PREDICTORS OF PERSISTENT NEUROBEHAVIORAL SYMPTOMS IN ADOLESCENTS WITH MILD TRAUMATIC BRAIN INJURY USING A NOVEL CLINICAL TOOL

APPROVED BY SUPERVISORY COMMITTEE

First Name Last Name, credentials

Karen Brewer-Mixon, Ph.D., CRC

Shannon B. Juengst, Ph.D., CRC

C. Munro Cullum, Ph.D., ABPP

Kim Hoggatt Krumwiede, Ph.D., CMI

Lauren Terhorst, Ph.D.

Kristin Wilmoth, Ph.D.

DEDICATION

I would like to thank each of the members of my dissertation committee for their time and dedication throughout this project. Their expertise and contributions have helped to improve these studies greatly. I would like to extend a special thank you to my mentor, Dr. Shannon Juengst, for her encouragement throughout my development as a researcher and for the countless edits she contributed across this project and other manuscripts. Thank you to my committee chair, Dr. Karen Brewer-Mixon, for her guidance throughout this process of completing my dissertation. Thank you to Novelle Kew, Andrew Nabasny, and Victor Blais for their constant support and feedback throughout the last two years. I would also like to thank each member of Dr. Juengst's lab as we are a team, and their support has been invaluable especially over the last few months. Lastly, I would like to thank my family and my husband, Dustin, as I truly would not have made it this far without their support.

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by

BRITTANY NICOLE WRIGHT

DISSERTATION

Presented to the Faculty of the Southwestern School of Health Professions

The University of Texas Southwestern Medical Center at Dallas

In Partial Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

The University of Texas Southwestern Medical Center at Dallas

Dallas, Texas

August, 2021

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Publication No. ________________

Brittany Nicole Wright, Ph.D.

The University of Texas Southwestern Medical Center at Dallas, 2021

Dissertation Mentor: Shannon B. Juengst, Ph.D., CRC
Dissertation Chair: Karen Brewer-Mixon, Ph.D., CRC

Persistent post-concussion symptoms in adolescents are non-specific and poorly understood. A small percentage of adolescents (roughly 20%) will experience persistent symptoms following mTBI that can be disruptive in many areas of daily functioning. Including measures in assessment that are specific to adolescents but capture symptoms beyond injury may lead to more insight as to why some adolescents experience persistent symptoms. Moreover, identifying predictors of persistent symptoms could aid in management and evaluation of symptoms. The current set of studies was designed to validate a measurement tool for adolescents and identify predictors of persistent symptoms in a cohort of adolescents with mTBI.

Study 1 was designed to further validate a tool (the BAST-A), which assesses persistent emotional and behavioral symptoms in adolescents. Another aim was to develop ordinal to continuous normed scores to aid in clinical interpretation. When assessing the

psychometric indicators of the tool, both the Negative Affect and Fatigue and Executive and Social Function subscales performed well. However, the Risk Behaviors subscale performed poorly in this sample of adolescents with sports-related concussion. Specifically, Risk Behaviors was not able to distinguish different severity levels in the sample. Results from this study suggest further psychometric validation of the BAST-A in adolescents with mTBI.

The aim of Study 2 was to utilize the ordinal to continuous normed scores in the first study to assess if a combination of predictors was associated with persistent neurobehavioral symptoms in adolescents with mTBI. A combination of pre-injury and injury predictors was significantly associated with self-reported Negative Affect and Fatigue symptoms ($F(8,93) = 6.09$, $p<.001$) and Executive and Social Function symptoms ($F(8,93) = 2.18$, $p=.036$). Due to limitations within the Risk Behaviors subscale, binary (Yes/No) outcomes were used. A combination of pre-injury and injury factors was also significantly associated with self-reported Risk Behaviors [$\chi^2(8) = 18.84$, $p=.016$]. Across subscales, total number of recent life stressors remained a significant predictor of persistent symptoms. The results from this study indicated that a combination of injury-related and personal factors is predictive of persistent symptoms and that recent life stressors contribute to the experience of these symptoms.

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PRIOR PUBLICATIONS

1. Juengst, S.B., Kajankova, M., **Wright, B.,** & Terhorst, L. (2020). Factor analysis of the adolescent version of the Behavioral Assessment Screening Tool (BAST-A) in adolescents with concussion. *Brain Injury*, 35(1), 130-137.
2. **Wright, B.,** Wilmoth, K., Juengst, S.B., Didehbani, N., Maize, R., & Cullum, C. M. (2021). Perceived recovery and self-reported functioning in adolescents with mild traumatic brain injury: The role of sleep, mood, and physical symptoms. *Developmental Neurorehabilitation,* 24(4), 237-243.
3. Juengst, S.B., Grattan, E., **Wright, B**., & Terhorst, L. (2021). Rasch Analysis of the Behavioral Assessment Screening Tool (BAST) in Chronic Traumatic Brain Injury. *Journal of Psychosocial Rehabilitation and Mental Health,* 1-16.
4. **Wright, B**., Kajankova, M., Terhorst, L., & Juengst, S.B. (2019). Factor Structure Differences in the Adolescent Versus Adult Versions of the BAST after TBI. *The Archives of Physical Medicine and Rehabilitation,* 100(10), e75-e76.

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LIST OF ABBREVIATIONS

mTBI – Mild Traumatic Brain Injury

ED – Emergency Department

BAST – Behavioral Assessment Screening Tool

BAST-A – Behavioral Assessment Screening Tool for Adolescents

LOC – Loss of Consciousness

SES – Socioeconomic Status

RULER – Rasch Reporting Guidelines in Rehabilitation Research

ConTex – The North Texas Concussion Registry

Mnsq – Mean-square

CHIP – Children's Health Insurance Program

ECQs– Environmental Context Questions

GLM– Generalized Linear Model

CHAPTER ONE
Introduction and Review of Literature

A subgroup of adolescents who sustain a mild TBI (mTBI) continue to report persistent, post-concussive physical and emotional symptoms. These post-concussive symptoms can also lead to cognitive and behavioral problems months to years after injury. Persistent symptoms in adolescent mTBI can be difficult to differentiate from pre-existing and non-concussion related psychological or somatization issues. Perhaps specific to the developmental state of adolescents, academic functioning, identity development, and social functioning can suffer because of these persistent symptoms. Given this transitional phase of development from childhood into adulthood, adolescents may experience symptoms differently than either adults or children. Identifying predictors of persistent symptoms can aid in alerting clinicians of individuals who may be at risk for developing these persistent symptoms. Identifying and knowing which adolescents may be more at risk for developing persistent symptoms will allow clinicians to efficiently expend resources to monitor them, as opposed to monitoring all adolescents following injury, most of whom will recover quickly. Future research in these areas could inform clinical monitoring of symptoms and treatment via different interventions based on types of symptoms endorsed. Unfortunately, adolescents are most often assessed for these symptoms in research using measures designed for children rather than for their unique teen developmental stage. A tool that specifically measures adolescent functioning following mTBI may be useful in evaluating and managing their symptoms.

Persistent Symptoms and mTBI in Adolescents

As many as 20 percent of adolescents who experience a mild traumatic brain injury (mTBI) each year continue to report problematic symptoms more than three months after injury (1–8). These symptoms can have a direct and sometimes lasting impact on adolescents' daily functioning. While there are some estimates of mTBI incidence rates in this population (roughly 812,000 in 2014) (9), these estimates may not be representative of the total number of children and adolescents affected each year. The incidence of mTBI is likely larger than published estimates suggest, since current rates are largely determined based on emergency department (ED) data (10–13). EDs often do not evaluate or formally diagnose mTBI, so these injuries are sometimes missed, even when those with mTBI meet criteria based on their symptoms (14,15). This may be due to other injuries that are more severe and receive more attention. In addition, many adolescents present to primary care physicians, athletic coordinators, or other professionals after mTBI injury instead of going to an ED (13,16). Because of barriers to healthcare (e.g., resources, education, and medical bias) that are experienced by various ethnoracial groups in the U.S., they may not be accurately represented in mTBI research that is based on data from emergency rooms (17,18). Even after appropriate diagnosis of mTBI, estimates for those who experience persistent symptoms may be difficult to ascertain.

Persistent symptoms after mTBI in adolescents manifest in many different areas of daily functioning. These symptoms are generally nonspecific, often overlap, and include aspects of emotional functioning, perceived cognitive functioning, and physical manifestations of symptoms (e.g., headache or sensitivity to noise) (19). It has been suggested that these persistent symptoms occur due to somatization in a small percentage of individuals rather than due to the mTBI per se (5,20). Regardless of the etiological nature of these symptoms, they can be disruptive to an adolescents’ functioning. Understanding these overlapping, nonspecific, and complex symptoms is often very challenging (21–23).

One factor that can impact persistent symptoms is the presence of mood disorder symptoms. In one study assessing new-onset psychiatric disorders following mTBI in children and young adolescents, 36% of the sample met criteria for a novel psychiatric disorder six months after the injury (24). A large-scale epidemiologic analysis consisting of mostly mild TBI participants found that children with TBI had more current or past mood disorders than those without TBI (25). Mood symptoms are related to both self-esteem and cognitive functioning in adolescent mTBI, but can also be predictive of perceived cognitive function, especially factors like depression, anxiety, and neuroticism (26). Children with mTBI often report more challenges related to school performance and more worry about their academic performance compared to uninjured peers (27). Persistent mTBI symptoms can increase these concerns about academic function in children and their parents (28). One study showed that after TBI (including mTBI), children reported lower self-esteem compared to uninjured peers. Those with lower self-esteem also had poorer cognitive performance and more depressive and anxiety symptoms (29). Persistent symptoms following mTBI are often non-specific, affect many adolescents, and can be disruptive to daily functioning.

Perceived Recovery and Persistent Symptoms

Despite limited and inconsistent evidence for performance based (e.g., cognitive functioning, return to play, return to school, etc.) challenges following mTBI, the experience of persistent symptoms may contribute to perceived recovery. There is some discrepancy between return to activity and the perception of being fully recovered. Even when individuals display normal cognitive and physiologic functioning (30–32), they may still indicate that they are experiencing prolonged recovery or persistent symptoms through self-reported measures. While there is some evidence that perceived recovery in adolescents after mTBI is related to actual neurocognitive dysfunction, a stronger relationship was found between self-perceived recovery and self-reported post-concussion (specifically somatic) symptoms (33). Similarly, in another study conducted on self-perceived recovery in adolescents and young adults, self-reported concussion symptoms (e.g. headache, trouble concentrating, feeling more emotional than usual), mood symptoms, and sleep symptoms were associated with the perception of not having fully returned to pre-injury “normal” status (34). By identifying those whose perceived recovery differs from what performance-based tests indicate, researchers may be able to identify other meaningful persistent symptoms not captured by performance-based tests or standard concussion symptom questionnaires alone. Understanding this discrepancy starts with assessing adolescents independently from children and adults and tailoring measures to capture their experience.

Adolescent Symptoms Compared to Children and Adults

Adolescence represents an important developmental phase as adolescents are transitioning from childhood to adulthood. While physical, cognitive, and/or emotional functioning may be affected after mTBI across age groups (3,19,23,35,36), some research suggests that adolescents may experience symptoms differently than children or adults. Specifically, adolescents who indicated that they were not recovered following concussion reported more academic challenges compared to children who reported that were not recovered (28). Research has been contradictory regarding whether adolescents report fewer or more concussion symptoms overall compared to children (38,39); however, other research has shown that adolescents experience more challenges with working memory after concussion compared to adults or children (37). These differences in symptom reporting and function between adolescents and other age groups suggest a further need to evaluate adolescents separately from other age groups.

Considerations for Measurement Tools

Self-report, easy-to-administer measures that are specific to adolescents' experiences are needed. Adolescents are often evaluated as children although their symptoms and recovery trajectories may be more comparable to those of adults (20,40–43). Additionally, physical and cognitive functioning (e.g., return to play/school and neuropsychological evaluations) are often used as benchmarks for recovery in research for children and adolescents (44,45). With research mostly focusing on performance-based outcomes (i.e., neuropsychological tests) or events like return to play/school, more subjective outcomes like quality of life and emotional/behavioral symptoms remain understudied (46–49). Along these lines, much of the research is focused on concussion symptom logs which include self-report of multiple symptom domains including physical, emotional, cognitive, and sleep symptoms (44,50,51). These measures are helpful in obtaining a comprehensive view of adolescents' symptoms following a concussion; however, these measures are specific to concussion symptoms and may not measure beyond typical concussion symptoms. Measures that assess self-perceived behavior and emotional functioning could provide insight into adolescents' daily challenges.

A Comprehensive Measurement Tool for Emotional and Behavioral Functioning

The BAST measures symptoms in the domains of perceived negative affect, fatigue, executive function, impulsivity, and substance abuse (52–54). Development of the BAST was based on a conceptual model that considered emotional, cognitive, and personal factors and their influences on behavior (54). The development of this tool also used prominent measures in the rehabilitation field to inform item selection and creation (e.g., Patient Health Questionnaire-9, Generalized Anxiety Disorders-7, Frontal Systems Behavior Scale) (54). This conceptual model was adapted to suggest that behavior results from a complex combination of internal (e.g. mood, cognition) and external (e.g. stressors, environment) factors (55). This view of symptoms post TBI provides a multi-dimensional assessment of behavioral function that can inform treatment and management of symptoms in adolescent mTBI.

