childhood with more consistent findings reporting fit of a one factor-model in early childhood (e.g., Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011), with multiple-component models being better represented in later childhood and adolescence (Huizinga et al., 2006; Lehto et al., 2003).

However, multiple-component models have been observed in preschool-aged children (e.g., Miller, Giesbrecht, Mcinerney, & Kerns, 2012; Usai, Viterbori, Traverso, & De Franchis, 2014). Sadeh, Burns, and Sullivan (2012) found that in kindergarten-aged children, Garcia-Barrera et al.'s (2011) four-factor model of executive functions represented executive functions best while Lee, Bull, and Ho (2013) noted two-factor executive models fit best at young ages. Often researchers have found a single differentiated component at the younger childhood years in tandem with a combined inhibition-set shifting model (e.g., Lee et al., 2013).

An alternative measurement approach for executive functioning. The latent variable approach has been established as an alternative method of examining executive functions without reliance on only one traditional executive task. Latent variables are those that are not directly observable and instead are inferred from other variables that are directly measured or observed. Thus, this method can be used to examine executive functions more reliably, as it designates executive functions (or its components) as the latent variable(s) and other measures (e.g., cognitive tasks, rating scale items) can be designated as the observed variables. Using the latent variable approach also enables the investigation of the fractionation of executive functions. And so, with respect to the purposes of this dissertation, the latent variable approach allows the examination of the common executive function variance driving performance in all tasks, at the same time reducing the effects of the non-executive components (Friedman et al., 2008; Hughes, 2011). Specifically, latent variables are typically thought to 1) be a purer measure of the investigated ability (in this case executive functions) and 2) lack measurement error as they extract the common variance from observed variables (e.g., the dependent measures on certain tasks; Miyake et al., 2000). Further, a latent variable can be thought of as an underlying ability that influences performance on a set of observed tasks, which are impure measures of the

construct as they often are the products of many skills. Using CFA, which is a theory-driven latent variable approach, many researchers have used this approach to examine the structure and development of executive functioning.

Behavioural screeners of executive functioning. The problems that were associated with the use of traditional, performance-based tests of executive functions have recently been tackled using behavioural rating scales. Although the use of latent variable analysis has mitigated the challenges associated with traditional measures of executive functioning, it does not rid us of all the corresponding issues, particularly the inherent lack of ecological validity. As such, researchers have suggested that as part of every standard neuropsychological assessment, rating scales should be used to augment the cognitive assessment. In general, ratings scales may be more ecologically valid as they query everyday behaviours typically observed in daily life. There are some additional benefits to using brief rating scales, or screeners: they are generally short in length, making completion of the measures more cost- and time-effective than performance-based executive measures, they are easy to administer, and they can be completed by multiple raters giving a wide and potentially varied perspective of behaviour (Flanagan, Bierman, & Kam, 2003; Isquith, Roth, & Gioia, 2013; Kamphaus, Thorpe, Kroncke, Dowdy, & Vandeventer, 2007).

Other advantages of behavioural screeners are that they are highly replicable and without practice effects, which makes them practical for use across groups (e.g., clinical vs. typical, demographic groups such as ages, gender, etc.), research designs (e.g., longitudinal), cross-cultures, and in future, perhaps used in place of traditional, performance-based executive functioning tasks (Kamphaus, Thorpe, Kroncke, Dowdy, & Vandeventer, 2007; Royall et al.,

2002). They are also sensitive and offer applications for early assessment and identification of executive dysfunctions, for instance in the case of ADHD (Garcia-Barrera et al., 2015).

Other advantages that have been related to using screening measures are that broader-based measures can be used as quick tools to identify boys and girls at risk for behavioural and emotional problems and in need of further diagnostic assessment or intervention (Kamphaus et al., 2007). When expanding the scope of screening tools to multiple raters, it has been noted that teacher ratings, in particular, are less expensive to administer than are peer- or parent-rating, or school observations (Flanagan et al., 2003). Flanagan et al. (2003) further suggest that teacher rating scales that combine information regarding children's regulatory ability and aggressive tendencies have better predictive ability of later problems than other screening measures or combination of rating measures. However, while there are advantages to having multiple raters such as teachers complete rating scales, it is important to note that using rating scales to measure children's behaviour can be problematic; some raters' may have negative (or positive) biases towards the child, environment, or themselves (De Los Reyes & Kazdin, 2005), and/or the requested informant may not be in a position to provide the most accurate rating of the child or may be "evaluating the child based on age-inappropriate behavioural expectations" (Müller & Kerns, 2015, p. 1109). Of note, one issue that may complicate the use of executive functioning rating scales is the previously described lack of consensus in the definition of executive functioning (e.g., Jurado & Rosselli, 2007); rating scales are developed in accordance to the theoretical conceptualization of executive functioning of the authors and are not based on a standard definition of executive functions.

Although there are a number of rating scales often used in adult populations to measure executive functions and a number of rating scales available for use with children and adolescents

(hereafter referred to as children), the most commonly used behavioural screener of executive functions for children is the Behavior Rating Inventory of Executive Functioning (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000; Rabin, Paolillo, & Barr, 2016; Toplak, West, & Stanovich, 2013). In addition, there are other executive functioning rating scales available for use with children. The common thread of these rating scales is that they often capture more global aspects of behaviour in children than traditional, performance-based tasks. Described below are summaries of some of the behavioural rating scales that can be used to assess executive functions in children.

Target executive function screeners for this dissertation.

Behavior Assessment System for Children (BASC). The Behavior Assessment System for Children-Second Edition (BASC-2; Reynolds & Kamphaus, 2004) is a well-established multimethod assessment tool which provides a quick and meaningful insight into individuals' current functioning, including behaviours (i.e., adaptive and clinical dimensions) and emotions (Reynolds & Kamphaus, 2002). This multimethod tool includes parent and teacher rating scales, self-report, a structured developmental history form, and a student observation system. Different versions of the ratings scale exist for preschoolers, school-aged children, adolescents, and college-aged students. It is a commonly used comprehensive measure, which has previously been found to correlate with some measures of executive functioning such as the BRIEF, in children (Jarratt, Riccio, & Siekierski, 2005) and adults (Duggan, Garcia-Barrera, & Müller, 2016).

This rating scale system was initially used for the assessment of self-regulatory behaviour. Because of the complexity of executive functions, it is thought that it is most helpful to assess executive functions in a number of ways. As previously mentioned, executive functions have typically been assessed used cognitive tasks; behaviour rating scales enable a behavioural

method to be included in the multimethod assessment system (Garcia-Barrera, Duggan, Karr, & Reynolds, 2014). The BASC has a number of advantages in that, as previously mentioned, it is multimethod and it is multidimensional (i.e., it examines many aspects of behaviour and personality). This behaviour assessment system enables assessors to examine children's behaviours in the home and school, allows evaluation of children's emotions, personality, and perceptions of self, and provides background information. The BASC collects information with respect to both cognitive and emotional control processes, which are the foundation of self-regulatory behaviours. During assessment, clinicians typically gather this information using many and varying sources of information (e.g., observation, clinical interview, other), which can be difficult to integrate. Using the BASC allows this information to be gathered in a systematic manner and helps to provide an integrated and complete understanding of the child (Garcia-Barrera et al., 2014).

Other advantages of using the BASC for the assessment of self-regulatory behaviour is that the questions are worded in multiple ways (i.e., positively and negatively worded items), which enables the reduction of response bias. In addition, the BASC incorporates observed behaviour with standardized measures of functioning during cognitive and psychosocial assessment. Further, it incorporates clinical measures (e.g., difficulties with attention, hyperactivity, anxiety) with adaptive measures (e.g., study skills, leadership, adaptability), and it evaluates overt and covert feelings, in addition to attitudes and cognitions.

The Frontal Lobe Executive Control (FLEC) is a supplementary scale that was originally developed by Barringer and Reynolds (1995) and used with the first version of the BASC. This scale included 18 items chosen from the parent version (child and adolescent) of the BASC and was intended to assess difficulties with frontal lobe and executive control functioning by

examining behaviours typically associated with executive dysfunctions (Reynolds & Kamphaus, 2002). It was thought that this scale could be useful in making clinical diagnoses that involved executive functioning deficits, such as for ADHD. The scale had high internal consistency, as rated by high Cronbach's alpha. Research examining executive functions using the FLEC found that children with clinical disorders had higher scores on the FLEC (i.e., increased difficulty) than typically developing children, suggesting that it was useful to use with respect to identifying behaviours related to executive dysfunction across ADHD and other clinical disorders (Sullivan & Riccio, 2006). They also found significant positive associations between the FLEC and the BRIEF, as well as the FLEC and the Conners' Parent Rating Scales Revised: Short Form (Conners, 1997). The Executive Functioning Content scale in the BASC-2 is based on the FLEC scale. Other research (e.g., Hass, Brown, Brady, & Johnson, 2012; Reck & Hund, 2011; Volker et al., 2010) have indicated that the FLEC/Executive Control scales are useful at identifying executive functioning difficulties in clinical populations.

Garcia-Barrera et al. (2011) derived a 25-item executive functioning screener from the BASC to validate a four-factor model of executive functioning. They found this executive functioning screener was a psychometrically and theoretically sound screening tool for executive functioning in children measuring four latent factors: problem solving, emotional control, behavioural control and attentional control. The problem solving factor refers to "the ability to plan, problem-solve, make decisions, and organize information towards the execution of a goal" (Garcia-Barrera et al., 2011, p. 67). The emotional control factor refers to "the ability to self-regulate emotional response to environmental and internal cues" (p. 68). The behavioral control factor refers to "the ability to self-regulate behavior, including inhibition and impulse control" (p. 67-68), and the attentional control factor refers to "the ability to focus, sustain, and shift

attention systems according to task demands” (p. 67). This screener was derived from executive-related items in the Teacher Report Scale (TRS) for the BASC.

Beginning with the initial derivation study (Garcia-Barrera et al., 2011), the reliability and validity of a behaviour screener of executive functions derived from the BASC have begun to be established. To set a consistent measurement mode across age, gender, and time and to identify whether this screener is valid across clinical diagnoses and culture, subsequent studies have evaluated this model of executive functioning, and it has been found to demonstrate good fit in typically developing American children (Garcia-Barrera et al., 2013), children from other cultures and children with ADHD (Garcia-Barrera, Karr, Duran, Dierenfeld, & Pineda, 2015), in a sample of kindergarten children (Sadeh et al., 2012), and in young adults (e.g., Duggan et al., 2016). Results of these studies have shown high internal consistency [all alpha values $\geq .80$, with the exception of emotional control (Cronbach’s alpha = .77) in Garcia Barrera et al., 2015] during the initial derivation and replication, with the studies demonstrating good statistical fit for a four-factor model. The screener has also demonstrated invariance across age, gender, time, developmental group, and culture, suggesting that consistent measurement of this model has been established.

Sadeh and colleagues’ (2012) study examined the use of the BASC executive functions screener in kindergarteners. They demonstrated that although the model presented with adequate fit, the executive functioning screener exhibited poor predictive validity. Specifically, they found that following regression analyses there were low effect sizes. These results suggested that the BASC screener did not predict kindergarten or first-grade achievement scores (i.e., reading or math achievement) when controlling for intelligence and gender. Sadeh et al. posited that although there is an emerging body of literature linking performance-based executive

functioning with achievement measures, rating scales may not be able to capture this relationship due to a lack of convergence between what they referred to as indirect measures of executive functioning and achievement measures. They further noted that the screener may not fully reflect both cognitive-based executive functions (e.g., planning) and emotion-based executive functions (e.g., emotional control).

The Behavior Rating Inventory of Executive Function (BRIEF). The BRIEF was developed as the first objective rating scale to specifically measure executive dysfunction in children. The BRIEF was developed based on a rational approach as a way to rate a variety of similar behaviours in multiple environments – the home and school – in which executive functioning might be observed. It consists of 86 items, measured on a 3-point Likert scale: *never, sometimes, often*. It measures eight components of executive functioning derived statistically and theoretically (i.e., Inhibition, Shifting, Emotional Control, Initiating, Organization of Materials, Planning/Organizing, Working Memory, and Monitoring), combining to produce three composites (i.e., Behavioral Regulation Index, Metacognition Index, and Global Executive Composite). Self, parent, and teacher reports are available for children ages 5-18 years. There is also an adult version of the BRIEF available (BRIEF-A), which will not be discussed in this review as adult rating scales are not a focus of this dissertation.

The standardization sample of the BRIEF was collected with the goal of approximating the US population according to certain demographic variables such as age, gender, ethnicity, and geographical population density. The original standardization sample, however, was mainly obtained from individuals in the state of Maryland, and therefore did not span the US geographic area (Roth, Isquith, & Gioia, 2014).

Internal consistency indicators for the BRIEF are high (Cronbach's alpha ranges from .80 -.98) for both parent and teacher ratings, in both typically developing and clinical populations. Test-retest reliability over a period of 2-5 weeks across all versions of the BRIEF were reported to be adequate ($r = .59 - .96$).

There are some issues associated with the BRIEF. One is that the BRIEF consists of only negatively worded items. While use of negatively worded items (e.g., *has a messy desk* rather than *has an organized desk*) was the choice of the BRIEF's developers, it has been found that negative information tends to influence individuals' evaluations more strongly than positive information (Ito, Larsen, Smith, & Cacioppo, 1998). Results of one study suggested that the BRIEF may be less of a measure of executive functioning but rather one of behavioural dysregulation (McAuley, Chen, Goos, Schachar, & Crosbie, 2010), in which individuals have difficulty controlling their actions not due to executive deficits but simply behaviour difficulties.

Non-target executive function screeners.

Barkley Deficits in Executive Function Scales (BDEFS and BDEFS-CA). The BDEFS (Barkley, 2011) was originally developed to evaluate clinically significant dimensions of executive functioning deficits in adults with ADHD based on Barkley's work with individuals with ADHD and his conceptualization of executive functioning (Barkley, 2014). The BDEFS-CA (Barkley, 2012) is a parent-rated, downward extension of the scale examining executive dysfunction symptoms over the previous six months for children and adolescents ages 6 to 17. Raters can complete either a long form (70 items) or short form (20 items) version, each measured on a 4-point Likert scale (rarely or not at all, sometimes, often, and very often). Additionally, an interview version of the short form is available; however, norms are not available for this form.

Items load onto five scales comprising of Self-Management to Time, Self-Organization and Problem Solving, Self-Restraint, Self-Motivation, and Self-Activation and Concentration. Items yield a total score called the Total EF summary score (i.e., the sum across all items), and a total symptom count can also be computed from all items rated as occurring ‘often’ or ‘very often’. Finally, an ADHD–EF index can be computed, based on the items most predictive of ADHD. To make it more suitable for use with children and adolescence, wording of the items was changed from first to third person, and items referring to out-of-range developmental contexts (e.g., work) were changed to reflect the appropriate context for the developmental stage (e.g., school; Barkley, 2014).

The scale was normed based on a representative American sample of 1800, with equal representation of mothers and fathers and males and females. The normative sample of parents approximated the results of the US census from 2000 according to most demographics. All geographic regions of the United States were sampled (unlike the BRIEF, see Barkley, 2014). Further, the sample was not designed to remove those with learning, developmental, psychiatric, or medical disorders, or those receiving psychiatric medications or special education services.

Internal consistency is high, with Cronbach’s alpha ranging from .95-.97 across the five scales. There also appears to be good test-retest reliability, ranging from .73-.82 across scales over 3-5 weeks.

