ABSTRACT

Title of Dissertation: THE ROLE OF PERSONALITY AND COGNITIVE-LINGUISTIC DEFICITS IN TEENS AND ADULTS WITH CONCUSSION

Melissa Dawn Stockbridge,
Doctor of Philosophy, 2018

Dissertation Directed By: Professor Rochelle S. Newman, Ph. D.,
Department of Hearing and Speech Sciences

Even the mildest form of traumatic brain injury, concussion, can result in adverse physical, cognitive, behavioral, and social consequences. Concussion injuries frequently result in patients who describe deficits in daily communication and overall "fogginess," but whose deficits are not consistently captured on traditional assessments of language. The purpose of this research was two-fold: first, to examine typed written communication in order to better understand the kinds of cognitive and language deficits that adolescents and adults experience immediately and chronically following a concussion; and second, to examine the influence of a particular trait-like dimension of personality and temperament, the propensity toward more frequent, intense, and enduring negative affect (called *dispositional negativity*), on exacerbation of these deficits.

Using a survey conducted entirely online, 92 participants aged 12-40 years old who had a recent concussion, a history of concussion, or no history of brain injury wrote two

narrative samples and an expository sample, completed multiple tasks targeting word-level and domain general cognitive skills, and provided rich self-report information important to better understanding their personality, temperament, and mental health. Performance by recently injured participants suggested that deficits in narrative language, though likely influenced by problems in word-finding, memory, and attention, also existed beyond what could be explained by those deficits alone. Narrative-specific deficits were observed in written content, organization, and cohesiveness. Moreover, including dispositional negativity in models of concussion history (group) and self-reported somatic symptomology improved the sensitivity and specificity of these models, which supports the value of considering individual differences in personality when engaged in concussion management.

THE ROLE OF PERSONALITY AND COGNITIVE-LINGUISTIC DEFICITS IN TEENS AND ADULTS WITH CONCUSSION

by

Melissa Dawn Stockbridge

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Hearing and Speech Sciences
2018

Advisory Committee:
Professor Rochelle S. Newman, Ph. D., Chair
Professor Nan Bernstein-Ratner, Ph. D., CCC-SLP
Professor Jan Edwards, Ph. D.
Assistant Professor Alexander J. Shackman
Dean's Representative: Professor Philip Resnik, Ph. D.

Dedication

To Ray Lipicky

"Why do you think *that*? How do you *know*?"

Acknowledgements

In my very favorite book, *Stranger in a Strange Land* (by Robert A. Heinlein), Michael says,

> "I've found out why people laugh. They laugh because it hurts so much, because it's the only thing that'll make it stop hurting. [...] The goodness is in the laughing itself. It is a bravery and a sharing against pain and sorrow and defeat."

I am immeasurably grateful to so many people for their enduring support of this and all of my academic and personal pursuits. Above all, I am grateful for those who have laughed with me and helped me to find joy throughout the last six years.

To Rochelle, thank you for each day providing me with a lived paragon of the inquisitive, pragmatic researcher, the warm, adaptive mentor, and the eager, humble learner I one day hope to become. I am honored to have had you as my mentor and to have had the opportunity to laugh and to learn with you during these years together. I am a better scientist, thinker, and person for having known you.

To Alex, thank you for helping me find my cohesive, unique voice and for instilling in me a healthy respect for the responsibility that comes with that voice: to communicate accessibly and to participate fully.

To Philip, thank you for your infectious enthusiasm and earnest perspective both when approaching academic topics and in life. I am thrilled at the prospect of continuing to grow under your mentorship.

To Nan, thank you for your intuitive empathy and frank wisdom. Your open door and dedication to providing guidance from anywhere in the world gave me courage to grow and to seek unconventional solutions as a clinician and a researcher.

To Jan, thank you for your unique perspectives and for introducing me to the international concussion research community.

I also am grateful to the amazing clinicians and students who contributed to and facilitated this work. Thank you, Robert G. Graw, M.D., and Anthony Doran, Psy. D., from RightTime Medical Care and Head First Sports Injury and Concussion Care centers for supporting the recruitment necessary to conduct this research. I gratefully acknowledge Kristin Slawson, of the University of Maryland Hearing and Speech Clinic, for providing invaluable clinical insight into this population and challenging me to examine new perspectives and think in new ways. I also would like to thank Colleen Worthington for inspiring me to always consider the real-world benefits of our clinical research for patients' everyday lives. Finally, I would like to acknowledge the wonderful undergraduate research assistants who joined me in driving countless miles to and from urgent care centers and embracing the challenge of approaching and assessing those with recent injuries in a healthcare environment and online: Sanuri Hennayake, Hanieh Javaheri, Hannah Benninger, Karen Bien, Hira Rahman, Thierry Jean-Pharuns, Destan Scott, Caitlin Read, Lindsay Kohan, and Isabella Swafford.

Above all, I am grateful to my family – Dad, thank you for teaching me to appreciate the absurdity of things, to strive for resilience and excellence, and to only place my modifiers before or after my verb phrases. Kyle, thank you for believing in me and for the stability that you have given me through all of the things you do to keep our life moving forward each and every day. Mom, thank you for teaching me to build joy consciously and tenaciously into my life every day. Thank you for your overwhelming support, innumerable suggestions, and unyielding belief in

the goodness of people and the inherent value in serving others. What you have given me, I could not begin to quantify or explain even with all of the possible resources and all of the possible tables and appendices I could generate in all the rest of my years. I promise to do my best to honor this tremendous gift and pay it forward.

Finally, I am grateful to those with whom I have laughed and shared the most. Thank you to my outstanding support network of friends and neighbors, for laughing and living with me through everything. Casey, Amritha, Julianne, Bronwyn, and Leeann, you are my true extended family, and I am so grateful and honored to grow together with you.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Overview

Even a relatively mild traumatic brain injury (mTBI) can result in adverse physical, cognitive, behavioral, and social consequences (Beauchamp & Anderson, 2010; Ponsford et al., 1999, 2001). While some individuals appear essentially unchanged after a TBI, others experience diverse, prolonged deficits and extreme distress (Collins, Lovell, Iverson, Ide, & Maroon, 2006; Field, Collins, Lovell, & Maroon, 2003; Guskiewicz & McLeod, 2011). Among the factors influencing the experience and sequelae of concussion, age appears to be a significant factor. In a recent meta-analysis of mTBI outcomes in children and adolescents, 6.8% of reviewed studies indicated adverse academic outcomes, 17.8% of reviewed studies indicated adverse neuropsychological outcomes, including deficits in discrete skills associated with cognition and language, and 48.9% of reviewed studies indicated adverse psychosocial outcomes (Lloyd, Wilson, Tenovuo, & Saarijärvi, 2015). These difficulties can manifest as poor performance in school and work, difficulty maintaining relationships, and challenges in successfully completing activities of daily living (Catale, Marique, Closset, & Meulemans, 2009; Ewing-Cobbs et al., 1997; Fay et al., 2010). In contrast, individuals who experience an mTBI as adults are considered less vulnerable to chronic neuropsychological dysfunction (Carroll et al., 2014; Hessen, Nestvold, & Anderson, 2007), though some evidence of enduring verbal learning deficits (Heitger et al., 2006) and increased risk of psychiatric diagnoses (Fann et al., 2004; Nielsen, Mortensen, O'Callaghan, Mors, & Ewald, 2002; Teasdale & Engberg, 2001) has been reported. Thus, examining individuals who experience concussions at different times in their lives informs a greater understanding of individual differences in injury outcomes.

Language is one domain in which a deficit can have particularly far-reaching ramifications. In adolescents and adults, one's ability to communicate new ideas and to demonstrate understanding of others' ideas frequently is measured by one's ability to express those ideas through writing and through speaking. Language deficits not only impact informal communication with family and friends, which are often critical to school, work, and mental health, but also impact written communication, which relies more heavily on crystalized expectations for what information is included and how it is organized for the reader. Whereas oral communication difficulties may be rectified by the back-and-forth between the speaker and listener that would aid in clarification if the content were incomplete or ambiguous, no analogous mechanism assists individuals in written communication, which is generally asynchronous. As such, though a speaker may be more aware of their deficits in informal communication, it is likely that such deficits actually may be more severe in structured writing. However, the vast majority of what has been studied in individuals with brain injury is oral language, not written. Moreover, deficits in language and cognitive abilities following injury have yet to be characterized adequately, particularly in adolescents, and there is need for more thorough, ecologically valid, and streamlined methods of assessment. This particularly is true for the mildest form of brain injury, concussion. Concussion injuries frequently result in patients who describe deficits in daily communication and overall "fogginess," but whose deficits are not consistently captured on traditional assessments of language. While a substantial and growing body of literature exists addressing mild TBI more generally, the generalizability of findings from groups spanning this broader range of severities to those with only the mildest and most common injuries is unclear. These gaps in the existing literature give

rise to the first aim of the proposed research: *Do adolescents and young adults with a recent concussion or history of concussion show deficits on diverse aspects of language, including complex writing tasks?*

The second aim of this work is to address the nature of the relationship between cognitive and linguistic deficits that are observed, as it relates to complex writing tasks. Prior work has provided evidence that a concussion impacts language at the lexical level, as evidenced by deficits in word-finding. One possibility is that deficits in larger, more complex units of language, if observed, are best characterized as lexical deficits simply impacting language at a larger scale. However, a second possibility is that deficits in complex writing that may be observed, while perhaps influenced by difficulties at the lexical level, are further exacerbated by difficulties in the kinds of cognitive-linguistic skills that are uniquely necessary when one is joining larger units of language, within and across sentences: planning, organization, and connection of ideas from one sentence to another. As such, the second aim of the proposed research is: *Are deficits in complex writing better characterized as uniquely lexical or as a result of poorly integrated cognitive-linguistic skills?*

As a tertiary investigation, factors leading to the wide variability in concussion deficits experienced by individuals are only beginning to be characterized. Injury characteristics vary widely among individuals with mTBI due to factors such as relative injury severity, past brain injury history, and mode of injury (e.g., blunt force, forces on the body in the absence of a direct traumatic force to the head). However, individual differences also exist in the emotional and psychological response to adversity. This is influenced by personality traits, or typical behaviors, thoughts, and feelings (Shiner &

Masten, 2012). Dispositional negativity, which identifies the propensity to experience and express more frequent, intense, and enduring negative affect, is one particular emotional and cognitive risk factor that consistently contributes to poorer medical outcomes in other areas, such as cardiac, respiratory, and immune health, mental health, and substance abuse (Barlow, Ellard, Sauer-Zavala, Bullis, & Carl, 2014; Clauss & Blackford, 2012; B. L. Goldstein & Klein, 2014; Kendler & Gardner, 2014; Kotov, Gamez, Schmidt, & Watson, 2010; Lahey, 2009; Ormel et al., 2013; Watson & Naragon-Gainey, 2014; Weston, Hill, & Jackson, 2014). For example, individuals with high dispositional negativity more frequently experience sleep problems (Hintsanen et al., 2014), metabolic syndrome (Phillips et al., 2010), and elevated cholesterol levels (Hengartner, Kawohl, Haker, Rössler, & Ajdacic-Gross, 2016; Shackman et al., 2016). These poorer outcomes impose tremendous social and economic burdens, in addition to personal difficulties, that can reach across the individual's lifespan (Cuijpers et al., 2010). Previous identification of high dispositional negativity is considered to be an important risk factor for poor recovery from traumatic injury, particularly in milder injuries (Ponsford et al., 2012; Silverberg et al., 2015; Vargas, Rabinowitz, Meyer, & Arnett, 2015). However, it is not known whether dispositional negativity has a measurable negative impact on objective cognitive and linguistic deficits following concussion in adolescents and adults or is purely a factor influencing subjective experience. This gap in the existing literature gives rise to the third aim of the proposed research: *Does high dispositional negativity have a measurable negative impact on observable cognitive and linguistic deficits following concussion?*

What is known is that individuals who experience a concussion can have wildly different experiences of deficits across the somatic, cognitive, linguistic, social, and psychiatric domains. The overarching purpose of this research, then, is to use written communication to better understand the kinds of cognitive and language deficits that adolescents and adults experience immediately and chronically following a concussion and to examine the possibility of a particular sub-clinical psychiatric exacerbating influence of personality and temperament on these deficits. Such knowledge can be applied to ongoing research and individualized medical, professional, and educational management of these individuals.

The following sections will provide a thorough review of the literature relevant to pursuing these aims. The first sections will define concussion clinically and physiologically as a distinguishable subset of mTBI. Next, there will be a review of the linguistic and cognitive deficits that have been observed across the spectrum of mTBI, culminating in a review of narrative language, the key instance of cognitive-linguistic integration utilized in the present study. Following that, the review will address how practical limitations on assessment procedures highlight the importance of examining individual differences. In the present work, individual differences specific to dispositional negativity are central to the investigation of the second aim. The review of the literature will conclude with an overview of what is known about dispositional negativity and the influence this trait-like individual difference in personality and temperament on medical outcomes, with a specific focus on what is known about the interaction between dispositional negativity, brain injury, and mental health.

1.2 Defining concussion

Mild head injuries are the most common form of brain injury, accounting for 70% to 90% of all of those receiving treatment (Cassidy et al., 2004). These injuries result in a substantial portion of healthcare costs associated with brain injury among civilians in the U.S. alone, which was estimated to be $221 billion in 2000 (Silver, McAllister, & Yudofsky, 2011). Mild brain injuries have been defined using various criteria in the literature. "Concussion" is sometimes used synonymously with "mild traumatic brain injury," but more specifically refers to the mildest form of mild brain injury that results in observable change in behavior and function. In reviewing the literature, an effort has been made to keep consistent with the terminology preferred by the original authors, as many studies of mTBI include a wider range of clinical profiles than those identifying their target population by concussion alone.

In hospital settings, severity of injury typically is determined by length of alteration of consciousness, which contributes to Glasgow Coma Scale score (13-15). In clinical practice outside of the hospital setting, which often is the environment where such mild injuries as concussions are diagnosed, the Acute Concussion Evaluation (ACE) frequently is used in addition to neuropsychological and peripheral nervous system evaluation, examining changes to cranial nerves, ocular-motor functioning, and balance functioning, to arrive at a concussion diagnosis. Concussions, then, are often defined in practice by the known event of a strong mechanical force having acted on the body resulting in mild somatic and cognitive symptoms, in the absence of symptoms that would indicate that a more severe brain injury had occurred, such as a mild-complicated or a moderate TBI. Many individuals who receive a diagnosis of concussion experience

neither a loss of consciousness nor a period of post-traumatic amnesia. However, if a loss of consciousness is reported, individuals must be unconscious for no more than one hour. Concussion diagnosis frequently follows from somatic symptoms such as nausea, vomiting, headache, dizziness, diplopia, ringing in the ears, or "seeing stars," following a force acting on the head or body, as long as the symptoms disappear rapidly.

1.3 Physiological sequelae of concussion

Although the classic account of concussion describes an inconsistent or consistently absent finding of neuromorphological and neurophysiological differences in the brain, recent studies employing greater technological and functional precision have increasingly provided evidence of observable structural differences in the brain. Concussions are thought to result in diffuse axonal injury (Inglese et al., 2005), specifically characterized by both global and local tissue damage resulting from axonal stretching and cell body damage, that leads to hypoconnectivity (Dall'Acqua et al., 2017) and cascading neurometabolic effects to surrounding tissues (Babikian, McArthur, & Asarnow, 2013; Giza & Hovda, 2014; Pasternak et al., 2014; Sussman et al., 2017; Xiong et al., 2014).

In adolescents, significantly decreased cerebral blood flow has been noted in fronto-temporal regions within the first year following a concussion (Wang et al., 2015). In young adults, recent work has shown reduced functional connectivity bilaterally in the anterior cingulate cortex (ACC), posterior cingulate cortex (PCC), superior temporal gyrus, and temporal pole, as well as the right amygdala (Dall'Acqua et al., 2017) within the week following injury. Individuals with concussion demonstrate significantly diminished measures of white matter volume, mean cortical thickness, and total cortical

volume within three months following injury, particularly in the left superior frontal gyrus, left post-central gyrus, and right parahippocampal gyrus (Sussman et al., 2017). Changes in function have been observed in the default mode network (Stephens et al., 2017) and portions of the hippocampal network, including the medial frontal gyrus, medial prefrontal cortex, middle frontal gyrus, and temporo-parietal conjunction area (Yan, Sun, Wang, & Bai, 2017; Zhao et al., 2017). However, modest correlations between structural changes and behavioral measures place a barrier to defining concussions for clinical purposes in purely structural terms (Dall'Acqua et al., 2017; McCrea et al., 2017).

1.4 The importance of age at injury

Understanding the effect of brain injury on cognitive-linguistic skills is of particular importance when it interacts with biophysiological and psychosocial maturation (Beauchamp & Anderson, 2010; Taylor, Barker, Heavey, & McHale, 2013). The young brain is fundamentally different from the mature brain, with functional and structural plasticity decreasing as learning drives increasingly dedicated circuits, which results in a changing response to insult (Elman et al., 1998). Adolescents further experience hormonal changes that lead to observed cognitive differences during puberty (Peper & Dahl, 2013; Powell, 2006; Ramsden et al., 2011), including changes in reward sensitivity and cognitive control (Luna, Paulsen, Padmanabhan, & Geier, 2013). Thus, it is no surprise that the profile of deficits observed following brain injury can differ drastically across the lifespan and based on other personal characteristics, necessitating very different recommendations for treatment (Stockbridge & Newman, 2017).

Although concussion results in immediate changes to the brain following injury (Babcock, Yuan, Leach, Nash, & Wade, 2015), cognitive and behavioral symptoms caused by mTBI typically will dissipate within weeks or months (Bernard, Ponsford, McKinlay, McKenzie, & Krieser, 2017). Three months typically is cited as the threshold before a diagnosis of *post-concussion syndrome*, the label given to somatic symptoms persisting beyond the typical window of recovery in a small proportion of individuals who experience a concussion (Bernard et al., 2017; McInnes, Friesen, MacKenzie, Westwood, & Boe, 2017). Also, while most individuals appear to recover from their injuries, as measured by cognitive assessments for concussion (Asarnow et al., 1995; Carroll et al., 2004; Ponsford et al., 1999, 2001), younger individuals have poorer overall outcomes when compared to adults (Aram & Eisele, 1994; Ganguly & Poo, 2013; Kolb, Pellis, & Robinson, 2004; Stein & Hoffman, 2003). Poor outcomes, including persistent somatic symptoms and measurable changes on more sensitive cognitive tasks, are most common among young people who have had prior head injuries, pre-existing learning difficulties, neurological or psychiatric problems, or family stressors (Ponsford et al., 1999; Yeates et al., 1997), although these findings have not been consistent in the literature (Iverson et al., 2017).

Recent trends toward the development of personalized and individualized medicine highlight the need for adapting medical management to each patient's unique characteristics, including his or her brain development, as well as personality and temperament (Boersma, Benthem, van Beek, van Dijk, & Scheurink, 2011; B. P. Chapman, Roberts, & Duberstein, 2011). Further research into the acute and chronic impact of concussion on cognition and communication in adolescents and young adults

will inform researchers, educators, and families and will provide important information for public health policy and medical management.

1.5 Evidence for linguistic deficits following mTBI

Individuals with mTBI appear to have more difficulty producing language rather than understanding language used by others. Even with relatively minor brain injuries, specific deficits have been found in relatively basic linguistic tasks in children, including naming (Barnes, Dennis, & Wilkinson, 1999; Ewing-Cobbs & Barnes, 2002; Shaffer, Bijur, Oliver, & Rutter, 1980; Wrightson, McGinn, & Gronwall, 1995), category verbal fluency (i.e., generating names of items with a common theme, such as all types of food or all words that begin with the letter "f"; Ewing-Cobbs, Levin, Eisenberg, & Fletcher, 1987; McCauley et al., 2014), repeating sentences aloud, and writing sentences in response to dictation (Ewing-Cobbs & Barnes, 2002; Ewing-Cobbs et al., 1987). Anomia, difficulty naming objects or people that are known and perceived correctly (essentially, severe “tip-of-the-tongue” experiences), is the most common reported disturbance (Ylvisaker, 1986), and has been observed in adults with even the mildest injuries, or concussions (K. A. King, Hough, Walker, Rastatter, & Holbert, 2006; Stockbridge, Doran, King, & Newman, 2018). Mild persistent linguistic deficits resulting from a single impact are thought to aggregate and become more severe over multiple impacts, regardless of whether the impact meets a somewhat arbitrary threshold for definition as a concussion (Moore, Lepine, & Ellemberg, 2017). For example, as individuals are exposed to concussions and sub-concussive impacts for longer periods of time, spoken linguistic complexity decreases (Berisha, Wang, LaCross, Liss, & Garcia-Filion, 2017).

While skills appear more significantly affected in language production, deficits have been observed in receptive language as well. Evidence of difficulty understanding language has been observed specifically when decoding words and pronounceable non-words (Barnes et al., 1999) in children with a history of TBI. Interestingly, words using uncommon orthographic or phonetic characteristics (e.g., "ache") are associated with the greatest deficit, suggesting potential difficulty accessing memorized word forms, with relatively less difficulty accessing rules for "sounding out" words. Moreover, recent work has suggested deficits in auditory processing of language, including both speech perception in quiet and in noise, among adolescents (Thompson et al., 2018) and young adults (Turgeon, Champoux, Lepore, Leclerc, & Ellemberg, 2011; Vander Werff & Rieger, 2017). Adults with mTBI show a similar pattern of deficits, including evidence of inefficient word finding (K. A. King et al., 2006), letter verbal fluency (i.e., naming as many words as one can that begin with a given letter, as in the FAS test), identifying relationships between the meanings of words, verbal memory, and story recall (Whelan & Murdoch, 2006; Whelan, Murdoch, & Bellamy, 2007; M. N. Wong, Murdoch, & Whelan, 2010). Deficits in passage comprehension have been linked specifically to word identification and processing, suggesting that difficulties in higher-level language processing may be the result of word-level deficits acting on a larger scale in individuals with brain injuries within the mTBI range of severity. It is possible that accounting for observed deficits in general cognitive skills following injury, particularly those cognitive skills specifically relied upon for organized and appropriate written prose and discourse, would provide a more thorough explanation of language processing than considering the impact of word-level deficits in isolation.

1.6 Evidence for general cognitive deficits following mTBI

Deficits that appear to be domain-specific to language may reflect broader cognitive skills, such as differences in delayed recall, working memory, attention, executive function, or core cognitive capacity (Bialunska & Salvatore, 2017; Blanchet, Paradis-Giroux, Pépin, & Mckerral, 2009; Borgaro, Prigatano, Kwasnica, & Rexer, 2003; Ewing-Cobbs, Brookshire, Scott, & Fletcher, 1998; Green, Keightley, Lobaugh, Dawson, & Mihailidis, 2018; McInnes et al., 2017; Petley et al., 2018; Rabinowitz & Levin, 2014), even when these broader cognitive differences remain within the normal range (Wäljas et al., 2014). Deficits in attention, information processing, fluency, and memory acquisition and recall following mTBI have been observed most frequently as task demands increase (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Belanger & Vanderploeg, 2005; Bohnen, Jolles, & Twijnstra, 1992; Gentilini et al., 1985; Leininger, Gramling, Farrell, Kreutzer, & Peck, 1990; MacFlynn, Montgomery, Fenton, & Rutherford, 1984), suggesting a depression in overall cognitive resources as an account of concussion effects. Recent studies have highlighted the presence of subtle memory impairments associated with concussion seen in tasks where attention is divided (Blanchet et al., 2009). Of note, mild deficits in problem solving, executive function, and delayed recall have been observed in adults with mTBI as long as *two years* after injury (Galetto, Andreetta, Zettin, & Marini, 2013). Sustaining more than one concussion, even when events occur many years apart, was associated with increased impairment in cognition (Karr, Areshenkoff, & Garcia-Barrera, 2014) and spatial learning (Dashnaw, Petraglia, & Bailes, 2012) compared to a single injury. Mild deficits may contribute to the often vague complaints of difficulties even reported by individuals following concussion (Bohnen et

al., 1992). Also, volume reduction in the left accumbens and right caudate have been noted in the 12 months following mild TBI, with left temporal thickness changes significantly associated with executive dysfunction after injury. Taken together, these findings provide preliminary evidence for the account that structural changes may underlie some functional deficits in broad cognitive skills (Hellstrom et al., 2017).

1.6.1 Processing efficiency

Slowed information processing is a classic observation following mTBI (Babikian & Asarnow, 2009; Tromp & Mulder, 1991) that has garnered increased attention in recent years, due to observable effects long after the mildest injuries. Response time deficits on visuomotor tasks have been observed in children and adults, particularly when task demands were high (Fueger, 2017; Gagnon, Swaine, Friedman, & Forget, 2004). In one recent study, high school students who complained of persistent "fogginess" following an mTBI demonstrated significantly slower reaction times and slower processing speed on subtests of the *Immediate Post-Concussion Assessment and Cognitive Testing* (ImPACT). Specifically, students' reaction times were slowed on visuospatial working memory tasks with distractor tasks (x's and o's), matching symbols to numbers, and a Stroop-like color-match task, in which the student had to click when and only when the color word written matched the color of the typeface (e.g., the word "red" written in red). In this study, the captured measure of timing is better characterized as "processing time," and it was not purely a matter of speed but was instead based on accuracy on the working memory task and on average accuracy on a second working memory task present with a distractor task (three letters task). These results suggest that there are, indeed, processing differences, which may underlie the perceived "fogginess"

that adolescents with mTBI report. These individuals are at least somewhat aware of their difficulties, particularly during tasks that are more complex and, thus, more closely resemble cognitive demands experienced in daily life.

In the clinic, cognitive-linguistic deficits traditionally have been observed using simple, focused assessments. Using these assessments, some studies have found that injured individuals recover fully, while other studies have found a lengthy or plateauing trajectory of recovery. This has led to discrepancies in the criteria used to determine the appropriate milestones relevant to discharge from concussion management and return to work, school, and sports; while some circumstances require individuals to "meet or beat" previous baseline performance on an array of selected cognitive measures (e.g., the ImPACT), other circumstances may only require that the individual feel subjectively able to participate without a prohibitive increase in somatic symptoms This leaves open the possibility that personality characteristics affecting one's perception of injury may indirectly impact their recovery timeline. If someone has high dispositional negativity inflating their somatic symptom reporting, this would influence the guidance they receive about rejoining chosen activities. Potential explanations for the discrepancy among measures of performance and perspectives on recovery may be that the assessments are not equally sensitive or that they are measuring different variables in the cognitive process. More sensitive measures related to *how* an individual's mind behaves, rather than *accuracy* of task performance, may capture a richer array of cognitive changes from mild brain injuries. Poor cognitive efficiency would lead to a particular pattern of difficulty that could be observed, increasing as task demands increased and influencing multifaceted tasks more significantly than simple ones. The individual may require a

greater amount of processing time before responding to a cognitive or linguistic task, such as naming or describing an object. Further, the individual may have no apparent difficulty with simpler tasks (e.g., word reading in isolation), but significant difficulty in more complex contexts (e.g., word reading in a paragraph).

