CLINICAL PHENOTYPE OF COGNITIVE-COMMUNICATION POST- CONCUSSION FOR HIGH SCHOOL STUDENTS

by

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Dedication Page

This dissertation is dedicated to my M (Mom), my D (Dad), and my G (Gregg)- my first teachers. Without you I would not be me.

And to the girl who during her first year of college would have never believed an accomplishment like this existed for her,

look what we did.

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To Erika, Ty, and Camden (who I will someday read this dissertation to as a bedtime story).

And to my heart, Corrine.

List of Abbreviations

traumatic brain injury (TBI)

mild TBI (mTBI)

speech-language pathologists (SLPs)

post-concussion syndrome (PCS)

diagnostic and statistical manual of mental disorders, fifth edition (DSM V)

Glasgow Coma Scale (GCS)

loss of consciousness (LOC)

post-traumatic amnesia (PTA)

sports-related concussion (SRC)

motor vehicle accidents (MVA)

reticular activation system (RAS)

Parent-Reported Outcomes Measurement Information System (PROMIS)

Behavior Rating Inventory of Executive Function (BRIEF)

Child Behavior Checklist (CBCL)

Behavior Assessment System for Children (BASC)

California Verbal Learning Test (CVLT)

Test of Memory and Learning (TOMAL)

Standardized Assessment of Concussion (SAC)

Test for Attentional Performance (TAP)

Comprehensive Assessment of Spoken Language - 2 (CASL-2)

acquired brain injury (ABI)

principle investigator (PI)

integrative language theory (ILT)

The Individuals with Disabilities Education Act (IDEA)

Internal Review Board (IRB)

grade point average (GPA)

General Language Ability Index (GLAI)

Receptive Language Index (RLI)

Expressive Language Index (ELI)

Lexical/Semantic Index (LSI)

Syntactic Index (SI)

Supra-Linguistic Index (SLI)

Standardized Assessment of Concussion (SAC)

Developmental Language Disorder (DLD)

Clinical Phenotype of Cognitive-Communication Post-Concussion for High School Students

Abstract

by

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Purpose: The identification and management of pediatric concussion is a public health concern and research in this area is rapidly evolving. While the literature has identified cognitive deficits that often occur in the acute concussion recovery period, cognitive- communication deficits associated with high-school youth concussion are less well identified. The overall aim of this dissertation was to create a cognitive-communication profile for high-school aged youth within 30 days post-concussion and to identify the impact of age and number of concussions on assessment performance. **Method:** This cross-sectional design included 20 participants (11 males and 9 females), who ranged from 14-17 years of age (M=16;0). Participants completed a 2-hour assessment battery, consisting of the Comprehensive Assessment of Spoken Language (CASL-2), Behavior Rating Inventory of Executive Function-Self Report (BRIEF-2), Parent-Reported Outcomes Measurement System (PROMIS) Pediatric Cognitive Function and Pediatric Peer Relationships, and the Standardized Assessment of Concussion (SAC) of the Sport Concussion Assessment Tool (SCAT-5). Parents of participants completed the BRIEF-Parent Report, PROMIS Cognitive Function, and PROMIS Peer Relationships. **Results:** Participants scored in clinically significant range on the SAC of the SCAT-5 including: delayed recall (59% accuracy), immediate recall (64.8% accuracy), concentration (68% accuracy), and total score (66.5% accuracy). No clinically significant areas were identified on the CASL-2, BRIEF-Self Report, BRIEF-Parent Report, or the PROMIS measures; however, subtests with discrepant performance were found in pragmatic language, grammaticality judgement, and syntactic index score on the CASL-2 and working memory on the BRIEF-Self. Age and number of concussions significantly contributed to the models of pragmatics (p=<0.05), delayed recall (p=0.004), immediate recall (p=0.033), and concentration (p=0.02). Coefficient analysis revealed significant relationships between age and sentence expression (p=0.032) and syntactic index (0.043), and number of concussions with delayed recall (p=0.001), immediate recall (p=0.01), orientation (p=0.037) and concentration (p=0.006).

Conclusion: This study identified the following that could be considered for a cognitive- communication profile: deficits in working memory, attention, pragmatic language, and syntax in high-school aged youth within 30 days post-concussion. This population is at risk for decreased academic and social success following a concussion and these results provide insight into academic needs and the direction of concussion assessment research.

Key words: Brain injury, concussion, cognitive-communication, speech therapy, pediatric.

INTRODUCTION

Traumatic brain injury (TBI) is the leading cause of death and disability for children and adolescents in the United States (CDC, 2010). According to the Centers for Disease Control and Prevention (2010), it is estimated that children have the highest incidence of mTBI (mild TBI) in the United States (Guerrero & Sniezek, 2000). Approximately 145,000 children and adolescents are estimated to be living with long- lasting limitations in social, behavioral, physical, and cognitive domains following a TBI (Zaloshnja, et al., 2008). Such epidemiological reports are believed to grossly underestimate the true incidence of concussion. Underestimated TBI incidence can be attributed to symptoms of concussion going unidentified and thus remaining uncounted (Meehan & Bachur, 2009).

While most research focuses on moderate and severe TBI, the media has placed increased emphasis on complications following mild TBI, also known as concussion, in children. This increased awareness has been accompanied by an influx of concussion management research in high-school youth, which is rapidly evolving (Zamarripa, et al., 2017; Davis et al., 2017, Taylor et al., 2018).

Emerging research has indicated that 10-20% of mild brain injuries result in persistent impairments that negatively impact academic and social outcomes (CDC, 2018). Longitudinal research has shown that some effects of a concussion may emerge later in a child's development (Ewing-Cobbs et al., 2004; Gerrard-Morris et al., 2010). This latent presentation may be associated with academic failure, chronic behavior problems, and social isolation that occur over time for high-school aged youth (Williams, et al., 2010).

Classification of TBI

Classification of Severity

Accurate classification of TBI severity can assist a clinician with acute management, avoiding misclassification, and predicting outcomes (Saatman, et al., 2008). TBI severity is characterized as mild, moderate, or severe. The gold-standard of severity classification is using the Glasgow Coma Scale (GCS) at the scene of the injury, during medical transport, or at in the emergency department. The GCS is a practical method of assessing the ocular response, verbal response, and motor response of an individual with a TBI.

In addition to the GCS, distinctions in TBI severity can be determined by duration of loss of consciousness (LOC), alteration of consciousness, length of post-traumatic amnesia (PTA), longer duration of hospitalization, and presence of cognitive deficits (CDC, 2010). Table 1 illustrates the criteria for the classification of TBI severity.

Table 1

TBI Severity

	GCS Score	**Duration of LOC**	**Duration of PTA**
Mild	13-15	0-30 minutes	Not greater than 24 hours
Moderate	9-12	>30 minutes <24 hours	>24 hours <7 days

Severe	3-8	>24 hours	> 7 days

Note.
GCS= Glasgow Coma Scale, LOC = Loss of Consciousness, PTA = Post- Traumatic Amnesia. Adapted from Friedland & Hutchinson (2013).

Mild TBI specifically can be further subcategorized as “complicated” or “uncomplicated”, which is determined by presence or absence of intracranial abnormality such as contusion, hemotoma, or edema (McCrory et al., 2005; Williams, Levin, and Eisenberg, 1990). A complicated mTBI is characterized by mild severity criteria (GCS: 13-15; duration of LOC: 0-30 minutes; duration of PTA: not greater than 24 hours) plus visible intracranial abnormality or depressed skull fracture (Iverson & Lange, 2011).

With the addition of visible anatomical changes complicated mTBI is considered more severe than uncomplicated mTBI and is associated with a higher likelihood of ongoing cognitive symptoms six months post-injury. For this reason, recovery trajectory of complicated mTBI more closely mirrors moderate TBI rather than uncomplicated mild TBI (Williams, Levin, and Eisenberg, 1990).

Classification by Injury Mechanism

According to the CDC (2018) Report to Congress regarding TBI in children, the cause or mechanism of TBI is an important consideration. In recent years the pediatric concussion literature has placed emphasis on sports-related concussion (SRC) which has resulted in specific prevention efforts and return-to-play policies for athletes (Halstead et al., 2013). However, as reviewed in the CDC (2018) report, concussions in children is not isolated to sport but often occurs during non-sports-related activities, as children are often injured during age-appropriate play and hobbies. The mechanisms of injury also vary by age. Additionally, mechanism of injury in concussion for children under the age of four years old are mostly due to falls or non-accidental trauma (CDC, 2010). In individuals between the ages of 15-24, brain injuries are most often caused by motor vehicle accidents (MVA), being struck by an object or against objects, and assaults.

Definition of Concussion

A consensus definition of concussion was reached at the Fourth International Conference on Concussion in Sport in Zurich (2008). This consensus statement defined concussion as, "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (McCrory et al., 2009, p.256; Harmon et al., 2013).

Biomechanical forces include acceleration and deceleration movements of the brain and skull. When a blow to the head occurs, the cranium suddenly accelerates and strikes the stationary brain (acceleration). Once the rapidly moving cranium stops, the brain continues to move and contacts the skull (deceleration). The consensus definition also indicated that:

1. Concussion may be caused by direct blow to the head, face, neck, or elsewhere on the body with an 'impulsive' force to the head.
2. Concussion typically results in rapid onset of short-lived neurological impairments that resolve spontaneously.
3. Concussion may result in neuropathological changes, but the acute

clinical symptoms largely reflect a functional disturbance rather than a structural injury; therefore, no abnormality is seen on standard neuroimaging studies.

4. Concussion results in a graded set of clinical symptoms that may involve a loss of consciousness. Resolution of clinical and cognitive symptoms typically follows a sequential course; however, in a small percentage of cases, post-concussion symptoms may be prolonged.

In a study of children admitted to the emergency room for emergency medical care for a brain injury, 85% of incidences were diagnosed within the mTBI category (Rivara et al., 2011). Most children with mTBI experience full spontaneous recovery of symptoms within 4-6 weeks; however, approximately 10-20% of children experience post-concussive syndrome (Langlois et al., 2006). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V; DSM-V, 2013) criteria includes concussion under the Neurocognitive Disorders, Major or Minor Neurocognitive Disorders due to Traumatic Brain Injury with symptom resolution within three months. For the individual with persistent symptoms after that period, a label of post-concussion syndrome (PCS) is often provided. Based on various factors including length of recovery trajectory, presentation of neuropathological (e.g., cerebral anemia) and cognitive deficits in concussion may differ. The describe these deficits, numerous theories have been developed.

Theoretical Framework

Neuropathophysiology

Several theories have been posited that attempt to explain the neuropathophysiology of concussion (Shaw, 2002), but an empirical consensus has yet to be established (Meehan & Bachur, 2009). Historically, the vascular hypothesis has attempted to describe the nature of concussion (Symonds, 1962; Denny Brown & Russell 1941). The precise neural mechanisms involved in the vascular hypothesis remains uncertain but the hypothesis is rooted in the concept that a brief ischemic event is triggered, in this case a concussion, and is often referred to as cerebral anemia (Trotter, 1924; Denny-Brown and Russell, 1941; Walker et al., 1944; Nilsson et al., 1990). It is hypothesized that the effects cerebral anemia begins at the superficial cortical structures in mild concussion and extends inward to diencephalic-mesencephalic structures with more severe concussion (Ommaya & Gennarelli, 1974).

More recently, in a review of concussion neurophysiology, Bigler (2007) specifically attributed vasospasm, vasoconstriction, and potential vasoparalysis of the internal carotid across the internal canal as the mechanism of cerebral anemia. Chesnut and colleagues (2012) identified a momentary rise in intracranial pressure, which is often associated with cranial deformation, as the triggering event of vasoparalysis. Although vasoparalysis can result in unconsciousness, the vascular hypothesis does not explain other symptoms associated with concussion, such as post-traumatic amnesia.

Furthermore, in a study of induced neurotrauma in rats, Nilsson and colleagues (1990) identified the presence of receptor-mediated events in extracellular fluid during focal ischemia. Specifically, a transient, profound increase in taurine, glutamate, aspartate and aminobutyric acid resulted. These results expand upon the vascular hypothesis because they indicate the presence of receptor-mediators as potential contributing factors to neural tissue disturbance, rather than solely loss of blood flow.

A more agreed upon theory for the pathophysiology of concussion is the reticular hypothesis (Plum & Posner, 1980; Levin et al., 1982; Adams et al., 1997). According to the reticular hypothesis, symptoms following a concussion (e.g., loss of consciousness, tremors, delayed processing time) are a result of the same processes that produce coma (Foltz & Schimdt, 1956): transient paralysis of the brainstem ascending reticular activation system (RAS). Plum and Posner (1980) demonstrated focal lesions, alterations in neuronal structure, and axonal degeneration within the reticular substance following concussion. Alterations in neural integrity at the level of the reticular activation system can be attributed to the acceleration and deceleration forces at the axis of the brainstem (Mendez, et al., 2015).

Although the reticular hypothesis attempts to incorporate axonal injury at the logical location of greatest acceleration/deceleration impact (brainstem), much like the vestibular hypothesis, it failed to describe the impact of the injury for cortical structures. Without inclusion of cortical structures, deficits such as impulsivity and emotional outbursts (frontal lobe) are less understood. Furthermore, the reticular hypothesis places sole emphasis on brainstem lesion, oversimplifying concussion symptomatology and neuropatholophysiology.

The centripetal hypothesis, proposed by Ommaya & Gennarelli (1974) emphasizes the presence of both cortical and subcortical neuropathophysiological deficit in concussion. Specifically, the centripetal hypothesis is stated as follows, “Concussive brain injuries include the phenomena of cerebral concussion and constitute a graded set of clinical syndromes following head injury wherein increasing severity of disturbance in level and content of consciousness is caused by mechanically induced strains affecting the brain in a centripetal sequence of function and structure” (Ommaya & Gennarelli, 1974, p. 639). It is theorized that these effects are the result of rotational components of trauma that begin at the surface of brain and extends inward to subcortical diencephalic- mesencephalic structures in relation to severity of injury. Less severe concussions correlate to superficial structural and functional involvement, whereas deep structures are associated with coma-producing levels of trauma. Arguably the most important tenant of the centripetal hypothesis is that damage to the brainstem does not occur in isolation but is related to diffuse superficial neuronal damage (Sahuquillo and Poca, 2002). This is noteworthy because white matter (axons of neurons) are highly susceptible to suffer shearing damage from tissue deformation during concussion (Smith, 2016) and diffuse neuronal damage results in heterogeneous cognitive deficit presentation.