Childhood Executive Functioning Inventory (CHEXI). The CHEXI (Thorell & Nyberg, 2008) was developed as a quick screening measure of executive functioning for children and adolescents ages 4-15, targeting specific components of executive functions rather than overall executive functioning. It is a 24-item questionnaire than can be completed by parents and teachers. It includes two subscales: *Working Memory*, which measures working memory and

planning, and *Inhibition*, which measures inhibition and regulation. Each item is rated on a Likert-type scale ranging from 1 (definitely not true) to 5 (definitely true), with higher scores indicative of larger executive functioning deficits (Thorell & Catale, 2014).

The scales of the CHEXI were based on Barkley's model of executive functioning, in which "inhibition, working memory, regulation and planning are seen as constituting the major EF deficits in children with ADHD" (Thorell & Catale, 2014, p. 361). However, factor analysis yielded a two-factor model as being most appropriate for this scale (Thorell & Catale, 2014). The items in the working memory scale were also influenced by the conceptualization of Baddeley and Hitch (1974) that working memory has multiple components including the storage of verbal and spatial information, and the processing of that information (Thorell & Nyberg, 2008).

The internal consistency of the CHEXI has been deemed appropriate for the two major factors, for both parent and teacher ratings. In addition, test-retest reliability for the CHEXI has been shown to be high using parent ratings collected 3-10 weeks apart (Thorell & Catale, 2014). The CHEXI was also found to be significantly related to laboratory measures of working memory ($r = .26$ for parents and $r = .39$ for teachers) and inhibition ($r = .28$ for parents and $r = .35$ for teachers; Thorell & Nyberg, 2008).

The Comprehensive Executive Function Inventory (CEFI). The CEFI (Naglieri & Goldstein, 2013) is a rating scale designed to assess behaviours associated with executive functioning that are observable in everyday, real-life settings. Its development was based on the three-factor conceptualization of executive functioning by Miyake et al. (2000). The test developers used both factor analysis and a rational approach to develop the scales and their contents. Two versions of this scale are available - a self rating form, for children ages 12-18, and an informant (parent and teachers) rating form for children ages 5-18. Each version consists

of 100 items (90 are distributed among the scales and 10 are validity measures) which combine to form a Full Scale score set to have a mean of 100 and a standard deviation of 15. Higher scores are suggestive of good executive functioning, and this total score represents the best measure of a child's executive functioning. To explain the behaviours that make up the Full Scale score, the inventory provides additional scores in nine areas, chosen for their content and ability to provide intervention: Attention, Emotion Regulation, Flexibility, Inhibitory Control, Initiation, Organization, Planning, Self-Monitoring, and Working Memory.

The normative sample was based on 3 500 ratings, with 2 800 parent or teacher informant ratings and 700 self raters. Each whole year age was rated by at least 50 males and 50 females and was "representative of the US population across several demographic variables" (Naglieri & Goldstein, 2014, p. 224). Approximately 900 children had a diagnosis of ADHD, mood disorder, brain injury, or other such classification.

The internal consistency of the Full Scale score and additional scales is high in the standardization sample (Cronbach's alpha is .97 or higher). Reliability was high for all raters. Test-retest reliability ranges from .77-.91 for the Full Scale and .74-.91 for the nine scales.

Delis Rating of Executive Functions (D-REF). The D-REF (Delis, 2012) is a 36-item executive functions rating scale for use in children and adolescents ages 5-18. There are three forms: parent, teacher, and self, which may only be used for children ages 11-18. It is conceptualized as a rating scale intended to survey executive functions that interfere with an individual's daily functioning, and may be a source of concern to the school, parents, and/or self. After the 36 items are completed, there is room for the rater to also select the five behaviours that are most stressful for the child.

There are three domains evaluated with the D-REF – emotional functioning, behavioural functioning, and executive functioning, which combine to generate a Total Composite score. Each core index score is reported as a *T* score with a mean of 50 and standard deviation of 10. Higher scores are suggestive of a problem in the specific domain in which there is a high score, with *T* scores higher than 60 considered at least mildly elevated. Clinical index scores are also available in order to facilitate interpretation and were based upon the DSM-IV-TR. They consist of: Attention/Working Memory, Activity Level/Impulse Control, Compliance/Anger Management, and Abstract Thinking/Problem Solving (this specifically is not available on the self-rating form).

The normative data were based on national samples representative of the US 2010 census data between ages 5-18 years. The sample included 1 062 individuals (parents, $n = 500$; teachers, $n = 342$; self, $n = 220$).

Internal consistency for the core index scores and Total Composite score, as measured by Cronbach's alpha, is good (alpha is between .86-.97) for the Parent Rating Form. The internal consistency is lower for the clinical indexes (alpha is between .76-.94). The internal consistency is more variable for the Teacher Rating Form (Cronbach's alpha ranges from .80 -.99 for the core and Total Composite scores; Delis, 2012).

The Dysexecutive Questionnaire for Children (DEX-C). The DEX-C (Emslie, Wilson, Burden, Nimmo-Smith, & Wilson, 2003) is a supplementary rating scale to the Behavioral Assessment of Dysexecutive Syndrome, assessing executive functioning in children 8-16 years old. The DEX-C is based on the conceptual models of working memory of Baddeley and Hitch (Baddeley & Hitch, 1974) and the Attentional Control System of Shallice (Shallice, 1982; see Baron, 2007). The DEX-C consists of 20 items, is a downward extension of the DEX, and can be

completed by either parents or teachers. It assesses executive functioning across four broad areas: emotional/personality, motivational, behavioural, and cognitive. Each item is scored on a 5-point Likert scale ranging from 0 (never) to 4 (very often), with higher scores suggestive of more executive functioning difficulties.

The normative sample was comprised of data that were collected from 265 control children balanced for gender across 8 age bands, with representativeness for general ability and socioeconomic status. Clinical samples included few children [e.g., ADHD (n=39); all other groups n < 10]. Up to this point in time, there has been limited research on the use of this system and its reliability and validity (Siu & Zhou, 2014). However, Baron (2007) noted that reliability was high.

The Current Study

Previous studies, including the initial derivation, have established the reliability and validity of behavioural screeners of executive functions using the BASC; this model of executive functioning has been found to demonstrate good fit in typically developing American school-age children, children from other cultures, children with ADHD, kindergarteners at risk for developing behavioural problems, and young adults (i.e., Duggan et al., 2016; Garcia-Barrera et al., 2013; Garcia-Barrera et al., 2015; Sadeh et al., 2012).

Although the four-factor model (i.e., problem solving, attention control, behavioural control, emotional control) has been examined with a number of different groups and in a number of different ways, this model of executive functions has not been examined in adolescents, and particularly, adolescents presenting with a neurological disorder. As discussed previously, individuals with neurological disorders are a population known to have executive dysfunction. It is useful to examine executive functioning deficits in adolescents with

neurological disorders using behavioural screeners because problems with executive functions are often observed as challenges with learning and behaviour regulation in school and social situations (Slomine et al., 2002), indicating that rating scales are useful tools by which parent concerns can be noted and addressed. Furthermore, different disorders are characterized by various and differing deficits in executive functioning (see Gioia et al., 2002; Pennington & Ozonoff, 1996; Slick, Lautzenhiser, Sherman, & Eyrl, 2006). Consequently, different profiles of strengths and weaknesses likely typify different disorders, and it is a unique opportunity to examine these profiles in this heterogeneous sample. The current study builds upon the previously derived behavioural screener of executive functions in children by examining the validity of this screener using the second edition of the BASC, and by examining the validity of the screener with a clinical population. The second goal of this study was to examine whether the items derived from the BASC-2 for the behavioural screener correlate with items from the BRIEF and traditional, performance-based executive function measures and demonstrate convergent validity.

Specifically, a number of predetermined performance-based executive functioning measures were evaluated against specific factor scores derived from the BASC-2 behavioural screener. The Tower of London task was evaluated against the Problem Solving factor. The Trail Making Test was evaluated against the Attentional Control factor. A Stroop task was evaluated against the Behavioral Control Factor. There was not a specific test evaluated against the Emotional Control factor. The Wisconsin Card Sorting Task was evaluated against all four factors. A description of the tests follows in the methods.

And finally, the third goal of this study was to examine the unique characteristics of executive functioning across this study's heterogeneous clinical population. In examining the

executive profile (e.g., strengths and weaknesses) of these clinical groups, we are intending to develop a characterization of executive functioning in this population.

Study aims and hypotheses.

- 1) To replicate the findings presented in Garcia-Barrera et al. (2011, 2013, 2015) in a clinical adolescent-aged population who are known to have executive dysfunctions, this time using the BASC, Second Edition Parent Rating Scales – Adolescent (BASC-2-PRS). It is expected that this sample will demonstrate the same four-factor executive function structure as observed in previous studies using this model.
- 2) To examine the convergent and validity of the BASC-2-PRS (i.e., BASC-2) derived screener of executive functions with the BRIEF (parent ratings), and other traditional, performance-based and established measures of executive functions. It is expected that the screener will demonstrate convergent validity with the BRIEF, which is another standardized measure of executive functioning, but that given the lack of ecological validity with some of the traditional neuropsychological tests, there may not be appropriate convergent validity among the BASC-2 screener and these tests.
- 3) To characterize the executive functioning in this heterogeneous clinical sample according to the latent factors from the BASC-2 derivation. It was expected that there would be different patterns of executive functioning across the various clinical groups analyzed for this study. More specifically, it was expected that while all types of TBI will have similar profiles of executive dysfunction, those with more severe brain injury will show more significant deficits (e.g., Gioia et al., 2002).

Methods

The UVic/VIHA Joint Research Ethics Sub-Committee approved the study protocols and procedures (#J2014-092), and parents or legal guardians provided written consent for the data to be used for research purposes.

Participants

This study examined the clinical data of 107 patients from Vancouver Island, British Columbia, seen for neuropsychological assessment through the Neuropsychology Program at Queen Alexandra Centre for Children's Health (QACCH)/Island Health, between 2006 and 2014. Participants were included in this study if they were between the ages of 12-18 years old (as it is a paediatric clinic, the oldest age seen for clinical assessments at QACCH is 18 years), a parent or guardian completed the BASC-2-PRS 12-21 (BASC-2-PRS), and were of at least low average intellectual abilities (i.e, Full Scale IQ > 79) as measured by the Wechsler intelligence tests [Wechsler Intelligence Scale for Children (WISC) or Wechsler Adult Intelligence Scale (WAIS)] or the Reynolds Intellectual Assessment Scales (RIAS). A subset of 35 parents or guardians also completed the BRIEF. Therefore, data from these 35 participants were used for all BASC-2 – BRIEF analyses. For the analyses involving test of cognitive functioning, there were a more varied number of participants. These data were collected as part of an archival study and as such there was not a standard assessment battery used with all eventual participants; individual neuropsychological assessments were designed based on individual participant's strengths and needs at the time of the neuropsychological assessment. A summary of the demographic characteristics of the sample can be seen in Table 1.

Patients were referred to QACCH for a variety of reasons including assessment of the child's cognitive and/or emotional strengths and weaknesses, to help with school planning, and

for post-concussive evaluations. Patients were primarily referred for an assessment by their primary-care physician, by emergency room physicians following a TBI, and by psychiatrists or clinical psychologists requesting an evaluation of their patient's cognitive strengths and weaknesses. The primary diagnostic categories for patients in the sample included children with a) moderate to severe TBI ($n = 9$), b) mild TBI ($n = 50$), c) brain tumor ($n = 2$), d) stroke ($n = 2$), e) epilepsy/seizure disorder ($n = 2$), f) CNS infections (i.e., encephalitis $n = 2$), g) neurodevelopmental issues [i.e., toxic exposure in utero/FAS ($n = 1$), ASD ($n = 2$), and other/not specifically categorized ($n = 8$), which could include chromosomal/genetic disorders, history of extreme birth complications or extremely low birth weight, neural tube closure defects, hydrocephalus, mild cerebral palsy, neurologic movement disorder, neurocutaneous disorder, degenerative disorder, etc.; total n in this group = 11], h) neuropsychiatric classifications [i.e., psychosis ($n = 2$), schizophrenia ($n = 2$), bipolar disorder ($n = 2$), other significant mood and anxiety symptoms/disorders ($n = 8$); total $n = 14$], i) any other medical condition affecting brain functioning [i.e., benign intracranial hypertension ($n = 1$), neurofibromatosis type 1 and arachnoid cyst ($n = 1$), progressive onset childhood ataxia ($n = 1$), hemolytic anemia/immune disorder ($n = 1$), microtia of right ear ($n = 1$), leukemia ($n = 1$) and other ($n = 2$), total n in this group = 8), and j) ADHD ($n = 1$; see Figure 1). Six participants did not have a formal diagnosis included in their chart; however, all patients seen at the Neuropsychology Program have a neurological concern. Typically, diagnoses were made by physicians and/or clinical psychologists prior to the patient's neuropsychological evaluation. Furthermore, 18.69% of the sample had more than one neurological concerns such as ADHD; these participants were classified according to their primary diagnosis to the Neuropsychology Program.

General Procedure

This dissertation was an archival study and data was gathered and analyzed two to nine years following the original assessment session. Data was extracted by reviewing paper files from the Neuropsychology Program. First, charts were reviewed to determine the participant met the inclusion criteria described above. Secondly, demographic information was extracted. Lastly, executive function measures were extracted, specifically from performance-based neuropsychological tests and from parent ratings of the BASC-2 and BRIEF.

Testing took place during the course of a one-or two-day clinical assessment. Specific cognitive tests (including all performance-based executive function tests) were administered during this clinical assessment. Administered cognitive tests were chosen based on the referral question, and following an individualized assessment design, and therefore not all performance-based tests were administered to each participant. Research consent was obtained prior to initiation of assessment. A packet was sent home along with the initial appointment confirmation up to two months pre-appointment. Parents filled out the BASC-2-PRS and the parent version of the BRIEF prior to the assessment or at the time of the assessment.

Measures

Behavioral Assessment System for Children – 2nd Edition (Reynolds & Kamphaus, 2004). As discussed in Chapter 1, the BASC-2-PRS consists of 150 items, and is a multidimensional measure that has been shown to be a valid and reliable measure of behaviour and personality for individuals ages 12-21 years old. When parents completed the BASC-2, they rated each item on a 4-point Likert scale (Never, Sometimes, Often, Almost Always) describing their child's behaviour over the several months prior to their child's neuropsychological assessment. In general, BASC-2 scale scores are provided as *T*- Scores, with higher scores

indicating a higher degree of impairment. Conversely, on the adaptive scales, a lower *T*-Score is indicative of a higher degree of impairment. For this study, *T*-scores were created for each of the four executive functioning factors used in the executive functions screener (i.e., Problem Solving, Attentional Control, Behavioral Control, and Emotional Control). Higher *T*-scores indicated a lower degree of impairment for Problem Solving, Attentional Control, and Emotional Control, and higher *T*-scores indicated a higher degree of impairment for Behavioral Control. To create these *T*-scores, BASC-2 items believed to represent one of the four executive factors were selected as indicators of executive behaviours. These indicators were further narrowed down to represent a brief executive functioning screener (this process is described below). For each executive functions construct, the selected items were summed to create a total raw construct score and then linearly-transformed to create the *T*-scores. To ensure accurate analysis, items that were not positively worded were reverse scored for Problem Solving, Attentional Control, and Emotional Control. Items that were not negatively worded were reverse scored for Behavioral Control.

Validity indices. For the PRS, there are three indices used as an indicator of validity: 1) the *F* index detects inordinately negative responses, 2) the *Response Pattern* index, which detects potentially patterned responding, and 3) the *Consistency* index, which identifies cases of inconsistent responses to similar items.