The Behavioral Assessment Screening Tool for Adolescents (BAST-A)

Like the BAST, the BAST-A is a self-report instrument that assesses emotional and behavioral functioning, but it was modified from the BAST to assess adolescents with mTBI/concussion and it was validated in this population (52). However, the BAST-A is not specific to TBI and was designed to measure behavioral and emotional challenges due to injury and beyond injury. Modifications to make the BAST-A specific to adolescents included adding items measuring social and school functioning (52). Additionally, items measuring substance abuse were changed to measure substance use. This change was made because minimal substance use in adolescents is illegal in the U.S. and admission of substance use could also capture risk-taking/problematic behavior (52). Initial factor analysis of the BAST-A in another sample of adolescents with mTBI revealed three domains, titled: Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors (52). The BAST-A was determined to show good content validity by a panel of experts (Content Validity Index=97.2%) and internal consistency reliabilities ranging from good to excellent for the three subscales (Cronbach's α=.80-.95) in initial factor analysis (52). While the BAST has undergone Rasch analysis in adults with mild to severe TBI and displayed good psychometric properties (56), the BAST-A has not yet been analyzed via Rasch in adolescents with mTBI. Using Rasch analysis in a sample of adolescents with mTBI will further validate the tool for measuring persistent self-reported emotional and behavioral symptoms.

The Importance of Rasch Analysis

Assessing the BAST-A using Rasch analysis would serve to further establish the psychometric properties of the tool. Rasch analysis has been used for other measures in the fields of rehabilitation and TBI, specifically to improve the development of new scales and to re-evaluate older scales (57–59). Rasch is desirable in the human sciences and in rehabilitation research, as it quantifies ordinal measures and standardizes units between ordinal data (60). Additionally, Rasch can provide item-level and person-level data that are helpful in designing and refining a tool. For example, Rasch analysis can display the order of items based on severity/difficulty, indicate if the severity/difficulty of items is appropriate for the sample, and characterize individual respondents who are outliers in the sample.

Many self-report measurement tools in pediatric and adolescent concussion do not account for the likelihood of endorsing individual items (61–64), thereby treating each individual item as equal in severity. Clearly, however, individuals may show a greater likelihood of endorsing some items and not others. For example, “I felt tired” is more likely to be endorsed than “I felt depressed or hopeless.” When the likelihood that an item will be endorsed (i.e., item endorsement “difficulty”) is not assessed, all items are assumed to be equally endorsed, as are all levels of the ordinal response scale. To aid in determining the clinical utility of a measure, ensuring that items are capturing what they were designed to measure (validity), determining if the measure is appropriate for the intended population, and assessing whether or not items cover a range of severity can be helpful. Rasch analysis is helpful in assessing these properties and may lead to an improvement in the BAST-A as a tool of emotional and behavioral functioning in adolescents.

Identifying Predictors of Persistent Symptoms

Persistent symptoms following concussion can result from many complex factors, including neurobiological complications, psychological factors, social factors, lack of resources, etc. (36). To date, multiple studies have assessed predictors individually to analyze their effect on outcomes (65–67); however, few studies have looked at the additive value of multiple predictors in a model and their association with prolonged recovery in an adolescent population (6,68,69). Building predictive models that include biological, personal, and injury-related factors in adolescent samples will allow us to better classify which individuals are at a greater risk for persistent symptoms based on factors such as socioeconomic status, psychiatric diagnoses prior to injury, loss of consciousness, etc.

There is currently little consensus on the factors that predict recovery, and there are several different definitions of recovery, which makes identifying predictors challenging (36,44). Potential predictors of persistent symptoms following mTBI supported by the literature include age and sex (6,44,70–72),(53,73) loss of consciousness (64), prior concussions (68), pre-injury psychiatric diagnoses (3,6,19), history of psychiatric diagnoses (69), familial stress (70), and socioeconomic status (65,71).

Risk Stratification and Future Directions

More research in the areas of risk stratification and predictive modeling can help clinicians better identify groups of individuals that are more at risk for developing persistent symptoms (36). Depending on the risk factors and types of symptoms, those identified as at risk could have more frequent follow-up visits with their provider(s) to help in symptom management. Such follow-up visits might include repeat assessment or informal questioning to closely monitor a high-risk adolescent's recovery progress. Adolescents at higher risk for persistent symptoms after mTBI might also receive individualized interventions/treatments designed to address different risk factors (e.g., psychotherapy, pharmacological interventions, vestibular intervention, academic accommodations) (77).

Scope of Research

The purpose of the current work is to further validate a measure designed specifically for adolescents to capture their persistent emotional and behavioral symptoms and to develop ordinal to continuous scores for better clinical interpretation. The second aim is to assess if a combination of injury-related and personal factors predicts these symptoms. Manuscript 1 is entitled "Rasch Analysis of the Behavioral Assessment Screening Tool for Adolescents (BAST-A) in Mild Traumatic Brain Injury." This study reports Rasch analysis of the BAST-A with the aim of further validating the psychometric properties of the tool and providing normed subscale scores. Manuscript 2 is entitled "Predictors of Persistent Behavioral Symptoms in Adolescents with Mild Traumatic Brain Injury." The aim of this study is to assess the predictive ability of a combination of injury and personal variables (e.g., LOC, psychiatric disorders, life stressors, history of concussion) for persistent symptoms on the BAST-A. Both papers will contribute to research on risk stratification of adolescents based on premorbid and injury-related factors and will provide information relevant to future work on clinical monitoring, treatment, and intervention.

CHAPTER TWO
Manuscript 1: Rasch Analysis of the Behavioral Assessment Screening Tool for Adolescents (BAST-A) in Mild Traumatic Brain Injury

Abstract

The Behavioral Assessment Screening Tool for Adolescents (BAST-A) (Juengst et al., 2020) is a measure of neurobehavioral function in adolescents with mild traumatic brain injury (mTBI). The aim of this study was to follow the Rasch Guidelines in Rehabilitation Research (RULER) framework to validate the BAST-A by assessing its psychometric properties and developing ordinal to continuous scores for all the subscales. According to the RULER framework, we assessed unidimensionality, item hierarchies, targeting, and symptom severity strata. Although seven items were misfitting, these items were retained in the analysis. While the subscales of Executive and Social Function and Negative Affect and Fatigue adequately targeted the sample, the Risk Behaviors subscale displayed more mistargeting, indicating that different severity levels may not have been adequately captured or represented in the sample. The Executive and Social Function subscale distinguished three strata, or distinct levels of symptom severity while the Negative Affect and Fatigue subscale distinguished five strata. Risk Behaviors did not distinguish any strata in this sample. Overall, the BAST-A displayed adequate psychometric properties for the Negative Affect and Fatigue and Executive and Social Function subscales, but not for the Risk Behaviors subscale. As a next step, the BAST-A will need to be tested further in a sample of adolescents who have persistent mTBI symptoms and with those have more severe injury, as the goal is for this measurement tool to be used in these populations.

Keywords: concussion, mild traumatic brain injury, measurement, emotions, behavior

Introduction

Persistent symptoms following a concussion/mild traumatic brain injury (mTBI) occur in as many as 20% of injured adolescents (Barlow, 2016; Barlow et al., 2010; Ewing-Cobbs et al., 2018; Graham et al., 2013; King, 2003; Ponsford et al., 2001; Quinn et al., 2018; Vidal et al., 2012). Several studies have shown that mild TBI can affect adolescents' cognitive, physical, and emotional functioning (Barlow, 2016; Iverson, 2019; Mullally, 2017; Polinder et al., 2018; Ryan & Warden, 2003), though most adolescents seem to fully recover. Currently, much of the research in pediatric concussion does not differentiate between adolescents and children and mostly captures physical and cognitive aspects of recovery (Finnanger et al., 2015; Iverson et al., 2017; Manzanero et al., 2017; McCauley et al., 2012; Nelson et al., 2016). In children/adolescents with mTBI specifically, mood-related symptoms are common for those that experience persistent challenges following the injury (Grubenhoff et al., 2015, 2016; Luis & Mittenberg, 2002; Max et al., 2013; Nelson et al., 2016; Root et al., 2016; Taylor et al., 2010). To better measure a fuller range of post-mTBI symptoms in adolescents, we created a neurobehavioral measure specifically for adolescents with TBI to capture Negative Affect and Fatigue, Executive and Social Function, and Risk Behavior symptoms (Juengst et al., 2020).

The Behavioral Assessment Screening Tool for Adolescents (BAST-A) was developed to assess neurobehavioral symptoms in adolescents following TBI and was adapted from the

BAST for adults (Juengst et al., 2020). The original BAST captured symptoms in five different subscales – Negative Affect, Fatigue, Executive Function, Substance Use, and Impulsivity. Compared to the BAST, exploratory factor analysis in the BAST-A development sample revealed Negative Affect and Fatigue were collapsed into one subscale and the Substance Use and Impulsivity subscales were collapsed into one subscale (Juengst et al., 2020; Wright et al., 2019). The BAST-A has demonstrated good content validity (97.2%) and the three subscales have demonstrated good to excellent internal consistency reliabilities (Cronbach's α=.80-.95) (Juengst et al., 2020). The current study uses Rasch analysis to further validate the BAST-A.

Rasch analysis has been used in the fields of rehabilitation and TBI (Granger et al., 1998; Souza et al., 2017; Tesio, 2003) and can provide useful item-level and person-level information about a measurement tool. While many measures add up total raw scores to calculate severity or symptom burden, Rasch standardizes ordinal units of measurement (Bond & Fox, 2015). This takes into account that adolescents may be more likely to endorse certain items and not others, depending on the severity of their symptoms (e.g., "I felt tired" versus "I felt depressed or hopeless"). Using Rasch analysis in this way can help improve a measure by determining if it is appropriate for the intended population.

Specific Aims/Hypotheses

Our primary objective in this study is to confirm the psychometric properties of the BAST-A following the standards of the Rasch Reporting Guidelines in Rehabilitation Research (RULER) framework. Our hypothesis is that each of the subscales will demonstrate appropriate unidimensionality and fit statistics, item hierarchies, targeting, and symptom severity strata using Rasch analysis. Another objective of the study is to generate continuous normed scores from the ordinal total scores for each BAST-A subscale for easier clinical interpretation of symptom severity in adolescents with mTBI.

Methods

Participants were adolescents aged 12-20. They were enrolled in the North Texas Concussion Registry (ConTex) (Cullum et al., 2020), which includes data from clinics at Children's Health Andrews and Dallas, Texas Scottish Rite Hospital for Children in Frisco, and UT Southwestern Medical Center. Inclusion criteria for the study were as follows: English speaking, a spinal cord injury ASIA score of D or better, initial visit within 30 days of the injury, enrolled between September 19, 2019, and February 25, 2021, and diagnosed with a concussion at the initial visit. For participants under the age of 18, written consent is obtained from the parent with verbal assent obtained from the participant. Adolescents were excluded from the analyses if they failed the validity checks on the BAST-A, which are described below. Participants completed a battery of questionnaires following the initial clinic visit either in-person or over the phone and they completed the BAST-A at the 3-month follow-up visit via a link to RedCap. Data from the study are stored securely in RedCap (Harris et al., 2009, 2019) and were analyzed using WinSteps version 4.8.0 (*Linacre, J. M.. Winsteps® Rasch Measurement Computer Program*).

Primary Measure: Behavioral Assessment Screening Tool for Adolescents (BAST-A)

The BAST-A is a 59-item measure designed to capture common emotional and behavioral symptoms among adolescents with mTBI. Items are rated on a 5-point ordinal scale (Never, Rarely, Sometimes, Often, Very Often). Participants are asked how often they have experienced symptoms over the past two weeks. The measure distinguishes symptoms in three subscales: Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors. The Negative Affect and Fatigue subscale contains 31 items, the Executive and Social Function subscale contains 12 items, and Risk Behaviors contains 7 items. Also included in the measure are two validity items ("I ate something during the day" and "I thought about something that I wanted to do") and a question on nightmares ("I had nightmares") as a potential screen for post-traumatic stress. While there are six additional coping items, they are only provided to participants if they endorsed feeling stressed and are designed to be used clinically for additional context rather than providing a score.

Nine participants who completed the BAST-A were excluded from analyses after failing validity checks. If individuals indicated a 1 (Never) for either validity question (i.e., "I ate something during the day" or "I thought about something that I wanted to do") then other validity checks were assessed. Participants were excluded if they completed the measure in under three minutes (indicating that they rushed through it), did not display significant variability in their answers (e.g., answered "Never" for many of the questions, despite some being positively oriented), or endorsed cognitive or physical fatigue but indicated they were never tired. If participants wrote a response to the short-answer questions indicating that they were attending adequately to the measure, then they were not excluded, even if they had other invalidating responses.