The Ommaya & Gennarelli centripetal hypothesis paper is the third most cited paper on concussion since 1974, which is indicative of its impact on the concussion literature (Gennarelli, 2015); however, it is not without limitation A flaw of the centripetal hypothesis is that primary brainstem injury can never exist in isolation, without the presence of peripheral damage (Shaw, 2002). A review of the theoretical and clinical concussion data (Symonds, 1962) indicated that concussion should include cases of varying symptoms, duration, and mechanism, making it difficult for a single model to encompass the complexity of concussion symptomatology and neuropathophysiology. Although a single neurophysiologic hypothesis has yet to be connected to the behavioral manifestations of concussion, in the centripetal hypothesis, it would be expected that cognitive, language, and communication symptoms would be present.

Cognitive Deficits

It is important to note that although similar in neuroanatomical structure, it would not be appropriate to generalize mechanisms of an adult concussion to that of a child (Davis et al., 2017). Researchers once believed that children were protected from the effects of concussion, compared to adults because of the plasticity of the developing brain (McKeever & Schatz, 2003; Webbe & Barth, 2003); however, this theory has been questioned due to a variety of developmental factors including incomplete myelination, hypotonic neck musculature, and elasticity of the skull (Karlin, 2011). These differences put children at risk for increased shearing of neuronal tissue and thus, diffuse injury. For this reason, concussion in a developing brain, results in unique deficits that require specialized treatment protocols. Attention must be placed on the recovery of lost skills (rehabilitation) in addition to continued cognitive development (habilitation) (Haarbauer- Krupa et al., 2016).

In the cognitive domain, immediately following a concussion, a child may experience fogginess, decreased processing time, difficulty with sustained attention, increased forgetfulness, and inability to multitask (Katz et al., 2015). In addition, Iverson and colleagues (2006) observed problems with learning and memory of new information immediately following all severities brain injury. It is also theorized that in comparison to children, adults who sustain concussions are better able to compensate for the challenge of acquiring new information (Russo et al., 2007). This may be due to the fact that children have less foundational knowledge to build upon. Evidence supports that disruption in cognitive development from concussion places children at higher risk for decreased quality of life and participation in school, social, and extracurricular activities (Karlin, 2011).

After TBI, deficits in executive function, memory and attention are often noted. Executive function is the most documented deficit area in children following a traumatic brain injury (Beers, 1992; Binder, 1986; Donders, 1993; Levin et al., 1988).

Executive functions refer to the collection of related yet distinct abilities that provide for intentional, goal-directed, problem-solving action (Gioa & Isquith, 2004; Anderson, 1998; Barkley, 2000). Proficient executive functions allow for an individual to mentally hold information with the intent of use for a future goal, to monitor and self-regulate behavior and to plan and organize one's self. Children with TBI demonstrate deficits of executive function in areas such as inhibition, planning, behavioral regulation, and cognitive flexibility (Levin et al., 1996; Heninger et al., 2006; Schwartz et al., 2003; Yeates et al., 2004). Specific executive function deficit presentation has been associated with a lack of integrity to the frontal and anterior temporal lobes of the brain, particularly vulnerable areas related to traumatic brain injury (Levin et al., 1993; Anderson et al., 2006). Damage to the prefrontal cortex of the frontal lobe is known to result in deficits of executive function such as planning, cognitive flexibility, behavioral inhibition, and poor organization (Keenan et al., 2018; Ylvisaker, Szekeres, & Hartwick, 1992; Scheibel & Levin, 1997; Ylvisaker, 1998). Deficits vary by severity of injury, with the more severe brain injuries resulting in increased executive dysfunction.

In addition to executive function deficits, working memory is also impaired after TBI. Working memory is the ability to temporarily store, process, and manipulate information to respond to immediate environmental demands (Baddeley & Logie, 2006). Neuroimaging studies demonstrate a strong relationship between working memory and the frontal lobe, a particularly vulnerable area of injury for individuals with TBI (Prabhakaran et al., 2000; Courtney et al., 1997; Jonides et al., 1993). Working memory impairments can interfere with a child's ability to learn new information, remember recent events, or acquire new skills. Due to the cognitive demands of development during childhood, working memory deficits can result in major difficulties with school and home environments.

Research has demonstrated working memory deficits in children with moderate- severe TBI (Keenan et al., 2018; Farmer et al., 1999; Kinsella et al., 1997; Yeates et al., 1995), with more recent work considering working memory post-concussion with equivocal results.

Paired with executive function and memory deficits are attention deficits after TBI. Attention deficits are commonly reported deficits following TBI (Keenan et al., 2018; Max et al., 2001; Gerring et al., 2000; Herskocits et al., 1999). Attention deficits following a TBI, much like executive function and memory deficits potentially result in decreased academic achievement and social development. The current literature emphasizes approximately 15%-20% of children with moderate-severe TBI will experience attention deficits or meet attention deficit hyperactivity (ADHD) requirements of the DSM-V (Gerring et al., 2000; Herskaovits et al., 1999; Keenanet al., 2018). Many assessment studies of attention primarily use interviews; however, standardized rating scales completed by family members have also been reported (Yeates et al., 2009).

Hanten and colleagues (2007) used the Schedule for Affective Disorders and Schizophrenia for School-Age Children, Present and Lifetime Version within one month after injury then also at 6, 12, and 24 months after injury and determined 23% of participants demonstrated attention deficits across all TBI severity. Increased use and development of standardized assessment of attention with children post-concussion is necessary to determine a reliable profile of attention. Taken together, deficits across cognitive areas are connected to difficulties in communication.

To determine the cognitive-communication deficits of high-school youth following a concussion, a theoretical framework must be applied. The cognitive neuropsychological model posits that the neurological system is composed of many interrelated and interdependent divisions. Diffuse breakdown of the neurological system can occur from brain injury of all types. In contrast to cognitive neuroscience, which studies specific neural mechanisms of the brain, the field of cognitive neuropsychology studies domains of cognition and their connection to each other. For example, cognitive neuropsychologists view cognition as the basis of communication and language (Coltheart, 2008); therefore, when cognition is disrupted from brain injury, communication deficits may result. For the present study, the application of the cognitive neuropsychology model is rooted in the model's main tenet that a neurological system is composed of many interrelated segments. If a segment is disrupted by an acquired circumstance, in this case a concussion, other areas of the system will likely be impacted. The literature review rendered evidence of diffuse neurophysiological deficits, which result in altered cognition. Although the current concussion literature has yet to establish a connection between cognitive deficit post-concussion and its impact on communication, tenets of the cognitive neuropsychology indicate its existence. The present study aims to describe this relationship and determine the impact of variables on performance outcomes (e.g., age, number of concussions).

Cognitive skills of executive functioning, memory, and attention are necessary for effective communication. Deficits in these areas of cognition may result in a communication breakdown, which is referred to as a cognitive-communication disorder (ASHA, 2005). Children with a cognitive-communication disorder following a moderate- severe TBI may present with difficulties in listening, speaking, reading, and writing.

Specifically, they may demonstrate topic perseveration, difficulty shifting topics, difficulty with abstract language, and hyper-verbosity (Togher et al., 2013). Douglas (2010) determined pragmatic deficits in individuals with severe TBI, characterized by deficits in quantity, relation, and manner of language.

In pediatric concussion, cognitive-communication deficits are not well understood; however, the current literature suggest the involvement of multiple variables such as age at injury, severity of injury, family and environment, and access to healthcare (Schuchat et al., 2018). These areas warrant systematic investigation.

Cognitive-communication deficits require the assessment and treatment by an SLP. According to the American Speech Language and Hearing Association (ASHA, 2005), SLPs are the primary professional involved in assessing and treating cognitive- communication disorders across brain injury populations. There are however, practical barriers to this as there is no current profile of cognitive-communication deficits for pediatric concussion broadly and there are no age-specific profiles including for high- school youth. This problem partially exists because there are very few standardized assessments or evidence-based assessment protocols designed for this population (Schuchat, Houry, & Baldwin, 2018). Without information regarding the cognitive- communication profile for this population, development of an individualized return-to- learn plan is challenging, potentially resulting in decreased outcomes in the classroom.

Following a concussion, cognitive and cognitive-communication deficits may pose challenges in the classroom (Halstead et al., 2013). For example, difficulty concentrating can result in challenges learning new tasks and comprehending new materials, which may result in decreased academic performance. Unfortunately, because deficits from a concussion are often "invisible" and under-identified, teachers and school staff may not make appropriate academic or environmental accommodations for the student.

Moreover, too often children return to the classroom prior to receiving the essential amount of cognitive, physical, and social rest and recovery (Halstead et al., 2013). These factors collectively have potential to prolong recovery and create compounded negative impact for the student as they attempt to return to school.

Return to School (Return to Learn)

Although the empirical evidence on cognitive rest is currently limited, there has been research to support the benefits of at least initial cognitive rest in the first 24-48 hours (Moser et al., 2012). Silverberg and Iverson (2013) reviewed the evidence on complete cognitive and physical rest following a concussion. The authors indicated that the best available evidence suggests complete rest exceeding three days is likely not beneficial and gradual resumption of pre-injury activities when tolerated may be advantageous to decreasing recovery time (Silverberg & Iverson, 2013). For this reason, specific plans for returning to learn have been created to attempt to balance cognitive exertion and cognitive rest.

The following is an example "return to learn" plan, adapted from the Center for Disease Control and Prevention Guideline on Management of Mild Traumatic Brain Injury Among Children (2018) that includes slow introduction to academic activity as tolerated:

(1) The child will first concentrate on generalized cognitive skills, such as thinking and organization and focus less on academic content while symptom presentation is monitored.

(2) As concussion symptoms begin to subside, the curriculum is

expanded to introduce more challenging content.

(3) The child's schedule is adjusted to avoid fatigue. Strategies include shortened days, extra time for assignments and tests, rest breaks, and reduced course load.

(4) The child's learning environment is modified to eliminate distractions and protect the student from environmental irritations, such as loud noises.

Due to the complex nature of pediatric concussion, a multi-disciplinary team approach is recommended to maximize recovery outcomes during the return to learn process (Rocky Mountain Youth Sports Medicine Institute, 2013). A team may consist of the student, parents/guardians, peers, primary care provider, clinical psychologist, teacher, social worker, school nurse, speech-language pathologist coach, or athletic trainer. The teams' job is to implement the return to school plan and make modifications on an individual basis to limit the chance that the student will experience an increase in symptoms creating a set-back for regular classroom activity. Monitoring of symptoms, and therefore dynamic and ongoing assessment, are critical components of the return to learn process.

State of Assessment

The research literature in pediatric concussion has placed emphasis on etiology and recovery in pediatric concussion and less importance on assessment and treatment protocols. For example, in a recent systematic review of 95 articles on social communication after pediatric TBI, Ciccia and colleagues (2018) determined that an overwhelming majority of articles on etiology, characteristics, and recovery of function of communication deficits in children with concussion and less than 5% focused on assessment and treatment. This systematic review highlights the critical shortage of research in the area of assessment and treatment in pediatric TBI. Furthermore, the assessment literature that does exist has numerous methodological limitations such as including a limited representation across the TBI severity continuum, use of single domain assessment (e.g., executive function only) and lack of discussion of variables that impact performance.

Executive Function

Assessment of executive functioning is challenging and there is no single assessment of executive function; therefore, the current assessment literature stresses the importance of combining standardized performance-based assessments with functional, real-world context of executive function (Gioia & Isquith, 2004). Executive function deficits on standardized assessment may be amplified in real-world settings such as classroom and home environments due to increased cognitive skill demand. Furthermore, the ecological validity of standardized tests for executive function has been challenged by researchers because the tests are highly structured and administered with minimal distractions, which are arguably different to a child's functional environment (Heniner et al., 2006, Fletcher et al., 1990; Goldberg & Podell, 2000). In functional settings, executive function deficits are linked to poor academic performance, decreased emotional regulation, and social incompetency (Eslinger, 1998; Eslinger et al., 1997; Eslinger & Gratten, 1991; Gioia & Isquith, 2004). The Behavior Rating Inventory of Executive Function (BRIEF) was developed to systematically determine executive function deficits in children in home and school environments across eight domains: inhibit, shift, emotional control, initiate, working memory, plan, organize, and self-monitor (Gioia, et al., 2000). Other functional assessment measures of executive functioning include the Child Behavior Checklist (CBCL) (Achenbach, 1991) and Behavior Assessment System for Children (BASC) (Reynolds & Kamphaus, 1992). In a study conducted by Yeates and colleagues (2004), broad-based neuropsychological assessment was paired with the BRIEF-Parent for children approximately 4 years post-TBI and compared to peers with orthopedic injuries. Scores on the BRIEF indicated a linear trend, with most severe executive function deficits associated with children with severe TBI.

Like Yeates and colleagues (2004), Keenan and colleagues (2018) indicated that children with TBI scored more poorly on the BRIEF compared with children with orthopedic injuries. Additionally, children with mild brain injury scored worse than controls. In both studies, a single informant completed the rating scales and the child did not complete a rating scale for their perceived deficits. Reliance on parent report for executive functioning symptoms may result in an inaccurate representation of deficits due to parents not experiencing the deficits first-hand.

Memory

Levin and colleagues (2002) demonstrated chronic working memory deficits using an “N-back task” for children with severe TBI, but not those with mild TBI. However, in a longitudinal study conducted in 2004, Levin and colleagues identified working memory deficits that improved steadily overtime for children with mild and moderate-severe TBI.