Behavior Rating Inventory of Executive Function (BRIEF; Parent form; Gioia et al., 2000). As previously mentioned, the BRIEF is a standardized 86-item information-rating scale which is valid and reliable for use in children and adolescents ages 5-18 years and measures executive functions across eight clinical executive functioning scales: Inhibit, Shift, Emotional Control (the three of which form the overall index of Behavioral Regulation), Initiate, Working

Memory, Plan/Organize, Organization of Materials, and Monitor (the five of which form the overall index of Metacognition). Two measures of validity are also provided: 1) the Negativity Scale, which measures the extent to which the respondent rated items in a negative manner, and the Inconsistency Scale, which reflects the extent to which the respondent rated similar items in an inconsistent manner. Parents or guardians rate their child's behaviour over the six months prior to the child's assessment on a 3-point Likert scale (Never, Sometimes, Often). Scales scores are provided as *T* Scores with scores greater than 65 indicating impairment on the specific scale and/or the overall index.

Tower of London (TOL; Shallice, 1982). This task was developed to assess problem solving and strategic planning and involves the inhibition of maladaptive responses. Nevertheless, this task is traditionally thought of as a measure of planning and problem solving as the individual completing the task attempts to map out a series of moves in preparation for successful completion of the task (Riccio, Wolfe, Romine, Davis, & Sullivan, 2004; Simon, 1975). Participants are asked to rearrange beads over three vertical rods to match a model presented by the examiner. Problems of increasing complexity are administered which require an increasing number of moves to solve. Dependent variables are the minimum number of moves needed to match the model and problems solved within the maximum number of trials allotted for each problem. As such, this task was used to evaluate convergent validity with the Problem Solving factor.

Color-Word Interference. This task comes from the Delis-Kaplan Executive Function System (DKEFS, Delis, Kaplan, & Kramer, 2001), which is a standardized set of tests used to assess executive functions in children, adolescents, and adults. The Stroop task is considered a prototypical test of behavioural inhibition (Miyake et al., 2000). The Color-Word Interference

task is similar to the Stroop task and is intended to provide a measure of inhibition. On the DKEFS, the Color-Word Interference task is a 4-part task that measures whether individuals can override their tendency to produce a more dominant, automatic verbal response. In this set of tasks, the primary outcome measure is the number of seconds it takes for the individual to complete the task. In the first condition, the participants read the names of colours as quickly as they could. In the second condition, participants named the colour of the ink as quickly as they could. In the third condition, participants named the colour of the ink the colour word was printed in as quickly as possible without reading the word. The dependent measure used was the amount of time it took to complete condition three. This dependent measure was used to examine the relationship between this test and the Behavioral Control factor.

Trail Making Test. This particular version of this task comes from the DKEFS. Traditionally, the Trail Making Test is composed of two conditions. Both conditions require visual search and motor planning, and the second condition is considered to place a heavy load on executive functions and is therefore a widely used test of executive functions (Stuss et al., 2001). Furthermore, via factor analytic approach, O'Donnell, MacGregor, Dabrowski, Oestreicher, and Romero (1994) found that Part B of the Trail Making Test loads on an attention factor over and above the cognitive factors required for the first part. As such, the relationship between this test and attentional control was examined. In this task ("Trial 4: number-letter switching"), participants draw a line connecting a number to a letter to a number and so forth as quickly as they can from the item noted "begin" to the item noted "end". Participants are told that if they make an error they must correct the error before continuing on. The dependent variable was time to complete this task.

Wisconsin Card Sorting Task. The purpose of this task is to evaluate one's ability in a number of areas including concept formation, shift and maintain set, and incorporate feedback. It also requires an individual to update task goals in their mind. This test was used to examine the relationship between all four factors and a performance-based task. The reason for this is that in the literature, some executive functions are considered to be more complex, in that when individuals complete these tasks they are thought to recruit multiple foundational executive processes such as attentional, behavioural control, and problem solving (Huizinga, Dolan, & van der Molen, 2006; Miyake et al., 2000). This test consists of four key cards and a set of 128 response cards, which can be sorted according to four different concepts. The individual completing the test is asked to match each of the response cards in the deck to one of four key cards. The individual is not told how to sort the cards but is given feedback as to whether he or she is right or wrong. The sorting rule changes a maximum of six times throughout the test, but the individual is not provided with warning that the sorting rule changes. There is no time limit to complete this test. The dependent variable is the raw number of perseverative errors obtained in this test as typically, it is one of the most commonly used measures of executive dysfunction and is also considered the most sensitive measure to executive dysfunction on this task.

Grip Strength. This task measures the strength of an individual's grip and was used to evaluate discriminant validity. A hand dynamometer consists of a grip and scale that measures the force produced when the grip is squeezed for both hands separately over two to three trials. The dependent variable is the raw mean of the two trials for each hand separately.

Statistical Analyses

Descriptive statistics, correlations, tests for multivariate and univariate normality, reliability coefficients, analysis of variance, and general linear models were calculated using

IBM SPSS Version 23 and Version 24. All analyses of factor structure and latent means were conducted using Mplus Version 7.4 (Muthén & Muthén, 2015). As the executive functions screener items involved noncontinuous data, the indicators were treated as polytomous, with specifications for categorical data used in each analysis. In this case, MPlus recruits an alternative estimator called the weighted least squares with mean and variance adjusted (WLSMV), which differs from the default maximum likelihood method of estimation used for continuous data. The WLSMV assumes that an underlying continuous latent response variable influences the observed categorical outcomes, resulting in threshold parameters replacing intercepts to distinguish between categorical responses. Unless determined otherwise from identification of data patterns, missing data was treated as missing at random or missing completely at random.

Study 1 (Screener derivation).

Item selection pool. To generate an item pool, the entire set of 150 items from the BASC-2-PRS was carefully reviewed and items that were potentially classified as executive in nature and were similar to the items in the original BASC screener were isolated. This isolation was based on the four-factor conceptualization of executive function providing the framework for the screener: Problem Solving, Attentional Control, Behavioral Control, and Emotional Control.

At this initial stage, all items corresponding to each of the theoretical underpinnings of the four latent constructs were extracted. Then, selected items were discussed within this writer's lab (serving as proxy for a panel of experts) to fully determine whether and how the items fit the specific executive construct and were required to be agreed upon at a 70% consensus rate. Two items that were originally selected to serve as indicators for Problem Solving and Emotional Control, respectively, were not deemed to fully reflect the factors and were discarded from the

screeners. Finally, items were compared to items being used in another BASC-2 analysis as a rough measure of reliability and were equivalent.

Data screening. Tests for multivariate normality and identification of significant outliers were performed. To evaluate multivariate normality, Mahalanobis distances were examined to determine whether any items were significantly different from normal. Multivariate normality (Kline, 2010) is one of the necessary assumptions to conduct analyses using structural equation modeling.

Item screening. Frequency distributions, including analysis of means, standard deviations, skewness, and kurtosis were analyzed. In accordance with the methods used in the original screener derivation study (Garcia-Barrera et al., 2011), and according to convention (see Byrne, 2013), a critical value of $|2.0|$ for skewness and $|7.0|$ for kurtosis were set.

Next, a correlation matrix was generated to analyze the relationships among items and potential collinearity effects. If correlations are too high, then collinearity is expected (Kline, 2010), which suggests that items that appear to be measuring different things, are in fact, measuring the same thing. Because all items in the scale are expected to analyze different aspects of the same construct, mainly moderate correlations were expected. In addition, it was expected that there could be weak correlations among unrelated items from separate executive constructs.

For the screener, it was expected that initially, there might have been more items extracted for the screener than needed. Some of these were expected to have been duplicates (e.g., “pays attention” and “listens attentively”), or some may not have fully related to the latent factor being measured (e.g., the quality of whether the item matched the latent construct may have been poor, or the items may have been considered to be too ambiguously worded). To

ensure the indicators captured the constructs of the four factors, these items were further evaluated during item screening and ultimately refined as needed.

Analyses of internal consistency. An attempt was made to evaluate internal consistency via the following two methods: 1) Cronbach's alpha, in accordance with Garcia-Barrera et al. (2011), and 2) omega hierarchical (omegaH) and omegaS values. For Cronbach's alpha, .8 is typically used as the acceptable cut-off value; however, in the case of complex psychological constructs values of .7 are more realistic (Hair, Black, Babin, & Anderson, 2010; Kline, 2013). In addition, an attempt was made to calculate omega values to indicate the reliability of the general and subscale dimensions within the context of a bifactor model (see Reise, Bonifay, & Haviland, 2013). In general, it is important to examine these values within the context of CFA as they are thought to be more informative than the alpha values in the context of the multidimensional scale (Garcia-Barrera et al., 2015). However, to calculate omegaH and omegaS values and a more complex bifactor model must be calculated, in which each indicator is correlated with one underlying latent factor (i.e., executive functions in this case) and their original factors from the baseline model (i.e., problem solving, attentional control, behavioral control, and emotional control). Additionally, the model must be designed so that the baseline latent factors do not correlate with each other and are set to 0. Unfortunately, this complex bifactor model did not converge and therefore, the bifactor model and its associated factor loadings could not be evaluated.

Estimation method.

Confirmatory factor analysis. CFA was used to evaluate the adequacy of the four-factor model and selected indicators. This model was also compared to three alternative models, consisting of a one-factor, two-factor, and three-factor model.

To evaluate model fit, the χ^2 test, which indicates the difference between the observed and expected covariance matrices, is considered an index of goodness of model fit. Nonsignificant p -values indicate adequate model fit, with χ^2 values closer to zero indicating better model fit. Additional fit indices, including the comparative fit index (CFI), a normed statistic ranging from 0 to 1, and the Tucker-Lewis Index (TLI), which is a nonnormed statistic that can extend outside of the range of 0 to 1. Both of these alternative fit indices are considered incremental fit indices and were assessed to evaluate the model more accurately. Incremental fit indices measure proportionate improvement in fit of a hypothesized model compared to a more restricted baseline model (Hu & Bentler, 1999). These alternative fit indices were developed to address some of the limitations associated with the χ^2 test, namely that it is sensitive to sample size and nonnormality (see Byrne, 2013 for a detailed discussion) For the alternative indices, models with fit below .90 can be improved (Bentler & Bonett, 1980), while models with values above .95 indicate optimal fit (Hu & Bentler, 1999). For this study, model fit between .90 - .95 was considered as representing acceptable fit (e.g., Garcia-Barrera et al., 2011; 2015). The root-mean-square-error of approximation (RMSEA) is another alternative fit index and approximates the lack of fit when compared to a saturated model. It is considered an absolute fit index and relies on how well the hypothesized model fits the sample data. Values between .05 - .08 were considered fair fit (e.g., Garcia-Barrera et al., 2015), and values greater than .08 are generally considered poor fit. The Δ CFI serves as a metric for evaluating fit change between models (Cheung & Rensvold, 2002); a change greater than or equal to 0.01 indicated significant change in model fit across comparisons. For each analysis, χ^2 , CFI, TLI, Δ CFI, and RMSEA fit indices were reported to assist with interpretation.

Model modifications. Following the establishment of a baseline model with good fit, potential model modification indices were evaluated. When conducting CFA analyses, model modification indices can be recommended if requested by the software program, which in this case was Mplus. Model modification indexes typically estimate the reduction in the value of the chi-square goodness-of-fit test if parameters that were previously fixed to 0 are subsequently estimated.

Study 2 (screener application).

Convergent validity. Convergent validity was assessed by evaluating Pearson r and Spearman's rho correlations between the four BASC-2 executive function factors (i.e., Attentional Control, Behavioral Control, Emotional Control, and Problem Solving) and the corresponding scales from the BRIEF (i.e., Working Memory, Inhibit, Emotional Control, and Plan/Organize, respectively), for a subset of participants (i.e., the 35 parents who completed the BRIEF). To do so, total scales scores were created for each of the four BASC-2 executive function factors. To generate a total scale score, raw scores for each item serving as an indicator of a latent factor were summed. Prior to summing the raw scores, some items first required reversal, so that scales were either consistently positively or negatively worded. For the total scales scores, individual items were reversed scored as follows: Item 136 was reversed for Attentional Control; Item 33 was reversed for Behavioral Control and items 68 and 82 were reversed for Emotional Control. After the total scale scores were generated, they were converted to linear T -scores. Next, each BASC-2-PRS scale was evaluated against its corresponding BRIEF target scale using pairwise correlations (i.e., BASC-2-PRS Problem Solving with BRIEF Plan/Organize; BASC-2-PRS Attentional Control with BRIEF Working Memory; BASC-2-PRS Behavioral Control with BRIEF Inhibit; and BASC-2-PRS Emotional Control with BRIEF

Emotional Control). Finally, each BASC-2-PRS scale was evaluated against the seven remaining BRIEF scales (e.g., BASC-2-PRS Problem Solving with BRIEF Working Memory, Inhibit, Emotional Control, Organization of Materials, Shift, Initiate, and Monitor). These comparisons were made in an effort to assess the specificity of the relations between the BASC-2-PRS scales and their target BRIEF scales (Duggan et al., 2016).

Pairwise correlations between the four executive function scales and performance-based executive function measures were also investigated to examine convergent validity. The Tower of London was evaluated against the Problem Solving scale, the Color-Word Interference Test against the Behavioral Control scale, the Trail Making Test Condition 4 against the Attentional Control scale, and the WCST against all four executive function scales. Finally, the four scales scores were correlated against grip strength to assess divergent validity.

Profile analysis. Differences among the clinical groups were analyzed across scales for the BASC-2-PRS. Following the method used by Gioia, Isquith, Kenworthy, and Barton (2002), profile analysis was used to evaluate the differences among the clinical groups on the BASC-2 executive functioning scales. A mixed repeated measures ANOVA was used to conduct the profile analysis, to determine whether there were differences in: 1) level (i.e., did some of the clinical groups have higher overall mean scores across the different variables than other groups?), 2) flatness (i.e., were some factors more elevated than others across groups), and 3) parallelism (i.e., was the pattern of scale elevations or depressions different among the clinical groups?). *T*-scores for each of the four executive function scales were within-subject measures and participant group (i.e., mild TBI, moderate/severe TBI, neurodevelopmental, and neuropsychiatric) were between-subject variables. To ensure that all scales scores were measured similarly, items on the Behavioral Control scale, with the exception of item 33, were reverse

scored so that higher scores were indicative of better functioning (similar to the other three executive function factors). Following a significant between-subject effect of “diagnostic group” in terms of level, pairwise comparisons were conducted to determine significant differences in global elevation regardless of individual BASC-2 scale profile. To further evaluate whether there were any significant differences between diagnostic group on each of the four scales, a one-way MANOVA was conducted. Diagnostic group was entered as a between-subjects factor, the four executive function scales as the within-subjects effect, and age as a covariate. All analyses were adjusted for multiple comparisons using the Bonferroni correction.

Results

Study 1 (Screening Derivation)

The main purpose of this study was to answer the questions of (1) whether an executive function screener for neurologically impaired adolescents could be derived from the BASC-2 PRS, and (2) was the four-factor executive functioning structure found in the prior screener derivation studies present in the current study, and if not, can a different factor structure more accurately describe the screener?