Statistical Analyses

We conducted Rasch analysis on the BAST-A using the Masters partial credit model in Winsteps, version 4.8.0. The Masters partial credit model does not assume that units of measurement are the same between levels of endorsement (i.e., the difference between endorsing "Never" and "Rarely" is not the same as endorsing between "Often" and "Very Often" on an ordinal scale) (Masters, 1982). Items on the Executive and Social Function subscale such as "I finished things that I started" or "I apologized when I did something wrong" were reverse scored prior to the analysis.

Unidimensionality

Although initial psychometric tests using an exploratory factor analysis revealed good unidimensionality in a similar sample of adolescents with mTBI (Juengst et al., 2020), psychometric properties for this sample have not yet been tested. The prior sample differed from the current sample as previous studies had different inclusion criteria (i.e., including those with longer time since injury). The three subscales of Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors were identified in our prior work (Juengst et al., 2020). As such, in the current study, we sought to establish unidimensionality by assessing the Cronbach's alphas for each of the subscales. Using Rasch analysis, we also analyzed individual item fit to assess unidimensionality. Fit statistics capture how much the items “fit” within the overarching construct as measured (i.e., subscale). For example, item fit would indicate how well an item like “I had low energy” was measuring the construct of Fatigue. For the proposed study, a Mean-square (Mnsq) value of less than 1.4 for the infit and outfit statistics would indicate good item fit (Bond & Fox, 2015). The ideal value is a Mnsq of 1.0 so using 1.4 accounts for 40% of additional variance and the value of 1.4 is the preferred cutoff for measures using a rating scale (Bond & Fox, 2015).

Handling of Misfitting Items

If items were misfitting (i.e., they are not appropriate for the construct), they were removed, and the average subscale scores and separation indices were reassessed to see if these values improve with the removal of the item. As the measures did not improve substantially upon removal, all items were retained in the subscale. Person fit was also assessed using the threshold of >2.0 to represent unmodeled noise (*Table 6.1 Person Statitstics in Misfit Order*, n.d.). Person fit measures the discrepancy between observed versus expected responses. Because subscales of the BAST-A overlap, unexpected responses on one subscale could be indicative of constructs in another subscale (e.g., an item measuring both Negative Affect and Fatigue and Executive and Social Function symptoms).

Item Hierarchies

We analyzed logit values as a representation of item difficulty/severity to assess item hierarchies. Logit values were assessed because they standardize units of measurement equally and relative item difficulty/severity is accounted for. For the BAST-A, items that are easier would have more participants reporting that they frequently experience these symptoms (i.e., very often), while items that are more difficult would have fewer participants with more severe symptoms reporting that they experience these symptoms “very often.” Items that displayed higher logit values indicated that these items were more difficult to endorse or represented more severe symptoms. Monotonicity for items would be indicated when the probabilities for selecting a higher rating category would increase and decrease as symptom severity increases and decreases.

Targeting

We assessed targeting to ensure that items in the measure were of the appropriate difficulty for the sample. Targeting indicates that items range in difficulty level throughout the sample (i.e., including items that are easier to endorse such as “I felt tired” and those that may be more difficult to endorse or indicate greater severity such as “I felt depressed or hopeless”). A cutoff of above 0.5 for average subscale measures indicates slight mistargeting and above 1.0 indicates greater mistargeting in average subscale measures (Duncan et al., 2003; Juengst et al., 2021).Less severe items (i.e., easier to endorse) are indicated by a negative value further from zero, while items with a greater positive value are more severe (i.e., more difficult to endorse).

For person and separation indices, or the extent to which item severity or person severity is spread across a subscale, the threshold of between 1.5 to 2.0 will be indicative of “acceptable” to “good” levels of separation (Duncan et al., 2003; Juengst et al., 2021). These separation indices will allow us to determine how many levels of symptom severity there are within each subscale: Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors.

Symptom Severity Strata

Strata are symptom severity levels. After obtaining the separation index, we used the equation ((4*Separation Index)+1)/3) to calculate strata for each subscale as this equation is commonly used and supported in the field (Silverstein et al., 1992; Wright & Masters, 1982). We also calculated the reliabilities of the subscales with an index of 1.5 being comparable to a Cronbach's alpha of .70 (acceptable) and 2.0 with a Cronbach's alpha of .80 (good) (Duncan et al., 2003; Juengst et al., 2021).

Sample Size Calculations

If the BAST-A subscales are appropriately targeted (i.e., include items that are of the appropriate severity for the sample), prior research suggests that a sample of at least 50 participants would be sufficient for the Rasch analysis (*Sample Size and Item Calibration or Person Measure Stability*, n.d.). Researchers in this field also recommend at least 10 responses per point on the rating scale (Linacre, 2002, 1999a, 1999b); given the 5-point rating scale of the BAST-A (i.e., never, rarely, sometimes, often, very often), a minimum of 50 participants would meet this recommendation. Given these considerations, our sample of n=107 was above the recommended 50 participants and should have displayed endorsement across the rating scale. We nevertheless assessed responses to ensure that different levels of item difficulty were endorsed.

Results

Participants

Participants (n=107) were adolescents aged 12-17 with a documented mTBI that presented to the clinic within 30 days of their injury and completed the BAST-A on average three to four months post-injury. Participant characteristics can be found in **Table 1**. Roughly half (54.3%) were female, and a majority were White (81.0%). Most of the participants were in high school at the time of consent to the study (63.0%). Injury mechanisms included motor vehicle accident, sports-related concussion, fall, hit (an object, or by an object), and assault. Most participants indicated that they sustained their mTBI due to a sports-related injury (74.1%). Regarding sports-related injuries, the most common occurred in football (27.3%), soccer (17.0%), and basketball (10.2%).

Unidimensionality

Although some prior research with exploratory factor analysis has been completed on the BAST-A (Juengst et al., 2020), this study was conducted in an overlapping sample of adolescents with concussion due to different inclusion criteria and additional recruitment since the prior study. A preliminary exploratory factor analysis replicated the three factors with communalities ranging from .564 to .927. Cronbach's alphas for the Negative Affect and Fatigue subscale (.960) and Executive and Social Function subscale (.829) ranged from good to excellent. The Risk Behaviors subscale (.630) was just below the acceptable range (Cronbach's α <.07) (George & Mallery, 2005).

Misfit statistics from the Rasch analysis indicated that five items from the Negative Affect and Fatigue subscale, one item from the Executive and Social Function subscale, and one item from the Risk Behaviors subscale displayed potential misfit, with Mnsq > 1.4. For Negative Affect and Fatigue the items were: "I limited my physical activities because of fatigue," "I avoided social activities," "I did things that made me feel embarrassed," "I felt guilty about something I had said or done," and "I felt like I did not fit in with my friends." From the Executive and Social Function subscale the item was: "I planned ahead" and from Risk Behaviors: "I took unnecessary risks." **See table 2** for infit and outfit values.

Handling of Misfitting Items and Sample Size Calculations

To address potential misfitting of items, we re-ran analyses without each item to determine if average subscale measures and standard error changed. For the full Negative Affect and Fatigue subscale, the average subscale measure was -1.06 and standard error was 0.28 before removal of items. The average subscale measures were lower and standard errors were higher with removal of 4 items: "I limited my activities because of physical fatigue" (Subscale: -1.07; SE: 0.29), "I avoided social activities" (Subscale: -1.07; SE: 0.29), "I did things that made me feel embarrassed" (Subscale: -1.06; SE:0.28), and "I felt guilty about something I had said or done" (Subscale: -1.10; SE:0.30). The item "I felt like I fit in with my friends" resulted in a higher average subscale measure (-1.04) and the same standard error (0.28) when removed. For Executive and Social Function, the average subscale measure was -0.60 and standard error 0.37. The one item that displayed potential misfit in Executive and Social Function ("I planned ahead") also exhibited a lower average subscale measure (-

0.72) and standard error (0.41) when removed. The Risk Behaviors average subscale measure was -3.38 and standard error was 1.34. When “I took unnecessary risks” was removed, the average subscale score was lower (-3.90) and standard error higher (1.53). For all five Negative Affect and Fatigue items, the item standard error stayed the same after removal of the item (0.12). For the item from Executive and Social Function, item standard error became higher after removal of the item (from 0.11 to 0.12). For Risk Behaviors, item standard error also became higher with removal of the item (from 0.42 to 0.52). As a result of minimal scale change with item removal, it was determined that potentially misfitting items would be kept in the scale.

Person Fit

For Negative Affect and Fatigue, the infit Mnsq values ranged from 0.28 to 2.76 and outfit Mnsq values ranged from 0.31 to 4.73. There were seven adolescents with values over the 2.0 threshold of person fit for Negative Affect and Fatigue. For Executive and Social Function, infit Mnsq values ranged from 0.13 to 3.23 and outfit Mnsq values ranged from 0.13 to 5.32. There were 11 adolescents with values over the 2.0 threshold for Executive and Social Function. For Risk Behaviors, the infit Mnsq values ranged from 0.04 to 2.97 and outfit Mnsq values ranged from 0.04 to 3.03 and five adolescents were over the 2.0 threshold. This indicates that individuals’ expected responses were different from their observed responses for these subscales. For example, an individual with more severe symptoms would be expected to endorse “Very Often” for an item that was less severe. If they did not respond in this way and had too many of these unexpected responses, this would affect person fit.

Individuals who surpassed the threshold for person fit were sustained in the analyses as many of the adolescents were misfitting on some subscales and not others. This is likely represented by the overlap in scales as they are weakly correlated (r=-.278 to .219) indicating some shared variance.

Item Difficulty Hierarchy

The average subscale values, represented by logits, provided in **Table 2** are a measure of severity of symptoms and difficulty of item endorsement. Logit values in this sample ranged from -1.14 to 2.11 across scales, with the largest spread of logit values being in the Risk Behaviors subscale. The easiest item to endorse was “I did things that were unsafe” and the hardest item to endorse was “I used tobacco.” Since the lower logit value was associated with “I did things that were unsafe,” more adolescents were endorsing this item “often” or “very often” compared to “I used tobacco.” While “I used tobacco” may not be an item endorsed by only those with more severe Risk Behaviors, endorsement in this sample did suggest that adolescents were less likely to use tobacco. Lack of endorsement could be due to the way the question was phrased (i.e., “I used tobacco” versus “I used products containing nicotine”), the decreasing popularity of using tobacco, or the fact that most of our sample consisted of adolescent athletes.

Figures 1-3 represent individual item-level and person-level endorsement and in these figures, average scores of individual items are shown across the ordinal-level rating categories. Items were well distributed in the Negative Affect and Fatigue subscale and the Executive and Social Function subscale. Person distribution on the Negative Affect and

Fatigue and Executive and Social Function subscales was concentrated toward the bottom of the figure, but the distribution of persons was not as poor as in the Risk Behaviors subscale. Both item and person distribution of Risk Behaviors clustered toward the bottom of the figure. These findings suggest that the adolescents generally experienced more Negative Affect and Fatigue and Executive and Social Function symptoms compared to Risk Behaviors, reflected in a wider distribution. The Risk Behaviors subscale may have a substantial floor effect and only those who are experiencing more frequent or severe symptoms will be captured in this subscale. Overall, the ordering of items in this sample made conceptual sense despite the lack of endorsement in some items.

Targeting

Table 3 depicts average subscale measures, person and item separation indices, and reliability statistics. The average subscale measure for Executive and Social Function (-0.60) displayed appropriate targeting for the sample and is therefore considered a subscale that can capture symptom severity. The average subscale measure for Negative Affect and Fatigue (-1.06) displayed mistargeting slightly above the threshold of 1.0. Additionally, the Risk Behaviors average subscale measure showed even greater levels of mistargeting (-3.38). The values of these two subscales may indicate that the subscales are unable to capture different severity levels in this sample or that the sample did not include participants at different severity levels for the scale to capture. All three subscales displayed negative values for the average subscale measure, indicating that the adolescents were reporting symptoms that were less severe compared to what was expected.

Table 3 depicts separation reliability and indices. Both the Negative Affect and Fatigue and the Executive and Social Function subscales displayed acceptable to excellent separation reliabilities ≥ 0.78, and Risk Behaviors demonstrated a good item separation reliability of 0.78; however, Risk Behaviors displayed poor person level reliability (0.00). Separation indices were above the 1.5 threshold for the Negative Affect and Fatigue and the Executive and Social Function subscales indicating good separation. While item level separation was above 1.5 for Risk Behaviors, person level separation was not.

Symptom Severity Strata

Two of the BAST-A subscales (Negative Affect and Fatigue and Executive and Social Function) were able to differentiate three to five strata of participants. Negative Affect and Fatigue distinguished 5 strata (4.97) and Executive and Social Function 3 strata (2.97). Risk Behaviors could not adequately distinguish strata in this sample (0.33). The Negative Affect and Fatigue subscale differentiated participants who were high, above average, average, below average, and low severity, and the Executive and Social Function subscale differentiated participants who were high, average, and low severity. Normed score conversions for the Negative Affect and Fatigue and the Executive and Social Function total ordinal scores are presented in **Table 4**.