Additionally, Yeates and colleagues (2004) identified a relationship between injury severity and working memory by assessing children 5-16 years of age using the children's version of the California Verbal Learning Test (CVLT). Children with mild and moderate brain injury performed as well as controls on learning trials but scored more poorly on a delayed recall task. Although there are varying results for memory impairment after childhood TBI with perhaps only a subset of children exhibiting working memory deficits post-injury (Babikian and Asarnow, 2009; McKinlay et al., 2010; Yeates and Taylor, 2005) , given the large quantity of children impacted by concussion and the resulting public health concern, deficits following concussion warrants further investigation (McKinlay et al., 2010).

Attention

Many assessment studies of attention primarily use interviews; however, standardized rating scales completed by family members have also been reported (Yeates et al., 2009). Hanten and colleagues (2007) used the Schedule for Affective Disorders and Schizophrenia for School-Age Children, Present and Lifetime Version within one month after injury then also at 6, 12, and 24 months after injury and determined 23% of participants demonstrated attention deficits across all TBI severity. Increased use and development of standardized assessment of attention with children post-concussion is necessary to determine a reliable profile of attention.

Limitations of Single Domain Assessments

Several researchers have focused their assessment protocols on a single cognitive domain assessment (e.g., Moore et al., 2015; Catale et al., 2009; Lovell et al., 2003). For example, Moore and colleagues (2015) examined cognitive flexibility, using a flanker task, in thirty-two children with histories of concussion. Although the results rendered important data on cognitive flexibility and suggested a decrease in cognitive flexibility for the concussion group, there was no information gathered about other possible areas of cognitive impairment. As another example, Catale and colleagues (2009) described the cognitive profile of fifteen children who experienced a concussion through the sole use of the Test for Attentional Performance (TAP) battery. Again, only measuring the single domain (i.e., attention) does not capture the complex nature of cognitive deficits post- concussion.

A multi-domain approach of assessment, which includes various testing batteries and assessment of multiple cognitive domains, is optimal to encompass the varying and often subtle deficits associated with pediatric concussion (Cook et al., 2011). While a single assessment domain or test battery provides valuable information for the cognitive domain addressed and most certainly contributes to the understanding of the cognitive impact of concussion, it is not enough for the creation of a comprehensive clinical profile.

Baseline and Self-Report Assessments

An important aspect of a comprehensive clinical assessment protocol are baseline and self-report assessments. Recently, the assessment of baseline neurological functioning has gained attention, particularly in sports where testing can be completed prior to the participation of a sports season (Randolph et al., 2005). The inclusion of baseline scores is believed to increase diagnostic accuracy and determine presence and extent of neurocognitive deficits by limiting pre-injury variance (Echemendia & Julian, 2001). While full baseline testing is not possible in all situations it is often limited to retrospective self-report and family-report. Self-report and family-report of both baseline cognitive function and cognitive deficits following a concussion provide information from the perspective of the child and/or family that cannot easily be rendered from traditional assessment (Maroon et al., 2000).

Researchers have attempted to address the issue of lack of baseline data through the use of control groups (Grubenhoff et al., 2010; Moore et al., 2015; Matser et al., 1999). In the concussion literature, age and gender matched individuals with orthopedic injuries most typically comprise control groups. Individuals with orthopedic injuries, similar to individuals with concussion, have been exposed to injury and have experienced comparable stressors associated with receiving medical attention; therefore, these individuals would control for the impact of injury experience on performance outcomes. However, in standardized assessment research that provides norm-referenced data, a control group may be less useful and the recruitment process may prove futile (Thomas et al., 2011; Campbell et al., 2013).

Impacting Factors

Few studies have examined the relationship between variables that are known to impact outcomes of TBI (e.g., age, number of concussions) and performance on assessment measures. Moser and colleagues (2005) determined increased cognitive deficits in high-school athletes with multiple concussions (tested 6-months following injury) compared to individuals with a single concussion within a week prior to assessment. In addition, Ashman and colleagues (2008) found that in moderate-severe TBI younger injuries have more severe outcomes compared to older individuals. Number of concussions and age, specifically in the high-school youth population with concussion are variables that require further examination to determine impact on cognitive- communication outcomes.

Summary

The current pediatric concussion literature places emphasis on etiology and recovery of pediatric concussion with less focus on assessment and creation of a clinical profile. The assessment studies that do exist are sparse, focus on moderate-severe traumatic brain injury in a wide age range of participants, and have many methodological limitations such as the use of a single domain assessment (e.g., attention) and the limited examination of multiple variables that impact performance. To date, there is no known assessment study in the pediatric concussion literature that discusses the specific performance on assessment measure of cognitive-communication skills or the relationship between cognitive-communication performance and variables that impact outcome such as age and number of concussions. Therefore, the aim of the present study was to identify a profile of cognitive-communication skills of high school students post- concussion through the use of a comprehensive multi-domain assessment battery that explores confounding variables (age and number of concussions) that may affect performance. To address this aim, the following specific research question was addressed: In high-school youth within 30 days post-concussion, what is the cognitive- communication profile, as determined by standardized and non-standardized assessments of cognition, language, and communication, and the impact age and number of concussions have on assessment performance?

Based on the literature, it was hypothesized that high-school students diagnosed with concussion would demonstrate clinically significant deficits in areas of cognition (working memory, delayed recall, and attention) and communication (pragmatics and organization). These deficits were expected to be present on both subjective and objective clinical measurements including the SAC of the SCAT-5, CASL-2, BRIEF-Self, BRIEF- Parent, and PROMIS. It was also hypothesized that age and number of concussions would be significant predictors of performance on these measures. It is specifically hypothesized that younger age and increased number of concussions will negatively impact outcome on assessment measures.

METHODOLOGY

The research question for this study was as follows:

In high-school youth within 30 days post-concussion, what is the cognitive-communication profile, as determined by standardized and non-standardized assessments of cognition, language, and communication, and the impact age and number of concussions have on assessment performance?

Participants

The participant group comprised of 20 children between the ages of 14;0 and 17;11. All participants were high-school students (grades 9-12) and sustained their concussion within 30 days at time of assessment. Participants were included in this study if they: (1) had a physician-diagnosed concussion, (2) had a date of birth between 1/1/2002 - 12/31/2005 (age 14-17 at time of injury) and (3) were less than 30-days post- concussion at time of assessment. Participants were excluded if they met any of the following criteria: (1) diagnosis of Acquired Brain Injury (ABI) as primary diagnosis, such as brain tumors, infection, hypoxia, ischemia, or substance abuse and developmental disabilities, (2) younger than age 14 or older than 17 at time of injury, (3) non-English speaking individuals, or (4) more than one-month post-injury at time of assessment.

Recruitment

Participants were recruited from University Hospital's Pediatric Sports Medicine Clinic (Ohio locations: Mentor, Solon, Medina, Westlake, North Olmsted, Beachwood) during the post-concussion follow-up appointment that generally occurred between 10-14 days post-concussion. Recruitment took place between

2/10/2019-2/01/2020.

Participants were recruited with the following procedure: (1) Physician completed chart review to determine if patient met inclusion criteria, (2) Physician contacted Principle Investigator (PI) with name of potential participant and time of upcoming appointment, (3) PI completed chart review to confirm patient meets inclusion criteria, (4) PI attended the patient's appointment and provided verbal and written education regarding study details and commitment associated with the project.

Once the potential participant and their parent/guardian was provided with education about the study, they were given the option to (1) decline participation, (2) agree to participate and schedule assessment session, or (3) request a follow-up from the PI, which was completed by phone within 5 days of initial meeting. At the time of follow-up call, the parent/guardian was given the opportunity to decline or accept participation. If participation was accepted, the date of assessment session was scheduled.

Assessing Clinician

The author of this dissertation, Alyssa Coreno, served as the assessing clinician for all participants. The author is a certified speech-language pathologist, who is a qualified professional to administer the assessment protocol.

Materials

Cognitive and communication tests were considered for the assessment protocol on the basis that they have been previously utilized in traumatic brain injury research and have been sensitive to deficits associated with TBI. It is important to note that since little assessment research has focused on cognitive-communication deficits after concussion the assessments have been used in studies with moderate-severe TBI population. Six total measures were completed, including two subjective measures for each the parent and child (Behavior Rating Inventory of Executive Function -2 and Parent-Reported Outcomes Measurement Information System) and two objective measures (Comprehensive Assessment of Spoken Language-2 and Sports Concussion Assessment Tool-5).

Specific Assessment Measures (Objective)

The CASL-2 (2016) is a comprehensive assessment of language skills in youth. The CASL-2 is based on the Integrative Language Theory (ILT), which suggests that structure of language (Lexical/Semantic, Syntactic, Supralinguistic, and Pragmatic) and processes of language (oral comprehension and oral expression) represent language proficiency (Carrow-Woodfolk, 1999). The CASL-2 is designed to measure comprehension, expression, and retrieval skills in the following six language indexes: Lexical/Semantic, Syntactic, Supralinguistic , General Language Ability, Receptive Language, and Expressive Language. The language index scales require approximately 45 minutes to complete.

The CASL-2, used for ages 3-21 years, provides age-base norms; therefore, it satisfies The Individuals with Disabilities Education Act (IDEA) (2004) requirements for identification of language impairment, a critical step in the processing for qualifying for learning support in an academic environment. The CASL-2 technical manual provides two means of evidence for reliability: internal consistency (whether items that propose to measure the same general construct produce similar scores) and test-retest reliability (stability of test scores over time). All internal consistencies of indexes range between .97-.99, indicating strong internal consistency. Additionally, test-retest reliability for indexes range from .88-.92, which is satisfactory.

Because deficits in cognitive-communication are evident across TBI populations, it is hypothesized that deficits on the CASL-2 will be identified in this sample.

The second objective measure, SCAT-5, can be completed in approximately 10- 15 minutes. The SCAT-5 is a standardized tool for evaluating concussion, which can be useful for describing post-injury characteristics. While the SCAT-5 is composed of an Immediate or On-Field Assessment and an Office or Off-Field Assessment. Specifically, the Off-Field, standardized assessment of concussion (SAC) component of the assessment was completed, which consists of orientation, immediate memory, concentration and delayed recall tests. Although the SCAT-5 is most typically used with athletes, it will be administered to all participants, regardless of mechanism of injury.

For the SCAT-5 in the present study, it is hypothesized that participants would demonstrate deficits in delayed recall and immediate recall. Due to the previously discussed connection between memory and attention (Catroppa & Anderson, 2005; Halstead, Walter, & Moffatt, 2018), attention deficits are also hypothesized to be present in this study (Concentration-SCAT-5).

Specific Assessment Measures (Subjective)

Behavior Rating Inventory of Executive Function (BRIEF, 2013) requires approximately 15 minutes to complete. The BRIEF allows for assessment of daily executive function skills in school and home environments for children and adolescents through the completion of self, parent and teacher questionnaires. For the BRIEF self- assessment, internal consistency is .96, indicating a high internal consistency. For the BRIEF teacher and parent assessments, internal consistency ranged from .80-.98, also indicating high internal consistency. Additionally, the test-retest reliability of the BRIEF self-assessment ranged between .59-.85 and BRIEF teacher and parent assessments ranged between .72-.84. The BRIEF includes the following self-assessment scales: inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, and monitor. Completion of the BRIEF by parents and teachers allow for understanding of the executive function skills of the child in functional environments.

During the return to learn process, the CDC recommends understanding the child's functional ability in the school environment (CDC, 2018). As discussed in *Procedures*, the BRIEF-Self and BRIEF-Parent were used for the present study. The BRIEF-Teacher could not be completed due to the recommendation from the Internal Review Board (IRB) to not contact teachers directly but rather requested the student to provide the information to the teacher to contact the PI. As a result, no teachers completed BRIEF- teacher.

Another set of subjective measure, the Patient-Reported Outcomes Measurement Information System (PROMIS, 2013) Pediatric Interaction with Peers and Pediatric Cognitive Function scales will be used. The PROMIS measures are self-reported measures available in a variety of clinical areas for individuals with neurological impairment between 8-17 years of age. These scales collectively required approximately 5 minutes to complete. The PROMIS is part of the standard recommended National Institute of Health (NIH) outcome measures for individuals with TBI (Keller, 2013). The social and cognitive assessments examine the child's view of his or her social relationships, interaction with peers, and cognitive ability in functional environments. Furthermore, the PROMIS results in the child analyzing his or her own skills, which will allow for an analysis of the child's awareness of deficits.

Because of potential impact for cognitive-communication deficits to be important for the return to school process, it is hypothesized that functional ratings of executive functioning (e.g., BRIEF and PROMIS-self and parent proxy measures) will identify deficits in memory, attention, and peer relationships. Table 2 summarizes the measurements used for assessment.

Table 2

Tools for Assessment.

Assessment Tool	Cognitive-Communication Skill Assessed
Comprehensive Assessment of Spoken Language (CASL-2)	Lexical/Semantic, Syntactic, Supralinguistic, and Pragmatic skills
Sport-Concussion Assessment Tool – 5th Edition (SCAT-5)	Orientation, immediate memory, concentration, delayed recall, decision making
Behavior Rating Inventory of Executive Function	Inhibit, shift, emotional control, initiate, working memory, plan/organize, organization of materials, and monitor (self-report, parent report)
Neuro QOL	Social relationships with peers and cognitive function (self-report)
PROMIS Social Clinical Assessments	Social relationships with peers and cognitive function (parent proxy report)

Procedures

Participants were provided with the choice to complete the assessment protocol in his/her home or at Case Western Reserve University in the Cognitive-Communication Laboratory of Dr. Angela Ciccia, located on the third floor of The Cleveland Hearing and Speech Center. Prior to completion of assessment materials, the participant and parent were provided with the assent and/or consent form to review and complete. Upon signing the assent and/or consent form, all measures were administered individually, in random order, to the participants during a single session lasting approximately two hours.