Data and item screening. The initial series of items from each of the scales were refined during multiple item screening steps. Initially, items were chosen to reflect items from the original screener based on the BASC. Following, items were reviewed to ensure that they met the theoretical underpinnings of the four-factor model of executive functioning and reduced redundancy within each scale. After review, two items were removed from the Problem Solving scale; 1 from the Behavioral Control scale; and 1 from the Emotional Control scale as they were determined to be somewhat redundant and/or nonspecific. Review of the BASC-2 validity indexes (i.e., *F* index, *Response Pattern* index, and the *Consistency* index) revealed a few elevations on the validity scales. Regardless, these cases were included in analyses. Review of the BRIEF validity indexes (Negativity and Inconsistency scales) also revealed elevations in some of the validity scales. Elevations in the BRIEF validity scales were not unexpected as some researchers have described the BRIEF as a tool in which scales may be elevated in children and adolescents who present with behavioural disruption and impairment unrelated to any underlying disorder (McAuley et al., 2010). Thus, these cases were also included in analyses. The data were inspected for multivariate and univariate normality. No significant multivariate outliers were identified using the DeCarlo macro (DeCarlo, 1997), which identifies significantly large

Mahalanobis distances. For the BASC-2 and BRIEF, no individual items exceeded the parameters of |2.0| or |7.0|, for skewness and kurtosis, respectively (see Table 2). Finally, inter-item correlations were examined for all BASC-2 items and ranged from low to high (see Table 3). In addition, all intra-correlations among factors were significant; however, nine inter-correlations were not significant. No inter-correlations were above .90, which suggests that collinearity was not a concern (Kline, 2010).

Internal consistency reliability. The internal consistencies (Cronbach's alpha) for the four executive function factors were in the good range, with alpha coefficients ranging from .807 for Emotional Control to .880 for Behavioral Control (see Table 2). Cronbach's alpha was .833 for Problem Solving and .873 for Attentional Control. Cronbach's alpha for the entire screener was lower (.693), suggesting multidimensionality for the entire screener.

Confirmatory factor analysis. The alternative models (see Figure 2) were consistent with the alternative models evaluated in prior studies by Duggan et al., 2016, Garcia-Barrera et al. 2011, 2013; 2015 and Sadeh et al., 2012. The first alternative model (Model 1) evaluated a 1-factor (unidimensional) model with 25 indicators. This model was called Unidimensional Executive Function as it contained all executive function indicators in the screener contributing to this factor. The second model (Model 2) was a two-factor model consisting of Problem Solving (6 indicators) and a second latent construct called Behavioral Self-Regulation (19 indicators). A third model (Model 3) consisted of three latent constructs, Problem Solving (6 indicators), Attentional Control (6 indicators), and Behavioral/Emotional control (13 items).

All models converged normally and the fit indexes are reported in Table 4. These three models demonstrated increasingly better fit in terms of improved model fit indexes, with the exception of the χ^2 test. However, it is important to note that adequate model fit is indicated by a

non-significant p -value for the χ^2 test. In this study, all p -values for the χ^2 tests were significant. However, this was not unexpected as this measure of goodness-of-fit is easily affected by sample size (see Byrne, 2013), and therefore the actual test statistic was examined during model evaluation and comparison, with lower values suggesting increasingly better fit. CFI and TLI values were in the acceptable range for all models; however, these indexes were optimal for the baseline model (i.e., Model 4). Model comparisons via Δ CFI demonstrated improved fit for Model 3 vs. Model 2 and for Model 4 vs. Model 3. RMSEA values indicated poor fit for Models 1-3, but suggested fair fit for Model 4. These results support the hypothesis that the four-factor BASC executive function screener (Garcia-Barrera et al., 2011) is replicable using the BASC-2 PRS - Adolescent 12-21. In addition, given that the four-factor model yielded the best fit, these results further support the that the screener provides information about multiple components of executive functioning.

Model modifications. Potential model modification indexes from Model 4 were examined to decide whether any further changes should be made in the target model. The modification indexes suggested the following: 1) allowing Item 68, *changes mood quickly*, and Item 82, *is easily upset*, to load onto the Problem Solving Factor for a drop in χ^2 of 12.258 and 10.750, respectively, and 2) allowing Item 86, *able to describe feelings accurately*, to load onto both the Problem Solving and Attentional Control factors for drops in χ^2 of 39.045 and 17.492, respectively. However, model modifications are driven by empirical fit and not theoretical considerations, and therefore should be interpreted with caution (see Byrne, 2013; Kline, 2010). As such, many researchers caution against undertaking model modifications. While some of the modifications suggested may incorporate some of the theoretical elements of the different suggested factors, it was unlikely that they would reflect the alternatively suggested factors over

and above the currently associated factor. Furthermore, the model modification indexes were all minimal, with the greatest modification index suggested a drop of 39.045 for the goodness-of-fit test. Therefore, no additional changes in model fit were considered.

Parameter estimates. The individual item factor loadings for the four-factor model (Model 4) are summarized in Table 5. Standardized factor loadings represent the strength of the association between the factor and the observed variable and the squared standardized loadings represent the proportion of explained variance that a factor explains for a given indicator. Standardized values greater than .70 were considered very strong (see Kline, 2010). The factor loadings of Model 4 ranged from |0.534| to |0.923| overall. More specifically, factor loadings for Problem Solving ranged from 0.554 to 0.873, Attentional Control ranged from |0.727| to |0.923|, Behavioral Control ranged from |0.534| to |0.918|, and Emotional Control ranged from |0.672| to |0.818|. All factor loadings were significant ($p < .001$), which supports the goodness of fit of the overall model.

Figure 3 shows the configuration of Model 4 (i.e., the baseline model) and the correlations among factors, which range from $r = -.710$ to $r = .859$. All correlations were significant ($p < .001$). As prior studies have found moderate to high correlations among the four factors (see Duggan, et al., 2016; Garcia-Barrera et al., 2011, 2013, 2015; and Sadeh et al., 2012), the strong and significant correlations among the four-factors was expected and further support the strong relationships that underlie the four latent factors of this executive functioning screener. Specifically, these inter-factor correlations provide further support that the latent variables represent unique constructs with some shared variance. Some negative correlations were observed. This is likely explained by the wording of some of the items; specifically all

Problem Solving items were positively worded as were all Attentional Control items and Emotional Control items. All Behavioral Control items were negatively worded.

Study 2 (Screener Application)

Convergent validity of the BASC-2 Executive Function Screener. The second objective of this study was to examine whether there was convergent validity of the four-factor BASC-2 executive function screener with 1) the BRIEF, which is the most widely used executive function rating scale, and 2) performance-based measures of executive functioning.

Correlations between the BASC-2 executive function screener and the BRIEF. The convergent validity of the BASC-2 executive function screener was evaluated by examining the correlations between the *T*-scores for its four factor scores (Problem Solving, Attentional Control, Behavioral Control, and Emotional Control) and the *T*-scores of their corresponding BRIEF target scores (Plan/Organize, Working Memory, Inhibit, and Emotional Control; see Table 6). High correlations were observed for both the BASC Behavioral Control scale with the BRIEF Inhibition scale ($r = .803, p < .001$; $\rho = .846, p < .001$) and for the BASC Emotional Control and the BRIEF Emotional Control scales ($r = -.816, p < .001$; $\rho = -.812, p < .001$). The relationship between the BASC Attentional Control scale and the BRIEF Working Memory scale was significant but somewhat lower although remained in the moderate range ($r = -.669, p < .001$; $\rho = -.699, p < .001$). The correlation between the BASC Problem Solving scale and the BRIEF Plan/Organize scale was the weakest, but significant as well ($r = -.555, p = .001$; $\rho = -.484, p = .003$).

Next, correlations were evaluated among the *T*-scores for the four BASC-2 scale scores and the *T*-scores for the non-target scales. In contrast to expectations, the relationships among the BASC-2 scale scores and the non-target BRIEF scales were generally in the moderate to high

range and significant (see Table 6). However, the correlations between the BASC-2 scales and target scales were overall stronger than between the BASC-2 scales and non-target scales, with the exception of Problem Solving. In that case, the relationship between Problem Solving and Plan/Organize remained one of the highest. Correlations between the BASC Behavioral Control scale and BRIEF non-target scales ranged from $r = .362$ to $r = .722$ and $\rho = .432$ to $\rho = .785$. For the BASC Emotional Control scale, correlations ranged from $r = -.307$ to $r = -.783$ and $\rho = -.303$ to $\rho = -.753$. For the BASC Attentional Control scale, correlations ranged from $r = -.318$ to $r = -.668$ and $\rho = -.416$ to $\rho = -.734$. Finally, for the BASC Problem Solving scale, correlations ranged from $r = -.432$ to $r = -.656$ and $\rho = -.362$ to $\rho = -.632$.

Correlations between the BASC-2 executive function scale scores and performance-based measures of executive functioning. The convergent validity of the BASC-2 executive function screener was then evaluated by examining the correlations between three of the four scale scores (Problem Solving, Attentional Control, and Behavioral Control) and their corresponding performance-based executive functioning measures. Bivariate correlations were also examined among the four scale scores (Problem Solving, Attentional Control, Behavioural Control, and Emotional Control) and a more complex measure of executive functioning, the Wisconsin Card Sorting Task. Finally, the divergent validity of the executive function screener was examined through bivariate correlations of the four scale scores and grip strength performance. For all analyses between the BASC-2 executive function screener and performance-based cognitive tasks, no significant correlations were observed (see Table 7).

Profile analysis. The third and final goal of the study was to conduct a profile analysis of the BASC-2. Diagnostic group demonstrated differences in global elevation irrespective of individual BASC-2 profile, $F(3,80) = 5.30$, $p = .002$, $\eta^2 = .166$, with the neurodevelopmental and

neuropsychiatric group showing significantly lower scores than the mild TBI group. No significant differences in elevations or depressions were seen between the mild TBI and moderate/severe TBI group, or among the Neurodevelopmental, Neuropsychiatric, and moderate/severe TBI groups (see Table 8). The multivariate test indicated that there were no differences in BASC-2 scale means irrespective of diagnostic group (i.e., flatness), Wilks's $\lambda = .987$, $F(3, 78) = 0.347$, $p = .792$, $\eta^2 = .013$, and BASC-2 profiles of scale elevations and depressions did not vary based on diagnostic group, although tended to do so (i.e., parallelism), Wilks's $\lambda = 1.822$, $F(9, 189.98) = 1.822$, $p = .067$, $\eta^2 = .065$.

Given that there was a trend in the profile of scale elevations to vary among diagnostic groups, subsequent analyses were conducted to evaluate differences among diagnostic groups for each of the four executive BASC-2 scales. The multivariate test was significant, Wilks's $\lambda = .646$, $F(12, 201) = 3.01$, $p = .001$, $\eta^2 = .135$. Univariate tests were also significant, with the exception of Attentional Control, $ps < .013$ after Bonferroni corrections were applied. Effect sizes ranged from $\eta^2 = .13$ for Problem solving, $\eta^2 = .15$ for Behavioral Control, $\eta^2 = .26$ for Emotional Control. Post-hoc pairwise comparisons indicated significant differences among some of the diagnostic groups across three of the BASC-2 scales.

Specifically, adolescents with neurodevelopmental disorders demonstrated significantly lower scores on the Problem Solving and Behavioral Control scales than adolescents with mTBI, and adolescents with neuropsychiatric disorders demonstrated significantly lower scores than adolescents with mTBI on the Behavioral Control and Emotional Control scales. There were no significant differences between adolescents with mTBI and adolescents with moderate/severe TBI across all scales. Similarly, adolescents with moderate/severe TBI and adolescents with neuropsychiatric and neurodevelopmental disorders were indistinguishable across scales.

Post-hoc Analyses

Three qualitative analyses were conducted to evaluate differences in profile among the sample, in order to (1) identify their level of executive dysfunction and (2) the accuracy rate of the BASC-2-EF screener in detecting dysfunction.

First, participants were identified who had at least three of four cognitive tests administered that were used to examine convergent validity with the BASC-2 executive function screener (i.e., Wisconsin Card Sorting Task, Tower of London, DKEFS Trail Making Test, and DKEFS Color-Word Inhibition). Twenty six participants (24.30%) were identified; 24 of them were administered three performance-based executive function tests and two participants were administered four performance-based executive function tests during their neuropsychological assessment process at Queen Alexandra Centre for Children's Health. Next, level of deficit on each performance-based executive function was determined by indicating whether performance was below one standard deviation from the mean. Specifically, tests from the DKEFS (i.e., Trail Making Test and Color-Word Inhibition) were identified as being impaired if participants obtained a scaled score of 6 or below (9th percentile, lowest end of low average range). For the TOL and WCST tests, participants were identified as being impaired if they had a standard score of 80 or below (9th percentile, lowest end of low average range). Then, these participants were identified as having or not having deficits on the target BRIEF scales (i.e., Inhibit, Emotional Control, Working Memory, Plan/Organize). Following the traditional clinical criterion for this instrument, participants were identified as having deficits if their *T*-score was 65 or above. Then, these participants were identified as having deficits on the BASC-2 executive function screener if they had *T* scores of 65 or higher on each of the four executive function scales, similar to classification in the BRIEF. To obtain BASC-2 *T*-scores that were comparable to those from the

BRIEF, all positively worded items were reverse scored and then all items for each scale were summed to create total sub-scale scores as detailed in the Methods section. All total raw scale scores were then compared against the normative database to obtain *T*-scores.

All together, this analysis indicated that only one of 26 participants had deficits on three performance-based executive function tests. This participant also had deficits on all eight scales of the BRIEF, and therefore all target BRIEF scales, and also presented with deficits in all four BASC screener components (see Table 9). Table 9 demonstrates the pattern of performance observed in this sample of 26 participants and indicates which participants were identified as having executive function impairments (based on the criterion described above) on performance-based and/or rating scale measures of executive functions. This table was used because it was not possible to run correlational analyses due to low power.

However, post-hoc correlation analyses were conducted to determine whether there were significant intercorrelations among the executive function performance based measures. There were no significant correlations among any of the four dependent variables (i.e., raw scores) for each performance-based test. When standard scores for each of the four performance-based measures were correlated, the Color-Word Interference Test was significantly correlated with the Trail Making Test, $r = .41, p = .01$.

Five of 26 participants had deficits on two performance-based executive function tasks. Of these participants, two participants were not administered the BRIEF but had 1 and 4 clinically significant BASC scales respectively. Of the three with all measurements, two participants had deficits on four target BRIEF scales, with 1 participant having deficits on all four BASC scales and one having deficits on only 2 BASC scales. Another participant had deficits on two BRIEF target scales and 1 BASC scale.

Another participant had no cognitive deficits identified (via performance-based executive function tasks), the BRIEF was not administered, and had deficits across all four BASC scales. Finally, another participant with no cognitive deficits demonstrated deficits on all of the BRIEF scales and 3 of four BASC scales. Taken together, these results indicate some qualitative correspondence between the BASC and BRIEF. However, there was not enough power in this subsample to determine whether significant impairment on performance-based measures of executive function are also reliably being picked up by the BASC-2 executive function screener and the BRIEF.

For the second analysis, the proportion of sample identified as having executive problems based on the BASC-2 executive function screener was examined across the entire sample using a criterion of impairment based on a *T*-score of 64 or higher. The criterion was changed in this instance to reflect level of impairment based on normative data, as $T = 64$ reflects performance in the borderline impaired range, rather than the traditional clinical criterion for the BRIEF. For this purpose, BASC-2 Executive Function screener norms for adolescents recently derived within our lab (Wong, Mrazik, Sakaluk, & Garcia-Barrera, in preparation) were employed in the analysis. To derive these norms, all items were coded to make them negatively oriented, in that higher scores reflected more impairment. Therefore, to use the normative data, an adjustment was made with the current data and all BASC scale scores were adjusted so that higher scores reflected greater impairment in functioning across all four scales. On the Problem Solving scale, 26.17% of participants demonstrated impairment. On the Attentional Control scale, 35.51% of participants demonstrated impairment. On the Behavioral Control scale, 28.97% demonstrated impairment, and on the Emotional Control scale, 36.45% demonstrated impairment. This suggests that the BASC-2 executive function screener was more sensitive in detecting executive

dysfunction with respect to behaviour, given that executive impairments would be expected in a clinical, neurological sample.