Sample Size Calculations

Both Negative Affect and Fatigue and Risk Behaviors demonstrated mistargeting. Additionally, each of the ordinal categories (1-5) was endorsed by at least 10 participants for each of the subscales except Risk Behaviors, which may explain why person separation was so poor. Our sample generally endorsed very mild symptoms (i.e., Never, Rarely, Sometimes). However, the Negative Affect and Fatigue and the Executive and Social Function subscales displayed more variability across categories and higher numbers in the Often and Very Often categories compared to Risk Behaviors. In the Risk Behaviors subscale, only the first three ordinal values (Never, Rarely, and Sometimes) reached the threshold of 10 responses.

Discussion

The purpose of the current study was to further validate a measure of neurobehavioral symptoms in adolescents with mTBI and to develop normed subscale scores for better clinical interpretation. We were able to meet our objectives for the current study by confirming the psychometric properties and developing ordinal to continuous normed scores for the Negative Affect and Fatigue and Executive and Social Function subscales. However, we were unable to confirm the psychometric properties or develop normed scores for the Risk Behaviors subscale in this sample. Additionally, our primary hypothesis was met for two of the subscales. We were able to confirm the psychometric properties for both the Negative Affect and Fatigue and the Executive and Social Function subscales via assessing unidimensionality, targeting, item difficulty hierarchies, and symptom severity strata. The Negative Affect and Fatigue subscale displayed mistargeting slightly above the threshold in this sample, but also displayed good person and item level separation. Moreover, the Negative Affect and Fatigue subscale distinguished 5 strata or severity levels. Considering the different psychometric indicators used in Rasch analysis, the scale was still determined to adequately measure symptoms of Negative Affect and Fatigue in this sample.

While one previous study assessed basic psychometric properties of the BAST-A (i.e. internal consistency reliability, content validity, etc.) (Juengst et al., 2020), the aim of the current study was to use modern test theory to assess item-level and person-level properties of the measure in a sample of adolescents with mTBI. Overall, the Negative Affect and Fatigue and the Executive and Social Function subscales performed well. However, the Risk Behaviors subscale was not adequately capturing a full range of severity in the sample, did not distinguish strata, and contained items that were too difficult for participants to endorse (i.e., the items were too severe).

Risk Behaviors demonstrated poor psychometric properties in this sample due to a lack of endorsement in items that were more severe. Conversely, additional items that are less severe may need to be included in the measure to adequately capture risk-taking symptoms of this sample. Overall, our sample generally endorsed very few symptoms and while Negative Affect and Fatigue and Executive and Social Function may have captured symptoms more common in the general population, Risk Behavior symptoms may only occur in a small number of adolescents. While future work is needed to test the Risk Behaviors and other subscales in a sample with a wider range of injury severity, this preliminary work shows promising applications for the Negative Affect and Fatigue and Executive and Social Function subscales in adolescent mTBI. A specific notable finding regarding these subscales was the different severity levels that they captured even in a sample that generally endorsed minimal symptoms. The Executive and Social Function subscale distinguished three strata and the Negative Affect and Fatigue subscale distinguished five, suggesting that in these adolescents there may be subtle differences between severity levels, especially in Negative Affect and Fatigue.

Results from the Rasch analysis and exploratory factor analysis showed that the measure demonstrated good unidimensionality for two of the subscales (i.e., Negative Affect and Fatigue and Executive and Social Function) but questionable unidimensionality for Risk Behaviors. Items from Negative Affect and Fatigue that misfit may have displayed values above the threshold because they are also capturing social themes in the Executive and Social Function subscale. This is supported in research, as adolescent mood and social functioning are closely related. For some athletes, if return to play and/or social interaction through activity are affected by mTBI, then both mood and social function could be affected (Conley et al., 2020; Eime et al., 2013; Weinstein & Mermelstein, 2008). While participating in sports does not guarantee social interaction, sports participation is generally associated with better psychological and social outcomes, with team sports in particular being related to better social outcomes (Eime et al., 2013). Moreover, the complex relationship between fatigue, quality of life, and participation (home, community, and school) in adolescents (van Markus-Doornbosch et al., 2020) may contribute to the overlap between these two subscales.

The item "I planned ahead" likely was misfitting due to the initiation required to plan ahead and because of the relationship between lack of initiation/motivation, neurological issues, and fatigue. Specifically, brain connectivity can be impacted following mTBI and can be associated with perceived effort and fatigue (Ramage et al., 2019) suggesting potential overlap between the Negative Affect and Fatigue and Social and Executive Function subscales for this item. “I took unnecessary risks” also was likely misfitting and may measure other factors in addition to Risk Behaviors in our current sample as this item could overlap with social pressures (Reniers et al., 2016) or mood-related symptoms (Waller et al., 2006). Although the average subscale measure and standard error did not improve upon removal, we chose to retain the item “I fit in with my friends” because the current sample generally endorsed very mild symptoms and we would like to see if this item performs similarly in a sample consisting of larger subgroups of mTBI due to other mechanisms of injury.

In the current study, there was potential unmodeled noise (i.e., items in subscales overlapping with items in other subscales) represented by many participants displaying fit values over the threshold of 2.0. The BAST-A subscales have been shown to be unidimensional in previous research (Juengst et al., 2020) and weakly correlated (r=-.278 to .219) with each other, indicative of a multidimensional total scale. Although the Risk Behaviors subscale demonstrated inadequate psychometric properties in this sample, endorsement of these items is still clinically relevant, as some of these items ask about illegal and/or harmful activities for an adolescent. Moreover, assessing these adolescents at a single time point may also be contributing to unmodeled noise, as prior research shows significant variability in individual self-reports across time points in stroke and TBI research (Juengst et al., 2019; Juengst et al., 2021; Terhorst et al., 2018). Because of these findings, the BAST-A may be best used as a screening tool across multiple time points to provide clinical monitoring. Additionally, the BAST-A could be used in conjunction with other commonly used concussion measures to aid clinicians in assessing persistent functional challenges for these adolescents.

Limitations

While the current study was able to provide further validation for a measure of self-reported functioning in adolescents, there were some limitations in the research. One limitation of the study was that our sample consisted of mostly athletes. Some research suggests that athletes particularly may underreport symptoms if symptom report is related to return to play (McDonald et al., 2016; Meier et al., 2015). Conversely, other research suggests that athletes are less likely to experience persistent symptoms compared to children, adolescents, and young adults that sustain a mTBI due to other mechanism (motor vehicle accident) (Tarkenton et al., 2021). These findings suggest either that athletes recover quickly compared to other adolescents that sustain a mTBI due to another mechanism of injury or that athletes may underreport symptoms compared to adolescents that experience other types of mTBI. As our sample was mostly sports-related concussion (74.1%), findings may not be generalizable to the experience of those that sustained a mTBI due to other mechanisms such as fall, assault, motor vehicle collision, etc. Another limitation of the study was that we did not have immediate post-injury BAST-A measures for this group of adolescents and could not compare symptoms directly post-injury to those 3 months after injury. In addition, we do not currently know what the base rates are regarding symptoms in adolescents who have not sustained a mTBI. As such, these findings cannot be compared to rates in the general population.

Future Directions

Due to some psychometric limitations of the study, future work could focus on acquiring a large sample of adolescents with multiple mechanisms of injury to assess the psychometric properties of the BAST-A in mTBI. Conversely, future research into the psychometric properties of the BAST-A could assess the full spectrum of TBI similar to our recent work in adults (Juengst et al., 2021). The BAST-A has also been translated for Spanish-speakers and future work should assess the Spanish version using Rasch analysis. Future studies could also assess differences in adolescents' symptom reports based on mechanism of injury. Prior work suggests that there may be differences in symptom reports between athletes and those that sustained an injury due to motor vehicle collision, with athletes reporting fewer post-concussion and emotional/behavioral symptoms (Tarkenton et al., 2021; Wright et al., 2020). In future iterations of this research, we will also be able to use differential item functioning to potentially analyze differences in response by sex, ethnicity, and injury mechanisms to better understand the tool's clinical utility and appropriateness for certain populations.

Table 1 Participant Characteristics (n=107)

	Mean (Range)
Age	14.33 (12-17)
Time Since Injury	7.70 days (0-30 days)
	N (%)
Gender (Female)	63 (54.3)
Race (White)	94 (81.0)
Education	
5th-7th	41(35.4)
8th-12th	73 (63.0)
Missing	2 (1.8)
Mechanism	
Sports-Related	86 (74.1)
Motor Vehicle Accident	4 (3.4)
Hit	13 (11.2)
Fall	11 (9.5)
Assault	2 (1.7)
Sports Injuries	
Football	24(27.3)
Wrestling	1(1.1)
Basketball	9(10.2)
Volleyball	3(3.4)
Soccer	15(17.0)
Softball	1(1.1)
Lacrosse	2(2.3)
Cheerleading	6(6.8)
Ice Hockey	2(2.3)
Gymnastics	1(1.1)
Ice Skating	1(1.1)
Roller Skating/Skateboarding	2(2.3)
Other	1(1.1)
BAST-A Subscales	**Mean (SD), Range**
Negative Affect and Fatigue	2.17 (0.82), 1.03-4.32
Executive and Social Function	2.40 (0.67), 1.25-4.25
Risk Behaviors	1.19 (0.29), 1.00-2.71

Table 2 Item fit statistics in order of difficulty within subscales

Subscale	Items	Measure across categories	Measure in middle category	SE	Infit MNSQ	Infit Zstd	Outfit MNSQ	Outfit Zstd
Negative Affect and Fatigue	"I felt like I did not fit in with my friends."	0.60	0.44	0.12	0.99	-0.04	1.75	2.21
	"I limited my activities because of physical fatigue."	0.53	0.48	0.12	1.61	3.17	2.87	4.00
	"I acted rudely."	0.49	0.56	0.13	0.86	-0.99	0.86	-0.92
	"I avoided social activities."	0.47	0.51	0.12	1.34	1.94	2.29	4.16
	"I did things that made me feel embarrassed."	0.45	0.41	0.12	1.57	3.40	2.16	4.22
	"I did not enjoy activities that I usually enjoy."	0.43	0.45	0.12	1.06	0.37	0.86	-0.32
	"I felt depressed or hopeless."	0.35	0.24	0.11	0.64	-2.44	0.47	-1.59
	"If something seemed too hard, I did not even try to do it."	0.28	0.27	0.12	1.08	0.61	0.93	-0.28
	"I struggled in school."	0.23	0.24	0.12	1.17	1.21	1.28	1.40

"I laughed or cried without a good reason."	0.21	0.11	0.11	1.04	0.30	0.90	-0.24
"I felt nervous."	0.18	0.22	0.12	0.71	-2.23	0.75	-1.39
"I lied or exaggerated."	0.17	0.42	0.12	1.32	1.92	1.25	1.43
"I felt lonely."	0.12	-0.01	0.11	0.82	-1.19	0.61	-1.45
"When something upset me, I had a hard time letting it go."	0.10	-0.06	0.11	1.03	0.27	0.96	-0.12
"I forgot important things."	0.07	0.02	0.11	1.07	0.52	1.01	0.10
"I needed to rest or nap to get through my day."	0.04	0.02	0.11	1.23	1.45	1.30	1.18
"I felt sad."	0.01	0.03	0.11	0.63	-3.01	0.59	-2.66
"I felt guilty about something I had said or done."	- 0.05	0.10	0.12	1.34	2.25	1.96	4.56
"I could not relax when I was upset."	-0.05	-0.10	0.11	0.83	-1.25	0.73	-1.40
"I reacted without thinking."	-0.12	-0.06	0.12	1.08	0.65	1.12	0.80

	"I felt too tired to finish tasks that required thinking."	-0.26	-0.13	0.11	0.93	-0.48	0.84	-0.83
	"I got mad easily."	-0.27	-0.30	0.11	1.00	0.07	1.05	0.36
	"I felt anxious."	-0.35	-0.34	0.10	0.89	-0.84	0.82	-0.92
	"I got frustrated easily."	-0.36	-0.39	0.11	0.94	-0.44	0.93	-0.41
	"I felt stressed."	-0.36	-0.41	0.10	0.71	-2.36	0.62	-2.00
	"Thoughts got stuck in my head and I could not stop thinking about them."	-0.37	-0.28	0.11	0.87	-0.96	0.79	-1.31
	"I had trouble sitting still."	-0.38	-0.46	0.11	1.31	2.16	1.16	0.92
	"I worried about things."	-0.44	-0.42	0.11	0.73	-2.26	0.68	-2.20
	"I had low energy."	-0.48	-0.38	0.10	0.88	-0.90	0.85	-0.89
	"I felt overwhelmed."	-0.50	-0.51	0.11	0.71	-2.38	0.66	-2.44
	"I felt tired."	-0.78	-0.71	0.11	0.90	-0.74	0.92	-0.56
Executive and Social Function	"I talked to my friends."	1.11	1.08	0.13	1.03	0.24	1.11	0.51