While the child completed the CASL-2, PROMIS Peer Interaction and PROMIS Cognitive Function, BRIEF-Self and SCAT-5 with the assessor, the parent completed the BRIEF-Parent and PROMIS Proxy Measures of Peer Interaction and Cognitive Function. Because this is not a diagnostic clinical assessment, participants were not provided with interpretation of the results. At the conclusion of the session, the participant was provided with their choice of a $15 Giant Eagle grocery store or iTunes gift card.

Data Analysis

The study used a non-experimental, explanatory, cross-sectional design that used descriptive and inferential statistics to address the primary aim. Statistical analyses were computed using JASP (2020) software package for MAC, a computer-based statistical analysis program. The assessments resulted in raw scores, standard scores, t-scores, standard deviations, percentile ranges, and age equivalence data. Table 3 provides details of the analysis for each assessment measure. Each assessment provided information regarding each participant’s performance and his/her cognitive-communication skills as compared to age-matched peers from the test standardization sample. Additionally, visualization of the data (scatterplots) was completed to determine patterns in performance.

In addition to descriptive statistics, relationships between age and number of concussions and assessment performance was examined using multiple linear regression and multiple regression. Significance was set at the level of $p < 0.05$

Table 3

Data Analysis

Assessment Tool	**Analysis Procedure**
Comprehensive Assessment of Spoken Language (CASL-2)	Raw scores, standard scores, mean, standard deviations, multi-linear regression
Sport-Concussion Assessment Tool – 5th Edition (SCAT- 5)	Raw scores, mean, standard deviations, multi-linear regression
Behavior Rating Inventory of Executive Function	Raw scores, mean, t-scores, standard deviations, multi- linear regression
PROMIS Pediatric Self Measures	Raw scores, t-scores, mean, standard deviations, multi- linear regression
PROMIS Parent Proxy Measures	Raw scores, t-scores, mean, standard deviations, multi- linear regression

RESULTS

Preliminary Analyses

Prior to conducting regression analyses, descriptive statistics were calculated for participant demographics, CASL-2 subtest measures, CASL-2 Index measures, SCAT-5 measures, PROMIS-self and PROMIS Parent Proxy, and BRIEF-self and BRIEF-parent

Participant Demographics

20 participants (11 male; 9 female) between the ages of 14;0 and 17;11 (M = 16;0; 192.30 months, SD = 13.76 months) completed the assessment protocol. Their education ranged from 9 to 11 years completed (M=9.65, SD = 2.47) and grade point average (GPA) ranged from 2.6 to 4.0 (M = 3.35, SD = 0.489). All participants sustained their concussion within 30 days at time of assessment (M = 14.6, SD = 7.89). Out of 20 participants, 85% sustained their concussion from sports, while 2/20 (10%) were due to falls and 1/20 (5%) occurred from a motor vehicle accident (MVA). Table 4 presents individual participant demographic characteristics and Table 5 provides descriptive statistics of the sample size. Additional tables can be viewed in appendix.

Table 4

Individual Participant Characteristics

	Age (Months; Years)	Gender	Current Grade	Average GPA	Days Post Injury	Mechanism of Injury	Number of Previous Concussions
P1	171 (14)	Male	9	3.2	5	Sports (Football)	0
P2	190 (16)	Female	11	4.0	19	Sports (Cross Country)	0
P3	209 (17)	Male	11	2.8	16	Sports (Diving)	2
P4	186 (15)	Male	10	3.5	10	Sports (Soccer)	3
P5	190 (15)	Female	10	3.4	6	Sports (Volleyball)	1
P6	210 (17)	Male	12	3.1	12	Fall	2
P7	207 (17)	Female	11	3.0	11	Sports (Soccer)	2
P8	170 (14)	Male	9	3.0	24	Sports (Basketball)	0
P9	192 (16)	Male	10	3.2	26	Sports (Football)	0
P10	189 (15)	Male	10	3.5	17	Sports (Football)	2
P11	194 (16)	Male	11	3.7	3	Sports (Hockey)	2
P12	183 (15)	Female	9	3.0	17	Sports (Basketball)	1
P13	186 (15)	Female	9	3.0	27	Sports (Soccer)	3
P14	206 (17)	Male	11	3.8	23	Sports (Basketball)	0

P15	210 (17)	Male	11	3.3	28	Sports (Hockey)	3
P16	207 (17)	Female	11	4.0	12	Sports (Basketball)	0
P17	183 (15)	Female	9	3.5	5	Sports (Volleyball)	1
P18	209 (17)	Female	11	3.0	14	Sports (Hockey)	2
P19	184 (15)	Female	9	2.6	6	Fall	2
P20	170 (14)	Male	9	3.0	11	MVA	0

Table 5

Description of Participant Demographics

Characteristic	Participants (N=20)
Gender:	
Female sex – no./total no. (%)	9/20 (45%)
Male sex – no./total no. (%)	11/20 (55%)
Grade:	
Ninth Grade- no./total no. (%)	7/20 (35%)
Tenth Grade- no./total no. (%)	4/20 (20%)
Eleventh Grade- no./total no. (%)	8/20 (40%)
Twelve Grade- no./total no. (%)	1/20 (5%)

Mechanism of Injury- no./total no. (%)	
Sports	17/20 (85%)
Basketball	4/17 (23.5%)
Football	3/17 (17.6%)
Soccer	3/17 (17.6%)
Volleyball	2/17 (11.8%)
Hockey	3/17 (17.6%)
Diving	1/17 (5.8%)
Cross Country	1/17 (5.8%)
Fall	2/20 (10%)
Motor Vehicle Accident	1/20 (5%)
Age - no./total no. (%)	
14	3/20 (15%)
15	7/20 (35%)
16	3/20 (15%)
17	7/20 (35%)

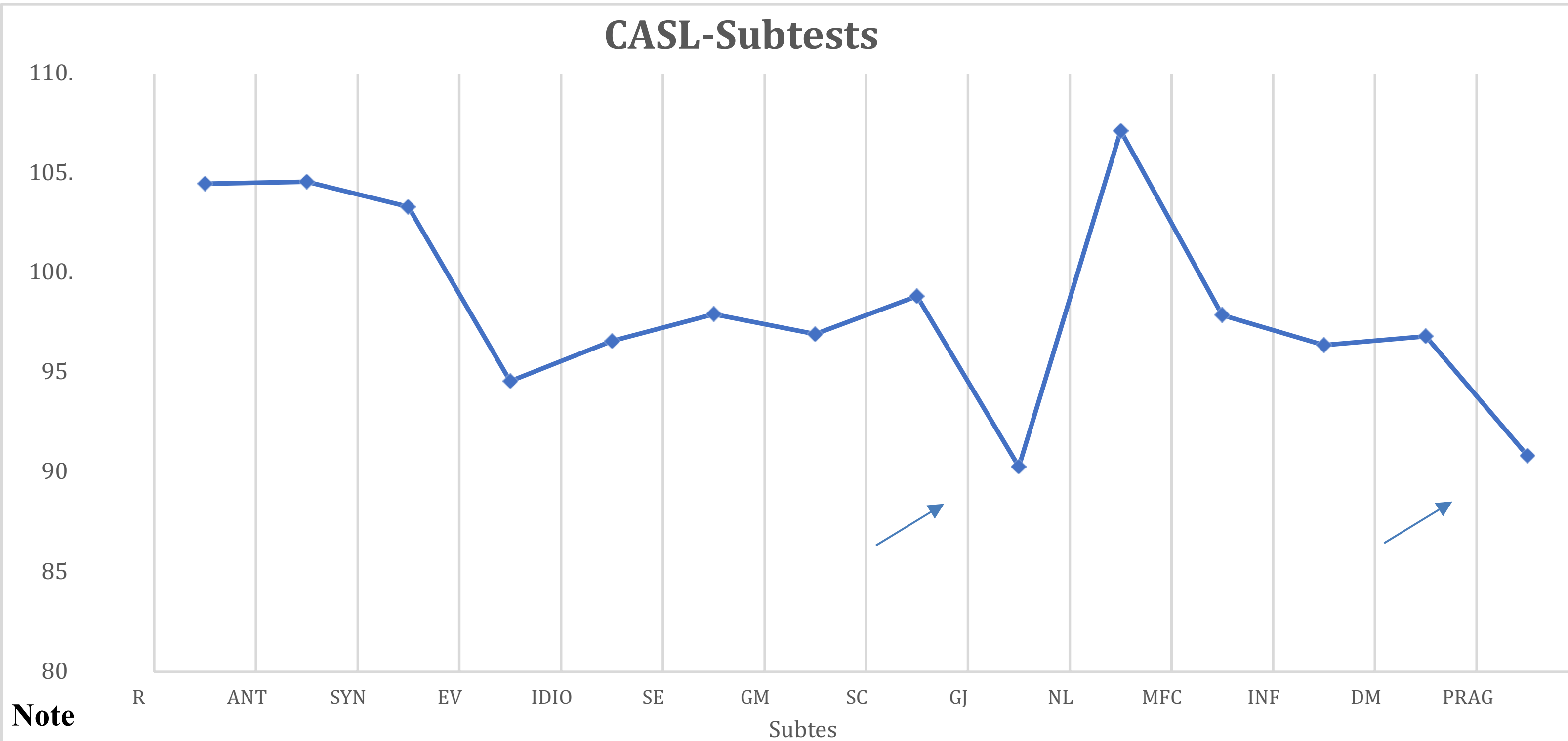
CASL-2 Subtest Descriptive Data

The CASL-2 subtest raw scores, were converted into standardized scores, reported as mean ± standard deviation with average scores occurring between 100±15. Within the normal standard deviation range, there are low average scores (85-90), which are also clinically referred to as descrepant scores. Although this range is still considered to be normal, low average scores may indicate potential areas of weakness. CASL-2 subtest results were as follows: receptive vocabulary (104.5 ± 10.78), antonyms (104.6 ± 8.82), synonyms (103.35 ± 13.43), expressive vocabulary (94.6 ± 8.3), idiomatic language (96.6 ± 9.54), sentence expression (97.95 ± 11.82), grammatical morphemes (96.95 ± 14.80), sentence comprehension

(98.85 ± 16.72), grammaticality judgement (90.300 ± 7.68), nonliteral language (107.15 ± 12.22), meaning from context (97.9 ± 12.27), inference (96.4 ± 9.2), double meaning (96.85 ± 78.0), pragmatic language (90.85± 9.64). Although the average standard scores for each of the CASL-2 subtests did not indicate clinically significant areas of deficit, Grammaticality Judgement and Pragmatic Language results indicated a discrepancy in performance. This is further visualized in Figure 2.

Figure 2

Discrepancy in CASL-Subtest Performance



Note

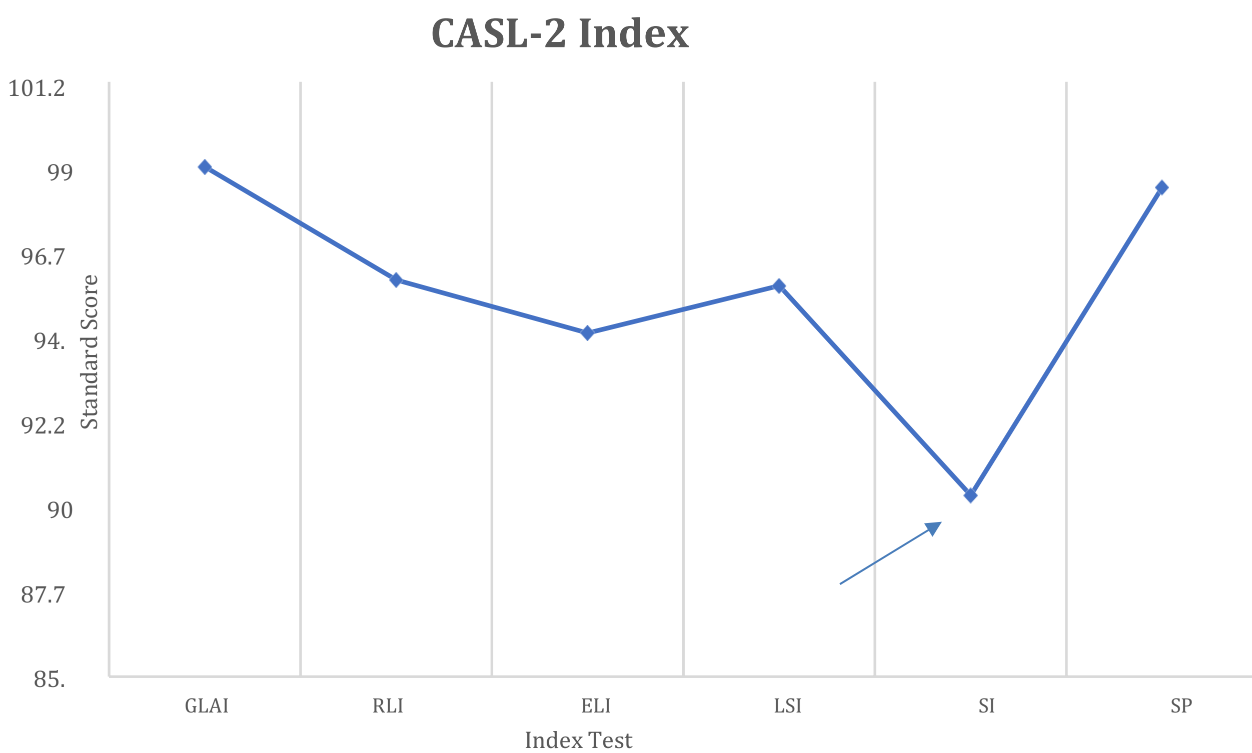
RV=Receptive Vocabulary, ANT=Antonyms, SYN=Synonyms, EV=Expressive Vocabulary, IDIO=Idiomatic Language, SE=Sentence Expression, GJ=Grammatical Morphemes, SC=Sentence Comprehension, GJ=Grammaticality Judgement, NL=Nonliteral Language, MFC=Meaning from Context, INF=Inference, DM=Double Meaning, PRAG=Pragmatics

CASL-2 Index Score Descriptive Data

In addition to subtest standard scores, indexed standard scores are available for the CASL-2. General Language Ability (GLAI) (99.0 ± 13.62) includes scores from subtests of synonyms, sentence expression, nonliteral language, meaning from context, and double meaning; Receptive Language Index (RLI) (96.0 ± 11.93) includes scores from the subtests of receptive vocabulary, synonyms, sentence comprehension, and meaning from context; Expressive Language Index (ELI) (94.6 ± 9.83) includes scores from the subtests of expressive vocabulary, sentence expression, grammatical morphemes, and inference; Lexical/Semantic Index (LSI) (95.85 ± 10.08) includes scores from the subtests of receptive vocabulary, antonyms, synonyms, and idiomatic language; Syntactic Index (SI) (90.35 ±13.91) includes performances on subtests of sentence expression, grammatical morphemes, and grammaticality judgement; and Supra-linguistic Index (SLI) (98.45 ± 9.96) includes scores from the subtests of nonliteral language, meaning from context, inference, and double meaning. Much like the CASL-2 subtests, the CASL-2 Index scores did not render clinically significant areas of deficit (standard score of <85); however, Figure 3 depicts discrepancy of performance.