Finally, for the third analysis, the proportion of deficit was compared across the BRIEF and BASC across the entire sample. Twenty-nine participants were identified as having at least one clinically significant target scale on the BRIEF. Of those participants, 24 were picked up by the BASC-2 executive functions screener as also having at least one area of difficulty. All 24 participants' BASC-2 areas of difficulty corresponded to the areas of clinical significant identified by the BRIEF. For example, if the BASC-2 only identified an area of difficulty in Attentional Control, Working Memory was identified as an area of significant on the BRIEF. Overall, these results suggest that overall the BASC-2 executive function screener is comparable to the BRIEF at identifying executive dysfunction.

Discussion

Summary

The main objective of this study was to develop and replicate the original BASC executive function screener using a newer version of the BASC (i.e., the BASC-2) in a clinical sample of adolescents with neurological disorders. Using CFA and consistent with the original derivation (i.e., Garcia-Barrera et al., 2011) and subsequent studies (e.g., Duggan et al., 2016; Garcia-Barrera et al., 2013; 2015), the four-factor executive functioning model, consisting of Problem Solving, Attentional Control, Behavioral Control, and Emotional Control was developed and replicated and presented with the most optimal model fit relative to three alternative models.

The second objective of the current study was to examine the convergent validity of the executive functions screener relative to other commonly used measures of executive function. To this end, the BASC-2 executive functions screener was compared to the BRIEF, which is the most commonly used self-report measure of executive functions (Rabin et al., 2016), and a number of performance-based measures of executive functioning.

In examining the convergent validity of the BASC-2 executive functioning screener with the BRIEF, the four executive functioning scales were compared to four target scales from the BRIEF and then to the remaining seven BRIEF scales. Overall, the strongest associations were observed between each scale and its corresponding target BRIEF scale, with the exception of Problem Solving. In addition, modest correlations were observed between each executive functioning scale from the screener and their non-target BRIEF scales. Although this was inconsistent with this study's hypotheses, it is not unanticipated. Given that there is some common unidimensionality (i.e., overall executive behaviour) among both the four-factor

screening and the BRIEF, it is expected that the scales would be correlated with other executive functioning screener measures.

Next, the four latent constructs of the executive functions BASC-2 screener were correlated with specific performance-based measures of executive functioning. In addition, a qualitative post-hoc analysis was conducted to evaluate the accuracy rate of the BASC-2-EF screener in detecting dysfunction as compared to performance-based measures. Consistent with other studies (e.g., Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Ready et al., 2001; Toplak, Bucciarelli, Jain, & Tannock, 2009; Vriezen & Pigott, 2002) in which poor relationships among behavioural questionnaires and performance-based cognitive tasks were observed, there were no significant relationships observed among the four latent executive functioning factors and the performance-based measures of executive functioning used in this task. Toplak et al. (2013) suggest that one explanation for a lack of correlations between behavioural questionnaires and performance-based tasks measure separate constructs. After examining almost 300 correlations between performance-based and rating scales of executive functioning, they found that only 24% of the correlations were statistically significant and that the median correlation was only $r = .19$ across studies. They explain that there are several reasons for a lack of correlation and their position that the two categories of measures are separable constructs, including psychometric, theoretical, and practical differentiations between the two types of measures. Psychometrically, Toplak and colleagues suggest that distinctions that contribute to performance-based measures and rating scales differences include typical (i.e., what someone will normally do with no imposed constraints) versus optimum (i.e., what someone will do when many constraints are placed on performance and that individual is told to maximize it) performance situations. More specifically, they stipulate that performance-based executive

functioning measures are more related to efficiency in cognitive functioning and about how people process information, in that people are measured on their ability to complete performance-based tasks quickly and accurately, whereas behavioural rating scales are considered “reflective” and are related to an individual’s behaviour in a real-world, everyday situation, which elicits goal-directed behaviours. Lastly, they discussed that performance-based measures and ratings scales cannot measure the same constructs as the environment in which they are measured differs: for performance-based measures, stimuli are presented in highly structured environments with strong controls over how information is presented to an individual, the specific prompts and feedback that individual receives, along with specific limits to performance potential. Toplak and colleagues (2013) explained that these situations do not provide the flexibility or strategizing required in real-life or account for the individual differences which affect responding in everyday situations, whereas the opposite is true for behaviour rating scales. Further, inconsistencies between performance-based tasks and rating scales might be due to differences in the “ecological focus” in that performance-based tasks are measured under controlled conditions and rating scales utilize everyday deployment of cognitive and social-cognition skills required in everyday situations (Dennis et al., 2001). Notably, there are also issues with behaviour-rating scales as they are affected by the context in which an individual is rated, personal biases, and the ways in which different individuals perceive behaviours.

Next, the divergent validity of the screener was evaluated by examining the relationship between the four latent factors of executive functioning and a largely unrelated measure, namely gross motor function (i.e., bilateral grip strength). There was no significant association found between any measure of executive functions from the screener and grip strength. Although this

finding is similar to that of the cognitive measures, it provides further support to our hypothesis that the selected items from the BASC-2 executive functions screener measure executive functions and not other measures of cognitive or neurological functioning.

The final objective of this study was to conduct a profile analysis of the four BASC-2 factors to determine level, flatness, and parallelism. Overall, there were a number of significant findings. 1) The neurodevelopmental and neuropsychiatric diagnostic groups presented with significantly lower scores across BASC-2 factors compared to the mTBI group, but not other group differences were observed and 2) there tended to be differences among groups at the individual executive function factor level. When examined post-hoc, there were significant differences between the mTBI group and neurodevelopmental and neuropsychiatric groups across the Problem Solving, Behavioral Control, and Emotional Control scales. No significant findings were found for flatness, which is a measure of degrees of difference among groups across BASC-2 scales.

Executive Functions Screener Derivation

As previously mentioned, a four-factor model, consisting of Problem Solving, Attentional Control, Behavioral Control, and Emotional Control provided the most optimal data fit, replicating the original findings of Garcia-Barrera et al. (2011) and subsequent studies examining the screener. It is thought that this is the first study supporting the use of this screener in a parent-rated, English speaking, adolescent neurological sample. To this end, an executive functions screener using the BASC-2-PRS 12-21 (Reynolds & Kamphaus, 2004) was derived, which was based on the previously derived BASC-TRS executive functions screener for children (Garcia-Barrera et al., 2011). The screener was developed to capture behaviours specifically associated with the four-factor model of executive functioning. As such, the aim of this executive functions

screener was to depict behaviours encompassing planning and goal initiation (Problem Solving), sustaining and focusing attention (Attentional Control), inhibiting inappropriate behaviours/behavioural self-regulation (Behavioral Control), and emotional self-regulation (Emotional Control). In the final version of the executive functions screener, a total of 25 items from the BASC-2-PRS 12-21 were chosen as indicators for the four components, which served as latent constructs of executive functions. As mentioned, although the three alternative unidimensional and multidimensional models were overall acceptable fits for the data, progressively better fit as the number of factors increased was observed, and the four-factor model fit the data most optimally, supporting the use of the four factor BASC-2-PRS executive function screener in this sample. This is consistent with results of other studies examining the development of executive functions, which demonstrate the increasingly multidimensional nature of executive functioning (i.e., working memory, inhibition, and shifting) across adolescent development (Huizinga et al., 2006). Commonly evaluated components of executive functions, have also been shown to reach adult level at different stages during childhood and adolescence (Welsh & Pennington, 1988). For example, Huizinga and colleagues (2006) found that adult levels of shifting were not reached until age 15 and that adult performance was reached by age 15 on two inhibition tasks but not until age 21 on another inhibition task (i.e., the Stroop task) and working memory tasks. They also found that on more complex tasks (i.e., Wisconsin Card Sort Task and Tower of London), adult levels on some measures were not reached until at least age 15 and sometimes continued to develop into adolescence, with only moderate correlations between working memory and shifting. Notably, Reynolds and MacNeill Horton (2008) found that executive functions reach their peak at different ages, including adulthood, depending on the specific task used to assess executive functions. These studies provide further support to the idea

that there are different and distinct developmental trends for the various components of executive functions.

However, it is also relevant to discuss that in the optimal four factor model, strong inter-factor correlations and relatively strong inter-item correlations were observed. These results suggested that there is an underlying general executive function factor along with separable specific unitary factors comprising the four factor model of executive functioning. This further support the notion that executive functions are dissociable yet connected (Miyake et al., 2000). This idea is reflective of the pattern of prefrontal brain development across childhood (Tsujiimoto, 2008) and of the increasing specificity of the functional connectivity of the prefrontal networks (Casey, Tottenham, Liston, & Durston, 2005; Liston et al., 2006). In addition, specific areas of the brain have been found to be associated with multiple executive functions (i.e., right intraparietal sulcus, the left superior parietal gyrus, the left lateral prefrontal cortex) and with specific executive functions in adults. Specifically, Collette et al. (2005) found that cerebral activity in the left frontopolar cortex, the left and right middle frontal gyrus, left inferior frontal, specific parietal regions, regions of the cerebellum, and the right lateral orbital regions were associated with working memory; and the right supramarginal gyrus, left precuneus, and left superior parietal cortex were associated with shifting.

Given the increasing specificity of functional connectivity in prefrontal networks during development, the strong interfactor correlations may reflect unidimensionality and the delayed neural development often seen in neurological populations. Researchers (e.g., Shaw et al., 2007; Church et al., 2009) have found that development of the prefrontal cortex and its connections (i.e., circuitry and other brain regions) is affected in children with neurological disorders who typically display executive functioning deficits, including those with ADHD, autism,

schizophrenia, epilepsy, and Tourette Syndrome (Amaral, Schumann, & Nordahl, 2008, Kates et al., 2002; Peterson et al., 2001; Shaw et al., 2007; Thompson et al., 2001). Moreover, atypical neural development in these neurological conditions may partially underlie deficits in executive functioning as there is thought to be a relationship between specific areas of the brain and their connections and specific executive functions (Collette et al., 2005). Further, individuals with acquired brain injuries also show disruption in development (Levin & Hanten, 2005).

As such, one outstanding question that remains unanswered is why the correlations among the four factors remain strong. And additionally, what is the mechanism under which differentiation into this four-factor model of executive functioning occurs? Although not measured directly in this study, findings from the developmental neuroscience literature may provide a possible explanation. Executive functions are thought to be likely subserved by prefrontal structures along with their subcortical and cortical connections (Collette et al., 2005; Collette, Hogge, Salmon, & Van der Linden, 2006; Best & Miller, 2010). Studies of brain development have found that structural development of the brain continues through adolescence, with prefrontal and intra-parietal areas developing last (Gogtay et al., 2004). Supporting the idea that development of brain structures, including pruning, myelination and synaptogenesis, may underlie executive function development is that prefrontal, parietal and subcortical structures involved in executive functions, have a protracted course of development through childhood and adolescence as do executive functions. Gogtay and colleagues suggest that that disruptions in brain development, including alterations in the nature and timing of basic maturational processes may underlie developmental disorders such as autism spectrum disorders and childhood-onset schizophrenia. Levin and Hanten (2005) posit that injury to the brain in the case of traumatic brain injury may have deleterious effects on the continued development of brain regions

important for executive functions. As such, strong inter-factor correlations may reflect delayed or altered development of circuitry efficiency involved in executive functions.

Generally, studies examining executive function structure using performance-based tests have found that the structure varies, with differentiation from a two-factor structure in early childhood to a three-factor structure in adolescence (Lee et al., 2013). Lee and colleagues suggest that throughout development executive functions become more highly specialized and independent. While the four-factor structure in this study fits the data well, the high inter-factor correlations suggest that there could be a high degree of connectedness among the factors and indicators, which is perhaps due to disruptions in development and a related lack of specialization in this neurologically-affected sample. Further, the correlations between the four components recently derived from a sample of typically developing adolescents in our lab (Wong et al., in preparation) were observed to be lower than in the clinical sample, further supporting the idea that there is a high degree of connectedness, and therefore unidimensionality, in this clinical sample

Levin and Hanten (2005) state that following pediatric TBI, injuries involving disruptions of the frontal regions and its connections may play a key role in executive dysfunction. Deficits in processing speed and attention are often also observed (Babikian et al., 2011; Levin et al., 2004; Wozniak et al., 2007). Furthermore, in mild and more severe cases of TBI, diffuse axonal injury and secondary brain insults including excitotoxicity, inflammation, and apoptosis due to metabolic cascade can also continue to impact the brain and its development following an initial TBI (Danov, 2014). Therefore, in this study's sample which largely comprises adolescents with mTBI, it is possible that the high degree of connectedness among the factors may be related to disruption or delays in the development of more widely distributed, and more efficient networks

in the brain. It is important to note that initial disruption in distributed networks may be due to focal damage in complicated mTBI or due to initial tearing, shearing, or stretching of axons.

Furthermore, Dennis et al. (2001) suggest that outcome after traumatic brain injuries, specifically closed head injuries, depends on a number of factors including injury severity, specific damage to the frontal lobes, age at head injury, time since recovery, and social factors, which include the post-injury family environment. Yeates et al. (1997) noted further that pre-injury environment also has an effect on post-injury outcome in TBI, with the pre-injury environment having a buffering effect in high functioning family and pre-injury environment having a detrimental effect in low functioning families. In a systematic review of meta-analyses, Karr, Areshenkoff, and Garcia-Barrera (2014) found that individuals with past neurological events, injury, or psychiatric problems were more likely to have persistent post-acute mTBI symptoms. They also demonstrated that with respect to cognitive outcomes, deficits in executive function were amongst the most vulnerable to multiple mTBIs. Taken together, other factors, which were not examined in this study may also affect this neurological sample and contribute to the interconnectedness observed among factors.

In addition, that the four-factor behaviour screener reflects the most optimal fit in the current study also suggests that in adolescents with neurological disorders, the components of executive functions are the same as in typically developing children, kindergarteners, and in university-aged individuals, as observed in previous BASC executive function derivations studies. However, although the componential structure of executive functions is similar, it is likely that if these executive functions were compared to a typically-developing control group, executive functions would be worse in the clinical sample. While not directly compared to a control group using parametric tests, a qualitative analysis was conducted post-hoc, indicating

that 26 – 36% of the sample were identified as having executive function impairments across the four scales when compared to the normative sample, suggestive of greater identification of executive impairment than would be expected in a healthy population. In general, individuals with neurologically-based disorders perform more poorly on performance-based tasks (e.g., Ozonoff & Jensen, 1999; Wozniak et al., 2007) and generally have worse scores on behavioural measures of executive functions (e.g., Gioia et al., 2002). This is likely due to the fact that brain development and also the organization of individuals with neurological issues (acquired or developmental) is different (e.g., Shaw et al., 2007). Danov (2014) and Levin and Hanten (2005) have also reported that metabolic changes occur following even mild TBI, which can have long-lasting effects on brain development, affecting social, emotional, and cognitive functioning long after recovery is traditionally expected. Notably, while metabolic changes such as decreases in *N*-acetyl aspartate (NAA) and choline levels (markers of cell functioning) have in the past been found in more severe cases of TBI, NAA concentration changes have also been observed in more mild cases of TBI, relating to axonal swelling, stretching, and myelin damage. In a sample of children and adolescents with mild and moderate TBI, Wozniak et al. (2007) found that processing speed, sustained attention, executive functions, and emotion regulation were impaired 6-12 months after injury, although general intelligence was comparable to age-matched controls. They also found decreased integrity in the inferior and superior frontal regions, and supracallosal regions, which was associated with reduced processing speed, executive functions, and parent ratings of behaviour. These results suggest that unlike core skills which are generally resilient to the effects of TBI, regulatory skills (e.g., behavioural and emotional control) and efficiency of cognitive processes are affected long term, perhaps due to effects on white matter development in brain-injured adolescents. It is possible that when white matter is affected in brain injury,

either by delayed and/or disruption myelination, or other metabolic processes, neural efficiency is reduced and that higher-level cognitive skills which may require scaffolding of the underlying structure are thereby affected in this population, and which is why executive functions in this clinical group as a whole would be expected to be worse than in a typically-developing population.