"I apologized when I did something wrong."	0.55	0.67	0.12	0.91	-0.55	0.81	-1.21
"I finished things that I started."	0.29	0.44	0.11	0.77	-1.65	0.77	-1.55
"I hung out with my friends."	0.22	0.21	0.10	1.30	2.06	1.27	1.68
"I followed through on my responsibilities."	0.19	0.39	0.11	0.99	0.00	1.06	0.44
"I understood how my actions made other people feel."	0.14	0.40	0.11	0.68	-2.35	0.65	-2.62
"I thought about how others were feeling."	0.10	0.30	0.11	1.12	0.85	1.13	0.90
"I was able to adapt when things did not go as planned."	-0.14	0.16	0.11	0.88	-0.88	0.86	-1.01
"I started activities on my own."	-0.36	-0.23	0.10	1.01	0.09	1.08	0.66
"I was able to pay attention to more than one thing at a time."	-0.56	-0.41	0.10	1.18	1.36	1.14	1.10
"I was organized."	-0.67	-0.51	0.10	0.84	-1.29	0.84	-1.24

	"I planned ahead."	-0.87	-0.80	0.09	1.43	3.06	1.51	3.15
Risk Behaviors	"I used tobacco."	2.11	--	1.03	0.96	0.26	0.22	-0.36
	"I used drugs for non-medical reasons."	0.52	0.52	0.47	0.48	-1.00	0.08	-1.26
	"I smoked."	0.11	0.11	0.41	0.65	-0.66	0.10	-0.67
	"I drank alcohol."	0.02	0.02	0.37	0.59	-1.03	0.34	-0.83
	"I got into trouble at school."	-0.64	-0.42	0.19	1.30	1.37	1.15	0.75
	"I took unnecessary risks."	-0.67	-0.45	0.20	1.52	2.09	1.26	1.26
	"I did things that were unsafe."	-1.44	-1.41	0.18	0.92	-0.29	0.81	-0.78

For Measure in Middle Category, Logit values were taken from the middle category (3-Sometimes). Two items: "I used tobacco" and "I did things that were unsafe" displayed an even number of categories (2 and 4, respectively). The logit for "I used tobacco" was not calculated as there was not middle category and the logit for "I did things that were unsafe" was calculated by averaging the values of the two middle categories.

Table 3 Person and item separation statistics

BAST-A Subscale	Persons				Items		
	Average Subscale Measure	SE of Measurement	Separation Index	Separation Reliability	SE of Measurement	Separation Index	Separation Reliability
Negative Affect and Fatigue	-1.06	0.28	3.48	0.92	0.12	2.84	0.89
Executive and Social Function	-0.60	0.37	1.89	0.78	0.11	4.58	0.95
Risk Behaviors	-3.38	1.34	0.00	0.00	0.42	1.86	0.78

Table 4 Ordinal to normed scale scores and percentiles conversion table

Ordinal Score	Negative Affect and Fatigue Mean: 59.06 Logit: 8.57		Executive and Social Function Mean: 57.37 Logit: 12.32	
	Normed	**Percentile**	**Normed**	**Percentile**
7	--	--	--	--
8	--	--	--	--
9	--	--	--	--
10	--	--	--	--
11	--	--	--	--
12	--	--	-5.8	0
13	--	--	9.4	0
14	--	--	18.4	0
15	--	--	23.9	1
16	--	--	27.9	2
17	--	--	31.2	4
18	--	--	33.9	6
19	--	--	36.3	7
20	--	--	38.4	10
21	--	--	40.3	16
22	--	--	42.1	21
23	--	--	43.7	27
24	--	--	45.2	35
25	--	--	46.7	40
26	--	--	48.0	43
27	--	--	49.3	47
28	--	--	50.5	53
29	--	--	51.7	58
30	--	--	52.8	62
31	11.1	0	53.9	64
32	21.3	1	55.0	68
33	27.2	3	56.0	72
34	30.5	4	57.0	73
35	32.9	6	58.0	74
36	34.7	8	59.0	79
37	36.3	9	59.9	83
38	37.5	12	60.9	86
39	38.6	14	61.8	88
40	39.6	16	62.8	90
41	40.5	17	63.7	93
42	41.3	17	64.6	94
43	42.0	18	65.6	94

44	42.7	20	66.5	95
45	43.4	21	67.5	96
46	44.0	22	68.5	98
47	44.5	25	69.5	98
48	45.1	28	70.6	98
49	45.6	29	71.7	98
50	46.1	31	72.9	98
51	46.5	33	74.2	99
52	47.0	34	75.6	100
53	47.4	35	77.1	100
54	47.8	36	78.9	100
55	48.2	37	80.9	100
56	48.6	40	83.3	100
57	49.0	43	86.4	100
58	49.4	44	90.8	100
59	49.7	46	98.4	100
60	50.1	48	112.3	100
61	50.4	49	--	--
62	50.8	50	--	--
63	51.1	51	--	--
64	51.4	52	--	--
65	51.7	53	--	--
66	52.1	55	--	--
67	52.4	57	--	--
68	52.7	58	--	--
69	52.9	59	--	--
70	53.2	61	--	--
71	53.5	62	--	--
72	53.8	63	--	--
73	54.1	65	--	--
74	54.4	65	--	--
75	54.6	66	--	--
76	54.9	67	--	--
77	55.2	68	--	--
78	55.4	69	--	--
79	55.7	70	--	--
80	55.9	71	--	--
81	56.2	72	--	--
82	56.5	73	--	--
83	56.7	73	--	--
84	57.0	74	--	--
85	57.2	75	--	--
86	57.5	76	--	--
87	57.7	77	--	--

88	57.9	79	--	--
89	58.2	79	--	--
90	58.4	79	--	--
91	58.7	79	--	--
92	58.9	79	--	--
93	59.2	80	--	--
94	59.4	81	--	--
95	59.6	81	--	--
96	59.9	81	--	--
97	60.1	83	--	--
98	60.4	85	--	--
99	60.6	86	--	--
100	60.8	87	--	--
101	61.1	87	--	--
102	61.3	88	--	--
103	61.6	88	--	--
104	61.8	89	--	--
105	62.1	90	--	--
106	62.3	90	--	--
107	62.6	90	--	--
108	62.8	92	--	--
109	63.1	93	--	--
110	63.3	94	--	--
111	63.6	94	--	--
112	63.9	94	--	--
113	64.1	95	--	--
114	64.4	95	--	--
115	64.7	95	--	--
116	64.9	95	--	--
117	65.2	95	--	--
118	65.5	95	--	--
119	65.8	95	--	--
120	66.1	96	--	--
121	66.4	98	--	--
122	66.7	98	--	--
123	67.0	98	--	--
124	67.3	98	--	--
125	67.6	99	--	--
126	68.0	99	--	--
127	68.3	99	--	--
128	68.6	99	--	--
129	69.0	99	--	--
130	69.4	99	--	--
131	69.8	99	--	--

132	70.1	99	--	--
133	70.6	99	--	--
134	71.0	99	--	--
135	71.4	100	--	--
136	71.9	100	--	--
137	72.4	100	--	--
138	72.9	100	--	--
139	73.4	100	--	--
140	74.0	100	--	--
141	74.6	100	--	--
142	75.2	100	--	--
143	75.9	100	--	--
144	76.7	100	--	--
145	77.5	100	--	--
146	78.4	100	--	--
147	79.4	100	--	--
148	80.5	100	--	--
149	81.8	100	--	--
150	83.3	100	--	--
151	85.2	100	--	--
152	87.7	100	--	--
153	91.1	100	--	--
154	97.0	100	--	--
155	107.3	100	--	--

Figure 1: Negative Affect and Fatigue: PERSON – Average Measures for Category Score

MEASURE	PERSON	MAP	NEVER	RARELY	SOMETIMES	OFTEN	VERY OFTEN
		MORE					
4		+					
4		+					
		|					
		|					Rudely
		|					
		|					
		|					Fit In
3		+					Embarrassed
		|					Let Go
		|					Forgot
		|					Struggled
		|					Give Up
		|					Reacted
		|					Physical Fatigue
		|					Avoided
		|					Nervous
		|					Sad
		|					Laugh Cry
		|					Lonely
		|					Depressed
		|					Relax
		|					Lied
		|					Guilty
		|					Mad
		|					Frustrated
		|					Still
		|					Enjoy
2		+					Worry
		|					Overwhelmed
		|					Nap
		|				Rudely	
		|					Anxious
		|					Stressed
		|					Stuck
		|				Embarrassed	Tired
		|					Cognitive

							Fatigue
		|					Energy
	X	|				Fit In	
		T|				Struggle	
		|				Give Up	
		|				Avoided	
		|				Physical Fatigue	
		|				Lied	
		|				Reacted	
		|				Nervous	
		|				Guilty	
1	X	+				Enjoy	
		|				Let Go	
		|				Forgot	
		|				Laugh Cry	
		|				Sad	
		|				Depressed	
	XXX	|				Relax	
		|				Lonely	
		|T				Mad	
		|				Nap	
		|				Worry	
		|				Frustrated	
	X	|			Rudely	Cognitive Fatigue	
		|			Avoided	Stuck	
		|				Anxious	
		|				Still	
		|				Overwhelmed	
	XXXXX	|S			Physical Fatigue	Energy	
		|			Enjoy	Stressed	
		|			Fit In		
		|			Lied		
		|			Embarrassed		
	XXX	|			Give Up	Tired	
		|			Struggled		
		|			Depressed		
		|			Nervous		
	XXXXXX	S|			Laugh Cry		
		|			Guilty		

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<tr><td>0</td><td>XX</td><td>+M</td><td></td><td></td><td>Sad</td><td></td><td></td></tr>
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		|		Frustrated			
	XXXXX	|	Fit In	Overwhelmed			
		|		Worry			
	XXXXXXX	|	Lonely				
		|	Laugh Cry				
		|	Avoided				
	X	|	Nap	Tired			
-2	XXX	+	Embarrassed				
		|	Let Go				
		|	Give Up				
	XX	S|	Nervous				
		|	Relax				
		|	Struggled				
		|	Stressed				
	X	|	Sad				
		|	Anxious				
		|	Cognitive Fatigue				
	XXXX	|	Forgot				
		|	Still				
	XX	|	Lied				
		|	Guilty				
		|	Stuck				
		|	Rudely				
		|	Mad				
	X	|	Frustrated				
		|	Energy				
		|	Worry				
-3	XXX	+	Overwhelmed				
		|	Reacted				
		|					
	X	|	Tired				
		T|					
		|					
	XX	|					
		|					
-4		+					
		|					
		|					
	XX	|					
		|					

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<tr><th rowspan="2">MEASURE</th><th rowspan="2">PERSON</th><th rowspan="2">MAP</th><th colspan="5">Figure 2: Executive and Social Function: PERSON – Average Measures for Category Score</th></tr>
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	|	Organized				
	|	Adapt				
	|					
	|					
	|					
	|					
-4	+					
	LESS	NEVER	RARELY	SOMETIMES	OFTEN	VERY OFTEN

Each "X" represents one individual. If items are higher on the y axis, then only participants with more severe symptoms are endorsing them. To the left hand of the figure under the "Person" column, individuals are represented by different symbols according to the subscale.

MEASURE	PERSON	MAP	Figure 3: Risk Behaviors: PERSON – Average Measures for Category Score				
			NEVER	RARELY	SOMETIMES	OFTEN	VERY OFTEN
		MORE					
		|					
		|					
		|					
		|					
		|					
		|					
		|		Tobacco			
		|					
		|					
-4		+					
		|					
		|					
		|					
		|					
		|					
		|					
		|					
		|T					
		|					
		|					
		|			Drugs		
		|					Risks
		|					Trouble in School
		|					
		|					
		|			Drank Alcohol		

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Each "#" represents 4 individuals and each "." represents 1 to 3 individuals. If items are higher on the y axis, then only participants with more severe symptoms are endorsing them. To the left hand of the figure under the "Person" column, individuals are represented by different symbols according to the subscale.

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CHAPTER THREE
Manuscript 2: Predictors of Persistent Neurobehavioral Symptoms in Adolescents with Mild Traumatic Brain Injury

Abstract

Objective: To determine risk factors for persistent post-concussion neurobehavioral symptoms measured by the Behavioral Assessment Screening Tool for Adolescents (BAST-A) three to four months after concussion.

Design: Cohort Study

Setting: Concussion clinic/community

Participants: Adolescents (n=107) diagnosed with a concussion.

Independent Variables: Independent variables were loss of consciousness, age at first mTBI, time since most recent concussion, previous brain injury, gender, insurance payor, presence of a previous psychiatric diagnosis, and recent life stressors.

Main Outcome Measures: The BAST-A is a 59-item neurobehavioral measure that assesses adolescent-reported symptoms related to traumatic brain injury. Subscales include Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors. The BAST-A also includes a 30-item checklist of life events in the past six months.