Figure 3

Discrepancy in CASL-2 Index Scores Performance



Note
GLAI=General Language Ability Index, RLI=Receptive Language Index, ELI=Expressive Language Index, LSI=Lexical/Semantic Index, SI=Syntactic Index, SPI=Supra-linguistic Index

SCAT-5 Descriptive Data

Cognitive subtests of orientation, immediate recall, concentration, and delayed recall resulted in raw scores and percentage of items correct. SCAT-5 was scored out of 50 (M=33.25/50, SD=7.69), with average percentage correct of 66.5%. Participants did not demonstrate orientation deficits (M=4.6/5, SD= 0.50; 92% correct); however, areas of immediate recall (M=19.45/30, SD=5.45; 64.8% correct), concentration (M=3.4/5, SD=1.35; 68% correct), and delayed recall (M=5.95/10, SD=2.1; 59.5% correct) resulted in decreased accuracy of completion for participants (DaCosta, Roccaforte, & Webbe, 2019).

BRIEF-Self Descriptive Data

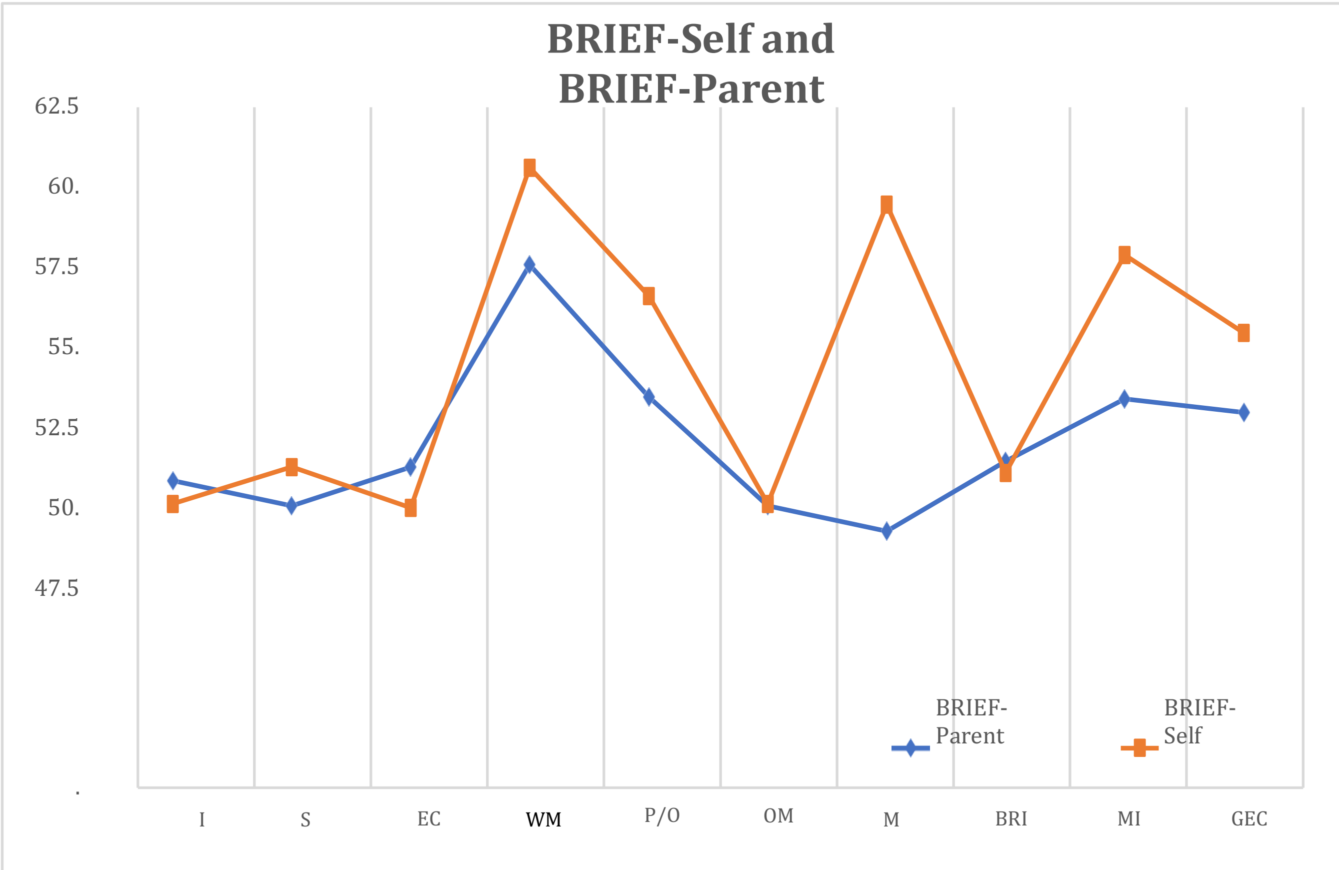
BRIEF-Self report resulted in raw scores which, were converted to t-scores, with a higher t-score representing increased reporting of difficulty in executive function. On the BRIEF, a t-score of 65 or greater is considered in the clinical range and t-scores between 60-64 are mildly elevated. The following are the results of the subdomains of executive function on the BRIEF: Inhibit (52.3 ± 11.81), Shift (53.25 ± 10.69), Emotional Control (52.2 ± 11.46), Monitor (52.55 ± 10.4), Working Memory (60.95 ± 10.97), Plan/Organize (57.65 ± 10.49), Organization of Materials (52.3 ± 11.54), Task Completion (60 ± 12.35), BRI (53.1 ± 11.07), MI (58.7 ± 11.12), GEC (56.7 ± 11.11), Behavioral Shift (50.3 ± 11.37), and Cognitive Shift (55.4 ± 8.96). While participants did not score in the clinical range, participants demonstrated discrepant scores in Working Memory and Task Completion in home and school environments.

BRIEF-Parent Descriptive Data

Like the BRIEF-Self, the BRIEF-Parent results in raw scores-which were converted to t-scores, with a higher t-score representing increased reported reporting of difficulties with executive function in the home environment. Scores from the BRIEF-Parent resulted in the following: Inhibit (53.9 ± 11.98), Shift (52.25 ± 11.79), Emotional Control (53.25 ± 12.20), Initiate (52.75 ± 12.17), Working Memory (58.45 ± 13.73), Plan/Organize (55.05 ± 13.24), Organization of Materials (52.25 ± 10.58), Monitor (51.6± 11.23), Behavioral Regulation Index (53.4 ± 12.58), Metacognitive Index (55.0 ± 13.08), General Executive Composite (54.65 ± 13.04). The BRIEF-Parent did not report executive function difficulties in the clinical range. Figure 4 represents a visualization of superimposed BRIEF-Self and BRIEF-parent results.

Figure 4

BRIEF-Self and BRIEF-Parent T-Scores



Note.
I=Initiate, S= Shift, EC=Emotional Control, WM=Working Memory, P/O=Plan/Organize, OM=Organization of Materials, M=Monitor, BRI=Behavior Regulation Index, MI=Metacognition, GEC=Global Executive Composite

PROMIS Measures Descriptive Data

Like the BRIEF-Self and BRIEF-Parent scales, the PROMIS-self and PROMIS-Parent Proxy resulted in raw scores-which were converted to t-scores. On the PROMIS Peer Interaction and Cognitive Function scales, a lower t-score indicates decreased satisfaction/parent observation of decreased satisfaction in peer relationships and/or decreased cognitive function. Clinical cutoff score for PROMIS measures are characterized by scores 35 or lower. Participant report on the Pediatric Cognitive Function PROMIS (39.4 ± 5.92) and Parent Proxy Cognitive Function (40.75 ± 8.59). Both child participants and parents reported minimal difficulties with peer interactions on Pediatric Peer Interactions PROMIS measure (49.45 ± 8.19), and Parent Proxy Peer Interactions PROMIS measure (50.9 ± 9.80).

Multiple Linear Regression Analysis

A multiple linear regression was calculated determine the contribution of age and number of concussions on the model examining standardized and functional test outcomes (individual subtests of CASL-2, CASL-2 Index scores, SCAT-5 raw scores, BRIEF-Self, BRIEF-Parent, PROMIS-self reports, and PROMIS parent proxy reports, based on age and number of concussions. individual subtests of CASL-2, CASL-2 Index scores, SCAT-5 raw scores, BRIEF- Self, BRIEF-Parent, PROMIS-self reports, and PROMIS parent proxy reports).

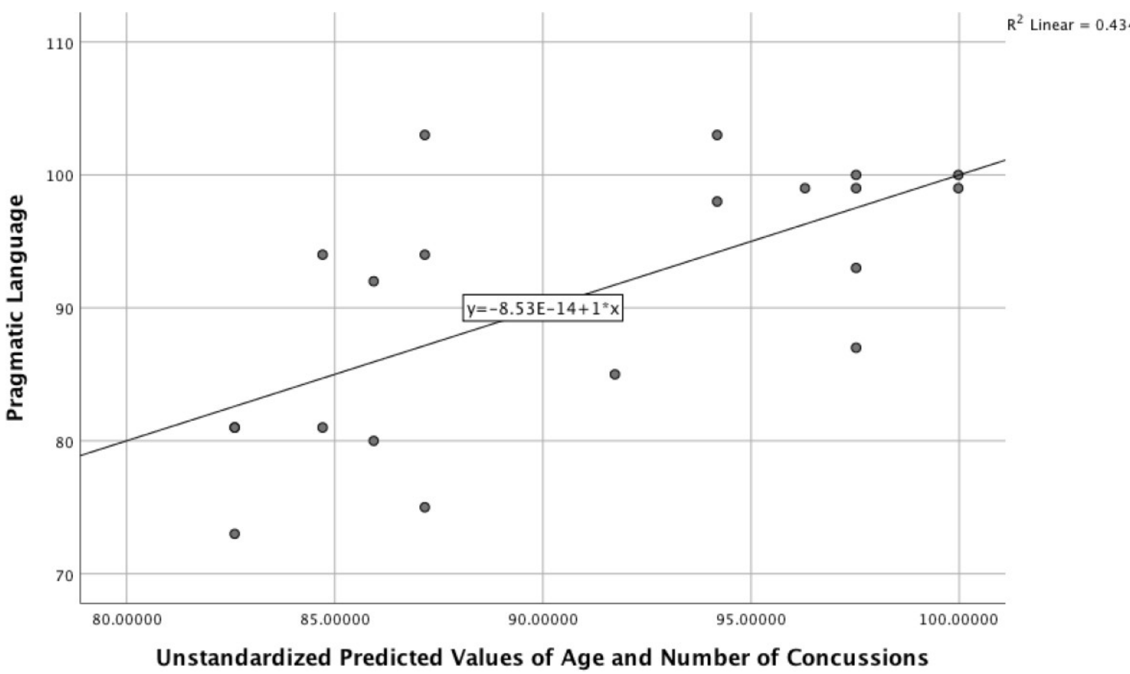
CASL-2 Subtest Regression Data

Age and number of concussions significantly contributed to the model examining pragmatic language ($R^2 = 0.434$, $F(2,17) = 6.514$, $p <0.05$). Coefficient analysis indicated a significant positive association between age and pragmatic language outcome

(B=0.678, p=.002) with younger participants scoring worse than older participants. However, there was no significant association between number of concussions and pragmatic language outcome (B=- 0.144, p=-0.764). Figure 5 depicts the scatterplot for unstandardized predicted values of age and number of concussions and the significant positive contribution to the model of pragmatic language outcomes.

Figure 5

Scatter Plot of Unstandardized Predicted Age and Number of Concussions on Pragmatic Language Outcomes



Furthermore, age and number of concussions did not significantly contribute to the model examining sentence expression, F(2,17)=2.715, p>.05; however, coefficient analysis indicated a significant positive association between age and sentence expression outcome (B=.507, p=0.032). Although participants did not demonstrate deficient sentence expression skills on this subtest, it is important to note this significant finding, as it reflects the pattern in this study that older participants scored higher on sentence expression tasks. The relationship between age and number of concussions and other subtest scores were not found to be clinically significant.

CASL-2 Index Scores Regression Data

Age and number of concussions did not significantly contribute to the model examining CASL-2 index scores; however, analysis of regression coefficients indicated a significant positive association between age and syntactic index (SI) ($B=0.502$, $p=0.043$). These results indicate that younger participants scored worse on SI than older participants. Figure 6 depicts the scatterplot for unstandardized predicted values of age and number of concussions and the significant positive contribution to the model of syntactic index outcome. Detailed results of CASL-2 Index Score multiple regression analyses is in Table 6.