1.7 Narrative language in mTBI

As described above, previous work has suggested that as cognitive demands are increased, individuals with concussion experience more profound deficits (Gronwall, 1989). Applying this to the domain of language suggests that structure and content of larger units of language, such as narrative or expository language samples, also should be more difficult for individuals with a recent concussion. This increased difficulty is perhaps further compounded by the interconnected nature of language as it increases in scale. It is not enough to simply produce more sentences as though they were in isolation. Narratives demand local and distal relationships both among sentence forms and across content (Glosser & Deser, 1992; Hudson & Shapiro, 1991). In this way, they place an exponentially greater demand on both cognitive and linguistic resources than word-level skills or skills specific to a largely isolated cognitive capacity.

1.7.1 The utility of narrative language samples

Language sample analysis is one of the oldest and most well-documented sources of knowledge about the performance and development of language (Heilmann, Miller, & Nockerts, 2010). Multiple statistics that are available from language samples, such as mean length of utterance, number of different words, words per minute, and type-token ratio, robustly correlate with morphological and syntactic performance across contexts and later language development (Klee & Fitzgerald, 1985; Miller & Chapman, 1981).

Over time, these methods of analysis have been computerized, making analysis of large samples more efficient to perform and providing opportunities to conduct more sophisticated analyses (Ratner & MacWhinney, 2016). Language samples of sufficient length have long been considered the gold standard for broad clinical observation of language ability in comparison to standardized language assessments that may contain unintentional biases (Evans & Craig, 1992; Heilmann, Nockerts, & Miller, 2010; Lund & Duchan, 1993; Norbury & Bishop, 2003), and language samples are considered more sensitive measures than assessments of phonological, lexical, or grammatical skills alone (Galetto et al., 2013).

Narrative samples represent a unique type of language sample that anticipates a specific structure ("story grammar") that can be measured and compared with the narratives of others. A narrative, based on a sentence prompt or a wordless book or movie, provides an opportunity for spontaneous language production while still controlling the individual's produced language with specific expected content.

1.7.2 Pattern of narrative language deficits observed in mTBI

Relatively little work has been done to examine the effects of concussion, specifically, on narrative language. Deficits specific to narrative language have been observed in pediatric populations when reporting on samples that include both mild and more severe injuries, including fewer overall utterances and words, fewer essential story components (e.g., setting, action), fewer transitions, decreased type-token ratio, increased use of ambiguous referents, and omissions of essential information (Biddle, McCabe, & Bliss, 1996; S. B. Chapman et al., 1992; Ewing-Cobbs et al., 1998). Similar patterns of deficits also have been observed in children with seizure disorders (Strekas, Ratner, Berl,

& Gaillard, 2013). Narratives of children with mTBI include fewer transitions between thoughts, less diverse language, and may leave referents, such as "him" or "they," ambiguous in interpretation (Biddle et al., 1996; S. B. Chapman et al., 1992; Ewing-Cobbs et al., 1998). In addition, children with mTBI more often repeat information and produce increased disfluencies, false starts, and fillers. When describing events, children with mTBIs make fewer inferences, referring more to literal than to implied information in a story (Dennis & Barnes, 2000). These differences contribute to significant increases in listener burden ratio. Many of these apparent narrative deficits could be the result of underlying lexical deficits. Ambiguous referents may be the result of difficult or inefficient access of semantically rich, less frequent nouns, while overall measures indicating fewer and less complex utterances, characterized by increased use of fillers and false starts, may be signs of word-finding difficulty. Decreased type-token ratio may also reflect difficulties at the level of lexical access. Although there are narrative measures that are less likely to be directly related to lexical access, such as analyses of story grammar (Brookshire, Chapman, Song, & Levin, 2000; S. B. Chapman et al., 1992; Preece, 1987) or the total number of propositions in a narrative (Biddle et al., 1996), the data on how these are affected by concussion are mixed. This highlights the importance of investigating deficits in language that may be present over and above those explained by lexical access difficulties.

Investigations of narrative language following mTBI in adults have suggested slower speech rate in the absence of significant differences in grammatical errors or paraphasias (Galetto et al., 2013). However, deficits were significant in so-called *macrolinguistic* features of the narratives: cohesive, abstract qualities of larger bodies of

language. Adults with a recent mTBI used a greater proportion of repetitive utterances, fillers, tangential or incongruent utterances, and a smaller proportion of lexical information units. These findings were correlated with poor cognitive inhibition, suggesting that a deficit in domain-general cognitive capacity was perhaps the underlying reason why individuals had included more frequent tangential and incongruent information in their narratives. In written language, macrolinguistic features could be improved after the majority of the content was written, through review and editing (presuming individuals suspected that such processes would improve their work). While some observations of oral language, such as filler use, may not have a direct correlation in formal written language, increasingly more often, younger individuals' written and spoken language in *informal* settings, such as in social media, demonstrate similar patterns in the use of features previously associated with oral language only. This suggests that many of the difficulties previously documented during oral language only may be more likely to occur in written language as well when considering younger individuals who have experienced a recent mTBI.

Story grammar, the pattern of introduction, rising and falling action or conflict, and resolution, present in typical descriptions of events, is unique in capturing the cohesion of a narrative that is more abstract and regarding a larger unit of language than the specific content of words and sentences. Structural coherence among parts of a text has been used as a measure of the ability to organize content in narratives when considering performance by individuals with language impairments (Coelho, Liles, & Duffy, 1995; Liles & Coelho, 1998). Following mTBI, adults demonstrate deficits in language cohesion and coherence, even in the absence of other language difficulties

(Marini et al., 2011) and even in the mildest forms of brain injury (Galetto et al., 2013; Tucker & Hanlon, 1998). Language cohesion and coherence is correlated with measures of executive function, specifically mental flexibility (Mozeiko, Le, Coelho, Krueger, & Grafman, 2011) and word-level language (Coelho, Grela, Corso, Gamble, & Feinn, 2005). It also has strong implications for social behavior, as difficulty in recounting events in a way understood by others results in social barriers. Unstructured narrative tasks, such as asking a person to recount an event, are important additions to the more commonly used structured narratives. These narratives can provide insight into the speaker's perspective on an event (Cleveland, Koss, & Lyons, 1999; Di Gallo, 2003). Moreover, these tasks are more demanding than highly structured narratives, relying heavily on implicit and explicit memory and resulting in decreased language fluency and complexity (Skehan & Foster, 1999). While cognitive-linguistic performance changes after injury have been observed, to date, no study has specifically addressed the etiology of higher-order written language production.

1.8 Limitations on assessment

Previous studies have attempted to describe the complicated landscape of cognitive-linguistic and neuropsychological evaluation in the overall mTBI population. These observations serve as an important reminder of the limitations of this kind of research, particularly when no baseline pre-injury measures of ability have been documented, but which even exist when baseline measures are recorded. Effort put forth by individuals at baseline can vary widely, artificially depressing performance on cognitive tasks (Lange, Iverson, Brooks, & Ashton Rennison, 2010), particularly in contexts where individuals are concerned that they must match or improve upon

performance documented at baseline in order to be permitted to rejoin desired activities. Further, participants whose attention is drawn to their health and injury status prior to engaging in a cognitive task may perform more poorly than similarly injured individuals who have not had their attention drawn to this factor ("diagnostic threat"; Ozen & Fernandes, 2011; Suhr & Gunstad, 2002). The measurement of changes in domain-general cognitive skills, such as memory, also is complicated by the poor correlation between cognitive skills demonstrated on objective assessments versus self-reported cognitive deficits (Spencer, Drag, Walker, & Bieliauskas, 2010). One potential explanation for this is that current objective measures are insufficiently sensitive to capture deficits that the individual is aware of in his or her daily life. However, individuals typically over-estimate their level of pre-injury functioning ("good old days" bias), inflating their self-reported impairment following injury (Brooks, Kadoura, et al., 2014; Gunstad & Suhr, 2001; Iverson, Lange, Brooks, & Lynn Ashton Rennison, 2010). Perception of current cognitive performance is negatively influenced further by co-morbid mental health diagnoses, such as anxiety and depression (Iverson & Lange, 2003; Max et al., 2013), leading some to suggest less isolating treatment regimens in concussion patient management (Silverberg & Iverson, 2013). However, the effect of personality and temperament, even those known to be risk factors for clinical anxiety and mood disorders, on concussion deficits remains incompletely understood.

1.9 The influence of differences in personality and temperament on medical outcomes

Differences in personality and temperament increasingly have drawn multidisciplinary attention (Kosslyn et al., 2002; Lahey, 2009; Moffitt, Poulton, & Caspi,

2013; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007; Underwood, 1975), with the most interest placed upon the individual and social implications of trait-like high dispositional negativity (DN). DN reflects the propensity to experience and express more frequent, intense, or enduring negative affect (Barlow, Sauer-Zavala, Carl, Bullis, & Ellard, 2013; Caspi, Roberts, & Shiner, 2005; Watson & Clark, 1984; Watson, Clark, McIntyre, & Hamaker, 1992), and encompasses anxious temperament, behavioral inhibition, harm avoidance, neuroticism, and trait anxiety (Barlow et al., 2013; Caspi et al., 2005). DN predicts a broad spectrum of physical diseases (Lahey, 2009), including heart conditions, lung disease, and hypertension (Weston et al., 2014), and it is a key risk factor for mental illness, including anxiety disorders (e.g., Separation Anxiety Disorder, Social Anxiety Disorder, Generalized Anxiety Disorder), depressive disorders, and substance abuse (Barlow et al., 2014; Clauss & Blackford, 2012; B. L. Goldstein & Klein, 2014; Kendler & Gardner, 2014; Kotov et al., 2010; Lahey, 2009; Ormel et al., 2013; Watson & Naragon-Gainey, 2014).

High DN reflects the interplay of three inter-related phenomena: increased negative affect in the absence of negative events, increased reactivity to negative events, and increased generation of negative events, particularly in times of stress. In particular, increased behavioral, psychophysiological, and neuroendocrine reactivity to negative life events makes high DN particularly interesting to examine in the context of acute brain injury (Buss, Davidson, Kalin, & Goldsmith, 2004; Buss, Goldsmith, & Davidson, 2005; A. S. Fox & Kalin, 2014; N. A. Fox, Henderson, Marshall, Nichols, & Ghera, 2005; Kagan, 1964; Kagan, Reznick, & Snidman, 1988; Shackman et al., 2013; Vaidyanathan, Patrick, & Cuthbert, 2009). In the period immediately following mTBI, patients

experience behavioral (Fletcher, Ewing-Cobbs, Miner, Levin, & Eisenberg, 1990; Warriner & Velikonja, 2006), psychophysiological (Bazarian et al., 2007; Leon-Carrion, Martin-Rodriguez, Damas-Lopez, Barroso y Martin, & Dominguez-Morales, 2009), and neuroendocrine (Lieberman, Oberoi, Gilkison, Masel, & Urban, 2001; McAllister, 2011) changes due to injury. When acting upon individuals with high DN, these changes may contribute to increased suicidal ideation in the months following injury, particularly associated with history of depression (Bethune, da Costa, van Niftrik, & Feinstein, 2016). Indeed, high DN is linked to increased risk for a multitude of mental disorders in the general population, as well as comorbidities among mental disorders (Lahey, 2009), resulting in more persistent disability. Regarding physical health, individuals with high DN experience increased rates of sleep problems (Hintsanen et al., 2014), chronic back pain (Currie & Wang, 2005), and disrupted immune response (Lahey, 2009; Robles, Glaser, & Kiecolt-Glaser, 2005; Smith & MacKenzie, 2006). Adults with high DN have higher rates of disease and chronic medical conditions (Buske-Kirschbaum, Geiben, & Hellhammer, 2001; Russo et al., 1997; Suls & Bunde, 2005), and DN predicts more rapid deterioration in chronic diseases, such as diabetes (Brickman, Yount, Blaney, Rothberg, & De-Nour, 1996).

When adults with high DN experience an adverse health event, such as coronary heart disease, they are at substantially greater risk for poorer outcomes (Deary, Weiss, & Batty, 2010; Pedersen & Denollet, 2006), though these findings have not been replicated in children. In children, individual differences in personality and temperament interact with alterations in language and cognition due to injury within the context of developmental trajectories of cognitive and linguistic skills (Courchesne, 1978; Goddings

et al., 2014; Hill & Schneider, 2006; Sizonenko & Aubert, 1986). Differences in personality and temperament are trait-like in their stability across the lifespan, from childhood into adulthood (Roberts & DelVecchio, 2000), suggesting that health impacts observed in adults are relevant to pediatric populations that share these risk factors. While these statistics reflect objective, measurable impacts of high DN on health, evidence also suggests that individuals with high DN both *experience* and *report* a magnified reactivity to negative events or other stressors, further elevating their overall level of disability and perception of disability (Shackman et al., 2016). This intersection makes high DN an important property to examine in those with TBI, both in terms of better characterizing individual differences in injury experience and in planning for treatment and discharge.

1.10 Mood disorders and recovery from brain injury

Previous research has established that affective disorders associated with high DN, including depression and post-traumatic stress, are important risk factors for poor mTBI recovery, particularly in milder injuries (Ponsford et al., 2012; Silverberg et al., 2015; Vargas et al., 2015). Recent studies have just begun to examine the injured individual's mood, rather than clinical mental health status, as a factor associated with recovery from concussion, and there have been mixed findings. There is conflicting evidence regarding whether significant negative emotional symptoms (e.g., lability, irritability, sadness, nervousness) slow the trajectory of symptom recovery (Howell, O'Brien, Beasley, Mannix, & Meehan, 2016; Stillman, Madigan, & Alexander, 2016). In examining sports-related concussion specifically in adolescents, a recent study showed that those with identified premorbid anxiety took almost twice as long to recover (Corwin et al., 2014). Moreover, brain injury in adolescence may result in changes to the neural

substrates of developing emotional processing circuits (Tlustos, Peter Chiu, Walz, & Wade, 2015), including clinically relevant changes, such as the emergence of significant anxiety or depression symptomatology (Stazyk, DeMatteo, Moll, & Missiuna, 2017), which may have a physiological basis (Sagarkar et al., 2017). However, a recent meta-analysis of 322 articles, regarding mood, anxiety, and mood disorders in individuals with mTBI across the lifespan, revealed no studies capturing multiple dimensions within the same individuals simultaneously, which would allow for a global perspective on these distinct facets (Rothschild, Maerlender, Caze, & Higgins, 2016). Only six studies examined mood, anxiety, and associated disorders as risk factors for poorer recovery, with no study that specifically examined dispositional negativity (Carroll et al., 2014; Panayiotou, Jackson, & Crowe, 2010; Silverberg et al., 2015). This meta-analysis further supports the notion that too little evidence yet exists to fully appraise the interaction between affect and recovery.

Differences in language usage have been noted in persons experiencing acute negative life events (Cohn, Mehl, & Pennebaker, 2004), clinical populations for whom high DN is a risk factor (Pennebaker, Mehl, & Niederhoffer, 2003; Rude, Gortner, & Pennebaker, 2004), and in populations noted for increased negative affect (Eichstaedt et al., 2015; Sanger, Hux, & Belau, 1997; Snow & Powell, 2004, 2005, 2012; Walsh & Ellis, 2007). Certain characteristics, such as a greater use of somatosensory, perceptual, and negative emotion words, may predict the later emergence of mental health conditions, assisting in the early identification of those at high risk (Ng, Ahishakiye, Miller, & Meyerowitz, 2015). While these differences are not used for clinical diagnosis,

they highlight the interconnected nature of affective, cognitive, and linguistic aspects of behavior and provide a theoretical basis for considering these three facets in conjunction.

1.10.1 Repeated impacts and mental health

Repeated injuries frequently are experienced in the context of sports and recreation participation (Giza et al., 2013), and the younger a child is when he or she experiences the first concussion, the more concussions that individual is likely to experience in their lifetime (Schmidt et al., 2018). Indeed, multiple concussions was the norm among participants in the present study in both the recent injury and injury history groups. Multiple impacts aggregated over time are thought to contribute to significantly increased risk for neurodegenerative diseases, such as dementia and Parkinson's disease, which carry complementary risk factors in mental health (Cummings & Masterman, 1999; Menza, Robertson-Hoffman, & Bonapace, 1993; Nuti et al., 2004; Seignourel, Kunik, Snow, Wilson, & Stanley, 2008). Of greatest concern is *chronic traumatic encephalopathy*, a disease defined explicitly by the etiology of repeated impact exposure (Carman et al., 2015). Chronic traumatic encephalopathy (CTE) or, more specifically, chronic neurocognitive impairment (CNI), is characterized behaviorally by anterograde amnesia, mood disorders, such as anxiety or depression, and dysexecutive symptoms.[1]

In addition to broad cognitive functional decline associated with multiple concussions, repeated head impact and concussion exposure (particularly exposure to

[1] CTE is characterized by neurofibrillary tangles due to the presence of abnormal proteins and atrophy, particularly in the frontal cortex, temporal cortex, and certain subcortical structures (Carman et al., 2015). However, the presence of these conditions cannot be diagnosed pre-mortem. Because of this diagnostic limitation, chronic neurocognitive impairment (CNI) is the more correct term to use when describing cognitive functional decline over time when repeated impact exposure is the anticipated etiology in the absence of, or prior to, post-mortem examination.

three impacts or more) has been correlated with increased risk for disordered mental health, including depression (Chrisman & Richardson, 2014; Didehbani, Munro Cullum, Mansinghani, Conover, & Hart, 2013; Guskiewicz et al., 2007), psychological distress (Cole & Bailie, 2016), and increased suicidality. Although data suggest strong perceived social support networks may lessen the risk of depression in acute or recovery phases following a single more severe injury (Gan, Campbell, Gemeinhardt, & McFadden, 2006), it is not yet known whether social support improves outcomes in individuals with repeated concussion, whose increased risk of depression has been associated with changes in white matter (Strain et al., 2013). As noted by the National Research Council Committee on Sports-Related Concussions in Youth (2014), individuals who have experienced repeated concussions and CNI show deficits in attention, working memory, and risk assessment, the very same cognitive skill deficits seen in those who engage in high lethality suicide attempts (Bridge et al., 2012; Keilp et al., 2001), which may suggest that repeated impacts are placing individuals at greater risk of suicide. Also, the physical symptoms associated with concussion, such as pain and sleep disturbance, are associated with suicidal behavior (T. R. Goldstein, Bridge, & Brent, 2008; M. M. Wong, Brower, & Zucker, 2011). Of note, much of this research has been specific to adolescents (Bridge et al., 2012; T. R. Goldstein et al., 2008; M. M. Wong et al., 2011).

1.11 Summary

In summary, concussions are the mildest, most common form of brain injury, and may be present even in the absence of a change in consciousness or post-traumatic amnesia. Although reliable metabolic markers for concussion are emerging, individuals who experience a concussion can have wildly different experiences of deficits across the

somatic, cognitive, linguistic, social, and psychiatric domains. Such variability substantially contributes to the difficulty in establishing a generalizable characterization of this population across the lifespan.

However, the emerging case for deficits in cognition and language as a hallmark of the profile for those with a recent concussion is compelling. Deficits in cognitive and cognitive-linguistic skills, such as auditory processing of language, verbal working memory, attention, and efficiency have been observed. Differences between the performance of healthy individuals and those with recent concussion often only emerge in experimental settings when demands on cognitive resources are quite high, such as in tasks with large and complex stimuli or time pressure, despite many individuals with recent injury reporting vague cognitive difficulties, such as "fogginess" or "fuzziness" in their everyday lives.

In language, individuals with a recent concussion appear to have more difficulty in production than comprehension. Particular deficits have been noted in word-level tasks, such as confrontation naming, single word reading, identifying related words, and letter fluency, and in higher-level language tasks, such as passage comprehension. Narrative language is a particular case in which the inclusion and organization of content are relatively more important to understanding the passage as a whole. Producing a thorough, organized, and easily understood narrative requires considerable cognitive and linguistic integration. Individuals with mild to moderate brain injuries have demonstrated deficits in both structural aspects of narratives and their content, both within and across sentences and in the broader macrolinguistic structure; however, evidence from concussion is minimal. These observations have motivated the first aim in the present

study, while understanding the relationship between these observations has motivated the second aim.

Moreover, despite its clinical relevance, the interaction between sub-clinical differences in personality and temperament and the differences in symptoms experienced by individuals with concussion is poorly understood. One dimension of personality, dispositional negativity, or the tendency toward more frequent, intense, and prolonged negative affect, has been associated with increased morbidity in a wide array of clinical profiles. Although clinical diagnoses associated with high dispositional negativity, such as post-traumatic stress disorder, have been examined for their influence on brain injury outcomes, the more prevalent sub-clinical differences that constitute risk factors for these mental health diagnoses have yet to be explored. Addressing this gap in the existing literature has motivated the third aim of the present study.

Chapter 2: Aims

2.1 Aim 1: Do adolescents and young adults with a recent concussion or history of concussion show deficits on diverse aspects language, including complex writing tasks?

Deficits following brain injury have been observed in all levels of language production, from the word level to building sentences and discourse. Deficits in generating narrative language have been observed in pediatric populations (Biddle et al., 1996; S. B. Chapman et al., 1992; Ewing-Cobbs et al., 1998) and adults (Galetto et al., 2013; Harvey, 2016; Kovach, 2015). However, these findings have combined clinical profiles across the mild brain injury spectrum, such that it is unclear to what extent these deficits are present in individuals with the mildest brain injuries, concussions. Moreover, the existing literature addressing mild TBI has overwhelmingly focused on the analysis of oral language, despite the importance of written communication to adolescents and young adults. While written language provides writers the opportunity to examine and revise what they have produced without the pressure to account for an immediate listener, it is hypothesized that the unique cognitive-linguistic demands of writing will result in deficits in the population of adolescents and young adults with concussion.

Hypothesis: Adolescents and young adults with a recent concussion or history of concussion will show deficits on complex writing tasks.

2.2 Aim 2: Are deficits in complex writing better characterized as uniquely lexical or as a result of poorly integrated cognitive-linguistic skills?

Should deficits in complex writing tasks be observed, it is unclear to what extent these would solely be the products of word-level deficits (K. A. King et al., 2006;

Stockbridge et al., 2018) impacting performance on a larger scale or whether deficits exist predominantly due to increased overall cognitive demand associated with generating more complex language. If deficits in language due to these extremely mild injuries are solely impacting word-level access, performance on larger and more complex language production tasks may include increased use of more general or empty words (e.g., general all-purpose, or GAP, verbs) or may simply result in less language produced overall in a given time, suggesting poor efficiency. However, deficits in language also could exist directly impacting the skills necessary for combining larger units of language – planning, organization, and inclusion of content necessary for the receiver, over and above difficulty in lexical access. Evidence of such deficits in this population has not yet been demonstrated in the literature but would include significant deficits in story grammar and cohesion, which should not be observed if the sole deficit is lexical. These two proposed etiologies, or "core" deficits, could lead to divergent treatment recommendations and distinguishing between them may improve treatment efficiency. Comparing holistic qualitative and quantitative measures of narratives while controlling for performance in domain-general cognitive skills will inform a better understanding of the cause of discourse-level specific deficits.

Hypothesis: Two competing accounts are supported by the literature in best characterizing these deficits, and the goal of this aim is to determine which account is best supported. It is hypothesized that deficits following a recent concussion will, indeed, include changes in story grammar and cohesion following concussion, supporting a more multifaceted account of language production deficits above and beyond word-finding difficulties.

2.3 Aim 3: Does high dispositional negativity have a measurable negative impact on deficits following concussion?

There is compelling evidence that individual differences in emotional reactivity are key determinants of recovery from mild TBI in adults (Ponsford et al., 2012; Silverberg et al., 2015; Vargas et al., 2015). Yet, the contribution of temperament to recovery remains unexplored. This work examines the benefit of considering such sub-clinical personality differences in adolescents and adults with a history of concussion over and above word- and discourse-level linguistic performance in distinguishing them from individuals with no such injury. If dispositional negativity improves on a model identifying individuals with a concussion history taking into account traditional cognitive-linguistic measures, it would provide preliminary support a broader cognitive-affective-linguistic model for considering individuals with concussion, particularly those experiencing deficits beyond the traditionally defined window of recovery.

Hypothesis: Individuals with high dispositional negativity will experience a greater severity of subjective and objectively measured cognitive-linguistic concussion symptoms particularly relevant when distinguishing individuals with a concussion history from those with no such history.

Chapter 3: Methods

3.1 Recruitment

All data were collected remotely through online surveys managed via the Qualtrics experience management software tools. Adolescents and adults with a recent concussion or history of concussion and healthy age-matched participants were recruited through many venues throughout the community, including clinician referral, use of the on-campus database of University of Maryland Psychology undergraduate students (Sona Systems), public advertisements, and notices. Participants were reached through doctor's offices, schools, and clinics via a letter with a link to the Qualtrics testing website and were encouraged to complete the assessment at concussion clinic computer facilities where applicable. Participants also were reached via phone and email through contacts within the community (e.g., club sports, community centers).

Methods of data collection via browser survey (Qualtrics) were specifically designed such that participants would not need to appear in person to participate in the proposed research. In this way, a far larger sample could be reached without limitations associated with transportation and lengthy in-person interviews. Remote behavioral data collection methods similar to those proposed here are becoming increasingly more common with the ubiquity of mobile technology (e.g., ecological momentary assessment, Shiffman, Stone, & Hufford, 2008), including studies completed exclusively on-line (Barak & English, 2002; Buchanan, Johnson, & Goldberg, 2005; Chuah, Drasgow, & Roberts, 2006; Illingworth, Morelli, Scott, & Boyd, 2015; Templer & Lange, 2008) and those relying on self-reported linguistic behaviors (James, Brumfitt, & Cowell, 2009). In one prior case, medical history, social and inter-personal relationships, personality

characteristics, and demographic variables were self-reported by adolescents aged 14-17 following concussion (Lewandowski, Rieger, Smyth, Perry, & Gathje, 2009). Recent work has suggested that online tools receive highly favorable user feedback in the adolescent mTBI population, specifically including the use of pictures and videos, bolstering the feasibility of similar uses of technology (Dexheimer et al., 2017).

The recruited study population included 375 individuals aged 12-40 within 50 days following a diagnosis of concussion, with a lifetime history significant for at least one concussion, and with no such history of brain injury (control subjects). Although studies operationalize concussion recency at various points (e.g., under 10 days, 14 days, 30 days; McCrory et al., 2013b; Meier et al., 2015; Putukian, Aubry, & McCrory, 2009), the more protracted window of 50 days was selected in light of increasing evidence of continued cognitive deficits beyond these timeframes (Howell, Osternig, & Chou, 2018; McInnes et al., 2017). All participants also were asked if they had a recent orthopedic traumatic injury, and individuals with a recent orthopedic injury were actively recruited through the urgent care concurrent with concussion patient recruitment. This addition was done out of an abundance of caution regarding the possible confounding effects of trauma more generally, despite recent observations that called into question the utility of orthopedic control groups (Mathias, Dennington, Bowden, & Bigler, 2013), particularly in pediatric TBI studies (Beauchamp, Landry-Roy, Gravel, Beaudoin, & Bernier, 2017) and in studies considering trait-like anxiety and mood individual differences (Turner et al., 2017).