Results: A combination of pre-injury and injury factors was associated with continuous severity scores of the Negative Affect and Fatigue ($F (8,93) = 6.09$, $p<.001$) and the Executive and Social Function ($F (8,93) = 2.18$, $p=.036$) subscales. A combination of pre-injury and injury factors was also associated with presence (Yes/No) of Risk Behaviors [$\chi^2(8) = 18.84$, $p=.016$]. Injury and personal factors accounted for 28.7% of variance in Negative Affect and Fatigue, 8.5% in Executive and Social Function, and 22.7% in Risk Behaviors. A higher number of recent life stressors reported by the participants was significantly associated with a higher number of

symptoms for all three subscales. Girls in our sample endorsed more Negative Affect and Fatigue symptoms than boys. Adolescents with Medicaid/CHIP coverage and no insurance endorsed more Executive and Social Function symptoms compared to those with commercial insurance. Those with Medicaid/CHIP coverage and no insurance also endorsed more Risk Behaviors than those with commercial insurance.

Conclusions: Results indicated that across all three subscales, total number of recent life stressors was a significant predictor of persistent symptoms. This highlights the need for psychosocial assessment of adolescents with a mTBI and has implications for interventions.

Introduction

The prevalence of persistent symptoms (i.e., lasting beyond typical symptom resolution of 1-2 weeks) following concussion in children (including adolescents) is estimated at 20%, although studies have returned both lower and higher prevalence estimates.[1–8] Some symptoms can continue for up to a year or longer after injury.[5,6,8] Persistent symptoms can affect emotional, physical, and cognitive function, which in turn may affect academic and social development in adolescents.[3,9–11] The cause of persistent symptoms is unknown; however, research has shown that those with persistent symptoms often have more somatization and psychological challenges than those without.[12–18] The ability of providers to identify predictors of persistent symptoms in the first few weeks after an adolescent's brain injury could help to identify individuals who are at more risk for developing persistent symptoms, to aid in clinical monitoring, and to inform treatment. Unfortunately, there are several barriers to identifying those with persistent symptoms. First, research on predictors of symptoms in brain injured adolescents is inconsistent.[10,19] A systematic review noted that researchers disagreed and provided contradictory evidence for common predictors of recovery (e.g., LOC, gender, age, etc) .[19] Second, adolescents are often grouped with younger children in research.[12,20,21] This procedure assumes that they are similar to children regarding their experience of persistent symptoms and risk factors for developing persistent symptoms, which may be inappropriate. In fact, research shows that adolescents' recovery may be more comparable to that of adults. [22,23] Third, there are only a few predictive models of recovery from mTBI in children and adolescents.[6,24,25] The problems with some of the current models is that they do not include pre-injury factors or they predominantly focus on variables directly related to injury.[24,25] An exception was one model which assessed non-injury factors such as SES, mood, and family functioning. [6] Fourth, most work in predictors of recovery focuses on only a few predictors at a time. [26–28] All of these challenges have led to a lack of consensus in the field on predictors of recovery and recovery outcomes [10,19] and the lack of consensus has been a barrier to research on predictors of recovery in adolescents.

In order to better understand why some adolescents report persistent symptoms and others do not, more research is needed to characterize the complex constellation of factors that contribute to persistent symptoms. Past research has focused on some injury-related and personal factors individually, such as age and sex,[6,19,29–31] history of concussions and loss of consciousness,[29,32] premorbid psychological diagnoses,[3,6,11] family stress and family history of psychological diagnoses,[33,34] and socioeconomic status. [26,30] The current study included a combination of injury-related and personal factors to assess which factors are significant when controlling for other potential predictors of persistent symptoms.

Some studies have used modeling to predict which individuals are more likely to experience persistent symptoms based on certain risk factors. One study assessed the impact of a variety of factors on the experience of persistent symptoms in children and looked at injury-related factors, symptom reporting, and medical/family medical history.[24] The final predictive model found that only injury-related factors/symptoms, balance issues, age, sex, and speed of answering questions were significant for predicting persistent symptoms. While psychological factors were included in the model (e.g., diagnoses of anxiety, depression, and/or ADHD), many of the variables were related to injury or were based on physical or cognitive symptoms.[35] Factors that were not directly related to the injury, such as stressful life events, socioeconomic status, etc., were not included in the final model. Moreover, some studies have looked at other outcomes such as academic function, psychological function, and cognitive function and participation. [36–38] However, few studies have assessed predictors of pediatric, and specifically adolescent, recovery from concussion.

Specific Aims/Hypotheses

The aim of the current study was to determine if a combination of injury-related and personal factors were predictive of persistent Negative Affect and Fatigue, Executive and Social Function, and Risk Behavior symptoms. One of the primary hypotheses was that personal factors, including more life stressors, gender, lower socioeconomic status (represented by insurance payor) and presence of premorbid psychological diagnoses, would significantly predict more severe neurobehavioral symptoms for each subscale. The other primary hypothesis was that injury-related factors, including younger age at first TBI, history of prior head injury, and loss of consciousness, would also predict more severe neurobehavioral symptoms for each subscale. We sought to assess a combination of injury-related and personal factors in order to control for commonly used predictors and assess the relative contribution of each factor to the model.

Methods

Participants

Participants were adolescents aged 12-17 enrolled in the North Texas Concussion Registry (ConTex). ConTex recruits from multiple clinics across the Dallas-Fort Worth Metroplex, including Children's Health - Andrews and Dallas, UT Southwestern Medical Center, and Texas Scottish Rite Hospital for Children in Frisco. Participants were included in the current study if they presented within 30 days of their injury to better control for time since injury. Other inclusion criteria were: English speaking, diagnosed with a concussion upon initial clinic visit (GCS=13-15), and completed the BAST-A at 3-month follow-up between February 21, 2020 to May 10, 2021. Participants were excluded if they were diagnosed with a moderate or severe TBI, had a visual or hearing impairment, and had a spinal cord injury ASIA score of C or worse. [39]

Procedure

Adolescents participating in the study completed a standard battery of assessments at the initial clinic visit. [39] Included were questionnaires regarding medical and injury-related history and socioeconomic status. Loss of consciousness, gender, insurance payor, history of mTBI, history of a psychiatric diagnosis, time since injury, and age at first concussion were all collected in the initial clinic visit. At 3-month follow-up, participants completed the BAST-A and environmental context questions (ECQs) via an emailed link to RedCap. Data were stored securely in RedCap [40,41] and were analyzed using SPSS version 27.[42]

Measures

The main outcome measure for this study was the BAST-A, which is a 59-item emotional and behavioral measure that captures symptoms in the domains of Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors. [43] Also included in the BAST-A research were ECQs, which are assessed via a list of 30 checkboxes indicating various stressful life events within the past six months.[43] For this analysis, the total number of ECQs was used to calculate the total number of life stressors that the adolescents had experienced in the past six months. They completed the ECQs at the follow-up period three months after their injury. Scores from the BAST-A for the Negative Affect and Fatigue subscale and the Executive and Social Function subscale were normed continuous scores derived from Rasch analysis. [44] Limitations in the Risk Behaviors subscale included weak psychometric properties determined via Rasch analysis in our sample of adolescents with mTBI and a large proportion of the sample that endorsed no risk behaviors (43.0%). [44] Given the limitations in this subscale, scores were dichotomized between those endorsing no risk behaviors and those endorsing any risk behavior, rather than converted to normed continuous scores. Other measures included loss of consciousness (Y/N), prior psychiatric diagnosis (Y/N), history of prior head injury (Y/N), SES as represented by insurance payor (Medicaid/CHIP and no insurance versus commercial insurance), gender, time since most recent injury (days), and age at first concussion. Due to a small subgroup of adolescents having no insurance (n=4) the no insurance and Medicaid/CHIP groups were combined.

Analyses

Descriptive analyses were conducted to characterize the sample. We then conducted linear regressions on the Rasch-adjusted scores for the Negative Affect and Fatigue subscale and for the Executive and Social Function subscale of the BAST-A.[44] We conducted a logistic regression (any risk behaviors versus no risk behaviors) on the Risk Behaviors subscale of the BAST-A, as norms could not be extrapolated in a previous study.[44] Covariates in each regression included injury-related factors (loss of consciousness, time since injury, age at first concussion, previous head injury history) and personal factors (insurance payor, gender, prior psychiatric diagnoses, and number of ECQs).

Results

Participant Characteristics

Participants (N = 107) were adolescents aged 12-17, with a mean of 14.43 years. Mean time from injury to initial clinic visit was just over a week (7.70 days, SD=6.77), and time from injury to BAST-A completion was 3-4 months. Participants were mostly White (81%) and just over half were female (54.3%). Most of the injuries were sports-related (74.1%). Participants, on average, had their first concussion at 13.59 years of age. Of the participants included in the sample, 30.2% indicated that they had a previous concussion and only a small number reported LOC at the time of concussion (n=15, 12.9%). Regarding personal factors, most of the participants were covered by commercial insurance (82.2%), and some indicated that they had a preinjury psychiatric disorder (15.5%). Compared to the general population, rates of psychological disorders are representative because roughly 20% of adolescents have a diagnosable psychological condition. [45] The mean number of stressful life events endorsed was 1.49, and the maximum score was seven out of a possible 30. A majority of the participants (60.7%) endorsed one or more stressful life events. See **Table 1**.

We also assessed types of ECQs endorsed by participants to better determine which stressful life events were being reported more frequently. ECQs related to challenges at school were reported most often in this sample. Specifically, failing a test/project (27.1%) and problems at school (11.2%) were two of the ECQs that were most often endorsed. Additionally, ECQs related to injury were endorsed by some participants. For example, frequent headaches or pain (9.3%) and personal injury/illness (6.5%) were also reported by some of the adolescents. Other notable ECQs in this sample that were endorsed were Injury/Illness of a Family Member/Friend, Violence on a National/Global Level, Change of School, Break-Up, Racism or Discrimination, Use of Assistive/Mobile Technology, etc. See **Figure 1.**

Linear and Logistic Regressions

Linear regressions were conducted on the Negative Affect and Fatigue and Executive and Social Function subscales to assess the contribution of injury-related and personal predictors to persistent symptoms in these domains. The model for Negative Affect and Fatigue was significant ($F(8,93) = 6.09$, $p < .001$) and all factors in the model accounted for 28.7% of the variance in Negative Affect and Fatigue symptoms. The strongest relative predictors in the model were gender ($\beta_{stand} = -.314$, $p = .001$) and total ECQs ($\beta_{stand} = .414$, $p < .001$), indicating that females and those with a greater number of stressful life events reported more frequent symptoms. The model for Executive and Social Function was also significant ($F(8,93) = 2.18$, $p = .036$) and accounted for 8.5% of the variance in symptoms. The strongest relative predictors were insurance payor ($\beta_{stand} = -.269$, $p = .009$) and total ECQs ($\beta_{stand} = .234$, $p = .020$), indicating that those with Medicaid/CHIP or no insurance and those with a greater number of stressful life events reported more frequent symptoms. A binomial logistic regression was conducted on the

Risk Behaviors subscale. The model was significant [$\chi^2(8) = 18.84$, p=.016.] and accounted for 22.7% of the variance in reported risk behaviors. Individually, total number of ECQs (Exp (β)=1.64, p=.005) was significant in the model. This means that, holding all other predictors constant, we would see a 64% increase in the odds of endorsing Risk Behaviors for a one-point increase in ECQs. Insurance payor was also significant in the model (Exp (β)=.220, p=.021). This suggests that those who have Medicaid/CHIP or no insurance had a reduction of 78% in the odds of endorsing Risk Behaviors than those with commercial insurance. See **Tables 2 and 3**.

Discussion

The specific aim of the current study was to establish a combination of injury-related and personal factors that were predictive of persistent symptoms and this aim was accomplished. However, our hypotheses were not supported, as many of the injury and personal factors were not individually predictive of persistent symptoms when controlling for other factors. Only total number of recent stressful life events was predictive across all models.

Analyses revealed that the most important predictor of neurobehavioral symptoms was the number of stressful life events experienced by adolescents in the past six months. Recent stressful life events may be more associated with neurobehavioral symptoms over other personal and injury-related factors. These stressors may be influencing symptom reporting beyond or independently of the injury. For example, if these predictors were to be tested in adolescents without mTBI, we may see similar patterns, as stressful life events could impact symptoms contained in the Negative Affect and Fatigue, Executive Function, and Risk Behaviors subscales. Alternatively, the injury may interact with or influence stressful life events to contribute to neurobehavioral symptoms. Specifically, prior research indicates that stressful life events may prime individuals with mTBI to experience poor outcomes.[46] These findings are supported by other research on stress after injury and positive coping styles [47,48] and suggest the need for more research to understand the complexities of relationships between the injury and outside factors.