Figure 6

Scatter Plot of Age and Number of Concussions on Syntactic Index Outcomes

Index Subtest	Regression Equation
General Language Ability Index (GLAI)	$F(2,17)=0.271$, $p=0.776$; $R^2=0.031$
Receptive Language Index (RLI)	$F(2,17)=0.307$, $p=0.740$; $R^2=0.035$
Expressive Language Index (ELI)	$F(2,17)=1.583$, $p=0.234$; $R^2=0.157$
Lexical/Semantic Index	$F(2,17)=0.229$, $p=0.798$; $R^2=0.026$
Syntactic Index (SI)	$F(2,17)=0.120$, $p=0.120$; $R^2=.221$

Supra-linguistic Index (SPI)	F(2,17)=1.204, p=0.324; R^2=0.124

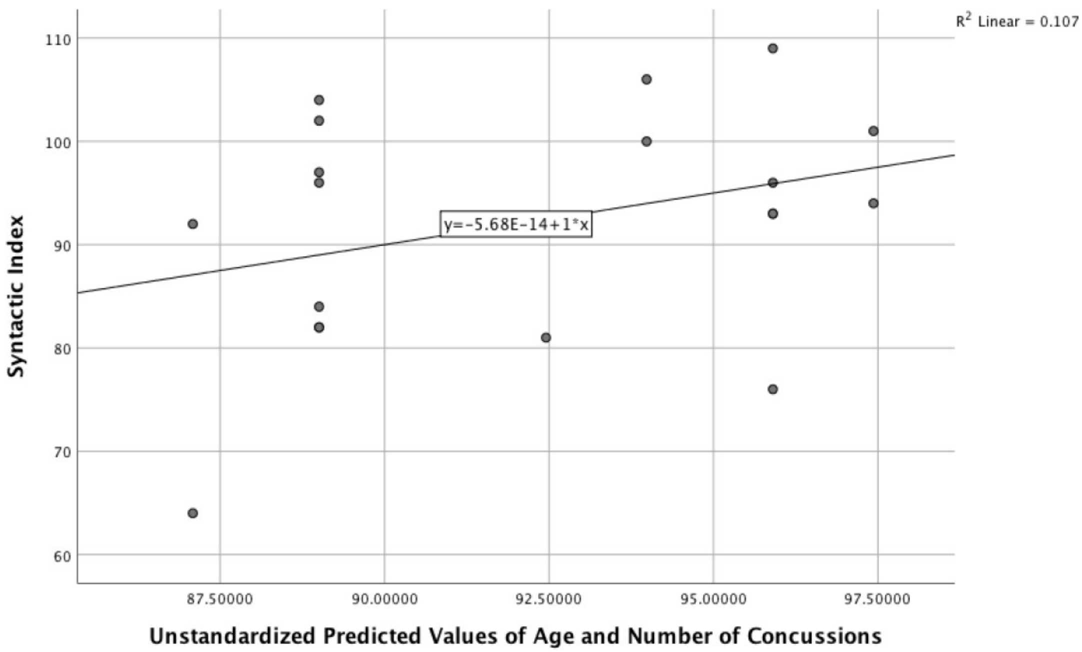


Table 6

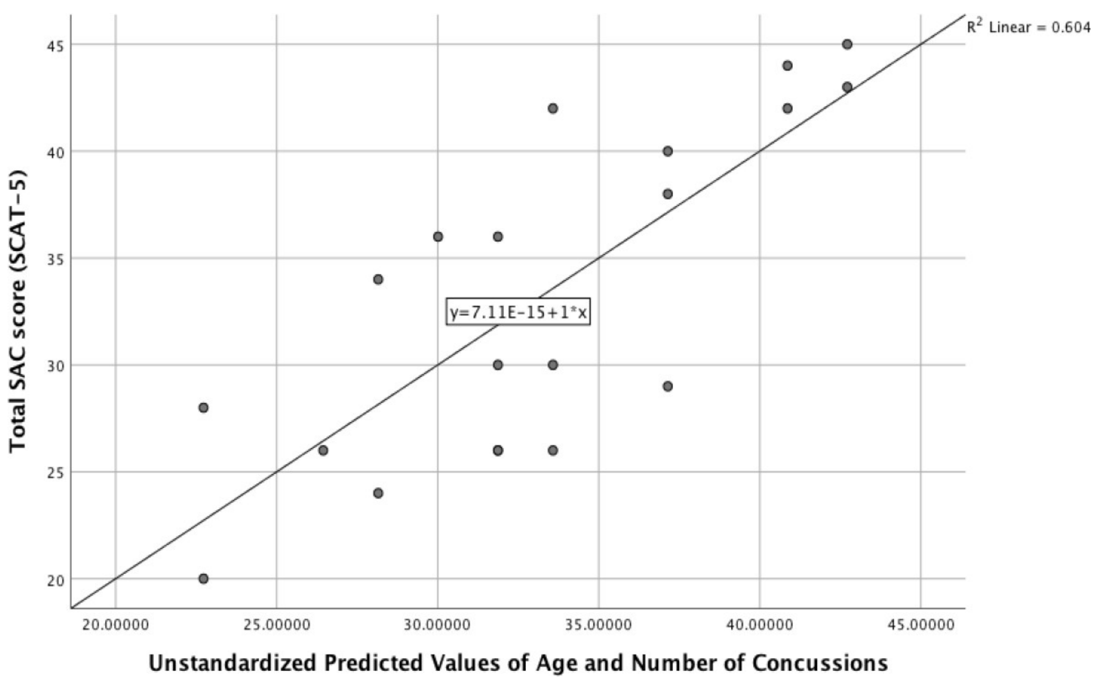
Multiple Regression Equations for CASL-2 Index Scores

SCAT-5 Regression Data

Age and number of concussions significantly contributed to the model examining total Standardized Assessment of Concussion (SAC) scores on the SCAT-5. The R^2 was 0.604, indicating 60.4% of the variance of SAC outcomes can be explained by age and number of concussions, $F(2,17) = 12.965$, $p < .001$. Coefficient analysis indicated a significant inverse association between number of previous concussions and total SCAT-5 score outcome (B=- 0.796, p=<.001). In other words, the participants with more concussion history scored worse. However, there was no significant contribution of age to the model examining total SAC scores (B=0.273, p=.101). Figure 7 depicts the scatterplot for unstandardized predicted values of age and number of concussions and the significant inverse contribution to the model of total SAC score on the SCAT-5 outcome.

Figure 7

Scatter Plot of Age and Number of Concussions on Total SAC Score Outcomes



Additionally, age and number of concussions did not significantly contribute to the model examining orientation performance outcomes; however coefficient analysis showed that number of previous concussions had an inverse relationship with orientation score (B=-0.491, p=0.037), which demonstrates that participants with more concussions score more poorly on the orientation measure.

Age and number of concussions significantly contributed to the model examining immediate recall outcomes F(2,17)=4.210, p=0.033. The R^2 was 0.331, indicating that 33.1% of the variance in the SCAT-5 immediate recall task can be explained by age and number of concussions. Coefficient analysis showed that number of concussions had an inverse relationship with immediate recall outcomes (B=-0.588, p=0.01). Age continued to not significantly contribute to the model examining immediate recall. Age and number of concussion significantly contributed to the model examining concentration F(2,17)=4.946, p=0.020. The R^2 was 0.368, indicating that 36.8% of the variance in the SCAT-5 concentration task can be explained by age and number of concussions. Coefficient analysis showed that number of concussions had an inverse relationship with concentration outcomes (B=-0.622, p=0.006).

Lastly, age and number of concussions significantly contributed to the model examining delayed recall outcomes F(2,17)=7.943, p=0.004. R^2 was 0.483, indicating that 48.3% of the variance in the delayed recall task on the SCAT-5 can be explained by age and number of concussions. Coefficient analysis showed that number of concussions had an inverse relationship with delayed recall outcomes (B=-.709, p=0.001).

BRIEF-Self Regression Data

Age and number of concussions did not significantly contribute to the model examining BRIEF-Self outcomes; however, coefficient analysis indicated number of concussions had a positive relationship with behavior shift (B=0.523, p=0.026). A similar significant positive relationship was demonstrated between previous concussions and shift (B=0.479, p=0.040), indicating increased number of concussions resulted in increased self-reporting of deficits in shift. Lastly, coefficient analysis revealed a significant inverse relationship between age and self- reporting of working memory deficits (B=-2.330, p=0.032). Figure 8 depicts the scatterplot for unstandardized predicted values of age and number of concussions and the significant positive contribution to the model of behavioral shift on the BRIEF-Self. Table 7 contains regression equations for each of the subtests of the BRIEF-Self.

Figure 8

Scatter Plot of Age and Number of Concussions on Behavior Shift of BRIEF-Self

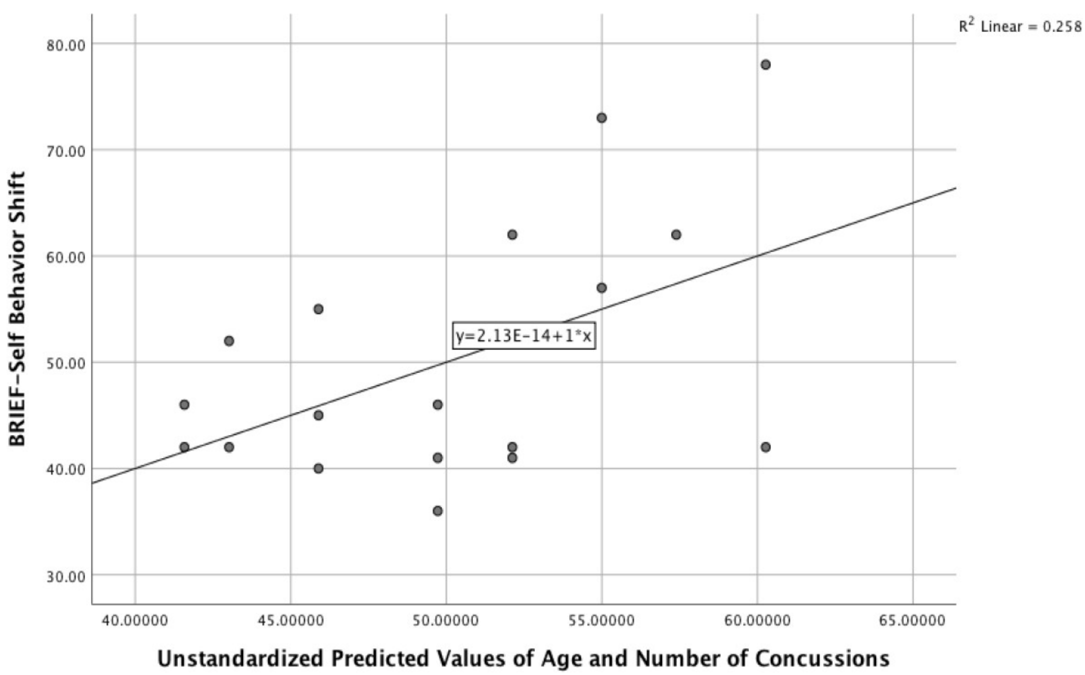


Table 7

Multiple Regression Equations for BRIEF-Self

BRIEF-Self Scale	**Regression Equation**
Plan/Organize	$F(2,17)=2.316$, $p=0.129$; $R^2=0.214$
Inhibit	$F(2,17)=0.781$, $p=0.474$; $R^2=0.084$
Emotional Control	$F(2,17)=0.907$, $p=0.422$; $R^2=0.096$
Monitor	$F(2,17)=0.293$, $p=0.750$; $R^2=0.033$
Cognitive Shift	$F(2,17)=2.546$, $p=0.108$; $R^2=0.231$
Organization of Materials	$F(2,17)=2.189$, $p=0.143$; $R^2=0.205$
BRI	$F(2,17)=1.456$, $p=0.261$; $R^2=0.146$
MI	$F(2,17)=3.021$, $p=0.075$; $R^2=0.262$
GEC	$F(2,17)=2.532$, $p=0.109$; $R^2=0.230$

BRIEF-Parent Report

Contrary to BRIEF-self results, age and number of concussions did not significantly contribute to the model examining BRIEF-Parent results. Table 8 depicts regression equations for each subscale of the BRIEF-Parent.

Table 8

Multiple Regression Equations for BRIEF-Parent

BRIEF-Parent Subscale	**Regression Equation**
Inhibit	$F(2,17)=1.112$, $p=0.352$; $R^2=0.116$
Emotional Control	$F(2,17)=0.770$, $p=0.479$; $R^2=0.083$
Initiate	$F(2,17)=0.713$, $p=0.504$; $R^2=0.077$
Monitor	$F(2,17)=1.435$, $p=0.266$; $R^2=0.144$
Working Memory	$F(2,17)=0.553$, $p=0.585$; $R^2=0.061$
Shift	$F(2,17)=0.321$, $p=0.730$; $R^2=0.036$
BRI	$F(2,17)=0.862$, $p=0.440$; $R^2=0.092$
MI	$F(2,17)=0.872$, $p=0.436$; $R^2=0.093$
GEC	$F(2,17)=0.988$, $p=0.393$; $R^2=0.104$

PROMIS Measures Regression Data

Age and number of concussions did not significantly contribute to the model examining peer relationships or cognitive function outcomes. Table 9 contains data on regression equations.

Table 9

Multiple Regression Equations for PROMIS Measures

PROMIS Measure	Regression Equation
Pediatric Peer Interaction	$F(2,17)=0.782$, $p=0.473$; $R^2=0.084$
Pediatric Cognitive Function	$F(2,17)=0.549$, $p=0.587$; $R^2=0.061$
Parent Proxy-Cognitive Function	$F(2,17)=0.667$, $p=0.526$; $R^2=0.073$
Parent Proxy-Peer Interaction	$F(2,17)=0.102$, $p=0.903$; $R^2=0.012$

The PI completed intra-rater reliability for 20% of the sample. Intra-rater reliability resulted in a 99.3% accuracy of scoring across all outcome measures.

DISCUSSION

The purpose of this study was to determine a cognitive-communication profile for high- school aged youth with concussion in the early acute recovery period and to identify the specific impact of age and number of concussions on outcomes on standardized and functional assessments. As expected based on the literature, (Rabinowitz & Levin, 2014; Halstead et al., 2018; Podell et al., 2017) significant deficits on the SCAT-5 were revealed in areas of delayed recall, immediate recall, and concentration, which supports the first hypothesis of this study.