The Center for Disease Control (CDC) has stated that estimating TBI incidence by race/ethnicity is difficult, with cause of injury more variable than overall incidence

(Langlois, Rutland-Brown, & Thomas, 2005). Based on epidemiological estimates of TBI published by the CDC in 2010, we estimated that approximately 40% of participants would be female. This was approximately true of the acute concussion group (45%); however, the recruitment of females across groups in actuality was much higher – 71 of the 92 participants were female (77.2%). Although results are mixed, some studies have found differences in outcomes for males and females after brain injury (Brooks, Mrazik, et al., 2014; Dougan, Horswill, & Geffen, 2014; McCrory et al., 2013a), leading to the inclusion of gender as a biographical variable that was examined in the planned multiple regression analysis (see below). Socio-economic status, estimated using maternal education, also was collected, such that this dimension could be considered as a source of inter-group variability (Coelho, 2002).

3.2 Eligibility criteria

Participants with a recent concussion were defined as those within 50 days following a traumatic injury. Severity of injury typically is determined by length of alteration of consciousness, worst achieved Glasgow Coma Scale Score (13-15), neurological examination including the Acute Concussion Evaluation (ACE) and cognitive testing using the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT). In addition, criteria used to diagnose concussion (rather than more severe injury) include having duration of unconsciousness no longer than 30 minutes and duration of post-traumatic amnesia no more than 24 hours.

Based on reported medical histories, individuals with complex medical histories or relevant diagnoses were excluded from both groups. These included pervasive developmental disorders, cognitive processing disorders, language disorders, language

delay, fluency disorders, speech and articulation disorders, auditory processing disorders, and diagnosed deficits in literacy. Individuals were asked to report any presence of speech, language, fluency, or learning disorder in their health history, including childhood. Additional information was not requested. Thus, essentially, any prior self-reported diagnosis in these domains was grounds for exclusion. The exception was that participants were retained if their sole diagnosis was a history of Attention Deficit Disorder/Attention Deficit-Hyperactivity Disorder due to the inflated prevalence of this diagnosis (in contrast to in individuals demonstrating these characteristics within the population) that impacted the target age range (Schwarz, 2013). Adolescents and adults with a diagnosis or history of neurological disorders, not including the present acute injury or history of concussion, also were excluded from the study (e.g., participants with histories of past severe brain injury, neurosurgery, or radiation therapy). Adolescents and adults who did not report normal or corrected-to-normal hearing and vision were excluded. Adolescents and adults for whom English was not their reported native language were excluded (minimum of 80% exposure), in order to mitigate the possibility that native language proficiency was negatively influencing performance or influencing the interpretation and reporting of biographical information.

3.3 Data collection

All data collection was conducted via an Internet browser using the Qualtrics survey application provided by University of Maryland. Participants were able to complete the study on their own home computers, but many participants were tested at HeadFirst Concussion Care centers. Obtaining consent was formally waived through IRB review (thus, the study was determined to be of sufficiently minimal risk to human

subjects as to not require consent), but informal consent and assent processes were done online through this application for parents and adult participants as a means of conveying study information. The informal consent process was included immediately following the link they received from recruitment materials and immediately prior to accessing the tasks for the study (e.g., wherever the participant chose to access the study link). All contact information for the primary investigator, doctoral student, and IRB office was provided at this time, such that the participant could contact the study leadership with any questions or concerns and was repeated at the end of the study. Once a participant agreed to the study, an anonymous identifier was generated to associate with their online performance. This prevented duplicate participation and provided privacy and confidentiality protection. While participants were instructed to complete the assessment in an environment that minimizes distraction, prior research suggests that auditory distraction does not significantly impact the qualities of the narrative most often examined (Cook, 2008).

Next, the participant was guided through various data collection forms (e.g. health history), and a combination of traditional standardized assessments of language and affect and language samples (Table 3.1). Health history included head injury history, orthopedic injury history, self-reported ratings of both somatic symptoms (adapted minimally from the Rivermead Post Concussion Symptoms Questionnaire by HeadFirst Concussion Care centers; N. King, Crawford, Wenden, Moss, & Wade, 1995) and cognitive changes, and history of developmental cognitive or linguistic diagnoses. For participants under age 18, parents also were asked about their referral to the study, their report of their child's behavior since injury, and other demographic factors (e.g., household income, education).

Experimental tasks, cognitive-linguistic tasks, and affective and personality data assessments were each randomized within their respective blocks so as to minimize order effects and fatigue while prioritizing hypothesis-driven objectives. Tasks were divided into two separate surveys, each less than one hour in length.

Table 3.1 *Data collection*

Experimental tasks (Appendix A)	
Task	Description
Structured narrative task based on familiar images	Participants viewed the illustrations of Disney's Cinderella embedded in Qualtrics and told the story of the images while being able to view them by typing in a recorded textbox. (5 minutes maximum)
Structured expository task based on social-pragmatic prompt	Participants were asked to write on the topic "Friends are important, but everyone has a different opinion of what makes a good friend. Explain what, in your opinion makes a good friend and why." (5 minutes maximum)
Structured narrative task based on provided video	Participants watched "Pigeon: Impossible" embedded in Qualtrics and told the story of the movie they just watched using a recorded textbox. (5 minutes maximum)
Health information	
Task	Description
Demographic questionnaire (Appendix B)*	Participants (or their parents) provided demographic and socioeconomic information.
Subjective perception of changes since injury (Likert series) – Parent (Appendix B)	Parents of participants under 18 years old provided a rating of their child's changes in ability to focus, mood, and ability to complete tasks.
Subjective perception of changes since injury (Likert series) – Patient (Appendix C)	Participants provided a rating of their own changes in ability to focus, mood, and ability to complete tasks.
Brief health questionnaire (Appendix C)	Basic health history and concussion history information
Sleepiness Scale (Appendix F; Wolfson & Carskadon, 1998)	Examine daytime sleepiness, commonly reported in concussion
Sleep/Wake Problems Behavior Scale (Appendix F; Wolfson & Carskadon, 1998)	Examine sleep disturbance, a related risk factor to high dispositional negativity and commonly

	reported in concussion
Cognitive-linguistic data (Appendix E unless otherwise specified)	
Task	Description
Letter fluency (FAS) task (Slomine et al., 2002)	Examine divergent/non-linear cognitive-linguistic reasoning
Naming task*	Examine confrontation naming
Digit span task (Backward only; McCrea, 2001)	Test of immediate and working memory
Flanker task (Levin, Hanten, Zhang, Swank, & Hunter, 2004; Mayr, Awh, & Laurey, 2003) via PsyToolkit (Stoet, 2016)	Test of response inhibition associated with executive control
Spot the difference task* (Nishiguchi et al., 2015)	Test of visual processing
Affective/Personality data (Appendix F)	
Task	Description
M.I.N.I. International Neuropsychiatric Interview (portions)* (Sheehan et al., 1998)	Structured psychiatric interview for ICD-10 disorders, including those associated with high dispositional negativity
Big 5 Inventory-2 (BFI-2) N/Ne (Soto & John, 2016)	Abbreviated measure of personality dimensions
State Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983)	Measure of self-reported state and trait anxiety
Multidimensional Scale of Perceived Social Support (MSPSS)* (Bruwer, Emsley, Kidd, Lochner, & Seedat, 2008; Zimet, Powell, Farley, Werkman, & Berkoff, 1990)	Measure of perceived support, a reducer of risk associated with high dispositional negativity
Brief Adolescent Life Event Scale (BALES)* (Shahar, Henrich, Reiner, & Little, 2003)	Determine presence of stressful events in recent past

* These tasks were included in the second survey portion of the study.

Narratives were timed to gain further insight into the average rate of production. Multiple questions required the participant to respond by typing into a recorded text box. Individual differences in overall typing ability, measured in words per minute, was assessed with a brief piece of directly transcribed text. Additionally, participants had the opportunity to provide researchers anonymous access to their social media activities (e.g.,

Twitter tweets), such that these sources of linguistic expression could be compared with more structured language production and assessment tasks at some point in the future. The two sessions did not exceed two hours, the length of a typical diagnostic session.

3.4 Planned analyses of written samples

Analyses were completed separately to examine the cognitive-linguistic and affective data. Expository samples were rated for organization and completeness. In contrast, narrative analysis was carried out using tools developed by the CHILDES project (MacWhinney, 2000), which was developed to automate and improve the language analysis process. These tools allow clinicians and researchers to transcribe language samples in a standard format and analyze them using over a dozen different programs to extract diverse information. Samples were examined for language measures that exist at the word, sentence, and paragraph levels. Because timed writing samples were utilized in place of speech samples, written samples were minimally edited prior to calculating language measures (samples in original and edited form are available from the corresponding author). Clear typographical, spelling (e.g. *slepe for "sleep") and orthographically identified usage errors (e.g., "they're" for "there") were corrected. Incomplete sentences at the end of the sample, suggesting the time had run out mid-sentence, were edited in order to preserve the greatest amount of correctly formed language. Those that included a complete independent clause (e.g., "She makes a dress with") were shortened to the remaining independent clause (e.g., "She makes a dress."). Those fragments that did not include any independent clause (e.g., "Then, she") were removed entirely. Self-talk or commenting (e.g., "I really have nothing else to say") were left in the sample for the purposes of this analysis. Language measures available in

CHILDES are numerous (see Table 3.2 for planned statistics and purpose in language analysis), though exploratory analysis of aim one focused on total utterances, mean length of utterance in morphemes (MLU), vocabulary diversity (VocD), and clausal density (estimated by verbs per sentence). Due to both the number of variables and their highly correlated nature, hypothesis testing of differences in performance on these variables between individuals with a recent concussion and those with no such history was controlled for Type I error and study-wide alpha by first including all variables of interest from CHILDES in a single omnibus analysis of variance. Only if the difference between groups was significant on this test would measures be explored individually. Once these statistics were computed, language samples in response to the different prompts were compared for all three experimental groups (and for individuals who reported a recent orthopedic injury across groups).

Table 3.2 *Statistics calculated from language samples*

Statistic	Description
Total time of the sample	Used for determining rate
Total number of sentences and propositions	Measure of overall productivity of participant
Average length of the sentence in words and meaning units (MLU)	Measure of sentence complexity
Type-token ratio (TTR)	Norm-referenced measure of lexical diversity (Miller & Leadholm, 1992)
Vocabulary diversity score (VocD)	Alternative measure of lexical diversity to TTR that is less influenced by sample size.
Average number of clauses per sentence	Measure of clausal density or grammatical complexity
Error and self-correction rates	Measure of error rates in language
Underspecified word choice (e.g., “thing” instead of “toaster”)	Indicator of word-finding difficulties

Cohesive ties	Measure of linking within discourse (Coelho et al., 1995)
Story grammar	Indicator of supra-structural organization of content (Coelho, 2002)
Expository goodness	Rating of content and organization (Lê, Coelho, Mozeiko, Krueger, & Grafman, 2011)

In addition to these statistics, the story grammar of each of the two structured narratives was analyzed. Story grammar refers to the features that all stories include, which build the course of events in time in a described context (Roth & Spekman, 1986). The seven features, or components, are setting, initiating events, response, plan, attempt, direct consequence, and reaction. Within a structured narrative, these components should be reasonably consistent. The story grammar for *Cinderella*[2] (see Appendix G) included 41 previously-established propositions reflecting the story's setting, events, conflict (or "complicating action"), resolution, and coda (Stark, 2010), based on the schematic structure put forth by Labov and colleagues (Labov & Waletzky, 2003). Of these 41 propositions, 23 were identified by consensus of ten healthy control participants to be the

[2] Although the *Cinderella* narrative task is very common in language research, studies vary in the visual stimuli utilized to assist participants in telling the story. The two most common stimulus sets are the Disney imagery available through the AphasiaBank protocol (https://aphasia.talkbank.org/protocol/pictures/Cinderella-book.pdf) and those used in the original Grimm story. While the two versions of the story, and their images, vary slightly (e.g., the Disney version has helpful anthropomorphic mice, the Grimm version includes sisters mutilating their feet), the key features of the narrative are consistent (e.g., Cinderella is a servant who goes to a ball and meets a prince, and the prince eventually finds her by traveling the kingdom and testing her lost shoe on potential brides). Of note, as in the example provided, the Grimm version of the story and its images tend to be more graphically violent, which may insulate the task from concerns about gender-biased performance (Fromm, MacWhinney, Forbes, & Holland, 2011). Although efforts have been made to utilize consistent images within certain contexts or when banking narrative samples, in practice, authors frequently do not identify the set of images they have utilized. In this study, the Disney images available from the AphasiaBank protocol were used, as these were the ones most familiar, readily available, and consistent with the previously published story grammar that was employed for the *Cinderella* narrative task analyses (Stark, 2010).

"constituent events," those considered to be crucial for the (re)telling of this fairy tale (Stark, 2010). As described by Stark, independent participants were asked to "analyze the list of propositions and to determine which propositions were necessary for a summary narration of the fairy tale Cinderella. On a second pass, the participants were asked to slim down their initial selection to the most essential, indispensable propositions. Those propositions agreed upon by (almost) all evaluators in this second-pass analysis are considered to be the constituent events." This method mirrored that found in Porter and Abbott (2005). In order to account for the differences between the telling of Cinderella from the previous study and the images utilized for the present study, seven novel propositions were substituted into the existing framework, impacting neither the final proposition nor constituent total scores.

A standard story grammar for the film, *Pigeon: Impossible*, was constructed by analogy to the process used to generate the existing *Cinderella* story grammar (see Appendix G) in Stark (2010). Forty-two propositions were identified through careful scrutiny of the film. In an analogous procedure for identifying constituent events, twelve healthy control participants were asked to analyze the film and identify a minimal list of events necessary to a summary of the film. As in Stark (2010), if the healthy speakers' selection of a single proposition within a section of the superstructure differed, those considered equally important were marked by [*]. For these propositions, any one of the two or three is considered to be crucial. As in the *Cinderella* story grammar generated by Stark, this circumstance only occurred within the setting/orientation and coda conditions of *Pigeon: Impossible*, how the story was introduced and concluded. A total of 20 constituent events were identified. Only factually correct propositions were scored;

incorrect statements (e.g., "The pigeon launched a missile to Russia.") were ignored. Propositional content could occur in any order, as long as the logical order of events remained intact. Reliability coding will be completed prior to seeking peer-review publication.

Cohesive ties were analyzed in the two narrative samples using a method based on a three-part procedural taxonomy adapted from Halliday and Hasan (1976): words used as cohesive ties were identified, the ties were classified into linguistically structured categories, and the adequacy of cohesive function was determined (Liles & Coelho, 1998). Words are identified as cohesive markers if the meaning cannot be understood without looking outside of the structural unit (each independent clause and its dependent clauses), such as presupposing shared knowledge (e.g., "*He* ate *the* ice cream." This sentence contains two words that suggest the reader must look outside of the sentence to fully understand meaning. Personal pronouns suggest that a male individual has been introduced previously. The use of a definite article suggests that the direct object also has been introduced previously or is shared knowledge between the speaker and listener.).[3] These words are then classified based on function, which can be simple, such as marking presupposed information (e.g., definite articles) or complex. Keeping with the analysis suggested in Liles and Coelho (1998), cohesive ties functioning in reference (e.g., personal pronouns, deictic words), conjunction (e.g., "because," "yet," "then," "and"),

[3] The original Liles & Coelho (1998) relies on the basic language structure of the T-unit, or minimal terminal unit, not the sentence. This unit arises from a protocol intended to break apart spoken language into minimal whole segments of content. However, for this analysis of written language, sentences were used since the writer's intended segmentation was made explicit by punctuation. The only exceptions to this rule were that independent clauses were considered separately, both when they were main clauses in compound sentences and when they were present in a chain of clauses joined by conjunctions (Lee, 1974).

and lexical items (i.e., a synonym is used, or a superordinate or general word is used to reiterate a concept) were used in the present analysis. Ties can be complete (e.g. "he" as in "The boy was hungry. Then *he* ate."), but they also may be judged to be incomplete, meaning the information referred to by the marker is not provided by the writer (e.g., The sisters played music. They saw that *he* wrote a letter.") or erroneous, meaning the reader is guided toward ambiguous information (e.g., "The sisters played music. *She* played the trumpet.") or an in interpretation that is known to be objectively false (e.g., "Kyle looked up at the sky. *It* was green."). The incompleteness or erroneousness of a cohesive attempt is inherited by future references made to that content until the speaker repairs the damage. These tied errors are identified and measured separately from, but provide additional insight into, the speaker or writer's awareness of potential for listener/reader breakdowns. Common quantifications of cohesive performance include the proportion of cohesive ties to "complete" ties (total ties/complete ties),[4] and the percentages of erroneous and incomplete ties.

3.5 Planned comparisons

Given the large number of independent and dependent variables being collected in this study, it is important to note that the following hypothesis-driven planned comparisons were expected:

[4] This statistic is the inverse of the more easily interpreted statistic that one could think of as "accuracy," which would be the number of complete ties divided by the total. Despite this, it is the one most commonly utilized in these authors' cohesions literature. It is likely that the inverse is used to correct for skewness due to the overwhelming number of complete ties in the majority of written samples. In the present work, this statistic is presented along with the more traditional estimate of accuracy for ease of readability. Non-parametric statistics are used throughout the cohesion analysis to account for non-normality in these data.

I. **Hypothesis (Aim 1):** Adolescents and young adults with a recent concussion or history of concussion will show deficits on complex writing tasks.

Comparisons:

1. Group differences in word-level task performance (Letter Fluency Task and Naming Task)
2. Group differences in narrative task performance (Story grammar in narrative language samples).
3. Group differences in working memory and attention (backward digit span).

Rationale: *If individuals with concussion and not more severe mild brain injuries have deficits, they should be apparent in differences in performance between injured and uninjured groups across a variety of cognitive and linguistic tasks, including word-finding, complex writing, and backward digit span*.

II. **Hypothesis (Aim 2):** Deficits in narrative language cannot be fully explained by difficulties observed at the word level and are better explained by the complex interplay between cognitive skills and language.

Comparisons:

4. Group differences in overall amount of language produced in a given time (Lexical account)
5. Group differences in use of more general or empty words (e.g., general all-purpose, or GAP, verbs) in written texts (Lexical account)
6. Group differences in story grammar (Cognitive-linguistic account)
7. Group differences in cohesion (Cognitive-linguistic account)

Rationale: *Story grammar performance in narratives may reflect either only word-level skills or may involve additional skills unique to combining larger units of language (i.e., higher level cognitive skills, such as organization and planning, which drive aspects of cohesion and story grammar). If word-finding skills are the primary deficit impacting narrative performance, then individuals with a concussion should demonstrate comparable deficits in tasks directly targeting word-level skills and in word-level skills applied within the narratives. However, if these additional skills are impacted by the injury, then one would expect to see deficits in story grammar and cohesion over and above what is evident when considering only the choices among single words.*

III. **Hypothesis (Aim 3):** Accounting for a richer appreciation of individual differences in personality and temperament will improve upon the models of severity and recovery that use physical and injury characteristics alone (i.e., age, symptom severity).

Comparison:

1. A multiple regression model using cognitive-linguistic task performance to predict concussion history status will be compared with a multiple regression model that includes the addition high dispositional negativity in order to determine which model best captures the variance in the dependent variables.

Rationale: *If affective and personality traits are meaningful interactive forces in the experience of brain injury, then their addition to the model should*

increase and not decrease the explained variance over and above linguistic and cognitive-linguistic performance.

3.6 Power analysis

The number of participants deemed necessary to observe the effects sought through this investigation were calculated using G*Power 3.1 statistical power analyses computation software based on reported participant numbers, means, and standard deviations from two recent studies of narratives in young adults with concussion (Harvey, 2016; Kovach, 2015). Both prior studies reported on findings from the Concussion Assessment and Rehabilitation Team (CAART) concussion screening/re-screening process at the University of Colorado Boulder's Speech, Language, and Hearing Center, which uses the Cinderella story retelling as the key measure of expressive language for student athletes. Cohen's *d* was calculated for three key narrative measures in which these previous studies found statistically significant group differences within that corpus: use of fillers and interjections (d = 0.59; Harvey, 2016), inclusion of tangential information, an error of global coherence (d = 0.87; Kovach, 2015), and number of thematic units, or details (d = .79; Kovach, 2015). Based on the smallest effect size reported among these measures, minimally 22 people would be required in order to capture the reported effect. Nevertheless, concerns about power arose due to immense challenges in recruitment of individuals with a recent concussion. In order to minimize multiple comparisons and resultant increases in Type I and II error, care was taken to limit exploration of less robust signals in the present investigation in the absence of significant findings in omnibus analysis of variance tests. Moreover, all significance testing was calculated two-tailed, essentially halving the alpha directly associated with

testing the hypotheses of interest across all analyses (i.e., there was no reason to expect individuals with a recent concussion or concussion history would perform better than individuals with no history of concussion on any task or measure associated with the present study, yet only $\alpha = 0.025$ was applied to this direction).

Chapter 4: Results

4.1 Study recruitment & participant characteristics

In total, 375 individuals responded to the study by visiting the website, go.umd.edu/concussion between 2017 and spring of 2018. Of these individuals, 237 began responding to self-report questions but discontinued the study prior to completing a single experimental task. Of the remaining 138, 7 were excluded due to being outside of the recruitment age range (12-40 years old), 29 were excluded due to reported English proficiency lower than 80% or prior diagnoses of learning, speech, language, reading, or fluency disorders, and 9 individuals were excluded from analysis due to a reported neurological history significant for events more severe than concussion (e.g., tumors, cancer, severe brain injury). Individuals with self-reported attention deficit or attention deficit hyperactivity disorder remained in the sample. The above exclusion criteria were established *a priori* to narrow the population of interest to those with a recent or lifetime concussion history. One individual was excluded from analysis after responding to the second session of the study while never responding to the primary session, which contained the key medical history questions that would allow the second session to be interpreted. Following the application of the exclusion criteria, 92 participants remained: 11 individuals with recent concussion (summarized in Table 4.1), 58 individuals with a history of at least one concussion or mild head injury but no injury within the last 50 days, and 23 individuals with no history of head injury (group statistics summarized in Table 4.2). Of those with a recent concussion, all but one also had a concussion history. This distribution was anticipated due to the prevalence of concussion history in the adult population and the nature of recruitment. Originally, there was a concern that individuals

with recent concussions may be distinct in the kinds of behavior they engaged in compared to individuals with no such history (e.g., increased risk-taking, greater participation in physical activity). Were such a difference significant, it could suggest other factors driving group differences beyond the effects of the concussion impact itself. Prior work considering this comparison directly has suggested that this confound is not one of particular concern. This has caused others to question the value of such comparison groups (Beauchamp et al., 2017; Mathias et al., 2013; Turner et al., 2017). Nevertheless, a small group of individuals who had experienced a recent orthopedic injury were actively recruited in the interest of utmost consideration for possible confounding factors. Across groups, 9 individuals reported a recent bodily injury within 30 days of testing. This small sample, which did not significantly differ in age, sleep behaviors, or somatic symptom reporting from those who did not report a recent head or bodily injury, did not demonstrate significantly different performance on any key variables utilized in the present study (Table 4.3). In light of these findings, the presence of an orthopedic subset group was ignored for the remainder of the analyses.

Table 4.1 *Event characteristics of injured group*

Participant	Age	Days	SS	CC	Part of Head	LOC	Cause
1	16; 9	10	13	2.67	LEFT		Softball
2	16; 5	26	0	2.33	FRONT		Cheer kick
3	37; 7	10	29	1	BACK	+	Fall on ice
4	18; 3	7	41	3.33	MULTI		Fall
5	28; 3	44	56	3.33	BACK		Hit
6	17; 2	46	7	2.67	NR	NR	NR
7	14; 5	9	0	2	LEFT		Skiing
8	15; 3	4	21	2.33	BACK		Ice hockey
9	26; 3	4	34	3.33	FRONT, BACK		Snowboarding
10	19; 7	8	55	3	FRONT	+	Football
11	23; 3	9	65	2.67	RIGHT		Basketball

NR = no response, Days = number of days from injury to testing, SS = symptom score, CC = cognitive change, LOC = loss of consciousness, Cause = cause of injury.

Table 4.2 *Group characteristics*

	Recent injury	History	Healthy
N	11	58	23
Age	21.24(7.05)	29.89(7.36)	23.75(7.21)
Proportion of males	0.55	0.17	0.22
Most recent injury	16.09(15.45) days	4.80(6.54) years	-
Total concussions	2.00(1.26)	2.76(3.11)	-
Self-report ratings			
Symptom score	29.18(23.14)	25.86(20.95)	10.52(12.40)
Cognitive change	2.61(0.70)	2.83(0.76)	-
Sleep behavior			
Sleepiness scale	17.78(5.36)	14.58(3.64)	14.50(6.39)
Sleep-wake problems	22.33(9.58)	20.19(6.70)	19.57(6.07)

Statistics are reported as Mean(SD) where applicable.

Table 4.3 *Means and standard deviations for recent bodily injury*

	Letter fluency	Story grammar	Backward DS	Flanker
Recent bodily injury	15.17(1.69)	0.23(0.14)	5.33(0.58)	82.80(82.95)
No recent injury	13.98(4.37)	0.27(0.17)	5.33(0.86)	116.36(154.20)

Values in the table are presented as Mean(Standard Deviation). Individuals with no recent injury include anyone who had no history of injury and those with a history of head injury, but no recent head injury. DS = digit span. The story grammar performance statistic reported here reflects the average total completeness of the two narrative samples based on the proportion of propositions included in each narrative.

A one-way analysis of variance across groups was significant for age ($F(2, 89) = 8.364$, $p < 0.001$). This was due to the fact that those individuals with a history of concussion were considerably older (M = 29.20 years, SD = 7.36 years) than either the healthy group (M = 23.75, SD = 7.21) or recently injured group (M = 21.24, SD = 7.05). Despite this age difference, those with a history of concussion were never directly compared to the other two groups in addressing the key aims. Moreover, age was not a significant factor influencing story grammar performance based on regression analyses that were conducted including the concussion history group. The difference in age between the healthy and recently injured groups was not significant ($p = 0.345$, two-tailed). Further group descriptive measures are summarized in Table 4.2 and addressed in

the sections that follow. The recently injured group included a larger proportion of males (approximately half) in comparison to the other two groups. While a growing body of literature has examined sex- and/or gender-based differences in concussion symptoms and recovery with mixed results, when an effect is found, nearly all suggest females fair worse (Baker et al., 2016; Bauman, Ray, & Joseph, 2017; Long et al., 2016). Given this, the relatively smaller, more even proportion of males to females in the recent concussion group suggests these analyses may be less likely to demonstrate group differences due to capturing an average performance across genders. However, should gender differences be observed, it seems unlikely that they would be artificially inflated by the discrepancies in gender makeup of the groups, Overwhelmingly, these analyses (4.1.1 - 4.1.4) suggest that the three groups were well-matched in terms of external characteristics, such as sleep behaviors, personality/temperament, and social support, which might otherwise contribute to differences in cognitive and linguistic performances observed across groups.