The fit indexes reported in this study are strong and support a four factor model of the screener. These data were collected in a heterogeneous sample of adolescents with clinically-significant difficulties who had a neuropsychological assessment at a children's healthcare centre in Victoria, BC, Canada, often because they had difficulties functioning in their everyday life. Additional studies using community samples in which children are not receiving a neuropsychological assessment for a specific (likely impairing) issue may be warranted to generalize the results of this behaviour screener further. Although relatively comparable to the factor correlations observed in the original derivation study, these results were obtained from a much more geographically homogeneous sample.

Another important consideration is that the four-factor structure of this dissertation reflects parent ratings of executive functions rather than teacher ratings, as in most of the prior studies examining the BASC executive functioning screener. While the literature supports use of teacher ratings over parent ratings for a number of reasons, it is relatively unlikely that the results of this screener would have been significantly altered, although it is possible. Sullivan and Riccio (2007) found that there was significant agreement among parent and teacher ratings, as measured by modest correlations between the two types of ratings in a mixed clinical sample of the BRIEF and Conners' Rating Scale Revised – Short Form (Conners, 1997). These findings specifically suggest that ratings were overall not setting dependent and were rather reflective of children's

observed behaviours as a whole. Similarly, De Los Reyes and Kazdin (2005) discuss that two meta-analyses (Achenbach, McConaughy, & Howell, 1987; Duhig, Renk, Epstein, & Phares, 2000) have found there is a higher level of agreement between informants' ratings of externalizing compared to internalizing disorders. However, many other studies (e.g., the study by De Los Reyes & Kazdin, 2005) have found discrepancies, or lack of agreement, between different informants' ratings of everyday behaviours, including social, emotional, and behavioural problems. Although possible that ratings for this study would have been setting dependent, it is anticipated that this would not result in changes in optimal factor structure, but rather in changes in level of the executive dysfunction. In the future, to evaluate the stability of the four-factor model, invariance testing could be conducted to determine if there are setting- or rater-dependent differences in executive function ratings. It does however, remain possible, and in fact likely, that children's behaviour will vary across setting and may be more disruptive in one setting (e.g., home) relative to another (e.g., school) or vice versa. Similarly, it would be helpful to analyze whether there are any differences in executive function structure when comparing parent- to teacher- and self-report.

Screener application: Convergent validity and profile analysis

As previously mentioned, there were significant associations between the BASC-2 executive function screener and the target BRIEF scales, in addition to significant relationships between the BASC and BRIEF in general. As discussed above, no significant relationships were found between the BASC-2 executive functions screener and performance-based measures of executive functioning.

The next goal of this study was characterizing the nature of executive functions by examining a select subset of this study's sample. Adolescents with mTBI demonstrated

significantly higher overall mean score than adolescents with neurodevelopmental and neuropsychiatric disorders. There was no significant difference between the mTBI and moderate to severe TBI groups. That there were some differences observed among this study's group is consistent with literature explaining that executive dysfunction is associated with a wide range of neurological disorders. One potential explanation as to why significantly lower overall executive function profiles were observed for these two groups relative to the mild TBI group may be related to the earlier discussion of neural development. Specifically, adolescents with neurodevelopmental and neuropsychiatric disorders are a distinct group from individuals with acquired brain disorders (subsuming the moderate/severe and mild TBI diagnostic groups). Furthermore, the trajectory of brain development is generally different for those with developmental versus acquired brain injury; in that in general adolescents with developmental disorders have a longstanding history of abnormal brain development whereas adolescents who sustained a TBI were likely to have experienced typical brain development prior to their injury. Therefore, brain functioning of those with developmental disorders versus acquired brain injuries are likely to be differentially affected simply due to the nature of their histories. As well, differences between the acquired versus neuropsychiatric/developmental groups may also be related to the idea that the ability to successfully complete different executive abilities requires developmental progression. Longstanding, pre-existing difficulties likely contribute to the reduced overall executive functioning score in the non-TBI groups at time of assessment (Reynolds & MacNeill Horton, 2008)

Further, it is likely that parent-rated differences between adolescents with neuropsychiatric or neurodevelopmental is reflective of prolonged periods of difficulty relating to having a developmental disorder. As previously mentioned, rating scales can often be

considered measures of distress. Furthermore, as the sample size between the two groups differed significantly, it is possible that these differences simply reflective of sample size differences.

In addition, it is likely that a more significant pattern of differences may have been observed across the profile analysis (i.e., level, flatness, and parallelism) with a larger and mixed clinical/typically developing group. As differences in executive functioning are typically observed between typically and clinically affected individuals, it is likely that having a mixed sample would have provided more characterization to the nature of executive functions in this group of adolescents with neurological disorders.

That being said, the assessment of executive functioning is imperative in those with neurological disorders, and it is important to understand what may (or may not) contribute to difficulties in one group versus another. For example, in this current study there were no significant differences observed between the mTBI and moderate to severe TBI groups. In addition to reasons previously mentioned (metabolic changes, disruption of brain development), other secondary emotional disturbances and the individual's environment may play contributory roles. In addition, even in those with mTBI, myelin degeneration is thought to occur for a number of years post injury and other structural changes have been observed over that same time period as well (Bigler, 2014). Therefore, while individuals who experience a mild TBI versus mild complicated TBI by definition will not have neuroimaging findings, meaning no focal neurological damage, their brain may be undergoing imperceptible metabolic changes which contribute to abnormal brain development and as a result, disruptions in attention, processing speed, and executive functioning will likely be observed. As such, adolescents with mTBI may have similar long-term effects as in those with moderate and severe TBI.

While discussing longer-term effects of mTBI on neuropsychological status, it is important to note that a common view with respect to mTBI is that many the injuries children and adolescents with mTBI may experience will resolve within 7-10 days (Semrud-Clikeman & Klipfel, 2015), with the exception of a subgroup of those who have recently been identified as experiencing cognitive effects beyond the expected recovery period (O'Neill et al., 2015). However, a review of the literature indicates that there are many factors which contribute to recovery following mTBI. In addition, Danov (2014) discusses that mTBI affects children and adolescents in all areas of functioning, because in addition to having difficulty using cognitive skills appropriately, they also have difficulty with social and emotional regulation which compromises social, academic, and family functioning. Therefore, while difficulties or deficits may appear mild, they can elicit ongoing and long-term difficulties in an individual's life. Further, because the brain undergoes a variety of changes as previously mentioned, particularly in the timeframe examined in this study (e.g., participants were evaluated 1-12 months post injury), injury to the brain at any point in time can elicit unique outcomes depending on its current state of development. As such, different outcomes (e.g., acute versus chronic effects) could be expected in this study's sample depending on when they sustained their TBI (i.e., younger adolescence versus mid-to-late adolescence) and what classification of TBI they sustained.

With respect to age, Williams, Puetz, Giza, and Broglio (2015) found that high-school aged athletes took longer to recover from TBI than college-aged athletes, suggestive of younger, less myelinated brains being more susceptible to insult than more developed brains. This is supported by the recent systematic review of meta-analyses by Karr et al. (2014) which demonstrated that as a group, adolescents compared to adults, are the most vulnerable to the

effects of mTBI. With respect to classification of TBI, there have been some reported differences between complicated and uncomplicated mTBI. For example, Power, Catroppa, Coleman, Ditchfield, and Anderson (2007) reported that sustaining frontal and extrafrontal lesions predicted attention difficulties after five years but severity of the specific lesions did not. On the other hand, researchers have also noted that some neural processes such as plasticity and functional reorganization are helpful in focal brain injury but not in more diffuse axonal injuries. Danov (2014) suggested that when there are no observable regions of focal damage, which is typically the case with mTBI, white matter damage could delay the advancement of existing abilities and also impede the ability to acquire and/or scaffold new higher-level cognitive abilities. Individuals with other conditions generally have more severe symptoms which are experienced for a longer time. Particularly important in this discussion is that many of the mTBI diagnostic group members sustained a concussion shortly prior to the assessment (minimum number of months prior = 1; maximum number of months prior = 12), and it is possible that the potential acute and chronic effects may contribute to lack of profile differences among the study's sample as a whole. Furthermore, Collins et al., (2003) noted that other factors which may influence recovery and number of symptoms is number of mTBIs experienced. They found that individuals who have experienced multiple mTBIs have more severe symptoms after each consecutive mTBI. Although a small subset of this study's sample also sustained prior mTBI, their course of injury was likely vastly different than the neurodevelopmental and neuropsychiatric groups. Therefore, it would be expected that the functional performance, measured in terms of everyday ecological validity of children with a lifetime of affected neurological development as well as the perceived behavioural, social, parental, child, stigma surrounding these factors, would have overall lower executive functioning than children who

have sustained an mTBI. Specifically, it is worth discussing that there is likely no specific mechanism or index which predicts outcome after brain injury, but that outcome is likely the result of the interaction of many factors relating to pre-injury and stage of development, injury, and psychosocial (e.g., family dynamics and environment, stressful events) and emotional factors (e.g., depression and other mental health conditions (Dennis et al., 2001; Levin & Hanten, 2005)).

Ecological Assessment of Executive Functions. Oftentimes, as mentioned earlier in this dissertation, performance-based measures of executive functioning on assessment often do not reflect real world executive functioning difficulties, for a number of reasons including the fact that they take place in a structured, time-limited setting, individuals are often given attention and feedback beyond what they would experience in the real world, and individuals are generally asked to complete only one task at a time. As well, performance-based tests are very good at picking up significant executive function deficits because that is how they were originally designed. However, they have much more difficulty picking up subtle deficits in perhaps only one or two aspects of executive functioning and are often considered not broad enough to provide us with answers about underlying executive functioning mechanisms (Snyder, Miyake, & Hankin, 2015).

In addition, during neuropsychological testing, most performance-based tasks examine individual components of executive functions (e.g., aspects of planning, organization, flexibility, etc.) rather than an integrated system requiring rationalization, priority-based decision making, and other demands (Gioia & Isquith, 2004). Related to this is the concept of “hot” (i.e., processes involved in motivationally and emotionally significant situations) and “cold” (i.e., processes that are involved in more emotionally neutral situations) executive functions. As previously mentioned, these are traditionally measured separately, and in daily life, both hot and cold

executive functions are relevant. However, in traditional neuropsychological evaluations, hot executive functions are not as frequently examined as cold executive functions. Further, Goldberg and Podell (2000) discern that executive functions in daily life require adaptive decision making. They explain that choices which individuals make in their daily lives are relative, and one choice is not necessarily better than the other; the choices simply takes into account different external and internal inputs from a person's milieu. In contrast, they consider traditional, performance-based executive functions tasks to be veridical, in that they either have a correct or incorrect answer, and do not take relative decision making into account. Goldberg and Podell (2000) suggest that the veridical decision making which comprise neuropsychological tests may be better suited as markers of posterior association cortex rather than prefrontal cortex. They explain that this is because the posterior association cortex is responsible for forming veridical non-organism representations of the world whereas the prefrontal cortex is responsible for organism-centred representations. Further, the veridical information is then used in prefrontal cortex mediated representations according to a particular context. All together, it may be that the nature of neuropsychological testing may mask executive functioning deficits (Slomine et al., 2002).

As the BASC-2-PRS executive function screener measures everyday executive behaviours associated with problem solving (e.g., organizing self, setting realistic goals, making decisions easily), attentional control (e.g., focusing, sustaining, and shifting attention), behavioral control (e.g., inhibiting inappropriate, negative, and maladaptive behaviours), and emotional control (e.g., controlling emotional expression at various times), it creates an opportunity to address the problem of the lack of ecological validity in traditional, performance-based executive function tasks. Further, it provides a method to integrate various approaches in

the assessment of executive functions by examining multiple components of executive functions through ratings in real-world settings.

Therefore, as a complement to performance-based tasks, the BASC-2-PRS executive function screener is an advantageous accompaniment to performance-based tasks. Having parent rating scales enables us to assess how adolescents are completing tasks in their everyday life, and whether they are successful. As the BASC-2 is a fulsome screener designed to examine several aspects of everyday functioning, items evaluated in this executive function screener assess a wide variety of situations and events. That the BASC-2 executive functions screener items map onto everyday functioning provides clinicians with a more ecologically valid, and perhaps reliable way to examine executive functioning.

While the convergence of the conventional executive function measures and the BASC-2 PRS executive function screener was not observed, strong correlations were observed between the BASC-2 PRS executive function screener and all scales of the BRIEF. This demonstrates that although there is a lack of correspondence between traditional tasks as mentioned before, and our screener, there is support for the construct validity of these questionnaires for an adolescent neurological population given the convergence between these two questionnaires of executive functioning.

Post-hoc Analyses: Performance-based Measures, Rating Scales, and the Correspondence Between the Two

Post-hoc analyses, like the analysis of convergent validity, indicated that there did not appear to be a correlation between performance-based measures of executive functions and rating scales. In addition, out of a subsample of 26 participants with three or more target executive function test measures, the majority did not show clinical impairment on these

measures. This is not to say that as a whole, the sample did not demonstrate executive dysfunction on performance-based measures, but it is possible that the remainder of the sample could be reflective of these 26 participants. Further, cases of clinical concern were relatively overidentified based on the BASC-2 executive functions screener and were related to functioning on the BRIEF, when administered.

There have been a number of research studies in which this pattern has also been identified – that of greater behavioural concerns, demonstrated by more clinically significant ratings on behaviour screeners, compared to cognitive concerns, demonstrated by clinical impairments on performance-based executive function measures. Brooks et al. (2013) observed that there was no support for worse neurocognitive functioning in adolescents who had multiple concussions but that were more reported subjective symptoms, akin to behavioural concerns, in the somatic, affective, and cognitive domains. Similarly, Raghubar, Mahone, Yeates, and Ris (2017) found that in a pediatric brain tumor population, that scores on performance-based measures of executive functions often do not reach levels of clinical concern, although are higher than the means. Further, they found that parents typically rate their children as having more difficulties on behavioural screeners than demonstrated on performance-based tasks.

As discussed previously, behavioural screeners may be viewed as more ecologically valid measures of executive functioning when compared to performance-based cognitive tests. This idea could explain why this dissertation's sample appeared to be a "healthy" neurological sample when only examining cognitive tests as a benchmark. Gioia et al. (2002) explained that children and adolescents with executive function impairments perform better in highly structured environments – it is possible that this overall "healthy" sample was able to perform optimally due to the structured conditions of the testing. While performance on cognitive tests may have

been at an optimal level, this does not influence behaviours in other settings and logically does not have an effect on parent ratings of their children's behaviours in other settings such as home, school, other activities, etc. Therefore, the highly structured setting in which cognitive ability was assessed may have contributed to the differential performance across the two types of measures in this dissertation.