More specifically, the number of concussions significantly accounted for performance on the SCAT-5 with participants with more than one concussion with worse performance over participants with a single concussion. Age did not significantly account for performance on the SCAT-5. While no subtest or index score was statistically significant on the CASL-2, grammaticality judgement, pragmatics, and syntactic index, were consistently identified as areas of weaknesses in performance. In contrast to the SCAT-5, CASL-2 performance was not influenced by number of concussions; however, age did significantly contribute to performance with younger participants doing worse than older participants on pragmatic language and grammaticality judgment. Lastly, on functional measures, participants reported trends of increased deficits in working memory and task completion on the BRIEF.

Cognitive Outcomes

Immediate recall, delayed recall and concentration were clinically significant areas of deficit on the SCAT-5. These findings are consistent with the current TBI literature, which has reported findings in cognitive dysfunction, including deficits in areas of executive function, memory, and attention in the acute phase of concussion recovery (Rabinowitz & Levin, 2014; Halstead et al., 2018; Podell et al., 2017). The Standardized Assessment of Concussion (SAC) portion of the SCAT-5 is a widely adopted standardized method of assessing concussion (Davis et al., 2017; Jingugi et al., 2012). Previous investigators have supported the SCAT-5's clinical validity in detecting cognitive dysfunction (McCrea et al., 1997; McCrea et al., 1998; Pottinger et al., 1999) and others have even demonstrated the detection of subtle deficits in memory and concentration (McCrea, 2005). Due to the inclusion of the SCAT-5 in this study and its sensitivity to determining cognitive dysfunction following concussion, it is not surprising that memory and concentration deficits in the acute phase of concussion were present in this sample.

Not only is the presence of these deficits on the SCAT-5 not surprising, but the occurrence of these deficits in the early phase of recovery is also expected. The results of the present study align with findings that cognitive deficits are most typically observed within the first thirty days post-concussion (Willer & Leddy, 2006). Specifically, 80-85% of children with concussion, who experience cognitive deficits, will resolve within 21-30 days following injury (Lumba-Brown et al., 2018), while approximately 15-20% of individuals may experience persisting cognitive deficits past the 30 day mark (Bigler et al., 2013).

Because of its established ability to identify cognitive deficits in the acute phase of recovery, the SCAT-5 could be used as an important data point for clinical considerations as a student returns to school after their initial rest period. During this acute phase, evidence-based recommendations are essential in reducing potential short-term and long-term effects of concussion (Brown et al., 2019); however, assessment and treatment during this recovery period does not currently follow a systematic protocol (Grubenhoff et al., 2015) and the SCAT-5 could begin to address this issue.

Identifying cognitive deficits within the first 30 days post-injury is useful information to individualize the return to school program including an appropriate timeline of returning to the classroom and the determination and implementation of necessary academic supports. Emerging return to learn literature recommends for a delicate balance of a short period of complete cognitive rest followed by a titrated return to academic activities (DeMatteo et al., 2020). For this reason, being able to adequately assess for cognitive deficits throughout the recovery process is critical for the creation of a return to school plan.

SLPs are essential to the interprofessional team involved in the return to learn process. SLPs bring specific and unique expertise regarding the impact of cognitive deficits on social, communicative and academic success (ASHA, 2005). Therefore, youth that are post-concussive and have associated cognitive deficits would benefit from special attention from an SLP in the return to school process.

For SLPs specifically, the SCAT-5 can be used as a quick and free-of-charge repeated measurement to determine change over time of cognitive recovery post-concussion and could potentially be useful in determining the types of support a student would need when returning to school.

Impact on Academic Success

In addition to deficits in memory and concentration that were evident on the SCAT-5, study participants reported having difficulty trying to return to school. Participant comments made during the project included: “It’s like I can’t remember anything anymore, (Participant #3)” “I used to love math and now it’s like I can’t complete a single problem, (Participant #18)” “My grades have really dropped since my concussion, (Participant #2)" "Now I forget things at school and can't do my homework, (Participant #11)" and "I can't remember anything I read (Participant #1)." These participant comments are consistent with the deficit pattern presented on the SCAT-5 and are consistent with concussion research regarding impacts of memory and concentration deficits on academic success in a variety of clinical groups. Working memory skills have been associated with new learning, comprehending language, acquiring literacy skills and completing problem-solving tasks (Alloway & Alloway, 2010; Cain et al., 2004). Gathercole and colleagues (2003) indicated children post-concussion with poor working memory demonstrate poorer overall academic outcomes.

Individuals with working memory and attention difficulties may demonstrate difficulties with new learning, auditory comprehension, and problem-solving/reasoning, which are all essential skills required, in some degree, for all coursework; therefore, the results of the present study further support the importance of individualized accommodations and support for children post-concussion.

In addition to the impacts on academic outcomes, a concussion in a developing neurologic system could potentially have a direct impact on cognitive development over the longer term and result in delayed development of age-appropriate cognitive skills (Fischer & Bullock, 1984). In the TBI population, Chapman and colleagues (2005) described this possibility as "neurocognitive stall". Neurocognitive stall refers to a "halting or slowing in stages of development beyond a year after brain injury" (Chapman et al., p. 103f, 2005; Babikian et al., 2009). Although most frequently described in individuals with severe brain injury, it is possible that the theory of neurocognitive stall may also apply to individuals with mild injuries. To truly determine the presence of neurocognitive stall in youth with concussion longitudinal studies are needed.

Communication Outcomes

While participants in this study did not demonstrate clinically or statistically significant deficits on the CASL-2 as hypothesized, it was notable participants had discrepant performance in pragmatics, grammaticality judgement, and syntactic index. While the suggestion of pragmatic language deficits was expected, the discrepant performance in grammar and syntax was unexpected because the current concussion literature had yet to indicate these findings.

Historically, standardized neuropsychological tests have been problematic in TBI populations, especially for higher level cognitive-communication deficits for those with milder injuries (McDonald et al., 1999). Although the CASL-2 has been used in moderate-severe TBI literature (Turkstra et al., 2008; Taylor et al., 2008) and has demonstrated sensitivity for moderate-severe TBI, it is possible that it is not sensitive to subtle communication deficits associated with concussion. Additional development of standardized measure of cognitive- communication deficits for concussion are necessary. Contemporary TBI assessment literature (Genova et al., 2019; Bellesi et al., 2019) and ASHA cognitive-communication assessment standards (2005) suggest clinicians consider standardized tests as a single piece of the assessment framework within a broader landscape that considers an individual's profile of strengths and weaknesses, performance in functional environments, and variables impacting performance (Turkstra, et al., 2005). Given this consideration, it is noteworthy to discuss weaknesses in performance on standardized measures as a starting point to tailor the rest of the assessment process.

Weakness in pragmatic language has been consistently noted in the moderate-severe TBI literature (Turkstra et al., 2008; Turkstra et al., 2008; Taylor et al., 2008); however, prior to this study, there is no known research that addresses pragmatic language within the early concussion recovery phase. The presence of weakness in pragmatic language on the CASL-2, paired with recommendations for functional assessment, would indicate that additional assessment approaches, including discourse assessment could be helpful, to identify and monitor pragmatic deficits following a concussion (Chapman et al., 2005). Pragmatic language is specifically important to teens both socially and academically as difficulty with pragmatic language may translate to an inability to alter language for a given context, use appropriate nonverbal communication (e.g., eye contact), or take conversational turns with communication partners. It is possible that pragmatic language may not be apparent in altering peer relationships in early recovery because the damage of relationships may be more noticeable in the later stages of recovery. For this reason, additional monitoring into the later stages of recovery may be warranted.

Another area of weakness demonstrated on the CASL-2 was grammaticality judgment, that is ability to judge the accuracy of syntax and to construct grammatically correct sentences. To the author's knowledge, these deficits have not yet been established in the concussion literature. Researchers in the fields of aphasia and developmental language disorder (DLD) have recognized a relationship between working memory and syntax (Cooke et al., 2002; Just & Carpenter, 1992). Specifically, previous work has indicated involvement of Broca's area and its reliance on a memory system to integrate and comprehend language, which is a necessary component in judging syntax (Caplan et al., 2013). Since Broca's area is located in the frontal lobe of the brain, which is the lobe most commonly impacted by the biomotion of concussion, it is possible that memory deficits noted on the SCAT-5 could contribute to this finding on the CASL-2. Given this possibility and the connection between memory and syntax deficits, the occurrence of working memory and grammaticality judgement deficits in this study is not believed to be coincidental. Additionally, in the DLD literature, persistent syntax deficits have been linked to increased risk for negative long-term outcomes such as academi underachievement, incarceration, and limited occupational options (Snow & Matthews, 2016; Pickles et al., 2014).

The relationship between communication weaknesses and implications for SLP practice are noteworthy to discuss. Although the CDC guidelines for return to learn following a concussion includes an SLP as an essential professional part of the interdisciplinary team, there are currently no consistent protocols for assessment and treatment (Brown et al., 2019). The CDC notes that early education support in the acute phase of injury improves outcomes following a concussion (Ponsford et al., 2001); therefore, the early identification of potential cognitive-communication weaknesses can be a critical component of concussion management. The weaknesses indicated in the present study provide a starting point for concussion assessment and early education.

Functional Outcomes

Performance on functional, daily-life measures of activity and participation, participants demonstrated some impact of their cognitive and communication deficits.

On the BRIEF-Self, participants reported mildly elevated scores in areas of working memory and task completion deficits, which align with the findings on the SCAT-5. That is, participants in this study were experiencing some impact in their daily-life abilities like the structured test performance.

Maillard-Wermelinger and colleagues (2009) documented reported deficits in organization of materials and working memory.

While BRIEF-Self report revealed some impact of executive function deficits in daily life, parent reporters on the BRIEF-Parent did not reveal any significant results. This is not consistent with the literature on the BRIEF-Parent report for those children with TBI, which states that due to executive function deficits and resulting reduced self-awareness post- concussion, parents are more likely than children to report observed deficits (Wilson et al., 2011). Other studies have indicated high validity and reliability of parental reports to determine executive function deficits post-concussion (Gioia et al., 2000). Clinically insignificant results on the BRIEF-Parent report could be secondary to the participant experiencing the deficits first- hand, while parents may be prioritizing the participant returning to school/play in the early days of recovery and be unaware of functional changes post-injury. Also, parents may be generous with their reporting of symptoms for various reasons, including that parents may wish to deny deficits, are unrealistic about concussion recovery, or the adolescent has not discussed symptom presentation with their parent. While the results in the literature suggest that parent-reporting of symptoms should be used in combination with self-reporting (Wilson et al., 2011) time post- injury could be important in determining when and how to apply these measures.

Neither parent nor child reported significant deficits in the Peer Relationship PROMIS measure. It is possible that this functional, participation level measures may not yet show deficits as the teen may have yet to experience the impacts of their deficits on peer relationships.

Because of the recency of the injury for the participants in this study, it would be important to further study how peer relationships are impacted by concussion in the chronic recovery period, especially given the weaknesses in pragmatic language that was identified during the initial recovery phase. Additionally, as these impacts may reveal themselves further into the return to school process when peer interactions would be expected to return to preinjury levels, the SLP should complete continued monitoring past the acute phase to determine if this is an area of concern.

Impact of Age and Number of Concussions on Assessment Outcomes

In addition to considering performance on specific measures that could highlight a cognitive-communication profile in early concussion recovery, it was important to consider variables that are known to impact outcome for TBI but have yet to be explored for these specific measures for this population.

Number of concussions and age were significant predictor variables for performance on all cognitive measures of the SCAT-5 (orientation, delayed recall, immediate recall, concentration), with number of concussions being the significant variable, indicating increased number of concussions predicted decreased outcome on concentration, orientation, and delayed/immediate recall assessment tasks. These results are consistent with Moser and colleagues (2005), who observed increased endorsement of cognitive deficits in high-school athletes following two or more concussions. These results further support that SLPs should assess and monitor children with multiple concussions.

Age and number of concussions were significant predictors of pragmatic performance on the CASL-2, indicating older participants (aged 16-17) and participants with fewer concussions scored higher on this subtest. These results are consistent with Ashman and colleagues (2008) findings with moderate-severe TBI, which suggest that younger injuries can experience more severe outcomes compared to older individuals. This result indicates the importance of a differential approach for age. Also, special attention should be placed on monitoring pragmatic skills in individuals with more than one concussion.

Age was a significant variable for the sentence expression subtest and syntactic index scale outcomes on the CASL-2, indicating younger participants scored worse on these assessments. Simply stated, sentence expression is the oral expression of accurate syntax (Carrow-Woolfolk, 2017); therefore, underlying difficulty with syntax may result in sentence expression deficits. Although sentence expression was not a clinically significant area of deficit for the participants in this study, the statistical significance between age and sentence expression and syntax deficits is worth additional exploration, and perhaps clinical attention in the early recovery phase post-concussion. Specifically, discourse analysis with younger children following injury could provide detailed information regarding three important aspects of syntactic skills: sentence length, subordination, and cohesion clause (Nippold, 1993). This information could provide insight regarding the specific syntactic breakdown, which would allow for appropriate individualized recommendations in the early recovery phase post-concussion for younger individuals.

Noteworthy is the fact that results of the data were not due to outliers impacting the distribution and pulling down the mean. For example, 7/20 participants scored in the low-average or below-average range on the Grammaticality Judgement Index score (Table 14) of the CASL-2 and 8/20 participants scored in the low average or below-average range on the Pragmatic Subtest of the CASL-2 (Table 13). Individual data in this study is rich and requires further exploration to determine individual performance on specific assessments of syntax and pragmatic language skills.

Limitations

Although the current study provides novel contributions to the literature, the results should be interpreted with caution considering various methodological limitations, including lack of control group, small sample size, and using psychometric measures sensitive to concussion.

First, because a control group was not included in this study, various independent variables may have obscured results on standardized and non-standardized assessments. Now that initial findings can guide future work, the inclusion of a control group would help to ensure deficit patterns can be attributed to concussion and not to other variables. Also, Type I error inflation may be present in this study due to multiple dependent variables in the multiple linear regression analysis. Also, the small sample size makes it difficult to generalize the findings of this work. Ideally, a larger sample size would be included, which could potentially be accomplished with additional clinical collaborators.