4.1.1 Subjective ratings & concussion history

All participants were asked to rate the severity of 18 somatic symptoms (SS) within the 24 hours prior to testing on a scale of 0 to 6, with 6 being the most severe (maximum score of 108; see Table 4.2). A one-way analysis of variance was significant for symptom scores ($F(2, 89) = 5.861$, $p = 0.004$). Levene's test of homogeneity of variances was significant $F(2, 89) = 4.445$, $p = 0.014$).[5] Participants with a recent concussion ($M = 29.18$, $SD = 23.14$) and those with a history of concussion ($M = 25.86$, $SD = 20.95$) did not differ in symptom score ($p = 0.637$, two-tailed). However, those with

[5] In order to correct for this violation, the Cochran & Cox (1957) adjustment for the standard error of the estimate and the Satterthwaite (1946) adjustment for the degrees of freedom were applied to follow-up statistics. This procedure was conducted in each case when Levene's test suggested the assumption of homogeneity of variance was not met.

a recent concussion had significantly more symptoms than those with no such history (M = 10.52, SD = 12.40; Levene's test of homogeneity of variances was significant F = 8.138, p = 0.008; t(12.82) = 2.508, p = 0.026, two-tailed), as did those individuals with a history of concussion (t(66.94) = 4.064, p < 0.001, two-tailed). It was expected that individuals with a recent concussion would describe a greater severity of somatic symptoms at testing than those with no injury history, as was shown here. The absence of a difference in symptom score reporting between those with recent injuries and an injury history might suggest that those with a history of concussion were still experiencing (or reporting) symptoms from their earlier concussion or are more sensitive to typical levels of these symptoms (e.g., headache, fatigue) since their injury. It could also be the case that some of these somatic factors also are ones that occur more commonly as one gets older.

Self-reported symptom score positively correlated with self-reported cognitive change rating (CC) for participants with any concussion history (r = 0.636, p < 0.001). Cognitive change was the average of responses to three questions put only to those with a recent injury or injury history: a. Has your ability to focus changed since the injury? b. Has your mood changed since the injury? c. Has your ability to complete tasks (e.g., make a sandwich, get ready to go out, finish homework) changed? Each of questions was rated on a 4-point scale of "Improved," "Stayed the same," "Gotten worse," and "Gotten much worse" (M = 2.77, SD = 0.75). As would be anticipated, those who reported more severe somatic symptoms also rated their function as having become more significantly worsened. Both self-reported symptom score and cognitive change were positively correlated with the cumulative number of concussions reported by those with a

concussion history or recent concussion (symptom score: $r = 0.356$, $p = 0.003$; CC: $r = 0.434$, $p < 0.001$).

Across the two groups of individuals with a history of concussion (N = 69), the average total number of concussions was 2.64 (SD = 2.91); those with a recent injury vs. an injury history did not differ in cumulative concussions ($p = 0.431$). This was unsurprising considering the increased likelihood of subsequent concussions following an individual's first concussion and the emergence of increasingly homogenized standards for retirement from contact sports due to frequency and severity of head trauma. Of note, age did not significantly correlate with the total number of concussions ($r = 0.038$, $p = 0.760$), symptom score ($r = 0.190$, $p = 0.069$), or CC ($r = 0.126$, $p = 0.295$), suggesting that years of life, as opposed to other factors, such as lifestyle and sports participation, is not in itself driving the relationship between these factors.

4.1.2 Sleep behavior

Due to the importance of sleep behavior and sleep disturbance to cognitive performance, multiple measures of sleep behavior were collected for all participants. In addition to questions about how many hours participants slept each night on average and how long after going to bed participants usually fell asleep, participants completed both the Sleepiness Scale (M = 15.05, SD = 4.74) and Sleep/Wake Problems Behavior Scale (M = 20.37, SD = 6.98; see Appendix F). On average, participants fell asleep between 15-30 minutes after going to bed and slept between 7 and 8 hours a night. A multivariate analysis of variance was conducted including all four related measures of sleep behavior. Box's test of equality of covariance matrices was not significant (Box's M = 35.424, $F(20, 2236.53) = 1.485$, $p = 0.076$), supporting the assumption that variance-covariance

matrices are the same across groups. No multivariate statistic showed significant differences in sleep behavior across groups (see Table 4.2). This suggests that, for this sample, sleep behavior is not meaningfully contributing to differences between groups on cognitive and linguistic tasks, and that recent concussions were not resulting in a significant increase in sleep disturbance within this sample.

4.1.3 Measures of affect & personality

A variety of psychological tools were completed by all participants, including the BFI-2 Negative Emotionality items, STAI, BALES, and MSPSS. The BFI ratings are used to calculate gendered T-scores for Negative Emotionality dimension score (T-score M = 48.24, SD = 10.44), as well as Anxiety (M = 47.71, SD = 12.10), Depression (M = 49.39, SD = 10.16), and Emotional Volatility (M = 49.73, SD = 10.35) sub-scores. Each T-score was calculated based on a norming sample of 313 men and 146 women (Soto & John, 2017). The STAI produces both state (M = 42.20, SD = 12.55) and trait (M = 45.73, SD = 10.30) anxiety scores. The BALES also produces a multitude of related scores (18 in total). For the purposes of the present research, only three have been calculated. Two are domain-level indices, calculated by collapsing across the interpersonal- and achievement-related domains: the negative interpersonal events (NIE; M = 5.13, SD = 3.52) and negative achievement-related events (NACE; M = 6.19, SD = 4.15) indices, respectively. The negative events index (NEG; M = 11.31, SD = 6.61) is the sum of the NIE and NACE. The MSPSS produces only one cumulative statistic (M = 5.37, SD = 1.26). Understandably, many of these measures were highly correlated (see Table 4.4).

A multivariate analysis of variance was conducted including all five related measures of affect and personality. Box's test of equality of covariance matrices was not significant (Box's M = 19.517, F(15, 507.661) = 0.848, p = 0.624), supporting the assumption that variance-covariance matrices are the same across groups. Calculated statistics differed slightly; however, only Roy's Largest Root, or the eigenvalue for the first variate, was significant and likely robust due to the Box's test result. When the subsequent analyses of variance on each constituent variable were considered, no single analysis of variance was significant (F-statistics ranged between 0.285 and 2.173). Further, the three groups demonstrated similar variability across these statistics (see Table 4.5). These findings suggest that it is unlikely that dispositional negativity and increased risk of poor mental health due to anxiety, poor social support, or recent life stressors disproportionately impacted individuals with a history of recent or past concussion compared to those without.

Table 4.4 *Correlation matrix for measures of affect & personality*

	BFI-2 NE T-score	MSPSS	BALES-NEG	STAI-S
MSPSS	0.092			
BALES-NEG	0.276*	-0.025		
STAI-S	0.413**	-0.190	0.351**	
STAI-T	0.561**	-0.080	0.415**	0.633**

Values in the table reflect Kendall's tau. * $p < 0.05$, ** $p < 0.001$

Table 4.5 *Means and standard deviations for measures of affect & personality*

	BFI-2 NE T-score	MSPSS	BALES-NEG	STAI-S
Recent injury	46.04(9.07)	6.50(0.30)	16.33(9.29)	42.78(13.53)
History	47.39(10.0)	5.15(1.26)	10.55(6.75)	42.61(13.28)
Healthy	51.78(12.17)	5.59(1.32)	11.57(4.79)	40.79(10.59)

Values in the table are presented as Mean(Standard Deviation).

4.1.4 General cognitive measures

Three cognitive tasks were administered to all participants: a selective attention flanker task (M = 111.74 seconds, SD = 144.10 seconds), a backward digit span task of

working memory (M = 5.19 digits, SD = 0.876 digits), and a spot-the-difference visual processing task (M = 25.8% accuracy, SD = 15.9% accuracy; see Table 4.6 for descriptive statistics by group). These measures each capture distinct cognitive skills and were not significantly correlated with one another. A multivariate analysis of variance was conducted including all three tasks. Box's test of equality of covariance matrices was significant (Box's M = 33.193, F(6, 165.944) = 3.268, p = 0.005), suggesting that the assumption that variance-covariance matrices are the same across groups was not supported.[6] Hotelling's Trace was not significant (T = 0.197, F(6, 32) = 0.526, p = 0.784, two-tailed, $\eta_P^2 = 0.090$). These findings suggest that gross differences in domain-general cognitive skills are not disproportionately impacting a single group. Despite this null finding (of note, all three measures result in null findings when considered independently in t-tests as well), it is worth recognizing that the mean flanker effect times, representing the mean difference in response times between congruent and incongruent conditions, are clearly larger for those with any concussion history, recent or lifetime, compared to individuals with no such history. The potential effect is obscured by substantial variance in this effect across individuals, which may have been due to an increased prioritization of accuracy over rapid automatized responses (accuracy on the flanker task was unexpectedly high, not falling below 90% for any group). However, it is also worth noting that null findings on this task previously have been reported in individuals following concussion (van Donkelaar et al., 2005), and it has more frequently been used in populations characterized by repeated concussion or high density sub-concussive blow exposure. Similarly, high variability also may have driven the null finding of differences

[6] Of the multivariate analysis statistics, Hotelling's T^2 is the most robust to this violation of assumptions (Hakstian, Roed, & Lind, 1979), and is reported as the critical statistic in this case.

in backward digit span, particularly considering the ubiquity of this task in assessments of concussion. In contrast, performance on the spot the difference task was unexpectedly poor.

Table 4.6 *Means and standard deviations for measures of cognition*

	Flanker	Backward digit span	Spot the difference
Recent injury	129.38(128.47)	4.67(0.87)	0.33(0.23)
History	137.64(176.78)	5.33(0.83)	0.24(0.16)
Healthy	67.01(71.61)	5.27(0.91)	0.29(0.13)

Values in the table are presented as Mean(Standard Deviation).

4.2 Testing assumptions for linear model

Descriptive statistics were calculated for all descriptive and all experimental variables. Skewness and kurtosis were interpreted by dividing each skewness measure by its standard error and applying a threshold of $|x| = 2$ in order to identify statistics that violated assumptions of normality. The vast majority of variables did not violate these assumptions. Seven standardized behavioral measures demonstrated statistics raising a concern about violating normality assumptions: symptom score (skewness = 0.980), sleepiness scale (skewness = 1.755; kurtosis = 4.520), sleep-wake problems behavior scale (skewness = 0.896), MSPSS (skewness = -1.536; kurtosis = 2.485), average total utterances across written samples (skewness = 0.599), average total type-token ratio (TTR) across written samples (skewness = 1.298; kurtosis = 1.978), and total verbs (kurtosis = 1.670). Only one cognitive statistic demonstrated significant positive skew and kurtosis, the flanker effect (skewness = 2.632; kurtosis = 8.807). However, when all dependent variables were included in a calculation of the Kolmogorov-Smirnov test of normality, of the suspect variables above, only MSPSS demonstrated a significant non-normality (Kolmogorov-Smirnov (8) = 0.350, p = 0.005). For this reason, and concerns

about the interpretation, no transformations were applied to these data. Statistical analyses should be interpreted accordingly.

4.3 Analyses for Aim 1

The first hypothesis tested was whether adolescents and young adults with a recent concussion or history of concussion show deficits on diverse aspects language, including complex writing tasks. The tasks most relevant for this comparison were the letter fluency task, confrontation naming task, and structured narrative tasks. We predicted that individuals who had experienced a concussion, no matter how long ago, would demonstrate deficits in language tasks, particularly given the unique challenge of a complex writing task. Three comparisons were planned: (1) examining group differences in word-level task performance based on performance in letter fluency and complex naming, (2) examining group differences in narrative task performance based on story grammar in narrative language samples, and (3) examining group differences in working memory and attention based on backward digit span.

In the letter fluency task, participants had one minute each to name as many words as they could beginning with the letters F, A, and S. In the confrontation naming task, participants read a series of 20 definitions and were asked to provide the word best fitting the definition. Response times were estimated as the time between when the page loaded and when the typed response was submitted. There was no limit on the amount of time permitted for each response. There were two structured narrative tasks. In the *Cinderella* task, participants reviewed 19 pictures from the story of *Cinderella* individually and wrote the story while able to view the images. In the *Pigeon: Impossible* task, participants viewed a short, animated, wordless movie and then wrote a summary

immediately afterward. Participants had five minutes to complete each narrative task. Sample narratives from each group based on each prompt are included in Appendix G.

Previous findings in Stockbridge et al. (2018) suggested that confrontation naming response time, not accuracy, was the primary variable of interest for this task. Unfortunately, relatively few participants completed the confrontation naming task: 7 healthy individuals (M = 8.99 seconds, SD = 2.44 seconds) and 2 individuals with recent injury (M = 15.15 seconds, SD = 3.96 seconds), as it was administered as part of the second session. Although the difference between groups on this task considered independently was significant ($t(8) = 3.076$, $p = 0.015$, two-tailed), the variable was excluded from the formal hypothesis testing in order to maximize degrees of freedom in the omnibus multivariate analysis of variance.

Letter fluency across F, A, and S were averaged and story grammar proposition scores for the two narrative tasks, *Cinderella* and *Pigeon: Impossible,* were averaged. Due to concerns about multiple comparisons, these statistics first were included in the multivariate analysis of variance to test this hypothesis. Box's test of equality of covariance matrices was not significant (Box's M = 2.180, $F(3, 17560.109) = 0.654$, $p = 0.581$), supporting the assumption that variance-covariance matrices are the same across groups. Roy's Largest Root (=0.382) was significant ($F(2, 22) = 4.21$, $p = 0.028$, two-tailed, $\eta_P^2 = 0.277$). Follow-up statistical tests demonstrated that both average letter fluency ($F(1, 23) = 4.655$, $p = 0.042$, two-tailed, $\eta_P^2 = 0.168$) and average proposition score ($F(1, 23) = 8.291$, $p = 0.008$, two-tailed, $\eta_P^2 = 0.265$) were significant for between-subjects effects. Individuals with a recent concussion produced fewer words in a letter fluency task than either those with a history of concussion or those with no concussion

history. Recently injured participants produced significantly fewer propositions in a story grammar task on average, while the difference between those with an injury history and those with no injury history approached significance ($p = 0.06$; See Table 4.7). Thus, individuals within 50 days of injury demonstrated clear deficits on these language tasks, though findings from purely cognitive tasks were non-significant (Table 4.6). In contrast, individuals with a history of injury did not demonstrate the same deficits, though their performance remained, in the case of story grammar, slightly below what was observed among those with no injury history whatsoever.

Table 4.7 *Means and standard deviations for key measures in Aim 1*

	Letter fluency	Average propositions
Recent injury	10.90(3.85)	11.77(3.58)
History	13.78(4.24)	12.89(5.34)
Healthy	14.58(4.37)	15.88(6.22)

Values in the table are presented as Mean(Standard Deviation).

4.4 Exploratory analyses for Aim 1 variables

In the interest of thoroughly addressing task performance, traditional analyses were conducted on the three language samples provided. These findings provide a more robust characterization of written language in those with recent concussions.

A spectrum of statistics was calculated automatically using tools from the CHILDES project based upon the three typed language samples, *Cinderella*, *Pigeon: Impossible*, and an expository sample, responding to the prompt to "describe what makes a good friend." As these measures all were produced from the same samples, they were first considered together. In a mixed repeated measures analysis of variance, concussion status (recent, history, or no history) was the between-subjects factor and total utterances, mean length of utterance in morphemes (MLU), vocabulary diversity (VocD), and clausal density (estimated by verbs per sentence) for each sample were repeated measures across

the three samples (group (3) x sample (3) x structural measure from sample (4)). Vocabulary diversity was selected over type-token ratio as it is more robust to samples of varying length. Measurements for each sample and group are presented in Table 4.8. Results showed a significant effect of sample, suggesting structural differences among the responses to the *Cinderella*, *Pigeon: Impossible*, and expository prompts ($\varepsilon(1.56) = 11.59$, $p < 0.001$). There also was a significant effect of measure, which measure of the four was considered ($\varepsilon(1.38) = 738.13$, $p < 0.001$). The interaction between measure and sample ($\varepsilon(1.80) = 18.36$, $p < 0.001$) also was significant, suggesting different samples produced significantly different levels of each statistic of interest.[7] However, the interactions between sample and concussion group, measure and concussion group, and the three variables considered together all were non-significant. Although the data were affected by the sample prompt, the way that the statistics were impacted was *not* different in those with a recent concussion, a history of concussion, and those with no such history. Moreover, the test of between-subjects effect of group was not significant ($F(2, 50) = 1.57$, $p = 0.22$, two-tailed, , $\eta_P^2 = 0.317$). This constituted strong statistical evidence that the effects within these statistics are not significant in differentiating those with concussion and those without.

Despite the appearance of trends in the performances by group apparent in the data, for example, those with recent injuries did appear to produce fewer sentences, with a slightly shorter MLU, and less vocabulary diversity, none of these differences reached

[7] Mauchly's Test of Sphericity was significant for sample ($W = 0.72$, $\chi^2(2) = 16.25$, $p < 0.001$), measure ($W = 0.07$, $\chi^2(5) = 132.94$, $p < 0.001$) and the interaction ($W < 0.001$, $\chi^2(20) = 436.57$, $p < 0.001$), supporting the assumption of sphericity was violated. For these variables, the Greenhouse-Geisser corrected ε is reported in place of the F-ratio.

significance. This was perhaps due to the comparisons being underpowered for this level of granularity in analysis. Given this finding, no further analyses were conducted regarding these statistics. However, it is interesting to note the comparison between these common structural language statistics and the previous analysis of propositional *content* in examining the distinction between performances of participants with concussion; differences in content were significant in the absence of significant differences in how much was written, the diversity of the words chosen, or the clausal density of the language used. It also is worth noting that, although considered separately from this omnibus analysis, the number of typographical errors present in the two narrative samples at their completion did not differ between groups. These findings demonstrate that structural measures of the written samples did not differ as a function of concussion exposure. At least in the context of the language targeted within the present study, simple lexical and grammatical skills were relatively intact in the individuals with a recent concussion and those with a concussion history.

Table 4.8 *Results calculated from language samples*

Statistic	Recent injury	History	Healthy
Cinderella			
Number of sentences	8.09(2.63)	10.50(4.01)	11.45(4.27)
MLU in morphemes	16.64(5.31)	17.08(4.25)	17.48(4.33)
TTR	0.56(0.08)	0.56(0.09)	0.54(0.05)
VocD	48.22(14.11)	56.78(11.35)	57.15(8.76)
Clauses per sentence	2.26(0.82)	2.29(0.54)	2.38(0.61)
Pigeon: Impossible			
Number of sentences	9.50(3.41)	8.92(3.57)	11.44(4.50)
MLU in morphemes	17.12(6.31)	19.35(4.39)	19.87(4.94)
TTR	0.52(0.09)	0.54(0.07)	0.47(0.07)
VocD	40.78(11.54)	44.22(10.09)	42.76(9.17)
Clauses per sentence	2.50(0.72)	2.60(0.60)	2.61(0.80)
Good Friend			
Number of sentences	6.20(2.82)	6.38(3.01)	7.61(3.97)
MLU in morphemes	18.78(4.62)	17.84(5.02)	19.62(4.96)
TTR	0.59(0.12)	0.60(0.13)	0.56(0.12)
VocD	58.76(23.24)	61.16(22.66)	61.89(22.53)
Clauses per sentence	3.24(1.09)	2.72(0.92)	2.89(0.84)

Total			
Number of sentences	8(2.20)	8.5(3.20)	9.57(3.87)
MLU in morphemes	17.44(4.42)	17.61(3.89)	19.38(3.97)
TTR	0.55(0.08)	0.57(0.09)	0.53(0.08)
VocD	48.23(11.07)	55.02(13.44)	54.72(10.22)
Clauses per sentence	2.63(0.71)	2.50(0.54)	2.71(0.65)

Values in the table are presented as Mean(Standard Deviation). MLU = mean length of utterance; TTR = type-token ratio; VocD = vocabulary diversity score.

4.5 Analyses for Aim 2

The second hypothesis was whether individuals with *recent* injuries demonstrated deficits in complex writing better characterized as uniquely lexical or as a result of poorly integrated cognitive-linguistic skills. While it is possible that deficits in narrative language would be solely the result of lexical-level deficits, it was hypothesized deficits following a recent concussion would include changes in story grammar and cohesion following a recent concussion, supporting a more multifaceted account of language production deficits above and beyond lexical difficulties.

4.5.1 Evidence for lexical account

Based on the analyses for the first aim, letter fluency (a lexical-level task) and average proposition measures were significantly positively correlated ($R = 0.634$, $p = 0.001$, two-tailed). This may suggest that lexical level skills are underlying the observed deficits in narrative language. However, the key comparisons providing evidence for this account of complex writing deficits were (1) differences in overall amount of language produced in a given time and (2) use of more general or empty words (e.g., general all-purpose, or GAP, verbs) in written texts.

Participants with a recent injury produced fewer words per minute both in directly copying written text (injured: $M = 34.44$, $SD = 8.50$; healthy: $M = 51.43$, $SD = 22.40$; Levene's test of homogeneity of variances was significant $F = 6.00$, $p = 0.020$; $t(30) =$

3.110, p = 0.004, two-tailed) and in generating responses to written prompts (injured: M = 23.40, SD = 8.48; healthy: M = 33.48 SD = 11.18; t(25) = 2.458, p = 0.021). While these findings at face value appear to support the lexical account of narrative task performance, the presence of group differences when copying text directly suggests the possibility that differences in motor pattern behavior may have contributed to the observed differences in overall written language production.

Over-reliance on high frequency or under-specified nouns and verbs in language can be another signal that an individual is experiencing word finding difficulties. Nouns such as "thing," "stuff," or "someone" are somewhat universally generic, regardless of context. Similarly, high-frequency general all-purpose (GAP) verbs often are examined in individuals suspected of language deficits (Thordardottir & Weismer, 2001). In contrast, other words are underspecified in a given context. For example, in *Pigeon: Impossible*, the story is clearly set in Washington, D.C., and the missile is heading toward Moscow, Russia. So, if an individual described the story as taking place in a city, that would be omitting or underspecifying the setting based on the information given. Ten words were identified for each of the three situations described above, universally general words, general all-purpose verbs, and contextually underspecified words (listed in Table 4.9).

The sum of the instances of each type of overly general word was counted and then the proportion of the overly general words to the total words was calculated for each participant. Individuals with a recent concussion used fewer universally general words (6.23 per 1000 words), GAP verbs (194.11 per 1000 verbs), and underspecified words (6.82 per 1000 words) than individuals with no history of injury (general: 11.41 per 1000 words, GAP: 228.79 per 1000 verbs, underspecified: 9.70 per 1000 words). Though these

differences were not significant, the trend was contrary to the anticipated direction of effects (i.e., that individuals with deficits in word-finding due to a concussion would produce a greater proportion of underspecified words). It is possible that this trend reflects the differing qualitative natures of samples from individuals with and without a recent concussion; anecdotally, healthy participants appeared to more frequently begin narrative retellings with a summary sentence whereas recently injured participants did not do so. However, these results do not support a lexical account of narrative performance.

Table 4.9 *Underspecified or overly general words*

Universally general	GAP verbs	Contextually underspecified
thing	go	person
things	have	place
stuff	get	lady
some	know	ride
something	say	shoe
somehow	put	guy
someone	come	bird
whenever	take	breakfast
whatever	try	weapon
whoever	make	city

4.5.2 Evidence for cognitive-linguistic account

Although performance on the domain-general cognitive tasks were not significantly different between groups, backward digit span, a measure of working memory and auditory attention, demonstrated a significant positive correlation with both average letter fluency ($R = 0.605$, $p = 0.008$, two-tailed) and average propositions ($R = 0.470$, $p = 0.036$, two-tailed). However, when this variable was included in the multivariate analysis of variance, the analysis no longer reached significance (Box's $M = 5.339$, $F(6, 1854.792) = 0.706$, $p = 0.645$; Roy's Largest Root = 0.630, $F(3, 14) = 2.941$, $p = 0.070$, two-tailed, $\eta_P^2 = 0.387$). Despite these mixed findings, the key group

comparisons of interest supporting the cognitive-linguistic account of complex language deficits were (1) differences story grammar and (2) cohesion.

Overall, individuals with a recent concussion produced samples with significantly less content when telling *Cinderella* (M = 10.18, SD = 5.510) compared to those with no such history (M = 15.20, SD = 6.135; t(29) = 2.255, p = 0.032, two-tailed, d = 0.861). This pattern also was observed in the retelling of *Pigeon: Impossible* (recent injury: M = 13.40, SD = 3.565; healthy: M = 17.63, SD = 7.312; Levene's test of homogeneity of variances was significant F = 10.472, p = 0.003, t(26.940) = 2.094, p = 0.046, two-tailed, d = 0.735). This score captures the sum of accurate propositions that the participant has included in their narrative sample. However, the story grammar analysis does not distinguish between propositions that are omitted entirely and those that are alluded to in an otherwise inaccurate statement about the story being told (essentially, factual errors). For example, if a participant wrote that Cinderella lost her *necklace* at the ball, this would not be counted toward the proposition that Cinderella lost her glass slipper at the ball. This is different from a situation where either the proposition was omitted entirely or where the details of the proposition were underspecified (e.g., Cinderella lost something at the ball), which also would result in that proposition being counted. This distinction could be relevant because poor time management or poor efficiency responding to the prompts could lead to omitted information, whereas errors would reflect the participant producing a similar amount of written content, despite some of that content not being relevant to the measurement of propositions. While individuals with a recent injury did provide fewer accurate propositions, the number of factual errors in the samples and proportion of factual errors to propositions did not differ between groups. This suggests

that the source of the difference in propositions between groups was likely due to omission and not a misunderstanding or misrepresentation of the prompt.

In addition to the broader proposition score, a constituent event score was calculated for each story, reflecting only the most important events necessary to the telling of the story. As this score represents a subset of the overall proposition score, it was not considered independently in the hypothesis testing. Interestingly, constituent event scores did not did not differ between groups on either narrative. This suggests that although individuals with a recent concussion included fewer details, they maintained the most important, salient events necessary for the story to be understood. These findings are particularly interesting in light of the differences in mnemonic supports in the two narrative prompts. Whether retelling a familiar story after viewing a series of images and then having continued access to those images or watching a brief wordless movie and then recounting the events without visual supports, individuals with a recent concussion demonstrated a consistent pattern of providing fewer details in their narratives than healthy individuals. Thus, participants with a recent injury primarily omitted information, specifically, details, but tended to retain the most salient and integral narrative events and did not include a greater proportion of inaccurate information. This pattern may have been influenced by cognitive skills required for the task as well as word retrieval.