Beyond stressful life events, females endorsed more Negative Affect and Fatigue than males and those with Medicaid/CHIP coverage or no insurance expressed more Executive and Social Function challenges. Findings with insurance payor and executive and social function symptoms may suggest potential health disparities, as our sample with commercial insurance was mostly White (86.4%). Our sample of those with Medicaid/CHIP coverage or no insurance was much smaller (n=19). However, compared to those with commercial insurance, our sample of adolescents with Medicaid/CHIP coverage or no insurance consisted of more Black adolescents (36.8%). As insurance was our proxy for socioeconomic status, our findings could suggest a link between lower socioeconomic status and more frequent executive and social function symptoms. Regarding socioeconomic differences, there is mixed literature, with some studies indicating SES does not play a role in symptoms following concussion [26,49] and others suggesting that lower SES is associated with higher ratings of self-reported cognitive challenges.[18] While we know that systemic factors disproportionately affect ethnoracial minorities, we were unable to test this directly. This study was not designed to test why insurance payor would affect self-reported executive function and social symptoms. Given that our sample was mostly white and privately insured, testing the effects of systemic racism (such as access to insurance and other factors) on social and executive function symptoms is necessary.

We also found that those with commercial insurance reported more Risk Behaviors compared to those with Medicaid/CHIP or no insurance. Though type of insurance may indicate a number of things about an adolescent, it is often used as a proxy indicator of socioeconomic status. Research on the relationship between socioeconomic status and risk behaviors varies.[50-52] However, findings from one study indicated that adolescents of families with a higher socioeconomic status reported more substance use.[53] This is consistent with our findings, as the BAST-A Risk behaviors subscale in our study includes items about substance use (i.e., I drank, I smoked, etc.). However, our sample size for Medicaid/CHIP/no insurance was small (n=19), and adolescent risk behaviors are multi-dimensional,[54-57] so these findings should be tested more in future research.

Regarding gender, differences in symptom report could suggest that females experience more mood and fatigue related symptoms. Specifically, in adolescent sports concussion, females tend to report more mood symptoms initially than males[50,51] and adolescent females generally report more total symptoms than males.[52] Some research suggests that females report more symptoms than males because of a desire for males to conform to masculine gender roles [53,54] or changes in hormones.[51] The current study supports the need for further research on gender differences and socioeconomic differences in adolescent concussion because of findings related to gender and insurance payor.

While there is some inconsistency regarding predictors of concussion recovery[19] generally, factors such as LOC, history of concussion, and pre-injury psychiatric diagnoses have been found to predict persistent symptoms in a number of investigations. [3,6,11,29,32] However, most studies on predictors have focused on self-reported concussion symptom measures as outcomes [19,31,33] These tools measure symptoms specific to concussion and may not capture symptoms as a result of other factors (i.e., life stressors). While most of the popular concussion symptom measures do capture different symptom domains (i.e., physical, emotional, cognitive, etc.), they do not assess life stressors and may not capture symptoms related to daily functioning in adolescents (e.g., "I planned ahead" or "I hung out with my friends"). Comparatively, the BAST-A may continue to measure symptoms even after initial post-concussive symptoms have resolved. Prior work in emotional and behavioral symptoms suggests the need to assess an individual while keeping overlapping symptom domains in mind.[55] Our work in a sample of adolescents with concussion similar to the current study indicated that LOC, pre-injury psychiatric diagnoses, prior concussion, age at first concussion, and time since injury were associated with Negative Affect and Fatigue and with Executive and Social Function. [56] However, that study used averages of the 1-5 ordinal scale for the BAST-A subscales, rather than Rasch-adjusted continuous scores; it also included individuals with longer time since injury. Longer time since injury in the previous study may have been associated with persistent symptoms as adolescents were included more than 30 days post-injury. Using averages for the subscale scores may have also enabled higher scores on certain items to influence the overall average scores. The previous study also did not include ECQs and these factors were significantly predictive of persistent neurobehavioral symptoms. As such, these factors may be highly associated with ECQs and future analyses could assess the role of ECQs in relation to other injury and pre-injury factors.

The current findings add to the literature indicating that recent life stressors play an important role in concussion recovery. Previous studies in children and adolescents indicated that parental stress was predictive of post-concussive symptoms[57] and that life stressors for those with sports-related concussion were associated with persistent symptoms.[33] Our findings add to this literature by indicating that recent life stressors (including stressors associated with household/parental distress such as "a family member leaving the home" or "increase in financial stress") were associated with persistent neurobehavioral symptoms in adolescents. Moreover, prior research suggests that stress directly impacts reports of post-concussion symptom reporting in adults and that severity of symptoms was directly related to amount of stress (specifically perceived stress). [58]

The results from this study suggest the need for early holistic assessment of adolescents with concussion, including the assessment of personal and non-injury related factors, in determining who is more at risk for persistent symptoms. In future studies, exploring the relationship between pre-injury factors and persistent symptoms is also needed. Being aware of pre-injury factors in a newly-injured adolescent may assist clinicians in treating modifiable factors (i.e., mood symptoms or family support) in order to lessen the experience of persistent symptoms.

Limitations

A significant limitation of our study was our lack of a control group. As such, we were unable to compare number of stressful life events and other factors reported by our sample versus those reported by a non-brain injury adolescent sample. While some research reports base rates for psychological diagnoses [45] we did not have base rate data from other studies on psychological diagnoses or stressful life events and this was another limitation of our study. Additionally, all factors (insurance payor, LOC, age at first concussion, gender, prior psychiatric diagnoses, history of prior head injury, time since injury, and recent stressful life events) within the study accounted for a significant portion of variance for social science research (roughly 8.5-28.7% depending on the subscale).[59] However, there was still a significant amount of variance especially in Executive and Social Function that remained unaccounted for indicating that these symptoms could be due to other variables not included in the analyses. Other factors more specific to these symptoms (i.e., post-traumatic amnesia, cognitive functioning, etc.) may need to be included in future research.

We used insurance payor as a proxy for socioeconomic status and a limitation of our work is that this factor may not be directly related to SES. Composite scores that consist of multiple variables related to SES (e.g., income, insurance, education, etc.) are sometimes preferred in assessing SES, and this may be a limitation of the study.[26,60] While insurance source may not be a direct indication of socioeconomic status, research indicates that insurance payor source may be directly related to health outcomes.[61,62]

Lastly, this research relied on self-report from adolescents regarding persistent neurobehavioral symptoms and reports from both adolescents and their parents about the adolescent's concussion history and events related to their concussion. This is a limitation of our study as self-report of neurobehavioral symptoms could be affected by adolescents who purposefully do not report symptom or adolescents that sustain multiple concussions and have difficulty recalling events. One study identified many instances of past mTBI were not recalled when compared with medical records. [63] However, prior work indicates that adolescents can reliably self-report concussion history. [64] Adolescents can also accurately report their experience of their symptoms and these reports may provide additional context in treatment and management[65,66] and may lead to faster symptom resolution.

Future Directions

Future research should focus on a larger sample of adolescents with mild TBI from more diverse mechanisms of injury in order to capture any potential differences in predictors based on mechanism. Most importantly, future work should focus on the relationships between the injury, stressful life events, and persistent symptoms in adolescents with mTBI in larger and more diverse samples. Some preliminary evidence has suggested an association between types of ECQs (i.e., relationships, school, etc.) and scores on the BAST-A and measures of mood symptoms (i.e., Patient Health Questionnaire-8 and Generalized Anxiety Disorder-7).[67] Further assessment of implications of certain life stressors (i.e., school stressors or headaches/pain due to the concussion) may be warranted. For better and more direct indicators of socioeconomic status, future work could use geocoding and assess census-tract data as representations of income and SES.

Table 1 Participant Characteristics (n=107)

	Mean (Range)
Age	14.33 (12-17)
Time Since Injury	7.70 days (0-30 days)
Age at First Concussion	13.59 (4-19)
Number of ECQs	1.49 (0-7)
	N (%)
Gender (Female)	63 (54.3)
Race (White)	94 (81.0)
Education	
5^{th}-7^{th}	41(35.4)
8^{th}-12^{th}	73 (63.0)
Missing	2 (1.8)
Mechanism	
Sports-Related	86 (74.1)
Motor Vehicle Accident	4 (3.4)
Hit	13 (11.2)
Fall	11 (9.5)
Assault	2 (1.7)
Insurance Payor	
Medicaid/CHIP/No Insurance/Self-Pay	19 (17.8)
Commercial	88 (82.2)
Previous Concussion (Yes)	35 (30.2)
LOC (Yes)	15 (12.9)
Preinjury Psych (Yes)	18 (15.5)

ECQs= Environmental Context Questions. LOC= Loss of Consciousness.

Figure 1: Frequency of ECQs

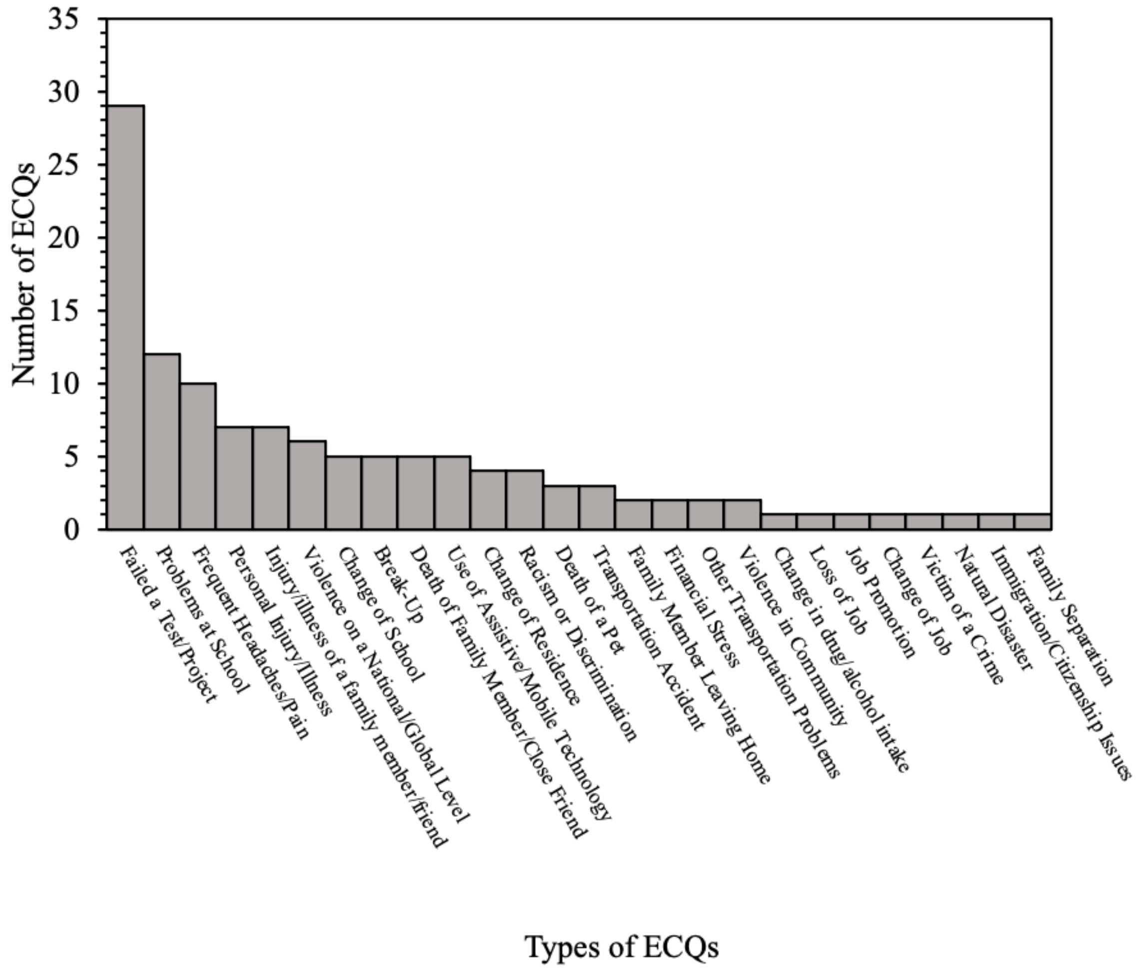

Table 2 Linear Regressions of Personal and Injury-Related Predictors for Negative Affect and Fatigue and Social and Executive Function

	Negative Affect and Fatigue				**Social and Executive Function**		
	β	β_{stand}	*P*		β	β_{stand}	*P*
Intercept	-		<.001	Intercept	-		<.001
LOC	-4.00	.140	.120	LOC	.115	.004	.969
Age at first concussion	.306	.068	.470	Age at first concussion	.072	.015	.884
Gender	**-6.37**	**-.314**	**.001**	Gender	1.03	.049	.623
Insurance Payor	-2.83	-.105	.244	Insurance Payor	**-7.53**	**-.269**	**.009**
Psychiatric Disorder	-1.15	-.043	.644	Psychiatric Disorder	3.43	.123	.241
Previous Head Injury	-.033	-.001	.987	Previous Head Injury	-.237	-.010	.922
Time Since Injury	.007	.005	.956	Time Since Injury	.036	.023	.814
Total ECQs	**2.41**	**.414**	**<.001**	Total ECQs	**1.41**	**.234**	**.020**
	R^2=.344 R^2_{Adj}=.287		**<.001**		R^2=.158 R^2_{Adj}=.085		**.036**

ECQs= Environmental Context Questions. LOC= Loss of Consciousness. LOC, Psychiatric Disorder, and Previous Concussion were all dichotomized yes/no variables. ECQs were based on the total raw score. Insurance payor was a categorical variable consisting of Medicaid/CHIP or no insurance versus commercial insurance.