Psychometric measures were selected based on utility with moderate-severe TBI, which may have not been sensitive to language deficits associated with concussion. One potential measure that could be sensitive to the cognitive-communication deficits of those with concussion, especially as they return to school, is the assessment of narrative discourse. The pediatric TBI literature contains growing evidence of impaired narrative discourse in pediatric brain injury (Cook et al., 2007). Specifically, difficulty with cohesion, failure to appropriately utilize story grammar components, utilizing words with fewer content units, and increased verbal disruptions (Chapman et al., 2005; Liles, et al., 1989). There is also evidence for discourse deficits being the result of underlying working memory and attention deficits (McDonald et al., 1999). It is theorized that working memory deficits may reduce the speed and accuracy of discourse comprehension and overall organization of language production (Hartley & Jensen, 1991; Caspari et al., 1998). Given the working memory and attention deficits determined on the SCAT-5 in this study, it can be inferred that a discourse analysis may have provided significant information regarding specific narrative discourse deficits. It is possible, therefore, that discourse analysis may have been sensitive to communication deficits that were unable to be detected on the CASL-2. A narrative discourse analysis was initially included in the methodology of this study; however, it had to be removed because of IRB concerns related to the risk of testing fatigue in early concussion recovery. In future studies, inclusion of discourse analysis is recommended.

Future Research Directions

Although the results of the current study provide interesting and exciting novel evidence of deficits and areas of weakness in performance on cognitive and communication measures, there are several additional avenues of research that have resulted from the present study. First, assessing pragmatic and syntax deficits with use of discourse sample and psychometric measures, when available, for these specific skills is necessary in understanding their specific relationship with concussion. Next, additional variables, such as mechanism of injury and days post-concussion as predictor variables with assessment outcome are also necessary to be explored to determine impact of other variables on assessment outcome. Additionally, because individual data is rich, exploration of individual performance would allow for more specific analyses of individual deficits. Lastly, alternative subjective measures, such as the Concussion Symptom Inventory, which is empirically driven similarly to the BRIEF, could be utilized, which may demonstrate to be more sensitive in detecting presence of cognitive and communication deficits in this population.

Conclusion

Summary of Cognitive-Communication Profile

In summary, the results of the present study indicated the following possibilities for a cognitive-communication profile in early concussion recovery, which could potentially be useful as a starting point for SLPs to assess, treat, and monitor this population in the return to school process: (1) Cognitive Deficits: immediate recall, delayed recall, concentration, (2) Communication Weaknesses: pragmatics, grammaticality judgment, and syntactic index, (3) Injury specific/demographic impacting factors: Older participants and participants with more concussions demonstrate weakness on pragmatic skills, younger participants perform worse on syntax and sentence expression skills, more concussions and older adolescents perform worse on cognitive measures.

Overall, the present study provides evidence of deficits in areas of working memory and attention in high-school aged youth post-concussion, in addition to weaknesses in areas of pragmatics and syntax. The major clinical implication of these findings is that high-school aged children are at risk for decreased academic and social success following a concussion and clinical professionals must develop assessment and treatment protocols to assist in transition to school and determine eligibility of services. The results also encourage examination of syntax deficits, which have not been previously established in the TBI literature. The novel findings of this research provide valuable insight into the necessary direction of concussion assessment research, which will assist in treating this vulnerable population.

Appendix

Table 10

Individual Demographic Data

	Age (Months)	Gender	Grade	GPA	Days Post Injury	Previous Concussions
Participant 1	171	M	9	3	5	1
Participant 2	190	F	11	4	19	1
Participant 3	209	M	11	3	16	3
Participant 4	186	F	10	4	10	4
Participant 5	190	M	10	3	6	2
Participant 6	210	M	12	3	12	3
Participant 7	207	F	11	3	11	3
Participant 8	170	M	9	3	24	1
Participant 9	192	M	0	3	26	1
Participant 10	189	M	10	4	17	3
Participant 11	194	M	11	4	3	3
Participant 12	183	F	9	3	17	2
Participant 13	186	F	9	4	27	4
Participant 14	206	M	11	3	23	1
Participant 15	210	M	11	4	28	4
Participant 16	207	F	11	4	12	1
Participant 17	183	F	9	3	5	2
Participant 18	209	F	11	3	14	3

Participant 19	184	F	9	3	6	3
Participant 20	170	M	9	3	11	1

Table 11

SAC of SCAT-5 Raw Scores

	Total Score	Orientation	Immediate Recall	Concentration	Delayed Recall
Participant 1	29	4	18	3	4
Participant 2	44	5	25	5	9
Participant 3	36	5	19	5	7
Participant 4	28	5	18	3	2
Participant 5	42	5	23	5	9
Participant 6	30	4	20	2	4
Participant 7	26	5	14	2	5
Participant 8	38	5	21	4	8
Participant 9	42	5	28	5	7
Participant 10	34	4	28	5	7
Participant 11	36	4	23	3	4
Participant 12	26	4	12	4	6
Participant 13	20	4	10	1	5
Participant 14	45	5	24	5	7
Participant 15	26	4	16	2	4
Participant 16	43	5	25	4	9
Participant 17	30	5	18	2	5
Participant 18	26	5	15	2	4
Participant 19	24	4	10	2	4

Participant 20	40	5	22	4	9

Table 12

CASL-2 Subtest Standard Scores

	RV	ANT	SYN	EV	IL	SE	GM	SC	GJ
Participant 1	98	91	95	85	85	77	64	91	76
Participant 2	122	106	122	97	111	112	106	109	90
Participant 3	118	112	123	106	117	117	113	115	101
Participant 4	113	117	117	99	98	100	113	101	99
Participant 5	113	113	125	97	107	90	109	127	102
Participant 6	118	102	95	87	100	98	104	104	88
Participant 7	95	95	84	95	92	81	80	75	87
Participant 8	116	107	116	112	110	106	85	83	98
Participant 9	106	115	118	97	111	114	115	91	93
Participant 10	117	98	102	93	93	102	102	112	92
Participant 11	114	104	104	85	90	89	89	87	83
Participant 12	95	125	103	89	88	83	98	98	81
Participant 13	98	102	98	97	86	95	81	98	88
Participant 14	106	104	99	97	95	105	112	120	94
Participant 15	90	104	101	102	96	108	97	83	94
Participant 16	95	99	109	91	94	108	100	104	96
Participant 17	95	110	96	108	91	98	118	127	97
Participant 18	93	101	84	89	89	102	87	63	87
Participant 19	93	96	79	85	89	93	86	98	84

Participant 20	95	91	97	81	90	79	80	91	76

Note. RV=Receptive Vocabulary; ANT=Antonym; SYN=Synonym; EV=Expressive Vocabulary; IL=Idiomatic Language; SE=Sentence Expression; GM=Grammatical Morphemes; SC=Sentence Comprehension; GJ=Grammaticality Judgement

Table 13

CASL-2 Subtest Standard Scores Continued

	NL	MFC	INF	DM	PRAG
Participant 1	91	83	79	78	81
Participant 2	115	106	102	101	103
Participant 3	117	116	111	121	99
Participant 4	108	111	103	110	94
Participant 5	128	111	89	96	94
Participant 6	92	106	94	100	93
Participant 7	94	83	92	85	87
Participant 8	116	111	87	98	73
Participant 9	117	107	106	101	98
Participant 10	110	96	96	101	80
Participant 11	92	86	85	84	85
Participant 12	104	80	98	96	75
Participant 13	100	91	81	83	81
Participant 14	121	107	101	98	100
Participant 15	113	97	102	112	99
Participant 16	123	103	100	102	99
Participant 17	118	109	113	103	103
Participant 18	92	93	94	95	100
Participant 19	100	78	93	89	92

Participant 20	92	84	102	84	81

Note.
NL=Nonliteral Language; MFC=Meaning from Context; INF=Inference; DM=Double Meaning; PRAG=Pragmatics

Table 14

CASL-2 Index Standard Scores

	General Language Ability	Receptive Language	Expressive Language	Lexical /Semantic	Syntactic	Supra-Linguistic
Participant 1	80	86	73	85	64	81
Participant 2	109	111	103	111	100	105
Participant 3	118	114	111	113	109	116
Participant 4	132	106	102	106	102	108
Participant 5	108	115	94	110	97	105
Participant 6	95	101	94	98	93	97
Participant 7	81	77	84	84	76	87
Participant 8	107	102	96	107	92	102
Participant 9	110	101	107	107	106	107
Participant 10	100	106	96	96	96	100
Participant 11	87	92	84	97	81	85
Participant 12	89	88	90	96	84	93
Participant 13	90	91	86	89	82	87
Participant 14	104	103	102	94	101	106
Participant 15	104	87	101	91	96	105
Participant 16	105	97	95	92	94	106
Participant 17	103	102	109	91	104	110

Participant 18	93	76	95	84	93	92
Participant 19	83	80	87	81	82	88
Participant 20	82	85	83	85	55	89

Table 15

BRIEF-Self T-Scores

	I	S	EC	M	WM	P/O	OM	TC	BRI	MI	GEC	BS	CS
Participant 1	43	43	52	40	50	49	36	55	44	48	46	40	48
Participant 2	47	55	64	47	60	52	50	56	55	53	54	52	58
Participant 3	71	61	57	61	75	76	72	73	66	77	74	62	57
Participant 4	50	52	46	56	61	50	52	50	51	54	52	42	63
Participant 5	44	49	54	37	68	66	46	81	47	54	51	46	52
Participant 6	53	40	49	52	45	44	42	47	48	44	46	42	41
Participant 7	44	49	59	47	60	52	42	68	50	58	57	52	47
Participant 8	51	63	57	58	69	71	49	78	58	71	66	55	67
Participant 9	53	46	46	56	54	54	49	55	50	54	52	42	52
Participant 10	46	58	38	56	52	68	62	70	48	65	58	57	57
Participant 11	50	52	41	37	56	54	55	45	46	53	50	52	52
Participant 12	83	46	47	62	72	52	58	49	62	59	62	36	58
Participant 13	68	80	84	57	89	75	77	70	80	83	84	78	74
Participant 14	44	46	38	66	59	52	49	39	46	52	49	42	52
Participant 15	42	58	51	56	54	48	42	58	42	51	47	62	52
Participant 16	47	49	49	47	44	47	46	46	48	43	45	46	52
Participant 17	44	40	39	57	68	73	61	62	42	70	57	41	41
Participant 18	42	49	54	42	53	47	42	70	47	55	51	41	58
Participant 19	73	77	72	77	70	66	73	75	80	75	79	73	74

Participant 20	51	52	47	40	60	57	43	53	52	55	54	45	53

Note.
I=Inhibit; S=Shift; EC=Emotional Control; M=Monitor; WM= Working Memory; P/O=Plan and Organize; OM=Organization of Materials; TC=Task Completion; BRI=Behavioral Regulation Index; MI=Metacognition Index; GEC=Global Executive Composite; BS=Behavior Shift; CS=Cognitive Shift

Table 16

BRIEF-Parent T-Scores

	I	S	EC	Initiate	WM	P/O	OM	M	BRI	MI	GEC
Participant 1	54	54	58	43	58	50	37	51	56	48	51
Participant 2	41	48	47	40	53	41	43	43	44	44	43
Participant 3	69	72	65	76	85	81	72	65	71	79	79
Participant 4	54	43	58	43	58	50	58	45	53	51	52
Participant 5	44	39	40	37	40	41	34	36	39	36	36
Participant 6	60	58	70	39	45	49	55	59	65	49	55
Participant 7	50	69	80	62	77	69	53	64	70	69	70
Participant 8	57	65	55	49	71	65	46	48	60	58	60
Participant 9	45	43	43	53	53	50	58	48	43	52	49
Participant 10	48	43	48	59	61	65	63	57	46	63	58
Participant 11	60	40	48	49	42	43	49	62	50	47	49
Participant 12	67	57	49	68	79	76	71	64	56	77	70
Participant 13	44	51	44	59	64	50	50	47	45	55	51
Participant 14	42	43	41	49	48	43	37	37	40	42	40
Participant 15	45	47	46	43	42	40	43	40	45	40	41
Participant 16	41	38	37	37	40	39	47	36	37	38	37
Participant 17	55	45	42	56	53	58	53	47	46	55	51
Participant 18	61	60	56	53	71	63	56	64	60	65	63

Participant 19	90	79	75	77	71	76	62	74	86	77	82
Participant 20	51	51	63	63	58	52	58	45	56	55	56

Note.
I=Inhibit; S=Shift; EC=Emotional Control; M=Monitor; WM= Working Memory; P/O=Plan and Organize; OM=Organization of Materials; TC=Task Completion; BRI=Behavioral Regulation Index; MI=Metacognition Index; GEC=Global Executive Composite; BS=Behavior Shift; CS=Cognitive Shift

Table 17

PROMIS Measure T-Scores

	Cog Peds	Cog Parent	Peer Peds	Peer Parent
Participant 1	44	43	47	62
Participant 2	37	30	51	49
Participant 3	45	48	55	37
Participant 4	48	48	44	56
Participant 5	46	48	60	56
Participant 6	33	31	48	38
Participant 7	39	48	47	62
Participant 8	33	37	60	62
Participant 9	39	44	41	45
Participant 10	41	35	44	53
Participant 11	48	40	64	45
Participant 12	35	33	41	29
Participant 13	33	35	34	45
Participant 14	32	35	54	51
Participant 15	40	48	53	62
Participant 16	40	63	45	62
Participant 17	45	45	51	49
Participant 18	32	38	64	62

Participant 19	31	26	44	42
Participant 20	47	40	42	51

Note. Cog PEDS=Cognitive Function Pediatric; Cog Parent=Cognitive Function Parent Proxy; Peer Peds=Peer Interaction Pediatric; Peer Parent=Peer Interaction Parent Proxy

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