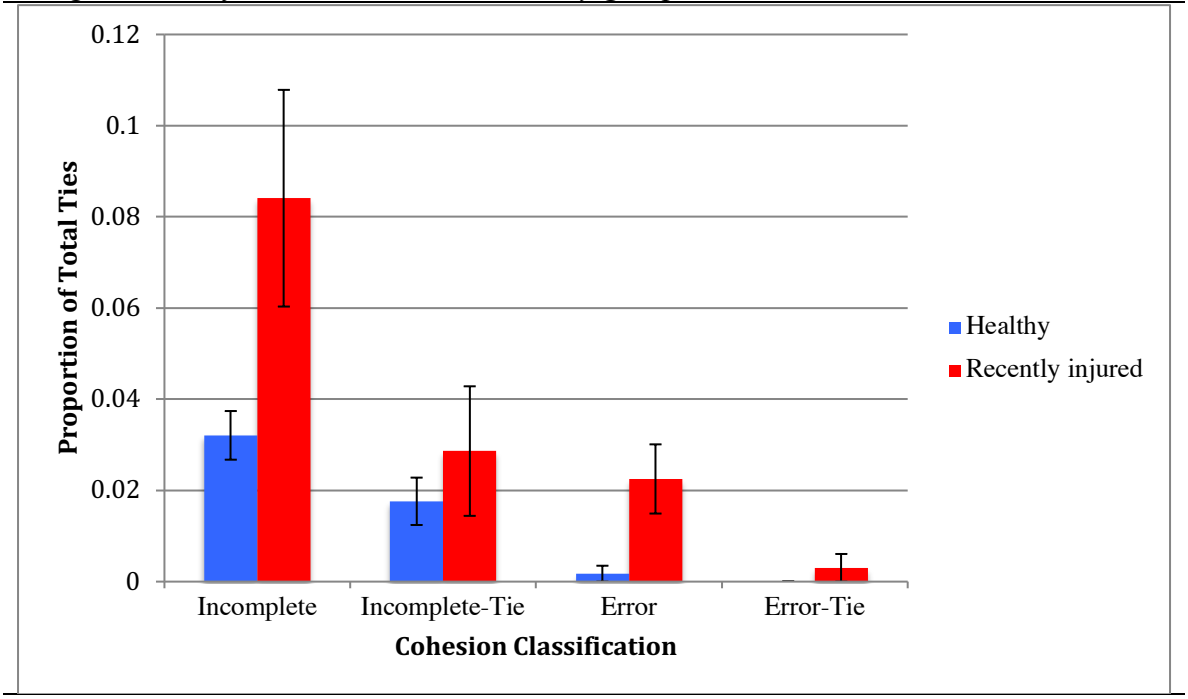
Examining cohesion provides a measure of a sample's structure and organization, qualities of a narrative above and beyond word-finding. Cohesive ties were analyzed by first identifying words used as cohesive ties, then classifying the ties, and determining their adequacy (Liles & Coelho, 1998). Cohesive ties functioning in reference, conjunction, and lexical items were identified in both the *Cinderella* and *Pigeon:*

Impossible narrative samples, then judged to be complete, incomplete, or erroneous. The proportion of cohesive ties to "complete" ties (total ties/complete ties), and the percentages of erroneous and incomplete ties were then calculated for each sample provided by each participant. Due to the considerable effort required to assess cohesion for each narrative sample provided by each individual, those with a history of concussion were excluded from analysis. As would be expected, the vast majority of all ties were complete, regardless of group (approximately 92% of the sample as a whole). Individuals with a recent concussion had a significantly greater proportion of cohesive ties to complete ties (Median = 1.16) when compared to healthy individuals (Median = 1.05) across narrative samples (Mann-Whitney U = 44.0, z = -2.84, p = 0.004, r = -0.50). Differences on the *Cinderella* (Median = 1.09) and *Pigeon: Impossible* (Median = 1.03) tasks were significant independent of group based on a Wilcoxon Signed Ranks Test (Z = -2.41, p = 0.016), and while differences between groups were significant when responding to *Pigeon: Impossible* (Injured: Median = 1.09; Healthy: Median = 1; U = 37.0, z = -2.79, p = 0.007, r = -0.52), they did not reach significance when responding to *Cinderella* (p = 0.08). This may have been due to occasional reliance on crystalized language in the retelling of Cinderella across groups, which often contains cohesive cues. This strategy was not possible in the retelling of *Pigeon: Impossible*.

Cohesive ties that are not complete can either be judged as incomplete (information is not present) or erroneous (information is ambiguous or misleading). Individuals with a recent concussion included a greater number of incomplete (Median = 0.06) markers in comparison to individuals with no injury history (Median = 0.03; U = 58.0, z = -2.29, p = 0.022, r = -0.40; see Figure 4.1). Those with a recent concussion also

included a greater number of erroneous markers (8 total errors across 6 of the participants; Median = 0.01) in comparison to individuals with no injury history, for whom this only occurred in 3 instances all within a single participant's samples (Median = 0; $U = 47.0$, $z = -3.57$, $p = 0.006$, $r = -0.61$). Groups didn't differ in the number of incomplete or error ties (errors carried through multiple references to a given marker) though this almost never occurred in the sample. These data suggest that individuals with concussion demonstrated poorer cohesion in their writing, particularly when introducing new information, rather than when carrying information through from reference to reference (the latter being more frequently seen in individuals with injuries of greater severity). In particular, the presence of errant information (information that caused the reader to experience a conflict between potential sentence meanings), rather than simply not including sufficient information, constitutes an interesting feature of narrative cohesion performed by individuals with concussion. This may suggest they had more difficulty monitoring for this kind of ambiguity in their writing. Importantly, unlike story grammar, group differences in cohesion performance have no straightforward lexical explanation. Thus, the presence of these deficits provides clear evidence in support of the cognitive-linguistic account of written deficits.

Figure 4.1 *Performance on cohesive ties by group*



Note: Error bars represent 1 standard error. * $p < 0.05$

4.6 Exploratory analyses for Aim 2 variables

In the interest of thoroughly addressing task performance, follow-up t-tests were conducted to examine the sub-tasks that made up the averaged narrative deficits variable used in the multivariate analysis of variance. Narrative samples produced by individuals with a recent injury and individuals with no injury history demonstrated a number of qualitative and quantitative differences that, together, characterize just how much difficulty recently injured individuals appeared to experience when completing these tasks.

4.6.1 Examining letter fluency as a moderator variable

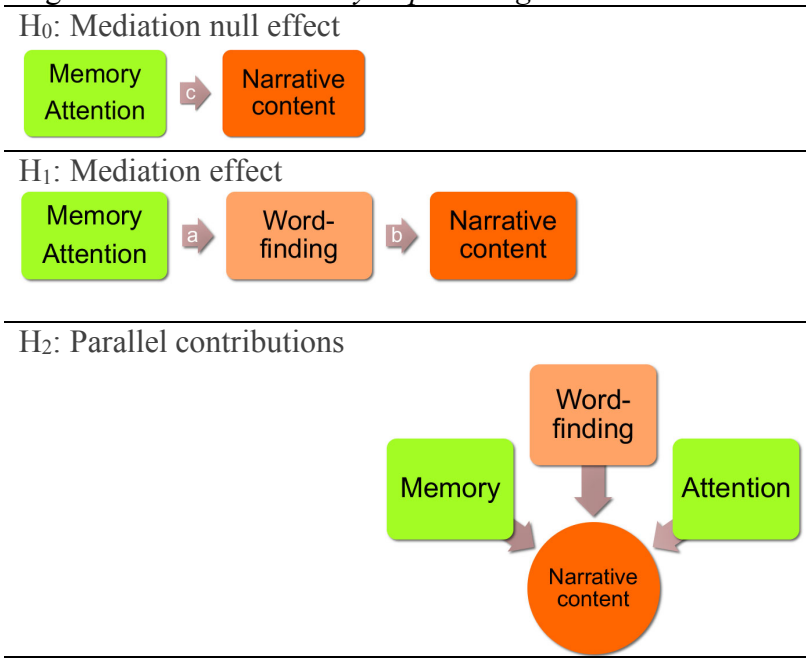
Prior work has suggested that domain-general cognitive deficits underlie apparent language difficulties in children with concussion (Stockbridge et al., under review). A related analysis that could inform the second aim is to determine whether word-level

performance, here operationalized as letter fluency, significantly mediates the relationship between auditory attention and working memory, as seen on the backward digit span, and story grammar performance (see Figure 4.2). On the one hand, cognitive difficulties could have driven difficulties on letter fluency tasks, which then influenced narrative language in turn (e.g., if cognitive resources that were necessary for simply coming up with single words were greater than typical, additional resources available for monitoring language at a broader scale of content may not have been be available). On the other hand, poor attention and poor memory could have influenced narrative content directly (e.g., if the participant were able to come up with words to use, if effortfully, but remembering what has already been said and continuing to attend to the task were equally challenging, and together these difficulties lead to poor narrative performance). A mediation analysis empirically examines this dynamic in the context of the present study, utilizing the M-test, which determines the sampling distribution of the *ab* product, not assuming normality, from *a, b,* and their standard errors (Tofighi & MacKinnon, 2011). In contrast to more widely used methods, the M-test provides a better balance of power and Type I error control.

First, a linear regression was calculated to predict letter fluency from backward digit span. A significant regression equation was found ($F(1, 16) = 9.246$, $p = 0.008$, $R^2 = 0.366$; $\beta = 2.850 = a$, $t(16) = 3.041$, $p = 0.008$). A second linear regression was calculated to predict story grammar proposition average from backward digit span. This regression equation also was significant ($F(1, 18) = 5.113$, $p = 0.036$, $R^2 = 0.221$; $\beta = 0.068 = c$, $t(18) = 2.261$, $p = 0.036$). The final linear regression was calculated to predict story grammar from letter fluency and backward digit span together. Although the regression

equation was significant ($F(2, 15) = 4.915$, $p = 0.023$, $R^2 = 0.394$), neither the unstandardized coefficient for backward digit span ($\beta = 0.047 = c'$, or the direct effect; $c' = c - ab$, $t(15) = 1.292$, $p = 0.216$) nor letter fluency, the mediator, ($\beta = 0.011 = b$, $t(18) = 1.492$, $p = 0.156$) was significant when considered separately. For $\hat{a} = 2.85$ (SE = 0.937) and $\hat{b} = 0.011$ (SE = 0.008), the indirect effect estimate was 0.036 (SE = 0.031). The distribution of the product of coefficients method 95% CI is [-0.007, 0.112]. These data very narrowly failed to support rejection of the null hypothesis, H_0: $ab_{pop} = 0$. Thus, letter fluency is better conceptualized as similarly contributing to story grammar in parallel with or possibly overshadowing memory and attention ($F(1, 23) = 15.531$, $p = 0.001$, $R^2 = 0.403$; $\beta = 0.020$, $t(23) = 3.941$, $p = 0.001$).

Figure 4.2 *Mediation analysis path diagram*



Note: ab: indirect effect, c: total effect

4.6.2 Completeness of episodes

In addition to considering the inclusion of propositions across the entirety of each narrative, proposition completeness was considered within each of the episodes. This was

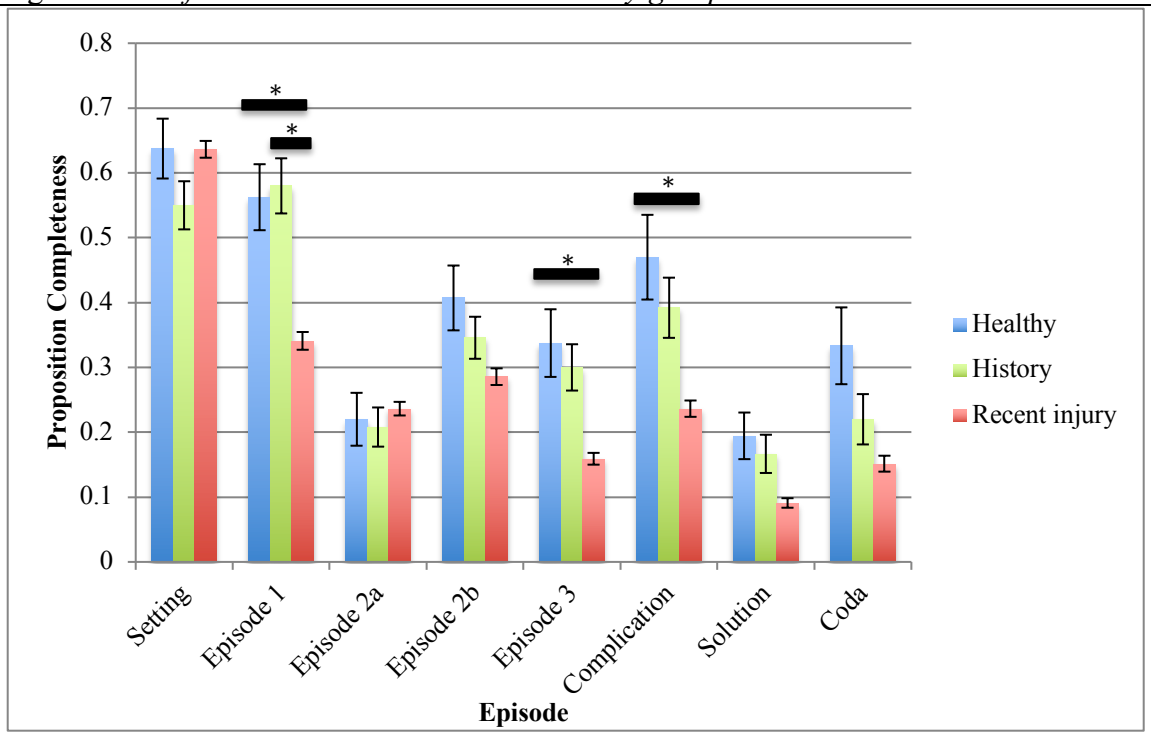
done to better understand whether the pattern of storytelling adopted by the two groups differed. While any individual proposition may or may not be included by an individual, whether or not a given episode was described more or less thoroughly on average provides insight into how performance differed across all three groups. In *Cinderella*, the identified sections were: (1) the Setting or Orientation, (2) Episode 1: preparing for the ball, (3) Episode 2a: attacked by the evil stepsisters, (4) Episode 2b: assisted by the fairy godmother, (5) Episode 3: attending the ball, (6) Episode 4/Complication: losing the slipper, (7) Episode 5/Solution: found by the prince, and (8) Coda. An analysis of variance on each section of the narrative suggested that only Episode 1 was significant ($F(2, 78) = 3.240$, $p = 0.045$, two-tailed, $\eta_P^2 = 0.077$). Performance by group considered pairwise for each section is summarized in Figure 4.3. Participants with a recent injury differed significantly from those with a history of injury in Episode 1. Participants with no history of injury and those with recent injuries differed significantly in the completeness of Episodes 1, 3 and 4, or the complicating action. These events correspond to describing Cinderella preparing for the ball, attending the ball, and losing the slipper. In contrast, the groups demonstrated no significant difference in the inclusion of key crystalized aspects of the story. Nearly all retellings, regardless of group, started with "Once upon a time," included mention of the fairy godmother, and ended with Cinderella marrying the prince.

In *Pigeon: Impossible*, the identified sections were: (1) the Setting or Orientation, (2) Episode 1: Walter encounters the pigeon, (3) Episode 2a: the pigeon attacks Walter, (4) Episode 2b: the pigeon wreaks havoc with the briefcase, (5) Episode 3: Walter lures the pigeon from the briefcase, (6) Episode 4/Complication: the bagel launches a nuclear

missile toward Moscow, (7) Episode 5/Solution: Walter rushes to stop the missile, and (8) Coda. An analysis of variance on each section suggested that setting ($F(2, 59) = 2.965$, $p = 0.059$, two-tailed, $\eta_P^2 = 0.091$), solution ($F(2, 59) = 3.492$, $p = 0.037$, two-tailed, $\eta_P^2 = 0.106$), and coda ($F(2, 59) = 4.468$, $p = 0.132$, two-tailed, $\eta_P^2 = 0.077$) were significant. Performance by group for each section is summarized in the Figure 4.4. Participants with a recent injury and those with no history of injury differed significantly in the use of propositions for the setting and coda. Participants with a recent injury differed from those with a history of injury on the setting and Episode 2a. Though it is unclear why they provided more complete descriptions of the pigeon attacking Walter than those without a recent concussion, this seems to have been part of their larger trend of describing early events from the story fairly well compared to later events. Finally, participants with a history of injury differed from those with no history of injury in the complication, solution, and coda. Healthy participants more frequently included similar levels of detail throughout the story. However, participants with a recent concussion or a concussion history more frequently omitted details as the story progressed. This may have been due to difficulty storing additional details in the working memory or due to implementing a poor strategy for responding to the question within the allotted time, resulting in participants more frequently running out of time before providing details of the end of the story. There is some evidence that this pattern of providing fewer details as the story progressed was seen in the *Cinderella* retellings as well (differences between the recently injured and no injury history groups approached significance for the coda, $p = 0.08$), though the apparent drop-off of details seemed to happen more quickly. The level of detail provided – the actual events of the story, even concerning the central

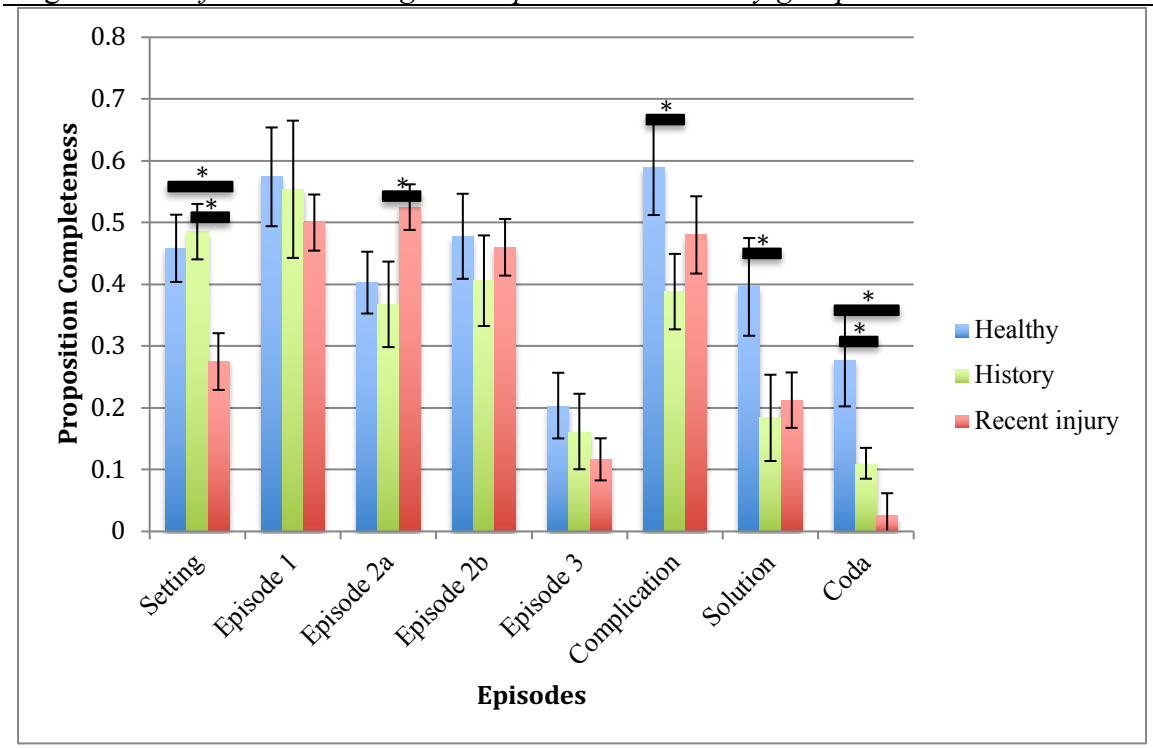
complicating action – were lacking. It is possible that, although similar amounts were written for the two tasks across groups that a greater degree of content had to be distilled based on the video versus the illustrations. However, the level of detail provided by the recently injured group across all following events was quite similar. This provides further evidence that there may have been difficulties in working memory or in planning that influenced performance on the narrative retelling tasks.

Figure 4.3 *Performance on Cinderella sections by group*



Note: Error bars represent 1 standard error. * $p < 0.05$

Figure 4.4 *Performance on Pigeon: Impossible sections by group*



Note: Error bars represent 1 standard error. * $p < 0.05$

4.6.3 Expository goodness ratings

Although expository samples were included in the broader language sample analyses described above, they were not otherwise utilized to the extent of the narratives. In order to examine another dimension of the expository samples, 10 unique raters were asked to examine the samples for the thoroughness and complexity of their exposition on a scale of 0 to 5, with a rating of 0 for samples where "no clear explanation is given" and 5 for samples where a "thorough or complete explanation is given." Raters also were asked to examine the samples for the effectiveness of organization on a similar 0 to 5 scale, with a rating of 0 for "listing traits/no clear organization" and 5 for samples where an "effective structured argument is present." Ratings were averaged for each expository sample. Groups did not differ on either completeness or organization rating (Table 4.10).

Table 4.10 *Means and standard deviations for expository goodness ratings*

	Completeness	Organization
Recent injury	3.98(0.66)	3.16(0.87)
Healthy	4.04(0.88)	3.28(0.99)

Values in the table are presented as Mean(Standard Deviation).

4.6.4 Summary

Aim 2 examined whether individuals with recent injuries and those with no history of injury differed in narrative language skills beyond that which could be explained by word-level deficits. It was predicted that deficits following a recent concussion would include changes in story grammar and cohesion following concussion, supporting a more multifaceted account of language production deficits above and beyond word-finding difficulties. The results provided some evidence to support this account of narrative language performance. While differences were observed in the overall amount written, individuals who had a recent concussion did not use a greater amount of overly-general words, which would have been a strong indicator of word-finding difficulties influencing performance. In contrast, clear deficits were observed in unique narrative language skills, story grammar and cohesion. Individuals with a recent concussion provided a similar number of essential story elements, called constituent events, but significantly fewer details when asked to retell the familiar *Cinderella* story or to describe a short novel video. They provided less cohesion in their narratives, leading to a greater amount of ambiguity.

In a complementary mediation analysis, while backward digit span predicted letter fluency and story grammar performance, the coefficients for the predictors were of borderline significance when these variables were combined. Thus, these data perhaps best support a theoretical account in which word-finding and memory/attention skills contribute to story grammar in parallel, not an account of lexical deficits as a mediator.

4.7 Analyses for Aim 3

The third hypothesis tested was whether including high dispositional negativity in a binary logistic regression predicting injury history, not just individuals with a recent injury, improved upon a model including word- and discourse-level cognitive-linguistic performance alone. As a part of this exploration, we also examined whether individuals with high dispositional negativity showed more cognitive-linguistic deficits and reported more somatic symptoms of greater severity. High dispositional negativity was operationalized as BFI 2 negative emotionality t-score greater than one standard deviation above the mean and entered as a categorical variable. Variables were entered via forced entry in three blocks: first, participant age and symptom score were included; next, either average proposition score (the measure of story grammar) or the interaction of letter fluency and average total propositions was included; and finally, high dispositional negativity.

A test of the symptom score only when controlling for age produced a significant model ($\chi^2 = 9.278$, $p = 0.010$, $df = 2$). Nagelkerke's R^2 of 0.202 indicates a modest relationship between prediction and grouping. Prediction success overall was 73%, with an accuracy of 95.7% in participants with a concussion history. That is, knowing an individual's self-reported somatic symptom severity aggregated over commonly experienced symptoms associated with concussion (symptom score), it is possible to predict whether they had a history of concussion. This is not surprising given the relative frequency of enduring somatic symptoms reported by patients long after returning to normal levels of activity and participation following a concussion.

When either average proposition score ($\chi^2 = 4.902$, $p = 0.027$, $df = 1$; Nagelkerke's R^2 of 0.327) or the interaction between letter fluency and average proposition score ($\chi^2 = 4.131$, $p = 0.042$, $df = 1$; Nagelkerke's R^2 of 0.283) was added to the model, it remained significant. When proposition score was entered, prediction success improved slightly from 73% to 75%. This reflected a considerable improvement in prediction of healthy individuals from 6.3% to 36.4% and only a slight decrease in accuracy predicting individuals with a concussion history (88.7%). Proposition score was a significant predictor of injury status when controlling for age and symptom score (Wald = 4.506, p = 0.034). Similarly, when the interaction was utilized instead, prediction success remained the same as with symptom score and age, 73%; however, accuracy of predicting healthy individuals improved significantly from 6.3% to 25% whereas prediction of individuals with a history of concussion only decreased minimally (89.4%). This interaction was a significant predictor of injury status after controlling for age and symptom score (Wald = 3.885, p = 0.049), emphasizing the added value of considering word- and discourse-level language tasks in examining grouping in individuals with a history of concussion.

Finally, high dispositional negativity was included in the analysis, improving the model when either the proposition score was used in the second step ($\chi^2 = 7.09$, $p = 0.008$, $df = 1$; Nagelkerke's R^2 of 0.419) or the interaction was used ($\chi^2 = 7.8$, $p = 0.005$, $df = 1$; Nagelkerke's R^2 of 0.422). When proposition score was used in the second step, the addition of high dispositional negativity only improved overall accuracy marginally, 77.4%, reflecting a healthy prediction accuracy of 40.9% and an injured prediction accuracy of 90.3%. When the interaction was used in the second step, prediction success

improved overall from the addition of dispositional negativity to 82.5%, reflecting both high accuracy in predicting individuals with a history of head injury (93.6%) and individuals with no such history (50%). These results provide strong support for the added value in considering sub-clinical dimensions of personality and temperament in characterizing individuals with who have experienced a concussion recently or otherwise, including those best captured by the so-called "chronic concussion" profile.

In a complementary analysis, story grammar performance was considered as the dependent variable instead of injury classification. This was, in essence, the more direct model of a clinically useful hypothesis: if high dispositional negativity results in clear cognitive-linguistic suppression or symptom exacerbation over and above other characteristics of injury, then that would provide a compelling basis for considering the factor in concussion management. As noted above, the regression consisted of variables entered via forced entry in three blocks: first, participant concussion history status, age, and symptom score were included together; next, average letter fluency was added; and finally, high dispositional negativity as a categorical variable. Here, the model predicting story grammar performance from age, symptom score, and head injury history alone was not significant ($R^2 = 0.118$, $F(3, 59) = 2.625$). This null finding provides strong evidence for the importance of word-finding skills in story grammar performance, providing insight into the second aim. It also supports an account that, despite significant group differences in age, age was not a significant factor influencing story grammar performance. However, the model improved significantly ($\Delta R^2 = 0.258$, $\Delta F(1, 58) = 24.03$, $p < 0.001$) when average letter fluency was added ($F(4, 58) = 8.745$, $p < 0.001$). Both head injury history ($t = 2.345$, $p = 0.022$) and letter fluency ($t = 4.902$, $p < 0.001$)

were significant predictors. When high dispositional negativity was included in the model, it remained significant ($F(5, 57) = 6.966$, $p < 0.001$), although the change to the model was not significant. Of note, when added to this omnibus model of story grammar performance, high dispositional negativity was not a significant predictor ($p = 0.596$), although both injury history status ($p = 0.043$) and letter fluency ($p < 0.001$) remained significant. These findings suggest that although high dispositional negativity may be useful in understanding the chronic concussion profile, it may not be specifically relevant to the narrative language skills captured by the story grammar task.

In contrast, a model predicting somatic symptom reporting from head injury history when controlling for age was not significant ($R^2 = 0.037$, $F(2, 50) = 1.990$). The model improved significantly ($\Delta R^2 = 0.116$, $\Delta F(1, 49) = 6.98$, $p = 0.011$) when BFI-2 negative emotionality t-score was added ($F(3, 52) = 3.814$, $p = 0.016$). In this model, both head injury history ($p = 0.019$) and BFI-2 Ne t-score ($p = 0.011$) were significant predictors. However, prior work has raised significant concerns about the inflation caused by overlapping content across measures capturing dimensions of neuroticism, anxiety, and mood disorders (Uliaszek et al., 2009). A comparison between dimensions of the somatic symptom rubric utilized in the study (Appendix C) and the BFI-2 items identified overlap on three items from the somatic symptom rating scale (p. Feeling easily saddened or depressed; q. Feeling easily angered; r. Feeling easily frustrated). However, when these duplicate items were removed from the somatic symptom score and the regression was reanalyzed, the pattern of results was unchanged. The model improved significantly ($\Delta R^2 = 0.074$, $\Delta F(1, 49) = 4.29$, $p = 0.044$) when BFI-2 negative emotionality t-score was added ($F(3, 49) = 2.967$, $p = 0.041$). As above, head injury history ($p = 0.024$) and BFI-2

Ne t-score ($p = 0.044$) were significant predictors. This suggests that, although the somatic scoring measure does capture some aspects of negative emotionality, individuals with higher dispositional negativity also are reporting significantly greater severity in bodily symptoms. These findings are particularly relevant in cases where patients are not discharged due to lingering reported bodily symptoms *in the absence* of evidence of objectively identified cognitive symptoms. In summary, high dispositional negativity does impact the diversity and severity of somatic symptoms that are reported among those with an injury history and contributes to the overall success in predicting individuals with an injury history. In contrast, high dispositional negativity does not appear to significantly influence cognitive-linguistic performance on the examined tasks.