Table 3 Binomial Logistic Regression of Injury-Related and Personal Predictors for Risk Behaviors

	Risk Behaviors		
	β	Exp(β)	*P*
Age at First Concussion	-.076	.926	.494
LOC (Yes)	.805	2.24	.218
Insurance (Commercial)	**-1.52**	**.220**	**.021**
Gender (Male)	-.389	.678	.401
Psychiatric Disorder (Yes)	.508	1.66	.422
Time Since injury	.032	1.03	.353
Previous Head Injury (Yes)	.604	1.83	.260
Total ECQ	**.492**	**1.64**	**.005**
Negelkerke R^2	.227		
Cox & Snell R^2	.169		
-2 Log likelihood	120.05		
No. of observations	107		
Chi-square	**18.84**		

ECQs= Environmental Context Questions. LOC= Loss of Consciousness. LOC, Psychiatric Disorder, and Previous Concussion were all dichotomized yes/no variables. ECQs were based on the total raw score. Insurance payor was a categorical variable consisting of Medicaid/CHIP or no insurance versus commercial insurance.

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CHAPTER FOUR
Conclusions

Though persistent symptoms affect a small subset of adolescents who experience a mTBI, there are more adolescents that experience persistent symptoms as rates of mTBI in adolescents are higher than most other age groups. Moreover, mTBI can affect many areas of an adolescent's daily life beyond the experience of physical symptoms as a result of the injury. Adolescence is a time in which a mTBI could potentially impact identity development through limiting an adolescent's ability to socialize, participate, and gain feelings of self-efficacy. Measures of additional life parameters beyond concussion symptoms alone are needed to adequately capture adolescents' experiences and may provide insight into why some individuals continue to experience persistent symptoms following mTBI. Additionally, identifying predictors of prolonged recovery in this population could lead to risk stratification of those more vs. less at risk for neurobehavioral problems, which might have implications for clinical monitoring for those at greater risk. Once identified, those individuals may need more follow-up visits and targeted interventions for managing symptoms (e.g., psychological intervention, academic accommodations, etc.).

The research in this dissertation adds further psychometric validation of a neurobehavioral assessment tool that captures adolescents' self-reported experiences and provides continuous normed scores for Negative Affect and Fatigue and for Executive and Social Function symptoms. Specifically, these subscales displayed unidimensionality, a wide range of item difficulty, and appropriate targeting for the Executive and Social Function subscale and targeting just over the threshold for the Negative Affect and Fatigue subscale. Rasch analysis of the Behavioral Assessment Screening Tool for Adolescents (BAST-A) also indicated multiple strata of symptom severity for Negative Affect and Fatigue and for Executive and Social Function. While some items were misfitting, we chose not to remove them until we can further analyze how the subscales performed in a sample with a full spectrum of TBI. Additionally, the misfitting symptoms likely represent overlap between subscales. However, one aim of the BAST study was to create a multidimensional tool, so overlapping subscales may not be a limitation.

In our studies, the Risk Behaviors subscale did not display appropriate targeting for the current sample and normed values could not be extrapolated. However, a large proportion of the sample (43.0%) indicated never experiencing these symptoms and as a result our sample may not be representative of all adolescents with mTBI, particularly those engaging in riskier behaviors. The research conducted in Manuscript 1: "Rasch analysis of the Behavioral Assessment Screening Tool for Adolescents (BAST-A) in mild traumatic brain injury" also highlights that although measures may meet criteria for a "good measure" using classic test theory, there are ways to improve upon the measure at the item-level and provide specific considerations for administering measures to different samples even if the samples are similar (i.e., different groups of adolescents with mTBI). Overall, this preliminary research paves the way for future work to improve the BAST-A and to assess the psychometric properties of the tool in other groups of adolescents with mTBI and those with more severe TBI.

Normed values obtained in Manuscript 1 for the Negative Affect and Fatigue and the Executive and Social Function subscales were used as outcomes for Manuscript 2: "Predictors of persistent neurobehavioral symptoms in adolescents with mild traumatic brain injury." As previously discussed, normed values could not be extrapolated from the Risk Behaviors subscale due to a lack of endorsement across severity; however, Risk Behaviors items were dichotomized to any risk behaviors versus no risk behaviors. Results from Manuscript 2 indicated that stressful life events (as measured by Environmental Context Questions) were associated with all three subscales of the BAST-A: Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors. Additionally, being female was associated with more Negative Affect and Fatigue symptoms and insurance payor was associated with Executive and Social Function problems and Risk Behaviors. The study also highlighted that regardless of associations between neurobehavioral symptom domains and individual factors, injury-related factors (LOC, previous concussion, time since injury, and age at first concussion) and personal factors (gender, insurance payor, psychiatric diagnoses, and recent life stressors) together were significantly associated with Negative Affect and Fatigue, Executive and Social Function, and Risk Behaviors.

Overall, this sample consisted mostly of athletes. As such, this research may not be generalizable to other groups with mTBI due to various mechanisms. Although by 3–4 months post-injury, concussion symptoms were mild, when present, the results did suggest that the BAST-A can capture adolescent neurobehavioral symptoms beyond traditional concussion scales. This research also suggests that pre-injury/personal factors outside of the injury may be contributing to the experience of persistent symptoms in adolescents.

CHAPTER FIVE
Suggestions for Future Research

Future directions of research include testing the BAST-A in other samples with mTBI and more severe TBI and expanding predictive modeling for self-reported symptoms. One aim of future research should be to determine why a portion of the population of adolescents with mTBI is indicating that they are not recovering from a concussion in typical fashion. First, research should focus on psychometric evaluation and validation of tools such as the BAST-A in larger, more representative samples that include individuals with different backgrounds, mTBI due to different mechanisms, and people that are experiencing persistent symptoms. In future applications of this work, we also will be assessing differences between various subgroups and how these groups experience and endorse persistent symptoms.

Future work will also be focused on adding more predictors to the model (e.g., genetic factors such as higher vs. lower levels of Brain Derived Neurotrophic Factor, psychological resilience) and narrowing down factors to only variables that are predictive of persistent symptoms in different domains (e.g., neurobehavioral functioning, emotional functioning, specific symptom reports). The goal of the research on predictors is to develop a tool that can be used by clinicians to input different risk factors and obtain probabilities for negative outcomes (e.g., the experience of persistent symptoms in different domains). With this future research, we may be able to determine who is more at risk for developing persistent symptoms in order to reduce symptom burden and severity for adolescents.

APPENDIX A

The BAST-A and Environmental Context Questions

<u>Instructions</u>: So that we can understand more about you and how you react to different situations, please carefully read and respond to the following statements. Think about how often you have experienced each statement <u>over the past two weeks</u>. Then, circle the response that corresponds to your answer.

Never Rarely Sometimes Often Very Often

	Statements	Scale
1.	I avoided social activities	**Never Rarely Sometimes Often Very Often**
2.	If something seemed too hard, I did not even try to do it.	**Never Rarely Sometimes Often Very Often**
3.	I got into trouble at school.	**Never Rarely Sometimes Often Very Often**
4.	When something upset me, I had a hard time letting it go.	**Never Rarely Sometimes Often Very Often**
5.	I could not relax when I was upset.	**Never Rarely Sometimes Often Very Often**
6.	I needed to rest or nap to get through my day.	**Never Rarely Sometimes Often Very Often**
7.	I felt like I did not fit in with my friends.	**Never Rarely Sometimes Often Very Often**
8.	I planned ahead.	**Never Rarely Sometimes Often Very Often**
9.	I ate something during the day.	**Never Rarely Sometimes Often Very Often**
10.	I got frustrated easily.	**Never Rarely Sometimes Often Very Often**

	Statements	Scale				
11.	I limited my physical activities because of fatigue.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
12.	I struggled in school.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
13.	I was able to pay attention to more than one thing at a time.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
14.	I followed through on my responsibilities.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
15.	I smoked.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
16.	I took unnecessary risks.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
17.	I finished things that I started.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
18.	I apologized when I did something wrong.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
19.	I talked to my friends.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
20.	I lied or exaggerated.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
21.	I hung out with my friends.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
22.	I acted rudely.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
23.	I thought about how others were feeling.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
	Statements	**Scale**				
24.	I did things that made me feel embarrassed.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**

25.	I used drugs for non-medical reasons.	**Never Rarely Sometimes Often Very Often**
26.	I was organized.	**Never Rarely Sometimes Often Very Often**
27.	I was able to adapt when things did not go as planned.	**Never Rarely Sometimes Often Very Often**
28.	I understood how my actions made other people feel.	**Never Rarely Sometimes Often Very Often**
29.	I used tobacco.	**Never Rarely Sometimes Often Very Often**
30.	I felt too tired to finish tasks that required thinking.	**Never Rarely Sometimes Often Very Often**
31.	I felt overwhelmed.	**Never Rarely Sometimes Often Very Often**
32.	I felt anxious.	**Never Rarely Sometimes Often Very Often**
33.	I worried about things.	**Never Rarely Sometimes Often Very Often**
34.	I had trouble sitting still.	**Never Rarely Sometimes Often Very Often**
	Statements	**Scale**
35.	I felt depressed or hopeless.	**Never Rarely Sometimes Often Very Often**
36.	I did not enjoy activities that I usually enjoy.	**Never Rarely Sometimes Often Very Often**
37.	I felt nervous.	**Never Rarely Sometimes Often Very Often**
38.	I felt tired.	**Never Rarely Sometimes Often Very Often**
39.	I had low energy.	**Never Rarely Sometimes Often Very Often**

40.	I felt guilty about something I had said or done.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
41.	I felt sad.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
42.	I got mad easily.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
43.	I laughed or cried without a good reason.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
44.	I had nightmares.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
45.	I reacted without thinking.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
46.	I felt lonely.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
47.	I thought about something I wanted to do.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
48.	I did things that were unsafe.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
49.	I forgot important things.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
50.	I started activities on my own.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
51.	I drank alcohol.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
52.	Thoughts got stuck in my head, and I could not stop thinking about them.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
53.	I felt stressed.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
If 1 = Stop Here	**If 2-5 = Continue**	STO				
54.	When I was stressed, I asked people I trust for help.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**

55.	When I was stressed, I wanted things I did not need.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
56.	When I was stressed, I took my emotions out on other people.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
57.	When I was stressed, I was unable to make decisions.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
58.	When I was stressed, I went for a walk or exercised.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**
59.	I went to sleep when I felt stressed.	**Never**	**Rarely**	**Sometimes**	**Often**	**Very Often**

Environmental Context Questions

Instructions: Please answer the following questions to give us a better understanding of the current stresses or problems you have experienced.

1. Have **you** experienced any of the following in the past 6 months? Check all that apply.
   - ☐ Change in drug/alcohol use
     If YES: ☐ Increase ☐ Decrease
   - ☐ Loss of employment
   - ☐ Promotion in employment
   - ☐ Change in occupation
   - ☐ Change in where you attend school
   - ☐ Failed a test/project
   - ☐ Problems at school
   - ☐ Change in where you were living
   - ☐ Family member leaving home
   - ☐ Break-up from a significant other
   - ☐ Increase in financial stresses

- ☐ Death of a family member or close friend
- ☐ Major personal injury/illness
- ☐ Injury/illness of family member or close friend
- ☐ Suicide of a family member or close friend
- ☐ Death of a pet
- ☐ Arrest or jail time
- ☐ Minor violations of the law
- ☐ Victim of a crime
- ☐ Transportation accident
- ☐ Other transportation problems
  If YES, please list problem: ___________________
- ☐ Natural disaster directly affecting you
- ☐ Violence in your community
- ☐ Violence on a national or global level that has caused you stress
- ☐ Repeated headaches or other pain
- ☐ Pregnancy
- ☐ Racism or other forms of social discrimination
- ☐ Fear or concern related to immigration/citizenship issues
- ☐ Family separation
- ☐ Use of assistive or mobile technology to support daily functioning
- ☐ Pregnancy
- ☐ Do you have a child/children/dependent(s)?
  If YES, have any of these occurred in the last 3 months:
    - ☐ Birth or adoption of a child
    - ☐ Change in parental rights
    - ☐ Changes in childcare situation

2. Is there anything else that has recently significantly affected you?
   - ☐ Yes
   - ☐ No

   If yes, please explain.

3. Are you being treated by a doctor, counselor, rehabilitation therapist, or other professional or do you feel you need additional support?
   - ☐ Yes
   - ☐ No

   If yes, please explain.

4. What was your greatest problem or need over the past 2 weeks?

   ____

   ____

   ____

You have reached the end of this survey.

Thank you!

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