Further, it is possible that use of the BASC-2 executive function screener identified more cases of executive dysfunction due to false positives. Given that this is an executive function screener, it can also be helpful to identify *more* cases, which then would likely necessitate further clinical assessment (Smith, McCarthy, & Anderson, 2000). In this manner, all individuals who are potentially at-risk for executive dysfunction can be evaluated further. DiStefano and Kamphaus (2007) stated that it can be more advantageous to have a high false positive rate, or overestimation of dysfunction, as individuals would likely experience future ongoing impairment if a possible disorder was not identified.

Gioia et al. (2002) also suggest that executive function ratings may in fact demonstrate stronger relationships with general behaviour, adaptive functioning, family distress and burden, social function, and academic achievement than performance-based measures. Barkley and Murphy (2010) examined performance-based and behaviour ratings of executive functions in adults with ADHD and their relation to occupational functioning. They attested that not observing deficits in cognitive performance did not mean that those with ADHD had no executive function concerns. In fact, Barkley and Murphy found that executive function ratings were more predictive of impairment in occupational functioning than level of performance on cognitive tests. Similarly, (Toplak et al., 2009) examined executive function ability by examining performance-based measures and behavioural ratings using the BRIEF in a clinical sample of

adolescents with executive function deficits (i.e., ADHD and Tourette Syndrome). They found that performance-based measures accounted for little unique variance when examined in conjunction with the BRIEF in predicting ADHD status. Taken together, it is not unexpected that there were few cognitive executive deficits observed in the subsample examined in post-hoc analyses.

Finally, treatment with medications was not considered in this dissertation. It is possible that more performance-based executive function impairments were not identified because of treatment-related medication effects. Bodnar, Prahme, Cutting, Denckla, and Mahone (2007) discussed that medication effects may have played a role in finding inconsistent relationships between performance-based measures of executive functions and the BRIEF in mixed clinical sample of children and adolescents. They explained that stimulant medication can improve performance on cognitive measures of executive functions in structured setting more so than in real-world environments. Therefore, it follows that individuals could demonstrate lower levels of executive function impairment while continuing to have difficulties in their everyday life. In addition, the role of intellectual ability was not examined in relation to performance-based executive function tests. The intellectual functioning of this dissertation's sample was broadly average. Mahone et al. (2002) investigated the validity of the BRIEF in a sample of children and adolescents with ADHD and Tourette Syndrome. They found that intellectual functioning was correlated with performance-based measures of executive functions but not the BRIEF, and it is known that there is a strong relationship between executive functions and intellectual functioning (Duggan & Garcia-Barrera, 2015). Therefore, it is possible that in this dissertation, intellectual functioning did not have an effect on behavioural concerns as measured by the BASC-2

executive functions screener but moderated performance on cognitive measures of executive function.

Conclusions

In this study, an executive functioning screener was derived and measured using a mixed-clinical sample, combining adolescents who had neurodevelopmental and neuropsychiatric disorders as well as acquired brain injuries. Further, convergent validity between rating scales was observed, and finally, significant differences in overall profile were observed among the mTBI group and the neuropsychiatric and neurodevelopmental group. Post-hoc analyses further supported these findings and indicated that qualitatively there was not correspondence between performance-based measures and behaviour screeners of executive function.

In future, to obtain more certainty of the factor structure, it would be beneficial to conduct an invariance analysis to examine whether there are any differences in executive functioning structure between the two groups, given the differences between neural development in those with developmental versus acquired disorders. Also, deriving a screener and conducting invariance testing with parent and self-rated BASC-2 executive functioning screeners would be informative. Relatedly, in this dissertation, many of the assessments of individuals with mTBI were conducted within the first few months following brain injury. As the brain continues to change (either recovery or continued negative changes) in the months immediately following mTBI, it may be helpful to further examine the structure of executive functions in this population following a longer period of recovery. This would provide greater clarity on the nature of acute versus chronic executive function deficits in adolescents with TBI.

To develop a stronger characterization regarding the development of executive functions, it would also be helpful to replicate this study with a larger sample size. Again, this would

provide further clarity and an opportunity to examine differences in factor structure and executive functioning within an overall adolescent group. Examining similarities and/or differences among a younger developmental group (i.e., ages 11-13), middle adolescent group (i.e., ages 14-15), and older adolescent group (i.e., ages 16-21) would also support the characterization that executive functions follow a protracted developmental course.

Notably, it is important to mention that this was a study which used archival data and as such, it was difficult to be stringent with participation criteria. Specifically, participation in many studies is limited based on exclusion criteria and therefore, individuals participating in studies will likely not have more than one diagnosis, comorbid disorders, or other factors which could influence or interact with study results. In this study, comorbidities could have influenced intellectual functioning, and in fact, having an additional ADHD diagnosis, for example, could have affected executive functioning differentially and above and beyond other diagnoses. It would be important to account for comorbidities in future studies. It would also be important to take into account other variables such as socioeconomic status, as socioeconomic status has been called a “fundamental cause of health and illness” (Link & Phelan, 1995). Studies have found that there is a positive correlation between socioeconomic status, or a proxy, such as parental education, and executive functions, and/or its components (Ardila, Rosselli, Matute, & Guajardo, 2005; Sarsour et al., 2011). As such, socioeconomic status may have contributed to this dissertation’s results, although it was not examined and so remains unknown. In addition, the main criterion used for participation in this group was an estimated full scale IQ of 80 or over (i.e., at least low average overall intellectual abilities). This was important as there is a close relationship between executive functions and intellectual functioning (Duggan & Garcia-Barrera, 2015), and having individuals with low intellectual functioning could have significantly affected

executive functioning, as discussed earlier. While the interaction of intellectual function on executive abilities may have been limited, the other factors mentioned above may have affected this study's outcomes.

Further, the results of this study were based on a fairly homogeneous demographic sample, the majority of whom were from a very specific geographical area and English speakers. Therefore, it would be helpful to extend these results by conducting a broader analysis of executive functions in adolescents with neurological disorders similar to the original derivation study, or at least representative of a more diverse population.

Finally, convergent validity was examined by evaluating specific performance based executive function tests against specific executive function factors with the exception of the Emotional Control factor. It is challenging to examine emotional control in the context of performance based tests typically administered during neuropsychological assessments as these tests are most often associated with dorsolateral frontal regions and not the emotional or affective characteristics mostly connected with the orbitofrontal cortex and associated medial regions (Happaney, Zelazo, & Stuss, 2004). To assess emotional factors, in particular affective "real life" decision making, the Iowa Gambling Task (Bechara, Damasio, Damasio, & Anderson, 1994) was developed and although not the only measure of affective decision making, it is one of the most commonly used measures. To evaluate orbitofrontal function in another manner, sense of smell (i.e., Cranial Nerve I function) can be used as a marker of damage to that region, as sense of smell is often affected by damage to the ventromedial region, due to the direct connections between the primary olfactory cortex, pyriform cortex, and then orbital frontal cortex (Rolls, 2004). As such, olfactory ability, or conversely, deficiency may be used as an indicator of emotion regulation and orbitofrontal/ventromedial dysfunction (Malloy, Bihrlé, Duffy, &

Cimino, 1993). However, for this study, collected data did not include cognitive tasks used to evaluate affective decision making, such as the Iowa Gambling Test, or a test of olfaction, and therefore the Emotional Control factor was not examined in relation to a specific cognitive task. In future, to fully examine the association between the factors, it would be beneficial to evaluate the convergent validity of the Emotional Control factor by comparing it with performance on a smell test and/or affective decision making task.

In summary, tests of executive function have been thought to “artificially and ambiguously fractionate an integrated system” (Burgess, 1997). However, it is increasingly evident that using rating scales provides a snapshot of individuals’ everyday behaviours and likely provides a more accurate measure of one’s executive functioning in day to day life. Furthermore, this study provides further support to, and complements, the existing literature on a four factor model of executive functions consisting of Problem Solving, Attentional Control, Behavioral Control, and Emotional Control. Given that the same four-factor structure was found as in previous studies, this study suggests that the structure of executive functions is similar in typically and atypically developing individuals, although the degree of executive functioning abilities likely varies. In addition, convergent validity was demonstrated between this executive function screener and the BRIEF. Taken together, these findings contribute to the body of literature supporting the BASC-2 executive functions screener as a complement to traditional, performance-based tasks. In this regard, it would also be important to complement any performance-based measure and executive function screener with a detailed clinical interview, observations, and adaptive functioning measures. Overall, this study highlights the importance of multi-level and multidimensional assessment in order to maximize our ability to capture one’s executive functioning abilities.

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Table 1
Demographics

	<u>BASC-2</u>	<u>BRIEF</u>
Sample Size	107	36
Age ($M \pm SD$ in years)	15.20 ± 1.85	14.91 ± 1.87
	<u>Representation by developmental age (%)</u>	
12	13.08	20.00
13	16.82	11.43
14	17.76	22.86
15	15.89	14.29
16	15.89	11.43
17	12.15	14.29
18	7.48	5.71
	<u>Representation by sex (%)</u>	
Female	46.70	36.10
Male	53.30	63.89

Table 2.

Descriptive statistics of the four factor screener.

<u>BASC-2 Factor and Item Number</u>	<u>Mean</u>	<u>SD</u>	<u>Skewness</u>	<u>Kurtosis</u>	<u>Cronbach's alpha</u>
Problem Solving					.833
i37	2.25	0.934	0.274	-0.784	
i56	2.36	0.894	0.337	-0.576	
i77	2.35	0.837	0.059	-0.576	
i93	1.94	0.827	0.735	0.206	
i111	2.29	0.765	0.225	-0.204	
i127	2.56	0.759	0.123	-0.356	
Attentional Control					.873
i5	2.47	0.694	0.473	-0.091	
i35	2.34	1.046	0.143	-1.173	
i65	2.50	0.720	0.311	-0.220	
i76	2.61	0.749	0.378	-0.540	
i106	2.30	0.767	0.705	0.310	
i136	2.24	0.970	0.188	-0.998	
Behavioral Control					.880
i20	2.35	0.862	0.435	-0.385	
i33	2.13	0.848	0.219	-0.711	
i45	2.03	0.902	0.679	-0.182	
i70	1.33	0.563	1.53	1.41	
i73	2.02	0.921	0.848	0.082	
i75	1.76	0.867	0.938	0.080	
i80	2.21	0.844	0.360	-0.367	
i135	1.60	0.752	1.21	1.26	
Emotional Control					.807
i18	2.36	0.974	0.230	-0.901	
i61	2.49	0.828	0.198	-0.494	
i68	2.59	0.993	-0.130	-0.750	
i82	2.63	0.908	-0.130	-0.750	
i86	2.59	0.903	0.108	-0.825	

Table 3.

Correlation matrix for BASC-2 items.

	i5	i18	i20	i33	i35	i37	i45	i56	i61	i65	i68	i70	i73	i75	i76	i77	i80	i82	i86	i93	i106	i111	i127	i135	i136
i5	1																								
i18	-.386	1																							
i20	-.420	-.477	1																						
i33	-.457	-.343	-.533	1																					
i35	-.559	-.391	.392	-.348	1																				
i37	.404	.445	-.364	-.267	.325	1																			
i45	-.451	-.589	.683	.525	-.526	-.405	1																		
i56	.489	.272	-.324	-.350	.422	.383	-.171	1																	
i61	.306	.554	-.250	-.239	.365	.399	-.356	.357	1																
i65	.609	.413	-.451	-.523	.412	.470	-.498	.442	.420	1															
i68	.323	.575	-.290	-.340	.479	.269	-.486	.272	.458	.347	1														
i70	-.204	-.214	.309	.325	-.045	-.227	.305	-.220	-.182	-.293	-.269	1													
i73	-.335	-.386	.624	.577	-.349	-.314	.702	-.192	-.222	-.424	-.383	.389	1												
i75	-.431	-.523	.595	.531	-.533	-.316	.743	-.201	-.399	-.498	-.532	.377	.667	1											
i76	.683	.439	-.548	-.512	.507	.354	-.430	.483	.386	.625	.370	-.252	-.399	-.468	1										
i77	.258	.415	-.275	-.264	.243	.254	-.212	.296	.409	.323	.293	-.022	-.265	-.338	.399	1									
i80	-.225	-.285	.369	.279	-.282	-.209	.439	-.125	-.252	-.274	-.340	.334	.335	.378	-.229	-.075	1								
i82	-.261	.492	-.321	-.205	.339	.339	-.409	.304	.464	.266	.646	-.262	-.306	-.401	.286	.253	-.345	1							
i86	.473	.411	-.292	-.486	.398	.500	-.410	.456	.382	.482	.292	-.202	-.364	-.379	.477	.425	-.131	.285	1						
i93	.564	.310	-.340	-.391	.462	.475	-.406	.530	.391	.592	.325	-.217	-.295	-.325	.491	.333	-.264	.333	.505	1					
i106	.628	.425	-.547	-.539	.508	.425	-.445	.472	.407	.686	.382	-.229	-.408	-.514	.682	.425	-.227	.333	.493	.566	1				
i111	.512	.418	-.472	-.554	.337	.550	-.460	.547	.386	.559	.382	-.288	-.396	-.505	.546	.432	-.225	.292	.554	.641	.622	1			
i127	.523	.468	-.552	-.470	.425	.504	-.531	.516	.462	.599	.264	-.306	-.431	-.460	.539	.349	-.235	.258	.574	.494	.639	.618	1		
i135	-.267	-.386	.475	.314	-.417	-.322	.578	-.263	-.235	-.338	-.389	.266	.402	.505	-.359	-.182	.489	-.305	-.272	-.358	-.301	-.358	-.284	1	
i136	-.419	.447	-.432	.257	.709	.261	-.531	.332	.345	.335	.387	-.009	-.396	-.468	.496	.279	-.281	.337	.277	.373	.497	.298	.350	-.449	1

Table 4

Model variation analyses for the BASC-2 PRS executive function screener

<u>Model</u>	<u>WLSMV χ^2</u>	<u>df</u>	<u>CFI</u>	<u>ΔCFI</u>	<u>TLI</u>	<u>RMSEA (90% CI)</u>
Model 1: 25 items; 1 factor	575.74	275	0.919		0.912	0.101 (0.090-0.113)
Model 2: 25 items; 2 factors	548.128	274	0.926	-0.01	0.919	0.907 (0.085-0.108)
Model 3: 25 items; 3 factors	480.773	272	0.944	-0.02	0.938	0.805 (0.072-0.097)
Model 4: 25 items; 4 factors	428.252	269	0.957	-0.013	0.952	0.074 (0.061-0.087)

Note. *WLSMV χ^2* = weighted least squares with mean and variance adjusted chi-squared; *df* = degrees of freedom; CFI = comparative fit index; Δ CFI = comparative fit index differences between models; TLI = Tucker-Lewis index; RMSEA = root-mean-square error of approximation.

Table 5*Factor loadings for CFA*

<u>BASC-2 Factor and Item Number</u>	<u>Unstandardized Factor Loadings</u>	<u>Standardized Factor Loadings</u>	<u>Standard Error</u>	<u>R²</u>
Problem Solving				
pi37	1.000	0.682	0.059	0.465
pi56	0.993	0.678	0.059	0.459
pi77	0.812	0.554	0.072	0.306
pi93	1.177	0.803	0.042	0.645
pi111	1.280	0.873	0.036	0.763
pi127	1.262	0.861	0.042	0.742
Attentional Control				
pi5	1.000	0.830	0.039	0.689
pi35	0.933	0.774	0.045	0.599
pi65	1.033	0.857	0.036	0.735
pi76	1.008	0.836	0.047	0.700
pi106	1.113	0.923	0.023	0.853
pi136	0.875	0.727	0.055	0.528
Behavioral Control				
pi20	1.000	0.814	0.048	0.663
pi33	0.979	0.797	0.061	0.635
pi45	1.127	0.918	0.029	0.843
pi70	0.661	0.538	0.105	0.290
pi73	0.967	0.787	0.042	0.620
pi75	1.125	0.916	0.036	0.840
pi80	0.656	0.534	0.078	0.286
pi135	0.893	0.727	0.063	0.529
Emotional Control				
pi18	1.000	0.818	0.051	0.669
pi61	0.852	0.697	0.065	0.486
pi68	0.920	0.753	0.051	0.567
pi82	0.821	0.672	0.062	0.451
pi86	0.977	0.799	0.063	0.639

Note. All factor loadings were statistically significant ($p < .001$)

Table 6.Correlation between the BASC-2 factor *T*-scores and the BRIEF scale *T*-scores.