Chapter 5: Discussion

The purpose of this research was to address three related aims in the context of better understanding the deficits experienced by adolescents and young adults who have had a concussion, either recently or at some time in their lives. The first aim of the study was to determine whether adolescents and young adults with a recent concussion or a history of concussion showed deficits in diverse linguistic and cognitive-linguistic tasks, including complex writing tasks. By and large, while individuals with a recent concussion demonstrated clear language deficits, those with a concussion history did not. The second aim of the study was to explore the nature of deficits in complex writing, to determine whether they were better characterized as arising from lexical deficits alone or from a cognitive-linguistic skills uniquely necessary to producing larger units of language. The majority of the evidence supported an account of narrative performance that was considerably influenced by poor cognitive-linguistic skills, though evidence of lexical deficits was observed. The third aim of the study was to determine whether high dispositional negativity had a measurable negative impact on deficits following concussion. While dispositional negativity did not predict cognitive-linguistic task performance, it did predict self-report ratings of somatic symptoms and improve models of concussion group. Findings from each of the planned comparisons relevant to these aims is summarized in Table 5.1. The aims will be discussed separately below, then a summary will be provided discussing the findings and limitations in the context of existing literature.

Table 5.1 *Results of planned comparisons*

Hypothesis 1: Those with a recent concussion or history of concussion will show deficits on complex writing tasks compared to those with no injury history.		
Recent injury	Supported	Unsupported
Word-level task performance	X	
Narrative task performance	X	
Working memory and attention		X
Injury history		
Word-level task performance		X
Narrative task performance		X
Working memory and attention		X
Hypothesis 2: Deficits in narrative language experienced by those with recent concussions are best explained by the complex interplay of cognition and language.		
Lexical account	Supported	Unsupported
Amount of language produced	X	
Use of general or empty words		X
Cognitive-linguistic account		
Story grammar	X	
Cohesion	X	
Hypothesis 3: Accounting for dispositional negativity (DN) will improve upon the models that use physical and injury characteristics alone.		
	Supported	Unsupported
DN improves prediction of injury group	X	
DN improves prediction of narrative performance		X
DN improves prediction of somatic symptoms	X	

5.1 Aim 1

Deficits following brain injury have been observed in all levels of language production, from the word level to building sentences to generating narrative language (Biddle et al., 1996; S. B. Chapman et al., 1992; Ewing-Cobbs et al., 1998; Galetto et al., 2013; Harvey, 2016; Kovach, 2015). However, investigations solely investigating those individuals with very mildest and most common brain injuries, or concussions, are only beginning to emerge in the literature. Thus, it is uncertain whether and to what extent language production deficits observed in mTBI more broadly are driven primarily by individuals with more severe injuries that are still classified as mild (i.e., mild-

complicated) versus the more common and mild concussions. Thus far, it has been established that adolescents and adults with a recent concussion name high frequency words more slowly (K. A. King et al., 2006; Stockbridge et al., 2018) and produce language that is less complex. However, individuals who have experienced a concussion frequently describe increased difficulties, confusion, or "fuzziness" when attempting more complex and integrative language tasks in everyday life, such as describing events and providing explanations, despite often performing analogous tasks with sufficient success in structured clinical settings. Thus, the first aim of the study was to determine whether the deficits observed in the broader mTBI group could be observed in individuals following a concussion, even when considering a broader window of recovery (50 days). Indeed, deficits in language were observed in those with a recent concussion, with modest evidence of deficits beyond 50 days.

Individuals with a recent concussion demonstrated significantly poorer performance on both letter fluency and story grammar than healthy individuals, despite being overwhelmingly well-matched on key variables frequently thought to influence performance on such complex and integrative tasks in real-world settings, including sleep behavior, general cognitive task performance, and self-report ratings of perceived social support, state and trait anxiety, recent negative life events, and overall dispositional negativity. These findings also are somewhat surprising given the expanded window of time considered for individuals with a recent concussion; while all participants in the recent concussion group remained under concussion management within 50 days since their injury, the majority had either begun to transition or fully returned to typical levels of academic and professional participation. Findings of significant deficits considering

this broader window of recovery are relatively unique to the present study, but consistent with the emerging account of concussion as an injury resulting in generalized and enduring, though often sub-clinical, deficits.

Although generally viewed within the field of communication sciences as an established lexical task, beyond this field the characterization of letter fluency as, fundamentally, a test of language rather than one of executive function actually remains the subject of some debate (Whiteside et al., 2016). If viewed parsimoniously as a task integrating both lexical-level language processing and relatively low-level executive functions, such as sustained attention to the task, monitoring (so as to not produce duplicative responses to the open-ended prompt), and inhibition (so as not to produce responses outside of the prompted phonemic category), significant deficits in performance on this task for individuals with a recent concussion could be construed as evidence of difficulty in these cognitive skills, even in the absence of significant findings on the dedicated cognitive tasks, such as the flanker task. However, individuals with concussion did not appear to make a greater number of errant responses; they simply provided fewer lexical exemplars of the phonemic category altogether in the time allotted. Thus, their performance on the letter fluency task strongly suggests that the central deficit is poor efficiency in lexical access, rather than suggesting deficits in more basic executive functions.

Uncommon in concussion research, a second group of individuals with a history of concussion an average of 5 years prior to the study, but no recent concussion, also completed the same series of tasks. While this group did not demonstrate significant differences from healthy individuals on the key experimental tasks, they consistently

perform at a level between that of the recently injured individuals and that of the healthy individuals. It is possible, then, that their performance is not truly "recovered" to pre-injury levels, but rather that it is improved on a continuum relative to recent injury. This highlights the need for future research considering this chronic concussion profile. Further analysis of this group may beneficially include examining years since concussion and number of concussions as continuous variables predicting performance within this group. Ideally, future research would include multiple timepoints of assessment within subjects, reflecting pre-injury, acute injury, and chronic injury status.

Despite the fact that individuals with a recent concussion wrote significantly less, the apparent deficits in language content and organization stood in contrast to otherwise preserved structural aspects of written language, such as the mean length of sentences, ratio of different words to total words, and number of clauses per sentence, as well as quality of diction for which individuals with a recent concussion demonstrated no differences from age-matched individuals with no history of concussion. As a group, individuals with a recent concussion did not produce a greater number of typographical errors (based on independent samples Mann-Whitney U-Tests), nor errors on words that contain uncommon orthographic or phonetic characteristics, which would potentially rely more heavily on recall of memorized lexical information. The structural measures included in this study constitute those most frequently employed in clinical decision-making about language production at the discourse level.

As described in the methods of this work, these measurements are generated with relative automaticity and can be compared to large samples of norming data. In contrast, the difficulty of objectively assessing content results in these methods being utilized less

frequently. This may shed light on the inconsistent findings of broader language deficits in this population. Many individuals with concussion report difficulties in daily activities, particularly when returning to the rigors of professional and academic life. Despite this, the majority of individuals with concussion are found to be performing within normal limits when provided with neuropsychological assessment. The contrast between easily derived frequently used structural measures of language and relatively laborious more experimental measures of content may explain the gap in what is captured by common assessments. If an individual provides fewer details in conversation or in written materials, this may result in poorer, less efficient and effective communication, or poorer performance in professional or academic contexts, but it is far less likely to be identified as a being the result of a *clinical* etiology compared to a more overt change in the complexity of structural language. Thus, a person with a concussion may have difficulties that are perceived by others as caused by a lack of motivation or effort, rather than an underlying deficit. The above analyses provide clear evidence for a both word- and prose-level deficits in language in this population, potentially exacerbated by, though not strictly driven by, low level deficits in domain general skills, such as attention and memory.

5.2 Aim 2

In addition to determining the presence of deficits across linguistic and cognitive-linguistic tasks, the second aim of the study was to examine the quality of narrative and expository samples more thoroughly than had been addressed previously within the population of those with a recent concussion. This was done in the hopes of contributing to the growing theoretical framework of understanding how challenges in everyday

communication following injury emerge from what are more concretely observable deficits in fundamental cognitive skills, such as word-finding, planning, organization, auditory attention, and working memory. With these goals in mind, it was predicted that adolescents and young adults with a recent concussion would show deficits on complex writing tasks that were best explained by a complex interrelationship of both cognitive and lexical skills, not by word-finding deficits alone.

Two key comparisons were identified in support of each of the two accounts of narrative performance. If the lexical account were wholly responsible for deficits, individuals with a recent concussion should demonstrate difficulty generating language for the written narrative tasks, as evidenced by shorter samples overall, in contrast to samples where they were asked to copy written tasks. Second, if the lexical account were wholly responsible for deficits, it was anticipated that individuals with a recent concussion would rely on a vocabulary when writing that included a greater number of more general words. Word-finding deficits were observed when this skill was targeted at a high level of complexity in isolation, as in the letter fluency and naming tasks. However, deficits in word-finding *based on the written samples* were not observed. It is possible that this was a result of the simplicity of the narrative prompts. While tasks examining word-finding in isolation could easily challenge the boundaries of this skill in terms of phonetic fluency or frequency of English word usage (e.g., having participants name items such as "periscope," "beaker," and "turban"), both narrative prompts relied upon a relatively frequent, simple vocabulary. This, along with minimal time pressure for generating a given word (the task as a whole was timed, but a larger timeframe was

allotted than was given in the word-finding tasks), may have constituted too easy a word-finding task for deficits in individuals with concussion to be observed.

In contrast, if the cognitive-linguistic account of narrative performance were supported, individuals with a recent concussion should demonstrate deficits in story grammar, as defined by the inclusion of accurate events and details important to the narrative, and cohesion. These skills together should be minimally impacted by word-finding. Instead, they are better characterized as the intersection of cognitive skills, such as planning, organization, and working memory, and language production. The presence of cognitive-linguistic deficits would not necessarily refute that word-finding deficits also may persist in individuals with concussion but would instead contribute to a broader understanding of the difficulties experienced after these injuries.

Individuals with a recent concussion demonstrated poorer overall story grammar performance characterized by a unique pattern of more specific difficulties within narrative language skills. However, they did not differ from healthy peers in the inclusion of constituent events. Those with a recent concussion were able to provide accounts of events that were grossly accurate. However, the contrast between this performance and the deficits in performance on the broader proposition score suggested that individuals with concussion provided significantly fewer supporting details recounting events. This pattern did not differ between the tested narrative conditions, whether more structured, as in the *Cinderella* task, or whether more similar to a real-world scenario, in which working memory and attentional demands were increased while still relying upon verifiable details. The absence of a significant difference in performance *between* these tasks on the proposition and constituent event measures for either group provides

additional evidence of poor strategic *utilization* of the provided information, seemingly independent of the increased overall cognitive load.

Perhaps more telling, groups did vary significantly in which parts of the story, or episodes, they tended to describe more completely. In retelling *Cinderella*, individuals with a recent injury more often left out details in the early introduction of the story and in the events immediately leading up to and describing the central conflict. For example,

> "There was a girl who had 2 stepsisters. the stepsisters thought they were hotter than her but they just weren't. they got in a fight over a prince but the pretty girl (Cinderella)won him over. they danced together at the ball all night. She ran away and left her glass slipper. The prince went all over town looking for her and found her in a locked room upstairs. they left and lived happily ever after"

In practice, this often resulted in narratives that seemed to arrive at the most salient and culturally ubiquitous aspects of the *Cinderella* story – the prince, the ball, the glass slipper – quite quickly and a bit vaguely. It is unclear what motivations are at play or how the events build upon one another. For example, in the retelling above, it is unclear why the stepsisters and Cinderella fought over the prince (also this isn't entirely accurate to the story itself), how Cinderella got to the ball, or why she ran away. Moreover, the fairy godmother, a key character in the story who was featured in multiple pictures during the story telling, never is mentioned in the retelling above. A contrasting pattern was observed when individuals with concussion recounted *Pigeon: Impossible*. In these samples, they tended to focus more on events of the narrative centered on the main conflict, and more often left out details associated with orientation and how the story resolved. For example,

> "Begining- CIA agent walks across the street, sits down and begins eating a pastry donught, a grey pigion flies in, agent hands him some of the doughtnut, pigioen not amsed, pigieion ataks agent, pigeion, flies into the computer powered briefcase, starts hiting buttons, atacks the agent, agent pics up donught, throws doughnut into the air, pigeon flies after it, donught lands on missles laucnh button, laucnhes missle that goes to Russia, agaent freaks out, goes after the rocket on the flying briefcase, donught is on the breaifcase,"

Omissions of later details of the story almost always appeared to be due to the individuals with recent injuries running out of time and unable to complete their narratives within the allotted five-minute window, as evidenced by multiple instances in which samples ended mid-clause or mid-word. Individuals without a history of concussion seemed to experience this far less frequently as a group. It seems possible, then, that individuals with a recent concussion were able to recount details, but perhaps it took them longer to generate those details or to formulate language that would efficiently describe the details that made up the events (of note, they did not produce a significantly greater number of inaccurate details). It also suggests that they may have been less likely to consider time-management strategies in their performance of the task, integrating both watching the provided clock and producing the narrative in real time. However, it also seemed that individuals with a recent injury often provided details or content that, while not strictly inaccurate, were beyond the level of granularity included by healthy individuals or were otherwise extraneous (e.g., listing events rather than summary). In these ways, content included by individuals with a recent concussion was consistently qualitatively markedly

different from that of healthy individuals in both narrative tasks in ways that uniquely support a cognitive-linguistic account (see Appendix G for additional narrative samples).

A striking aspect of the narratives produced by individuals with a recent concussion was that they seemed to have been produced by younger people (despite the ages of the recent and healthy groups being the same) in a way that was difficult to clearly define. Although, as a group, samples from individuals with a recent concussion did not demonstrate a greater number of factual (e.g., stating that Cinderella lost her *necklace* at the ball, instead of her shoe), grammatical (e.g., errors in subject-verb agreement), or typographical errors (e.g., "slepe" for "sleep"), they were simpler and seemed to jump from one topic to the next. In developmental literature, this has been called a proto-narrative, where statements and events are listed, but more complex relationships among ideas are minimal or absent. This quality, which was not captured as a function of the story grammar or in structural statistics, seems to have been somewhat captured in the measures of cohesion. In this analysis, the variety of ways that sentences can refer to one another are quantified and judged for whether they are clear or whether they impede understanding of the text in some way. Individuals with a recent concussion and those with no such history utilized similar numbers of cohesive markers; however, the effectiveness of these markers was less successful for those who were recently injured. While healthy individuals did, occasionally, omit content in a way that made interpretation difficult, those with a recent injury did so more frequently and, unlike those with no injury history, included cohesive markers that left ambiguity or misdirection in the text. This difference captures a facet of the holistic impression one gets when reading samples from the different groups in a way that is unique compared to other measures

used in the study. However, measures of cohesion are inflated by fairly rudimentary relationships, such as whether or not information has been previously introduced or can otherwise be assumed to be shared. Neither this measure nor story grammar distinguish the presence of relationships across content at this higher level, and the present findings seem to suggest the need for tools that do so.

The broader observation that individuals with a recent concussion provided significantly fewer supporting details when recounting narratives complements the findings from another recent study, in which far younger children (aged 4.5-10 years old) with a recent concussion were asked to listen to a story, told entirely without visual supports, in which certain words were highlighted by the speaker as targets for the child to remember (Stockbridge et al., under review). Next, the children were presented with an image for the target and a plausible foil (e.g., "dog" for "cat"), and asked to identify the target in each dyad. Under these circumstances, which relied heavily on auditory rather than visual attention, young children with a recent injury performed significantly more poorly in recognizing the targets than an age-matched group with no history of injury. While auditory attention has been the focus of much recent work in the field of concussion (Thompson et al., 2018; Turgeon et al., 2011; Vander Werff & Rieger, 2017), performance on the *Pigeon: Impossible* retelling, which relied on a wordless movie, could be interpreted as providing support for the presence of a visual attention deficit, a memory deficit for details, or a broader information processing difficulty (Bernstein, 2002) in individuals following a recent concussion.

Findings from the narrative tasks must be interpreted in light of the broader cognitive tasks included in the present study. Individuals with a recent concussion

performed similarly to healthy individuals in the flanker task (targeting response inhibition and executive control), backward digit span (targeting auditory working memory and attention), and spot the difference task (targeting visual working memory and problem solving). The three tasks were not significantly correlated with one another and, with the exception of a significant correlation between backward digit span and average letter fluency ($p = 0.008$, two-tailed), did not correlate with any of the primary dependent variables included in the study. These findings puzzlingly stood in contrast to the extensive literature on cognitive deficits observed in individuals with recent concussion (summarized previously). It is possible that the cognitive tasks administered in the online survey format were subject to less performance and time pressure due to the online and at-home environment for testing, which would have resulted in fewer differences in accuracy. This explanation is supported by the observation that accuracy on the flanker task was unexpectedly high (92.1% for healthy participants, 91.1% for participants with a recent injury) and flanker effect standard deviation for the injured group was nearly equivalent to the mean, suggesting that participants weren't responding sufficiently quickly and automatically to experience the typical effect of congruent and incongruent conditions. In contrast, backward digit span may have been subject to additional time pressure simply by design. Since it relied on participants' manipulation of information presented auditorily, performance was naturally subject to additional time pressure. Given these findings, it is unclear whether true cognitive deficits can be ruled out as contributory factors to the profile of individuals with recent concussion.

Further informing the broader conceptual framework across these diverse tasks, performance on letter fluency and story grammar measures was significantly positively

correlated, affirming their conceptual relationship. However, when a task of working memory and attention, backward digit span, was included in the general linear model based analysis, group differences were no longer significant. In a complementary analysis, it was posited that lexical-level difficulties mediated the relationship between general cognitive skills and narrative story grammar. Although backward digit span predicted letter fluency and story grammar performance, the overall mediation effect reached only borderline significance. Taken together, it seems highly plausible that narrative performance may be influenced by memory, attention, and lexical access acting in parallel, rather than cognitive skills driving lexical ones. Importantly, this finding has therapeutic relevance, and supports the investigation of therapies that target these fundamental skills concurrent with increasing linguistic demands associated with returning to academic and professional activities.

5.3 Aim 3

Individuals with high DN demonstrate a greater negative outlook in the absence of a recent negative event, as well as more rapid decline and poorer outcomes when they experience an adverse health event. Importantly, they both *experience* and *report* magnified reactivity to negative events, such as injury, further elevating their overall level of disability and perception of disability (Shackman et al., 2016). As the overwhelming majority of individuals who experience a concussion have never been assessed to establish a pre-injury baseline of symptom reporting, cognitive, or linguistic performance, an individual's internal emotional reactivity to a concussion injury is largely assessed at face value and compared, for the sake of clinical interpretation, to an estimation of the average emotional response to the injury given the individual's personal

characteristics and circumstances (e.g., a child who received a concussion in the context of bullying may be considered typically more emotionally reactive to the event than an adult who hit their head on a table in their home). Were symptom reporting solely utilized in concussion management as a secondary measure to objective cognitive or cognitive-linguistic performance, this approximated clinical judgment would be largely inconsequential. However, in practice, symptom severity can play a more central role. Despite a patient demonstrating what is termed to be "recovery" based on their performance on accepted cognitive measures, if the patient continues to report somatic symptoms of sufficient severity, it is not uncommon for he or she to be barred from engaging in a full return to academic, professional, or athletic activities. It is in these cases, when a patient can be withheld from typical activities seemingly indefinitely, when the possibility that the patient had a pre-morbid temperament characterized by high DN has particular clinical relevance.

High dispositional negativity, a sub-clinical individual difference, is thought to be a risk factor for many affective disorders, such as depression, anxiety, and post-traumatic stress. Prior studies have found that individuals with these diagnoses are at a greater risk of poor mTBI "recovery," as defined by a full return to pre-injury levels of activity and participation. These individuals may experience a more prolonged symptomatic period or may never fully rejoin their pre-injury level of participation. This effect has been particularly noted in individuals who have experienced milder injuries (Corwin et al., 2014; Ponsford et al., 2012; Silverberg et al., 2015; Vargas et al., 2015), as these individuals' objective cognitive and physical limitations due to injury are generally less debilitating. Individuals who demonstrate severe negative emotional symptoms,

regardless of their pre-morbid temperament, (Howell et al., 2016; Stillman et al., 2016) also may be at similar risk of poor outcomes. However, sub-clinical differences in temperament (in the absence of overt emotional signs) have not been examined previously for the possibility of resulting in poor recovery as well. Personality and temperament are integrated facets of the lived experience, particularly salient in their influence on responses to adversities such as injury. Determining the presence and nature of the relationship between this key trait-like risk factor and both objective and subjective measures used for individualized concussion management is of high clinical relevance. This intersection makes high DN an important property to examine in those with concussion, both in terms of better characterizing individual differences in injury experience and in planning for treatment and discharge. It was predicted that the inclusion of dispositional negativity would improve on a model identifying individuals with a concussion history taking into account traditional somatic and individual characteristics. Indeed, this was found to be true.

Identifying individuals with a history of concussion was improved by the inclusion of high dispositional negativity over and above the profile of cognitive-linguistic deficits when controlling for age and symptom score. Meanwhile, predicting somatic symptoms, but not objective narrative task performance, was improved by the inclusion of negative emotionality. This finding is congruent with existing work in dispositional negativity. Negative emotionality predicts a broad spectrum of physical diseases and mental morbidities, but fundamentally reflects a pattern of negative event reactivity: those individuals who experience more frequent, intense, and enduring negative affect. When adults with high negative emotionality experience an adverse

health event, they are at substantially greater risk for poorer outcomes. For individuals with concussion, both cognitive and somatic symptoms are used as indicators of outcome. A patient can be refused return to play or to learn based on either cognitive or somatic symptoms, or, as is most often the case, a combination of the two.

Despite the fact that groups did not differ in their reported experiences of recent negative events, in their self-reported perception of the social support present in their environments, or even in their state of anxiety (each of which may have signaled other interactive factors further exacerbating the bad experiences of recent injury), recent injury and underlying, trait-like negative emotionality *both* were significant predictors of the somatic symptoms that participants reported. This suggests a confounding factor in considering somatic symptoms when determining recovery, particularly concerning among individuals for whom baseline data information is unavailable. It is important to note that evidence suggests that magnified reactivity to negative events is *real*, in the sense that it is neither malingering nor solely psychosomatic, and is capable of driving both greater perceived disability and greater actual disability (Shackman et al., 2016). However, in this case, performance on the key objective cognitive-linguistic measure was not significantly influenced by individuals' dispositional negativity. In contrast, it did appear to inflate physical somatic symptom reporting. Because of the nature of discharge from concussion and the complex medical and legal interplay associated with rejoining activities following injury, this sub-clinical difference in personality and temperament could lead to longer periods of isolation from activities and social supports in some individuals, increasing their risk for poor mental health outcomes following concussion above their already increased risk for developing these clinical profiles.

More work is needed to better understand the influence of personality and temperament on the clinical experiences of those with high dispositional negativity when experiencing a concussion. However, these findings provide justification for the utility of personality and temperament, not just anxiety and depression disorders (Ponsford et al., 2012; Silverberg et al., 2015; Vargas et al., 2015), in the field of concussion management and strongly support a more thorough dedicate investigation into the utility of these measures for clinicians.

5.4 Interpreting these findings in the context of existing literature

Although many of the tasks utilized in the present study were previously reported in the literature, prior studies of brain injury often included small groups or combined individuals with relatively diverse injury and personal characteristics. Much of what makes existing literature difficult to interpret is that concussion, the mildest of mild brain injuries, historically was not differentiated from the broader spectrum of what could constitute mild injury. Occasionally, particularly in pediatric literature, studies combined injury severities entirely. Similarly, previous work often spans fairly large age ranges. Thus, in these studies, it is unclear the extent to which greater injury severities or incremental developmental changes drove group differences, as well as whether studies had sufficient power to reliably find effects. Here, too, the sample size of recently injured participants is small, which limited the ability to reliably examine age or repeated concussion exposure as continuous variables. However, those with a recent injury and no injury history were remarkably well-matched not just in demographic factors, but also in characteristics such as sleep behavior, social support, and stressful life events –

dimensions thought to inflate estimates of truly *cognitive* deficits that trace their etiology to the concussion injury.

In the present study, evidence of letter or phonemic verbal fluency deficits were observed in individuals with a recent concussion. This task, often referred to as the FAS test, examines the ability to name as many items as one can beginning with a given letter. Successful performance requires skills in both executive function and word-finding. The finding of significant group differences replicated a commonly held finding in the concussion literature and served as validation that the injured group here was similar to others reported in the literature. Deficits in verbal fluency tasks, including naming items in a semantic category (e.g., animals), consistently have been reported in the literature, including in adolescents with a history of brain injury ranging in severity (Ewing-Cobbs et al., 1987), adolescents with mild brain injury (McCauley et al., 2014), adults with mild brain injury (Ge et al., 2009) and adults with the mildest concussions (Leininger et al., 1990). Due to its ease of administration and consistent effects, the task is favored among researchers and frequently is included in both sideline and comprehensive neuropsychological assessments.

Although likely underpowered, differences in response time also were significant between the recently injured and healthy individuals when completing a complex naming measure targeting infrequent vocabulary. Findings of naming speed deficits on high frequency words in adults previously have been reported following concussion (K. A. King et al., 2006; Stockbridge et al., 2018). However, findings in children have been inconsistent. In a now classic pediatric brain injury investigation, Barnes, Dennis & Wilkinson (1999) found deficits in naming accuracy among 55 children whose inclusion

criteria was simply any head injury of sufficient severity to merit hospital admission. Based on lowest reported Glasgow Coma Scale scores, 19 children had a mild brain injury, but severities included those well into the severe range. The study did not differentiate mild from other severities, as the focus was on age at injury, not injury severity. While our examination of naming *accuracy* yielded a null result (as did Stockbridge et al., 2018), our finding of significantly slower response times by individuals with a recent concussion when producing low frequency words are consistent with and serve to expand upon previous findings in high frequency words. As it was included in the secondary survey, this task garnered less participation than the primary survey. It was unclear, therefore, to what extent self-selection biases influenced findings on tasks included in the second survey, which was only advertised once someone had completed the first survey in entirety. Thus, the interpretation of this finding would be considerably strengthened by replication in a larger sample.