BASC-2 Factor			<i>r</i>	<i>p</i>	ρ	<i>p</i>
Problem Solving	Target BRIEF scale:	Plan/Organize	-.555	.001	-.484	.003
	Non-target BRIEF scale:	Inhibit	-.538	.001	-.564	<.001
		Shift	-.618	<.001	-.592	<.001
		Emotional Control	-.519	.001	-.494	.003
		Initiate	-.530	.001	-.504	.002
		Working Memory	-.339	.046	-.362	.032
		Organization of Materials	-.432	.010	-.435	.009
		Monitor	-.656	<.001	-.632	<.001
Attentional Control	Target BRIEF scale:	Working Memory	-.669	<.001	-.699	<.001
	Non-target BRIEF scale:	Inhibit	-.658	<.001	-.707	<.001
		Shift	-.627	<.001	-.709	<.001
		Emotional Control	-.408	.015	-.489	.003
		Initiate	-.555	.001	-.641	<.001
		Plan/Organize	-.628	<.001	-.645	<.001
		Organization of Materials	-.318	.063	-.416	.013
		Monitor	-.668	<.001	-.734	<.001
Behavioral Control	Target BRIEF scale:	Inhibit	.803	<.001	.846	<.001
	Non-target BRIEF scale:	Shift	.685	<.001	.605	<.001
		Emotional Control	.643	<.001	.614	<.001
		Initiate	.453	.006	.503	.002
		Working Memory	.362	.032	.435	.009
		Plan/Organize	.563	<.001	.627	<.001
		Organization of Materials	.449	.007	.432	.010
		Monitor	.722	<.001	.785	<.001
Emotional Control	Target BRIEF scale:	Emotional Control	-.816	<.001	-.812	<.001
	Non-target BRIEF scale:	Inhibit	-.617	<.001	-.662	<.001
		Shift	-.783	<.001	-.753	<.001
		Initiate	-.470	.004	-.479	.004
		Working Memory	-.307	.073	-.303	.077
		Plan/Organize	-.340	.046	-.329	.053
		Organization of Materials	-.428	.010	-.425	.011
		Monitor	-.679	<.001	-.666	<.001

Table 7.

Correlation between the BASC-2 factor scores and performance based measures.

BASC-2 Factor			r	p	p	p
Problem Solving	Target performance-based executive function tasks:	TOL: total number of moves	.001	.994	-.053	.754
		TOL: number of problems solved in minimum move count	-.198	.234	-.124	.458
	Complex performance-based executive function task	WCST: number of perseverative errors	.308	.086	.262	.148
	Divergent Validity	Grip Strength: dominant hand	.098	.416	.120	.320
		Grip Strength: nondominant hand	.040	.738	.063	.602
Attentional Control	Target performance-based executive function task:	TMT: Number-letter Switching	-.098	.407	-.152	.201
		Complex performance-based executive function task	WCST: number of perseverative errors	.026	.890	.015
	Divergent Validity	Grip Strength: dominant hand	.078	.517	.075	.536
		Grip Strength: nondominant hand	.042	.730	.038	.751
Behavioral Control	Target performance-based executive function task:	Color-Word Interference: Time	-.055	.731	.022	.889
		Complex performance-based executive function task	WCST: number of perseverative errors	-.153	.403	-.247
	Divergent Validity	Grip Strength: dominant hand	-.011	.927	-.034	.775
		Grip Strength: nondominant hand	.014	.905	.021	.864
Emotional Control	Target performance-based executive function task:	none	--	--	--	--
		Complex performance-based executive function task	WCST: number of perseverative errors	.152	.407	.080
	Divergent Validity	Grip Strength: dominant hand	.003	.978	.011	.928
		Grip Strength: nondominant hand	.051	.670	.074	.542

Table 8

Mean and standard errors of diagnostic group on BASC-2 scales

BASC-2 Scale	Diagnostic Group				<i>F</i>	<i>p</i>	η^2
	Mild TBI <i>M (SE)</i>	Moderate/Severe TBI	Neurodevelopmental	Neuropsychiatric			
Problem Solving	51.53 (1.30)	52.67 (3.08)	43.10 (2.76)	44.95 (2.54)	3.91	.012	.129
Attentional Control	51.55 (1.32)	48.37 (3.12)	44.44 (2.80)	44.70 (2.57)	3.02	.035	.103
Behavioral Control	51.74 (1.31)	48.81 (3.10)	43.35 (2.78)	42.62 (2.56)	4.79	.004	.154
Emotional Control	53.25 (1.22)	48.84 (2.88)	46.90 (2.58)	39.40 (2.38)	9.35	<.001	.262
Mean (SE)	51.81 (1.10)	49.02 (2.59)	44.51 (2.34)	44.03 (2.07)			

Note. Means are adjusted with the covariate, Age, at the following value: Age = 14.95.

Table 9

Correspondence between multi-method measures of executive functions.

	Performance Test				BASC-2 EF				BRIEF			
	TMT	WCST	TOL	CWI	PS	AC	BC	EC	P/O	WM	Inhib	ECont
Case 1	--	--	✓		--	✓	--	--	✓	✓	--	--
Case 2	--	--	✓		✓	✓	✓	✓	✓	✓	✓	✓
Case 3	--	--	✓		--	--	--	--	--	--	--	✓
Case 4	--	--	--		--	--	--	--	--	--	--	--
Case 5	--	--	--		--	--	--	--				
Case 6	--	--	--		--	✓	--	--				
Case 7	--	✓	✓		--	--	--	✓				
Case 8	--	--	✓		--	✓	--	--				
Case 9	--	✓		✓	✓	✓	✓	✓				
Case 10	--	--		✓	--	✓	✓	✓	✓	✓	✓	✓
Case 11	--	--		--	--	✓	✓	--				
Case 12	--	--		--	✓	✓	✓	✓				
Case 13	--	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Case 14	--	--		--	--	--	--	--				
Case 15	--		✓	--	--	✓	--	✓	--	✓	✓	✓
Case 16	--	--	--		✓	--	--	--	✓	--	--	--
Case 17	--	--	--		--	--	--	--	--	✓	--	--
Case 18	--	--		--	--	--	--	--				
Case 19	✓	--	✓		--	✓	--	--	✓	✓	--	--
Case 20	--	--	--		--	--	--	✓	--	✓	✓	✓

Case 21	--	--		✓	--	--	--	--				
Case 22	✓	--	--		--	✓	--	--	✓	✓	✓	--
Case 23	--	--	--		--	✓	--	--	✓	✓	✓	--
Case 24	--	--	--		--	--	--	--				
Case 25	✓	--	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Case 26	✓	--	--	✓	--	✓	--	✓	✓	✓	✓	✓

Note. ✓ denotes an executive impairment on the performance-based executive function test or on the executive function rating scale; -- denotes no executive impairment. A blank space indicates that that test was not administered for that Case; BASC-2 EF = BASC-2 executive functions screener; TMT = DKEFS Trail Making Test; TOL = Tower of London; CWI = DKEFS Color Word Interference; WCST = Wisconsin Card Sorting Test; P/O = Plan/Organize; WM = Working Memory; Inhib = Inhibit; ECont = Emotional Control; PS = Problem Solving; AC = Attentional Control; BC = Behavioral Control; EC = Emotional Control. Blank cells indicate that those measures were not administered for that specific case.

Figure 1. *Composition of diagnosis group in this sample.*

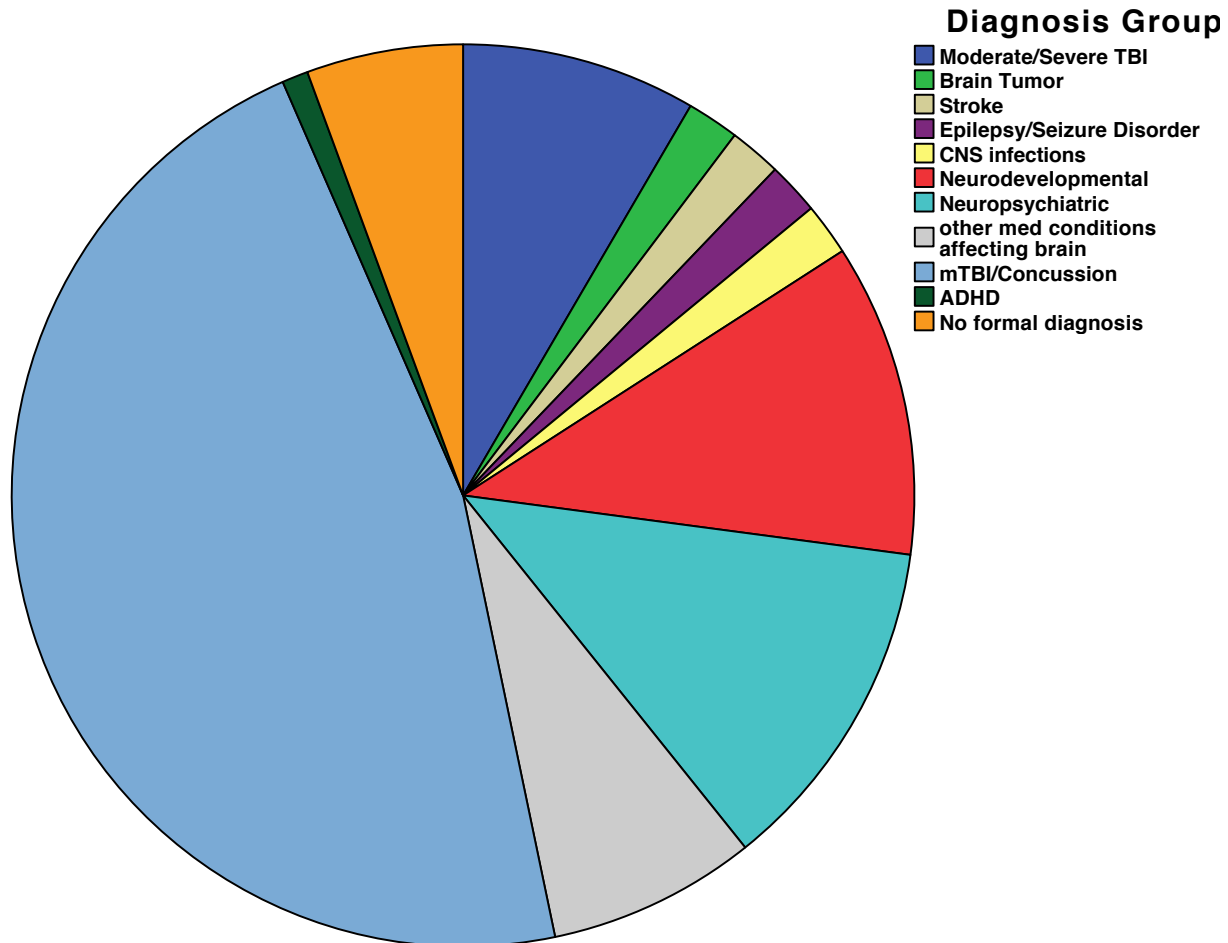


Figure 2. Three alternative models tested.

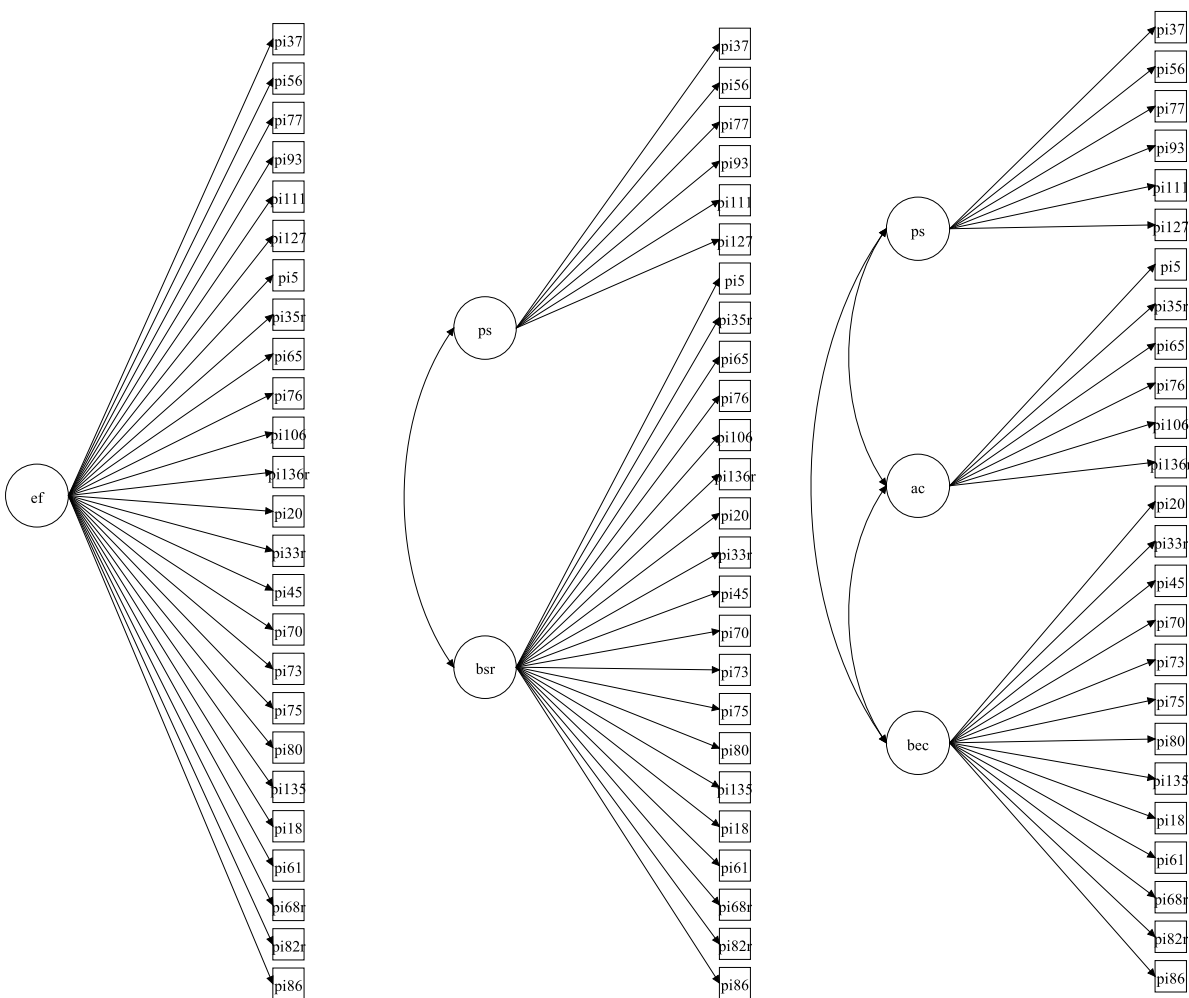


Figure 3. Final confirmatory factor analysis model for the BASC-2-PRS executive functions screener