Prior literature has reported deficits in working memory on a digit span task, even among those with the mildest concussions (Leininger et al., 1990). Backward digit span is an extremely common aspect of both sideline and neuropsychological evaluation that consistently elucidates deficits in the period immediately following injury – indeed, the digit span items used in this study were from the Standardized Assessment of Concussion (McCrea et al., 1998). As with the letter fluency task, the effect of concussion on backward digit span was replicated here in order to more completely characterize *these* patients, rather than in an attempt to elucidate novel findings regarding deficits due to concussion. In contrast to the existing literature, significant differences in performance between those with a recent concussion and those with no such history were not observed

in the backward digit span task administered in this study. It seems likely that this null finding was due to an atypically large variance in performance, which may have been driven by changes in the task necessary for the online format of administration. Completion of the backward digit span task required the individual to grant permission to the survey website through their browser to allow the audio stimulus providing the numbers to be played.[8] Unfortunately, technical difficulties were reported more on this task than on any other and could not be effectively resolved due to the remote nature of data collection. Moreover, in order to prohibit participants from listening to the digit span stimuli multiple times, media player controls (i.e., buttons allowing the participant to start, pause, and rewind at will) were not provided. Thus, if a participant did experience some kind of distraction while completing the task, he or she may not have had an opportunity to complete that item. This resulted in a considerable inflexibility in the administration of digit span items in this study in comparison to the more ubiquitous sideline assessment, during which the administrator and the individual completing the task interact in person. Despite this null finding, backward digit span performance nonetheless improved regression models of group and performance, affirming the broader notion that attention and working memory are key factors in the acute concussion profile.

In examining the various written samples, individuals with a recent injury typed responses less efficiently, both when copying written text and when responding to prompts. This finding was similar to prior effects reported in the literature, in which children with injury histories of diverse severities demonstrated difficulty writing

[8] Unlike *Pigeon: Impossible*, the only other task to include audio, the audio stimuli for the backward digit span task were native rather than embedded. Thus, browser security permissions were specific to Qualtrics. This was the only task to require such permissions.

sentences in response to dictation. However, writing in response to spoken dictation relies heavily on auditory attention, a known area of weakness among individuals with concussion (Thompson et al., 2018; Turgeon et al., 2011; Vander Werff & Rieger, 2017). Thus, a deficit in writing to dictation would have been expected. In contrast, copying written text relies on visual skills, which have been found to be relatively robust to the effects of concussion, both as seen here in the spot the difference task and as reported previously in the literature. This makes the observed effect that much more surprising. No known prior study has examined the effect of concussion in isolation (as opposed to a group comprised of individuals with more diverse injury characteristics) on the ability to type copied pieces of text.

In contrast to findings regarding semantic content at the word-level, as seen in the deficits on the verbal fluency task, word-level analyses conducted within the narrative samples, namely measures of vocabulary diversity and underspecified or overly general words, did not provide further evidence of group differences. This is particularly puzzling considering that, generally, language samples are considered *more sensitive* than measures targeting only lexical skills (Galetto et al., 2013), and prior studies have reported differences in vocabulary usage in children with a wider range of mild brain injuries (Biddle et al., 1996; S. B. Chapman et al., 1992; Ewing-Cobbs et al., 1998), though these findings were not always consistent in adults (Galetto et al., 2013). Considering age in light of our own null findings, it seems possible that these skills are more vulnerable in children developing language than in adolescents or adults. However, it also seems plausible that across groups participants did not view the narrative tasks as similarly linguistically demanding in comparison to the letter fluency task. That is,

perhaps, particularly given the online format, the brief, timed letter fluency task evoked behavior more similar to that of a school-age vocabulary test; in contrast, many narrative samples – regardless of group – were highly conversational in tone and, perhaps, did not inspire people to write in more advanced or complex ways, regardless of their capacity to do so. By design, narratives also rely heavily on a small closed set of common nouns (e.g., spy, pigeon, briefcase, bagel, missile), which may have artificially deflated measures of vocabulary diversity in a way that a spontaneous conversational sample would not have. Moreover, written samples varied considerably in length, though most were below the standard 50-100 words. This, too, could have led to the null finding in vocabulary diversity across groups.

It may be all the more surprising, then, that participants with a recent concussion did demonstrate deficits in their inclusion of key content and in properly signaling local and distal relationships organizing ideas throughout their written samples. These conflicting findings may be driven, in part, by the relatively isolated nature of word-level skills in contrast to narrative language skills, which place high demands on synergistic language and executive function. Prior studies have found deficits in the provision of essential story information, use of transitions, and cohesion when reporting on pediatric clinical samples that include both mild and more severe injuries (Biddle et al., 1996; Brookshire et al., 2000; S. B. Chapman et al., 1992; Ewing-Cobbs et al., 1998) or adults with mild brain injury more generally (Galetto et al., 2013; Marini et al., 2011; Tucker & Hanlon, 1998). However, until recently, narrative content and organization deficits following concussion exclusively were less explored. With the recent publication of Kovach (2015) and Harvey (2016), both based on spoken *Cinderella* retellings collected

by the Concussion Assessment and Rehabilitation Team (CAART) at the University of Colorado Boulder's Speech, Language, and Hearing Center, spoken narrative content and cohesion were more thoroughly explored and clear deficits were reported among those with the mildest brain injuries. The present research builds upon these findings by providing complementary evidence of these effects in written language and extends the discussion of narratives beyond the *Cinderella* retelling to that of a novel, more dynamic wordless cartoon. Despite concerns about power in the present study, considerable effect sizes observed in story grammar (d = 0.735-0.861) and cohesion (approximate d = 1.15)[9] were similar to those reported by Kovach and Harvey (story grammar: d = 0.79; cohesion: d = 0.87). This parallel lends further confidence to the findings and interpretations discussed in spite of these concerns.

[9] This was calculated based on transformations from Rosenthal *et al.* (Rosenthal, 1994). Due to a highly non-normal distribution in cohesion scores, non-parametric statistics were used in the original analyses and effect sizes were reported in terms of *r*.

Chapter 6: Conclusions & Future directions

The broader purpose of this research was to understand better the kinds of cognitive-linguistic deficits experienced by adolescents and young adults after concussion and to build upon what was known about factors that may influence these deficits. An estimated 1.7 million people sustain TBIs each year in the United States alone, with nearly 80% (1.365 million) treated and released from an emergency department. (Faul, Xu, Wald, & Coronado, 2010). These statistics highlight the importance of continued effective management for the 80% who are treated and released.

These findings support the consideration of certain new ideas in the clinical domain. First, language content and organization remain domains of deficit beyond the commonly cited 14-30 day windows of recovery, even when more commonly used measurements of language, particularly structural measurements or simple word-finding tasks, may appear typical. It is important that clinicians complete comprehensive evaluations of complex, infrequent, and larger units of language in addition to more common assessments of basic language skills. This recommendation is congruent with the difficulties that patients most commonly report in the most demanding social, professional, or academic contexts, but which clinicians often find little evidence of in evaluation. This research provides support for the validity of using video stimuli, particularly when examining narrative structure and organization. Videos provide increased complexity and ecological validity that better parallels the contexts of patient complaints. Finally, concussion is a cognitively and linguistically impactful brain injury, but its effects filter through a patient's underlying trait-like personality and temperament, contributing to the high individual variability among experiences and outcomes of injury.

Patients reporting persistent symptoms or those who report prolonged disability may plateau if subjected to a streamlined neuropsychological/cognitive concussion management model, and may benefit from more integrated multidisciplinary management, particularly if the decision is made that re-integration into normal activities is contingent upon the individual reporting minimal somatic symptoms.

The diverse nature of this data collection also is well suited to future analyses. For example, each language sample and written task was recorded for keystroke timing, which allows for the investigation of how different groups edited their responses and how differences in generation of language varied over the course of a word generation, narrative, or expository production task. This allows for a variety of hypothesis-driven analyses, such as examining relative efficiency in generating typed nouns and verbs in longer written samples or examining strategies used in the letter fluency task. Further, analyses such as story grammar and cohesion done here based on analog methods have begun to emerge in the computational natural language processing field as well. Re-analysis of these dimensions of the narrative samples using computational methods would allow for a more realistic and multidimensional assessment of a greater number of individuals, which would improve our overall understanding. Computational analyses may capture aspects of the narrative samples, such as the proto-narrative structure observed in some individuals with concussion, which could provide greater information relevant to clinical interventions. Moreover, prior work has provided some evidence of indicators of risks associated with dispositional negativity found in narratives, associated with the increased usage of certain words. However, as many of these variables have never been examined in this population, their analysis could only begin to lay the

foundation for future work. Data sharing agreements included in the study open these data to the opportunity for diverse future analyses to better understand the multifaceted concussion experience.

Appendix A

Experimental Tasks

Structured narrative task based on familiar images

Participants viewed the illustrations of Disney's *Cinderella*, included below. Participants are not told the title of the story, but the task is followed by a question probing their familiarity with the story of *Cinderella*.

Look at the following pictures. Together, they tell a story. You will be asked to write the story of the events in the pictures. Before writing, you can preview each picture for no more than one minute each, but you will be able to view them again when you write the story.

Appendix B

Parent Questionnaire

In order to better understand our participants, we have a few optional questions for parents before their children begin the remainder of the survey.

1. How did you hear about this study? (Multiple choice)
    a. HeadFirst Concussion Centers
    b. School, community organization, or club sport
    c. Friend
    d. Other healthcare provider
    e. Prefer not to answer
    f. Other (please specify)

2. Where is your child currently attending school?

3. Has your child experienced a head injury in the past 30 days? (Multiple choice)
    a. Yes
    b. Maybe
    c. No (If no, skip to question 6)

4. Please answer the following questions regarding changes you may have noticed in your child since his or her injury. (A 4-point scale is presented: "Improved," "Stayed the same," "Gotten worse," and "Gotten much worse.")
    a. Has your child's ability to focus changed since the injury?
    b. Has your child's mood changed since the injury?
    c. Has your child's ability to complete tasks (e.g., make a sandwich, get ready to go out, finish homework) changed?

(If the parent only reports, "Stay the same" for all 3 questions, skip to question 6)

5. What moods or emotions have been affected since the injury? Check as many as apply.
    a. Anger
    b. Frustration
    c. Irritability
    d. Sad/depressed
    e. Other, please explain.

6. What is your current household income? (Multiple choice)
    a. Less than $10,000
    b. $10,000 to $19,999
    c. $20,000 to $29,999
    d. $30,000 to $39,999
    e. $40,000 to $49,999

f. $50,000 to $59,999
g. $60,000 to $69,999
h. $70,000 to $79,999
i. $80,000 to $89,999
j. $90,000 to $99,999
k. $100,000 to $149,999
l. $150,000 or more
m. Prefer not to answer

7. How many adults live in your child's household?

8. Of the adults, how many contribute to the household income?

9. How many children under the age of 18 live in your household (including the child participating in the study)?

10. What is your current marital status (multiple choice)
a. Now married
b. Widowed
c. Divorced
d. Separated
e. Never married

11. Who is/are the child's primary caregiver(s)? (multiple choice)
a. Biological mother
b. Biological father
c. Two parents, split equally
d. Adoptive mother
e. Adoptive father
f. Grandmother
g. Grandfather
h. Other, please specify

12. What is the highest level of education of the participant's primary caregiver? (multiple choice)
a. No schooling completed
b. Nursery school to 8th grade
c. 9th, 10th or 11th grade 12th grade, no diploma
d. High school graduate - high school diploma or the equivalent (for example: GED)
e. Some college credit, but less than 1 year
f. 1 or more years of college, no degree
g. Associate degree (for example: AA, AS)
h. Bachelor's degree (for example: BA, AB, BS)
i. Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA)
j. Professional degree (for example: MD, DDS, DVM, LLB, JD)

k. Doctorate degree (for example: PhD, EdD)

13. What is the primary caregiver's occupation (or previous occupation if retired or disabled)?

(If the primary caregiver selected in question 11 is not "Biological mother," questions 14-15 are displayed)

14. What is the highest level of education of the participant's primary mother figure? (multiple choice)

a. No schooling completed
b. Nursery school to 8th grade
c. 9th, 10th or 11th grade 12th grade, no diploma
d. High school graduate - high school diploma or the equivalent (for example: GED)
e. Some college credit, but less than 1 year
f. 1 or more years of college, no degree
g. Associate degree (for example: AA, AS)
h. Bachelor's degree (for example: BA, AB, BS)
i. Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA)
j. Professional degree (for example: MD, DDS, DVM, LLB, JD)
k. Doctorate degree (for example: PhD, EdD)

15. What is the biological mother's occupation (or previous occupation if retired or disabled)?

(If the primary caregiver selected in question 11 is not "Biological father," questions 16-17 are displayed)

16. What is the highest level of education of the participant's primary father figure? (multiple choice)

a. No schooling completed
b. Nursery school to 8th grade
c. 9th, 10th or 11th grade 12th grade, no diploma
d. High school graduate - high school diploma or the equivalent (for example: GED)
e. Some college credit, but less than 1 year
f. 1 or more years of college, no degree
g. Associate degree (for example: AA, AS)
h. Bachelor's degree (for example: BA, AB, BS)
i. Master's degree (for example: MA, MS, MEng, MEd, MSW, MBA)
j. Professional degree (for example: MD, DDS, DVM, LLB, JD)
k. Doctorate degree (for example: PhD, EdD)

17. What is the biological father's occupation (or previous occupation if retired or disabled)?

18. We are interested in reaching out to families at a later date, in approximately 1 month, to have participants answer a very brief (no more than 10 minutes) follow-up question. If you would be willing to be contacted again, please provide an email address.

Appendix C

Health Questionnaire

Thank you for agreeing to participate in the study!
Please answer the following questions related to yourself and your current health status.

1. Date of Birth?

2. I identify my gender as (multiple choice)
   a. Male
   b. Female
   c. Trans*
   d. Non-binary
   e. Other, please specify _____

3. In the past 24 hours, have you experienced any of the following? Please select the severity of your symptoms, with 0 being "none" and 6 being "extremely severe" symptoms.
   a. Headaches
   b. Dizziness
   c. Cuts and/or bruising on the head or face
   d. Nausea
   e. Vomiting
   f. Fatigue
   g. Restlessness
   h. Sleeping more than normal
   i. Sleeping less than normal
   j. Sensitivity to noise
   k. Sensitivity to light
   l. Blurred vision
   m. Double vision
   n. Poor concentration
   o. Poor memory/more forgetful
   p. Feeling easily saddened or depressed
   q. Feeling easily angered
   r. Feeling easily frustrated

4. Did you experience a head injury in the past 30 days? (multiple choice)
   a. Yes
   b. Maybe
   c. No

(If "No" is selected, skip to question ###)

5. Date of accident

6. How did the accident happen? What were you doing (e.g., playing football, riding a bike)?

7. What part of your head was hit?

8. Were you knocked out? (multiple choice)
   a. Yes
   b. Maybe
   c. No

9. Did someone diagnose you with a concussion or brain injury? (multiple choice)
   a. Yes
   b. No

10. What was the severity of that injury? (multiple choice)
   a. Concussion
   b. Mild brain injury
   c. Moderate brain injury

11. People react to changes in different ways. How do you feel about the injury you've experienced? (multiple choice)
   a. Very frustrated/angry
   b. Sometimes negative
   c. Neutral
   d. Sometimes comfortable
   e. Very comfortable
   f. Other, please explain

12. Please answer the following questions regarding changes you may have noticed since your injury. (A 4-point scale is presented: "Improved," "Stayed the same," "Gotten worse," and "Gotten much worse.")
   a. Has your ability to focus changed since the injury?
   b. Has your mood changed since the injury?
   c. Has your ability to complete tasks (e.g., make a sandwich, get ready to go out, finish homework) changed?

(If the participant only reports "Stay the same" for all 3 questions, skip to question 16)

13. People react to changes in different ways. How do you feel about the changes in thinking that you've experienced? (multiple choice)
   a. Very frustrated/angry
   b. Sometimes negative
   c. Neutral
   d. Sometimes comfortable

e. Very comfortable
f. Other, please explain

14. What moods or emotions have been affected since injury? Check as many as apply.
a. Anger
b. Frustration
c. Irritability
d. Sad/depressed
e. Other, please explain

15. People react to changes in different ways. How do you feel about the changes in emotion or mood that you've experienced? (multiple choice)
a. Very frustrated/angry
b. Somewhat frustrated
c. Neutral
d. Sometimes comfortable
e. Very comfortable
f. Other, please explain

16. Have you ever had a concussion or brain injury before? (multiple choice)
a. Yes
b. Maybe
c. No

(If "Maybe" is selected, question 17 is displayed)

17. Please explain the suspected injury.

(If "Yes" is selected, question 18 is displayed)

18. How many prior concussions or brain injuries have you had?

19. Did you experience a bodily injury in the past 30 days that was NOT a head injury, for example a sprain, torn ligament, or broken bone?
a. Yes
b. No

20. Please describe the injury you've experienced, and how it has impacted your participation in activities.

21. Are there any other languages besides English spoken in your home, or which were spoken in your home when you were younger? (multiple choice)
a. No, English only
b. Yes, but 8-% or more of my language is English
c. Yes, multiple languages

(If "No, English only" is selected, skip to question 21)

22. If you speak multiple language, please briefly describe which ones and in what contexts.

23. What grade are you in? (multiple choice)
    a. 6th
    b 7th
    c. 8th
    d. 9th
    e. 10th
    f. 11th
    g. 12th
    h. College
    i. Other

24. Do you typically receive special services in school? (multiple choice)
    a. Yes
    b. No

25. Are you currently receiving short-term special services in school? (multiple choice)
    a. Yes
    b. No

26. Please describe any services or accommodations

27. Have you ever been diagnosed with any of the following? ("Yes" or "No" multiple choice)
    Learning disability?
    ADD/ADHD?
    Speech-language disorder?
    Stutter?
    Dyslexia?

28. Do you have a family history of cognitive or language difficulties? If "Yes," please describe.

29. Have you ever been diagnosed with epilepsy or have a history or seizures? (multiple choice)
    a. Yes
    b. No

30. In order to get a better understanding of our participants' language and communication, we would love the opportunity to view your public Twitter posts. If you are willing to allow us access, please enter your Twitter handle below.

Appendix D

Typing Test

Next you are going to see a story and a text box. Click the text box and begin typing the story exactly as you see it. Type as quickly and accurately as you can! Do NOT click "Next" until you are ready to begin, and begin right away as soon as you see the text box.

Aesop was one of the great Greek writers. He is best known for his fables, stories that have a moral. They teach us something about how we should live our lives. Aesop wrote thousands of these stories. Here are a few.

The Wolf in Sheep's Clothing

Once upon a time, a Wolf decided to disguise the way he looked. He thought it would help him get food more easily. He put on the skin of a sheep, then he went out with the flock into the pasture. Even the shepherd was fooled by his clever costume. In the evening, the shepherd put him in with the rest of the sheep. He closed the gate and made sure it was secure before he went to bed. In the middle of the night, he came back to the fold to get some meat for the next day. Instead of a sheep, though, he grabbed the Wolf, killing him instantly. Those who look to harm others will be harmed themselves.

The Bat and the Weasel

A Bat fell on the ground and was caught by a Weasel. It begged the Weasel to spare its life, but the Weasel refused. It told the Bat that birds, by nature, were its enemy. The Bat assured him that it was not a bird, it was a mouse. The Weasel thought a moment, then set it free. A while later, the Bat fell again to the ground, and it was caught by another Weasel. It begged this Weasel not to eat him, either. The Weasel, though, said it did not like mice at all and would eat it. The Bat told the Weasel that it was not a mouse, but a bat. The second Weasel had no good answer, so he let it go. The Bat knew it is always wise to turn events to your advantage.

The Lion and the Mouse

A sleeping Lion was woken up by a Mouse running over his face. He got up angrily and caught the scared little Mouse. He was about to kill the Mouse, but it said in its squeaky little voice, "If you would only spare my life, I would be sure to repay your kindness." The Lion laughed at such nonsense, but he let him go. A short time later, though, the Lion was caught by some hunters. They bound him by ropes to the ground. The Mouse recognized his roar, and he rushed over and gnawed the rope with his teeth, setting the Lion free. The Mouse said "You laughed at the idea of my ever being able to help you. Now you know that it is possible for even a small little Mouse to help a great big Lion."

Appendix E

Cognitive Tasks

FAS test

Now, I'd like you to say as many words as you can that begin with a particular letter. They cannot be proper nouns, though, so they cannot be names of people or places, for example. Also, you may not use words that have different endings, like "fish" and "fishing".

I'd like you to type words that begin with "F." Please type your response.

I'd like you to type words that begin with "A." Please type your response.

I'd like you to type words that begin with "S." Please type your response.

Complex naming task

Now you will answer some questions. Each question is going to refer to an uncommon word. Do your best to name it as quickly and accurately as you can.

1. What is a flask for carrying drinking water, as on a hike? (canteen)
2. Who is a person employed to drive a private automobile? (chauffer)
3. What is a type of cane-like grass eaten by pandas? (bamboo)
4. What is the illusion of seeing water, often in the desert? (mirage)
5. What are grotesque figures used as ornaments on Gothic churches? (gargoyle)
6. What is a type of semi-musical signing or call done by individuals high up in the Swiss Alps? (yodel)
7. What is what someone does who is running for political office; the work of the candidate to try and get himself or herself elected? (campaign)
8. What is a team sport in which players use a long-handled stick with a webbed pouch to maneuver a ball into the opposing team's goal? (lacrosse)

9. What is a small bomb that is thrown by hand? (grenade)

10. What is a covering of silk or similar material spun by caterpillars as protection for their pupal stage (as they change into butterflies)? (cocoon)

11. What is an inoculation, designed to prevent the organism from contracting a particular disease, also referred to as a shot? (vaccine)

12. What is the Japanese art of folding paper into flowers, birds, or other shapes? (origami)

13. What is a seasonal wind in South Asia that brings heavy rains? (monsoon)

14. What is a deep narrow chasm with steep cliff walls, worn into the Earth's surface by running water? (canyon)

15. What is a piece of fabric worn over the front of an outfit in order to protect it from dirt; traditionally worn by cooks? (apron)

16. What is a small mallet used by a judge to signal for order? (gavel)

17. What is monetary demand in exchange for hostages? (ransom)

18. What is a mollusk that can create a pearl? (oyster)

19. What is a crime of willfully setting fire to a building? (arson)

20. What is a type of vegetable similar to lettuce used for making coleslaw? (cabbage)

Digit span backward (SAC Concentration task Form B)

Now, I am going to say some more numbers. When I am through, say them to me in reverse order. So, if I say, "8, 9" then YOU say "9, 8." Listen carefully.

5-2-6 4-1-5

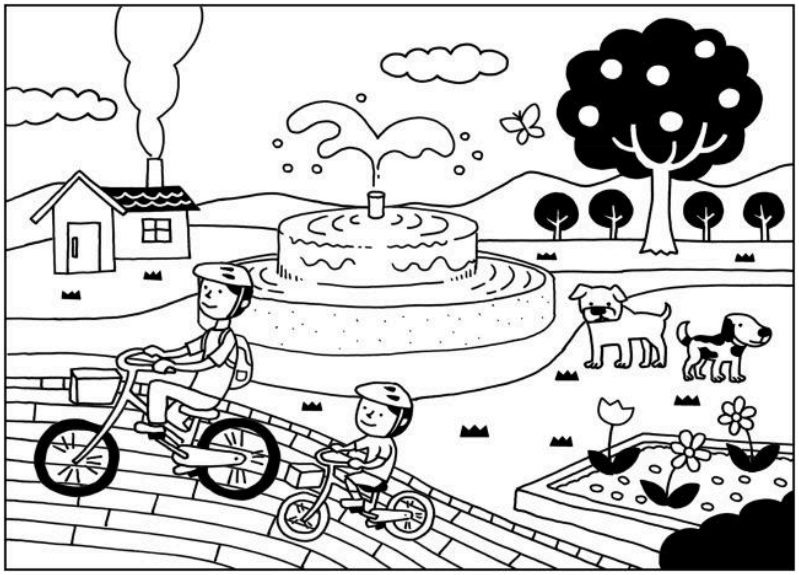
1-7-9-5 4-9-6-8

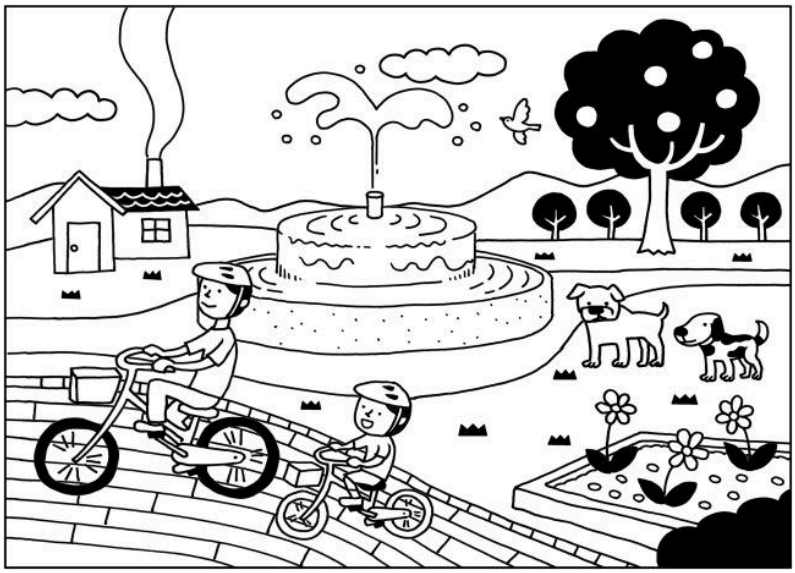
4-8-5-2-7 6-1-8-4-3

8-3-1-9-6-4 7-2-4-8-6-5

Spot the difference

Now, I am going to show you some pictures. First, I will show you a picture for 30 seconds. Scan the picture and try to remember as much as you can. Next, I will show you a similar picture. Click the things that make the second picture different from the first picture. Do NOT click continue until you are ready!





Appendix F

Behavioral and Mental Health Questionnaires

M.I.N.I. International Neuropsychiatric Interview

(Sheehan et al., 1998)

A. Major Depressive Episode

At any time in your life:

A1. a. Did you feel sad or depressed? Felt down or empty? Felt grouchy or annoyed? Did you feel this way most of the time, for at least 2 weeks?

IF YES TO ANY, CONTINUE. IF NO TO ALL, CODE NO TO A1a AND A1b

b. For the past 2 weeks, did you feel this way, most of the day, nearly every day?

At any time in your life:

A2. a. Were you bored a lot or much less interested in things (Like playing your favorite games)?

Have you felt that you couldn't enjoy things?

Did you feel this way most of the time, for at least 2 weeks?

IF YES TO ANY, CONTINUE. IF NO TO ALL, CODE NO TO A2a AND A2b.

b. For the past 2 weeks, did you feel this way, most of the day, nearly every day?

A3 If A1b or A2b = YES: explore the current and the most symptomatic past episode, otherwise

If A1b and A2b = NO: explore only the most symptomatic past episode
In the past two weeks, when you felt depressed / grouchy / uninterested:

a. Were you less hungry or more hungry most days? Did you lose or gain weight without trying? [i.e., by ± 5% of body weight in the past month]?
If YES to either, code YES

b. Did you have trouble sleeping almost every night ("trouble sleeping" means trouble falling asleep, waking up in the middle of the night, waking up too early or sleeping too much)?

c. Did you talk or move slower than usual? Were you fidgety, restless or couldn't sit still almost every day?
If YES to either, code YES

d. Did you feel tired most of the time?

   Did you feel bad about yourself most of the time? Did you feel guilty most of the time? If YES to either, code YES. If YES, ASK FOR EXAMPLES.
   THE EXAMPLES ARE CONSISTENT WITH A DELUSIONAL IDEA. Yes
   No

e. Did you have trouble concentrating or did you have trouble making up your mind?

   If YES to either, code YES

f. Did you feel so bad that you wished that you were dead? Did you think about hurting yourself? Did you have thoughts of death? Did you think about killing yourself?

   If YES to either, code YES

A4 Did these sad, depressed feelings cause a lot of problems at home? At school? With friends? With other people? Or in some other important way?

A5 In between your times of depression, were you free of depression for at least 2 months?

A6 How many episodes of depression did you have in your lifetime? Between each episode there must be at least 2 months without any significant depression. **(Please enter a number)**

(NOTE: Questions about subtypes of anxiety are gated by an omnibus question about anxiety NOT part of the original MINI. If the answer "No" is selected, this block is not seen by the participant.)

Do you ever feel anxious, scared, or worried to the point that you do not participate fully in activities or do the things you want to do?

a. Yes
b. Maybe
c. No

F. Agoraphobia

F1. Do you feel anxious, scared, or uneasy in places or situations where you might become really frightened; like being in a crowd, standing in a line (queue), when you are all alone, or when crossing a bridge, or traveling in a bus, train or car?
IF NO, CODE NO TO F1 AND F2

F2. Are you so afraid of these things that you try to stay away from them? Or you can only do them if someone is with you? Or you do them, but it's really hard for you?

G. Separation Anxiety Disorder

G1. a. In the past month, have you been really afraid about being away from someone close to you; or have you been really afraid that you would lose somebody you are close to? (Like getting lost from your parents or having something bad happen to them)

IF YES to either, code YES

b. Who are you afraid of losing or being away from?

(The following questions use the target's name generated in G1. b. As this is done automatically, the place for this target is marked as a # within the questions presented here.)

G2. a. Did you get upset a lot when you were away from #?
Did you get upset a lot when you thought you would be away from #?

IF YES to either, code YES

b. Did you get really worried that you would lose #? Did you get really worried that something bad would happen to #? (like having a car accident or dying).

IF YES to either, code YES

c. Did you get really worried that you would be separated from #? (like getting lost or being kidnapped?)

d. Did you refuse to go to school or other places because you were afraid to be away from #?

e. Did you get really afraid being at home if # wasn't there?

f. Did you not want to go to sleep unless # was there?

g. Did you have nightmares about being away from #? Did this happen more than once?

If NO to either, code NO

h. Did you feel sick a lot (like headaches, stomach aches, nausea or vomiting, heart beating fast or feeling dizzy) when you were away from #? Did you feel sick a lot when you thought you were going to be away from #?

If YES to either, code YES

G3. Did this last for at least 4 weeks?

G4. Did your fears of being away from # really bother you a lot? Cause you a lot of problems at home? At school? With friends? In any other way?

If YES to any, code YES

H. Social Phobia

H1. In the past month, were you afraid or embarrassed when others your age were watching you? Were you afraid of being teased? Like talking in front of the class? Or eating or writing in front of others?

If YES to any, code YES

H2. Are you more afraid of these things than other kids your age?

H3. Are you so afraid of these things that you try to stay away from them? Or you can only do them if someone is with you? Or you do them but it's really hard for you?

H4. Do these social fears have a big effect on your life? Do they cause problems when you interact with others or in your relationships? Do they cause a lot of problems at school or at work? Do they cause you to feel upset and want to be alone?

If YES to any, code YES

H5. Did this social fear/social anxiety last at least 6 months?

H6. Do you fear and avoid 4 or more social situations?

I. Specific Phobia

I1. In the past month, have you been really afraid of something like: snakes or bugs? Dogs or other animals? High places? Storms? The dark? Or seeing blood or needles?

I2. List any specific phobias.

(The following questions use the target's phobias generated in I2. As this is done automatically, the place for this target is marked as a # within the questions presented here.)

I3. Are you more afraid of # than other kids your age are?

I4. Are you so afraid of # that you try to stay away it / them? Or you can only be around it / them if someone is with you? Or can you be around it / them but it's really hard for you?

If YES to any, code YES

I5. Does this fear really bother you a lot? Does it cause you problems at home NO YES
or at school? Does it keep you from doing things you want to do?

If YES to any, code YES

K. Post-traumatic Stress Disorder

K1. Has anything really awful ever happened to you? Like being in a flood, tornado or earthquake? Like being in a fire or a really bad accident? Like seeing someone being killed or badly hurt. Have you ever been attacked by someone?

K2. Did you respond with intense fear, or feel helpless or upset?

K3. In the past month, has this awful thing come back to you in some way? Like dreaming about it or having a strong memory of it or feeling it in your body?

K4. In the past month:
a. Have you tried not to think about or talk about this awful thing?
b. Have you tried to stay away from things that might remind you of it?
c. Have you had trouble remembering some important part of what happened?
d. Have you been much less interested in your hobbies or your friends?
e. Have you felt cut off from other people?
f. Have you noticed that your feelings are less than before?
g. Have you felt that your life will be shortened or that you will die sooner than other people?

K5. In the past month:
a. Have you had trouble sleeping?
b. Have you been moody or angry for no reason?
c. Have you had trouble paying attention?
d. Were you nervous or watching out in case something bad might happen? Would you jump when you heard noises? Or when you saw something out of the corner of your eye?

K6. In the past month, have these problems upset you a lot? Have they caused you to have problems at school? At home? With your friends?

U. Generalized Anxiety Disorder

U1. a. For the past 6 months, have you worried a lot or been nervous? Have you been worried or nervous about several things, like school, your health, or something bad happening? Have you been more worried than other kids your age?

b. Do you worry most days?

U2. Do you find it hard to stop worrying? Do the worries make it hard for you to pay attention to what you are doing?

U3. When you are worried, do you, most of the time:
a. Feel like you can't sit still?
b. Feel tense in your muscles?
c. Feel tired, weak, or exhausted easily?
d. Have a hard time paying attention to what you are doing? Does your mind go blank?
e. Feel grouchy or annoyed?
Have trouble sleeping ("trouble sleeping" means trouble falling asleep, waking up in the middle of the night, waking up too early or sleeping too much)?

U4. Do these worries or anxieties cause a lot of problems at school or with your friends or at home or at work with other people?

Big 5 Inventory-2

N/Ne Questions (Soto & John, 2016)
Use the rating scale to describe how well each statement describes you. Describe yourself as you generally are, not as you wish to be in the future or how you were in the past. Describe yourself honestly. Your responses will be held in the strictest confidence. Please read each statement and then choose the most accurate answer for you.

I AM SOMEONE WHO...

4. Is relaxed, handles stress well
9. Stays optimistic after experiencing a setback
14. Is moody, has up and down mood swings
19. Can be tense
24. Feels secure, comfortable with self
29. Is emotionally stable, not easily upset
34. Worries a lot
39. Often feels sad
44. Keeps their emotions under control
49. Rarely feels anxious or afraid
54. Tends to feel depressed, blue
59. Is temperamental, gets emotional easily

Multidimensional Scale of Perceived Social Support
(Bruwer et al., 2008; Zimet et al., 1990)

We are interested in how you feel about the following statements. Read each statement carefully. Indicate how you feel about each statement.

Circle the "1" if you Very Strongly Disagree

Circle the “2” if you Strongly Disagree
Circle the “3” if you Mildly Disagree
Circle the “4” if you are Neutral
Circle the “5” if you Mildly Agree
Circle the “6” if you Strongly Agree
Circle the “7” if you Very Strongly Agree

1. There is a special person who is around when I am in need.
2. There is a special person with whom I can share my joys and sorrows.
3. My family really tries to help me.
4. I get the emotional help and support I need from my family.
5. I have a special person who is a real source of comfort to me.
6. My friends really try to help me.
7. I can count on my friends when things go wrong.
8. I can talk about my problems with my family.
9. I have friends with whom I can share my joys and sorrows.
10. There is a special person in my life who cares about my feelings.
11. My family is willing to help me make decisions.
12. I can talk about my problems with my friends.

State Trait Anxiety Inventory
(Spielberger et al., 1983)

A number of statements which people have used to describe themselves are given below. Read each statement and then select the appropriate description to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement, but give the answer which seems to describe how your present feelings best.

Circle the “1” if Not at all
Circle the “2” if Somewhat
Circle the “3” if Moderately so
Circle the “4” if Very much so

1. I feel calm
2. I feel secure
3. I am tense
4. I feel strained
5. I feel at ease
6. I feel upset
7. I am presently worrying over possible misfortunes
8. I feel satisfied
9. I feel frightened
10. I feel comfortable
11. I feel self-confident
12. I feel nervous

13. I am jittery
14. I feel indecisive
15. I am relaxed
16. I feel content
17. I am worried
18. I feel confused
19. I feel steady
20. I feel pleasant

A number of statements which people have used to describe themselves are given below. Read each statement and then select the appropriate description to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement, but give the answer, which seems to describe how you generally feel.

21. I feel pleasant
22. I feel nervous and restless
23. I feel satisfied with myself
24. I wish I could be as happy as others seem to be
25. I feel like a failure
26. I feel rested
27. I am "calm, cool, and collected."
28. I feel that difficulties are piling up so that I cannot overcome them
29. I worry too much over something that really doesn't matter
30. I am happy
31. I have disturbing thoughts
32. I lack self-confidence
33. I feel secure
34. I make decisions easily
35. I feel inadequate
36. I am content
37. Some unimportant through runs through my mind and bothers me
38. I take disappointments so keenly that I can't put them out of my mind
39. I am a steady person
40. I get in a state of tension or turmoil as I think over my recent concerns and interests

Brief Adolescent Life Event Scale
(Shahar et al., 2003)

Circle the "0" if Never
Circle the "1" if Sometimes
Circle the "2" if About half the time
Circle the "3" if A lot

Family Events
I argued with a family member
I made up with a family member
I got help from a family member when I needed it
I did NOT get help from a family member when I needed it
I was allowed to do something I wanted to
I was NOT allowed to do something that I wanted to do

School Events
I got a bad grade in school
I got a good grade in school
I completed an important assignment (on time)
I did NOT complete an important assignment (or was late)
A teacher told me I did well on an assignment
A teacher told me I did poorly on an assignment

Close Friends Events
I argued with a friend
I made up with a friend
I got help from a friend when I needed it
I did NOT get help from a friend when I needed it
A friend joined me for a special event when I asked
A friend did NOT join me for a special event when I asked

Work and Non-School Events
I discovered I can do something better than someone else
I discovered I can NOT do something better than someone else
I did something I felt embarrassed by
I did something I felt proud of
I did something outside of school that I was praised for
I did something outside of school that I was criticized for

Peer Events
A classmate teased or threatened me
A classmate defended me from others
I was invited to join in with a group event
I was excluded from a group event
I had an enjoyable romantic date
I had a disappointing romantic date

Health and Body Events
My body changed in a way I wanted
My body changed in a way I did not want
I became sick or got injured
I got well after a sickness or recovered from an injury
Someone insulted me because of the way I look

Someone complimented me because of the way I look

Sleepiness Scale & Sleep/Wake Problems Behavior Scale
(Wolfson & Carskadon, 1998)

1. How many hours of sleep do you get on most nights?
   a. 9-11 hours
   b. 8-9 hours
   c. 7-8 hours
   d. 5-7 hours
   e. Less than 5 hours

2. How long after going to bed to you usually fall asleep
   a. Less than 15 minutes
   b. 15-30 minutes
   c. 30-45 minutes
   d. 45-60 minutes
   e. More than 1 hour

Sleepiness Scale

During the last two weeks, have you struggled to stay awake (fought sleep) or fallen asleep in the following situations? (Mark one answer for every item.)

Circle the "1" if No
Circle the "2" if Struggled to stay awake
Circle the "3" if Fallen asleep
Circle the "4" if Both

1. In a face-to-face conversation with another person
2. Traveling in a bus, train, plane, or car
3. Attending a performance (movie, concert, play)
4. Watching television or listening to the radio or stereo
5. Reading, studying, or doing homework
6. During a test
7. In a class at school
8. While doing work on a computer or typewriter
9. Playing video games
10. Driving a car

Sleep/Wake Problems Behavior Scale

In the last two weeks, how often have you…. (Mark one answer for every item.)
Circle the "5" if Everyday/night
Circle the "4" if Several times
Circle the "3" if Twice

Circle the “2” if Once
Circle the “1” if Never

1. Felt satisfied with your sleep?
2. Arrived late to class because you overslept?
3. Fallen asleep in a morning class?
4. Fallen asleep in an afternoon class?
5. Awakened too early in the morning and couldn’t get back to sleep?
6. Stayed up until at least 3 a.m.?
7. Stayed up all night?
8. Slept in past noon?
9. Felt tired, dragged out, or sleepy during the day?
10. Needed more than one reminder to get up in the morning?
11. Had an extremely hard time falling asleep?
12. Had nightmares or bad dreams during the night?
13. Gone to bed because you just could not stay awake any longer?
14. Done dangerous things without thinking?
15. Had a good night’s sleep?

Appendix G

Story Grammar: Cinderella

Section	Con	P#	Content
Setting/ Orientation	[*]	P 1	be [Cinderella]: Once upon a time // A long time ago there was a girl/woman called Cinderella
Setting/ Orientation	[*]	P 2	live [Cinderella, with stepfamily]: Cinderella lived with her stepmother and her stepsisters
Setting/ Orientation		P 3	do [Cinderella, housework]: Cinderella has to do the housework
Setting/ Orientation	*	P 4	boss around/be mean [stepsisters, Cinderella]: The (spoiled) stepsisters boss Cinderella around/ are mean to Cinderella
Episode 1		P 5	dream [Cinderella]: Cinderella dreams of escaping/living in the castle.
Episode 1	*	P 6	invite [prince, single women, ball, palace]: The prince invites all young single women to his ball in the palace
Episode 1		P 7	finds [Cinderella, dress, old]: Cinderella finds an old dress in the attic.
Episode 1	*	P 8	decorates/changes [Cinderella, dress, animals]: Cinderella decorates the dress with the help of her animal friends.
Episode 2a		P 9	dress [stepsisters /stepmother, for ball]: The stepsisters and the stepmother dress for the ball
Episode 2a		P 10	see [stepsisters/stepmother, Cinderella]: The stepsisters see Cinderella in her gown.
Episode 2a	*	P 11	attack/rip [stepsisters, Cinderella]: The stepsisters attack Cinderella/The stepsisters rip Cinderella's gown.
Episode 2a	*	P 12	be sad/cry [Cinderella]: Cinderella is sad/cries
Episode 2a		P 13	leave [stepsisters/stepmother, for ball]: The stepsisters and stepmother leave for the ball in a coach
Episode 2b	*	P 14	appear/be here [fairy godmother]: The fairy godmother appears/is here
Episode 2b		P 15	see/find [fairy godmother, Cinderella (crying/sad)]: The fairy godmother sees/finds Cinderella (crying/sad)
Episode 2b	*	P 16	perform [fairy godmother, magic]: The fairy godmother performs magic
Episode 2b	*	P 17	turn into [fairy godmother, Cinderella, enchanting woman]: The fairy godmother turns Cinderella into an enchanting woman (dressed up in a gown with glass slippers)
Episode 2b		P 18	turn into [fairy godmother, pumpkin, coach and driver]: The fairy godmother turns a pumpkin into a coach and/with a driver
Episode 2b		P 19	turn into [fairy godmother, (two) mice, horses]: The fairy godmother turns (two) mice into horses
Episode 2b	*	P 20	warn [fairy godmother, Cinderella, about midnight]: The fairy godmother warns Cinderella about leaving the ball by midnight
Episode 3		P 21	be/arrive [Cinderella, at palace]: Cinderella is/arrives at the palace
Episode 3	*	P 22	see [prince, with Cinderella]: The prince sees Cinderella
Episode 3	*	P 23	dance [prince, with Cinderella]: The prince/He dances with her
Episode 3		P 24	watch [guests, Cinderella and prince]: The stepsisters/All the

			guests are watching them
Complication	*	P 25	strike [clock, midnight]: The clock strikes midnight
Complication		P 26	leave/run out of [Cinderella, palace]: Cinderella leaves/ runs out of the palace
Complication	*	P 27	lose [Cinderella, glass slipper]: Cinderella loses a glass slipper
Complication	*	P 28	find [Prince, glass slipper]: The prince finds the glass slipper
Complication		P 29	be transformed into [Cinderella/coach and driver, original state]: Cinderella /the coach and the driver are transformed (back) into their original state
Solution		P 30	want [Prince, find owner]: The prince wants to find the owner of the glass slipper/Cinderella
Solution	*	P 31	go [Prince (and servant), from town to town/door to door]: On the following days the prince (and his servant) go from town to town/door to door
Solution	*	P 32	look for [Prince and servants, Cinderella]: Prince (and servant) looks (look) for Cinderella/the person whose foot fits into the glass slipper
Solution		P 33	lock away/hide [stepmother, Cinderella]: The stepmother locks Cinderella away.
Solution		P 34	try on [stepsisters, glass slipper]: (At Cinderella's house) The stepsisters try on the glass slipper
Solution		P 35	not fit [glass slipper, stepsisters]: The glass slipper does not fit the stepsisters
Solution		P 36	free/help [animals, Cinderella]: Animals help Cinderella escape.
Solution	*	P 37	try on [Cinderella, glass slipper]: Cinderella tries on the glass slipper
Solution	*	P 38	fit [glass slipper, Cinderella]: The glass slipper/It fits Cinderella
Coda	[*]	P 39	be happy/together [prince and Cinderella]: The prince and Cinderella are happy/together again
Coda	[*]	P 40	marry/get married [prince and Cinderella]: The prince and Cinderella marry/get married
Coda	[*]	P 41	live [prince and Cinderella, happily]: They live happily ever after

Con: constituent

Cinderella sample narratives

Healthy participant

The wicked stepmother and her two young daughters look sullen as a man introduces them to Cinderella. Cinderella curtsies politely with her dog at her side. Fast forward several years and The wicked stepsisters are rudely bossing around Cinderella, who is now their maid. Cinderella longingly looks out the window at the castle, and then resumes her chores while the wicked stepmother plays on the piano. The stepsisters sing

along, badly out of key. Meanwhile, Cinderella begins sewing a dress to wear to the ball. She looks in a book for directions but must abandon her sewing to complete her chores. The mice and birds sew her dress, but her jealous stepfamily ruins the dress, horrified that Cinderella is more beautiful than they are. The Fairy Godmother comes to the rescue and makes Cinderella a beautiful gown with a carriage, horses, and horseman to take her to the ball. She dances with the prince but must leave early before the clock strikes 12. She runs down the stairs, having lost a slipper, and returns to find her carriage has turned back into a pumpkin. The next day, the prince searches for the lady who lost a slipper. Cinderella's family locks her in a closet in hopes that the slipper will fit one of them. the king's men find her anyway, the slipper fits, and Cinderella gets to marry the prince.

Participant with a history of concussion

Cinderella's father got married to a woman with two nasty girls. They were rude to Cinderella and never liked her much. Years have passed and the father has unfortunately passed away leaving Cinderella in the hands of her evil Stepmother. The nasty girls continued to be rude to her and Cinderella was in charge of chores around the house and waiting on the three of them hand and foot. There was a royal ball that they all got invited to,so she made a dress with the help of her mice friends. The Stepmother would not let Cinderella go because she didn't deserve to go and she had too many chores. So the girls ripped up her dress and laughed that she thought she could come. Her fairy godmother helped and gave her a dress and ride to the ball

Participant with recent concussion

Cinderella met her new stepsisters and stepmother. They were very mean to her. Cinderella wanted to go to the ball and the castle but could only go if she had a dress.

Once she finished her dress. the stepsisters ripped it up so Cinderella could not go to the ball. Her godmother apeared and made her a new dress so that cinderella could go to the ball.

Story Grammar: Pigeon: Impossible

Section	Con	P#	Content
Setting/ Orientation	[*]	P 1	be [Walter Beckett]: There was a man.
Setting/ Orientation	[*]	P 2	be/working [Walter Beckett]: Walter worked in Washington, D.C.
Setting/ Orientation		P 3	be distracted/clumsy/accident prone [Walter Beckett]: Walter was accident prone./Walter almost was hit by passing cars/almost walked into a tree.
Setting/ Orientation		P 4	be [Walter Beckett]: Walter worked as a junior agent for the CIA.
Episode 1	*	P 5	received [Walter, unnamed agent]: Walter received a briefcase from another agent.
Episode 1		P 6	sat [Walter, briefcase, bagel]: Walter sat on a bench eating a bagel
Episode 1	*	P 7	lands [pigeon]: A pigeon lands on the bench beside the agent.
Episode 1		P 8	wants [pigeon, bagel]: The pigeon wants a piece of the bagel.
Episode 1		P 9	gives/throws [Walter, pigeon, piece of bagel]: Walter gives/throws the pigeon a small piece of bagel.
Episode 1		P 10	wants [pigeon, bagel, whole]: The pigeon wants the whole bagel.
Episode 2a	*	P 11	fly/attack [pigeon, Walter]: The pigeon flies at/attacks Walter.
Episode 2a		P 12	throw [Walter, bagel]: Walter throws the whole bagel.
Episode 2a		P 13	chase [pigeon]: The pigeon chases the bagel.
Episode 2a	*	P 14	trapped [pigeon, briefcase]: The briefcase falls, and the pigeon is trapped inside.
Episode 2b	*	P 15	pecking/pressing [pigeon, buttons]: The pigeon begins pressing buttons in the briefcase.
Episode 2b		P 16	chase [pigeon, briefcase, Walter]: The pigeon makes the briefcase chase Walter and another woman on the street.
Episode 2b	*	P 17	fire lasers [pigeon, briefcase]: The pigeon makes the briefcase fire lasers.
Episode 2b		P 18	takeoff/launch [pigeon, briefcase]: The pigeon makes the briefcase launch down the sidewalk.
Episode 2b		P 19	shoot at/attack [pigeon, briefcase, Walter]: The pigeon uses the briefcase to shoot at Walter.
Episode 3	*	P 20	offer/distract/lure [Walter, bagel, pigeon]: Walter offers the whole bagel to the pigeon./Walter distracts the pigeon with the bagel.
Episode 3		P 21	see [pigeon, bagel]: The pigeon sees the bagel.
Episode 3		P 22	threaten [Walter, bagel]: Walter threatens to burn the bagel in the flaming car.

Episode 3	*	P 23	land/open [pigeon, briefcase]: The pigeon lands the briefcase and opens it.
Episode 3		P 24	run/rush [Walter, briefcase]: Walter rushes to get the briefcase
Episode 3		P 25	aim [pigeon, rocket]: The pigeon aims a rocket at Walter.
Complication		P 26	throw [Walter, bagel]: Walter throws the whole bagel into the air.
Complication		P 27	hit/knock [Walter, pigeon, briefcase]: Walter knocks the pigeon out of the briefcase.
Complication	*	P 28	fall down/land [bagel, button]: The bagel falls down onto the Big Red Button.
Complication	*	P 29	launch [button, missile]: The button launches a nuclear missile out of the Washington monument.
Complication		P 30	go [missile, Russia]: The missile is going toward Moscow, Russia.
Solution	*	P 31	chase/fly [Walter, missile, briefcase]: Walter uses the briefcase to chase the missile into the sky.
Solution		P 32	hit [pigeon, Walter]: The pigeon hits Walter.
Solution	*	P 33	block [pigeon, rocket, missile]: The pigeon blocks Walter from shooting the rocket at the missile.
Solution	*	P 34	open [Walter, briefcase, bagel]: Walter opens the briefcase.
Solution	*	P 35	fall [pigeon, bagel]: The bagel falls out of the briefcase.
Solution	*	P 36	chase [pigeon, bagel]: The pigeon chases the bagel away.
Solution	*	P 37	hit/shoot [Walter, rocket, missile]: Walter shoots the missile out of the sky.
Solution		P 38	explode [missile]: The missile explodes in the air.
Coda		P 39	save the day [Walter]: Walter saves the day.
Coda		P 40	eat [pigeon, bagel]: The pigeon happily eats the bagel.
Coda	[*]	P 41	walks [Walter, briefcase]: Walter casually walks away with the briefcase.
Coda	[*]	P 42	hit/squish [pigeon, missile]: The pigeon is hit by the falling missile debris.

Con: constituent

Pigeon: Impossible sample narratives

Healthy participant

A pigeon, through the power of luck and chance, falls into a briefcase containing the button to bomb Russia. This pigeon, being an animal trapped in a box, starts pecking things around him like a pigeon. It eventually hits a button that starts shooting things and flying. This pigeon is lured out of the box with a bagel, but the bagel falls on the launch button. The agent who was handling the box had to stop the rocket by flying up to the rocket by the means of the briefcase, which, as mentioned before, can fly. The agent is

almost stopped by the pigeon, who still wants the bagel. The agent gives it the bagel and saves the day by blowing up the rocket, The pigeon almost started a war because it was an animal and wanted food.

Participant with a history of concussion

A CIA analyst in Washington, DC was eating a bagel on a bench. He had his briefcase of spy equipment with him. He saw a pigeon watching him and tried to share his bagel. The pigeon got angry and attacked the analyst. In the ensuing skirmish, the briefcase opened, and the pigeon ended up shut inside. The pigeon started poking around and pushing buttons. He started shooting beams out of the briefcase and cars started to catch on fire. The analyst tried to tempt the pigeon out of the briefcase with the bagel. Eventually, the pigeon pressed a button that made the Washington Monument turn into a rocket and take off. Eventually, the rocket landed where the pigeon was eating the bagel.

Participant with recent concussion

The story, which is setting is in Washington D.C, is based on a FBI agent who prevents a nuclear missile to hit Russia. / In the beginning of the story a unknown person hands him a suitcase. He walks down the street and sits down on a bench to eat his bagel. Then the watcher learns that the suitcase is not an ordinary suitcase. It's a high-tech suitcase which can fly, shoot and has the ability to shoot a nuclear missile. All of a sudden a pigeon sits next to the FBI agent and looks at his bagel. The pigeon gets trapped in the suitcase and starts shooting and doing all kinds of things which

References

Aram, D. M., & Eisele, J. A. (1994). Intellectual stability in children with unilateral brain lesions. *Neuropsychologia, 32*(1), 85-95.

Asarnow, R. F., Satz, P., Light, R., Zaucha, K., Lewis, R., & McCleary, C. (1995). The UCLA study of mild closed head injury in children and adolescents. In S. Broman & M. E. Michel (Eds.), *Traumatic Head Injury in Children and Adolescents.* (pp. 117-146). New York: Oxford University Press.

Babcock, L., Yuan, W., Leach, J., Nash, T., & Wade, S. (2015). White matter alterations in youth with acute mild traumatic brain injury. *Journal of pediatric rehabilitation medicine, 8*(4), 285-296.

Babikian, T., & Asarnow, R. (2009). Neurocognitive outcomes and recovery after pediatric TBI: meta-analytic review of the literature. *Neuropsychology, 23*(3), 283.

Babikian, T., McArthur, D., & Asarnow, R. F. (2013). Predictors of 1-month and 1-year neurocognitive functioning from the UCLA longitudinal mild, uncomplicated, pediatric traumatic brain injury study. *Journal of the International Neuropsychological Society, 19*(02), 145-154.

Baker, J. G., Leddy, J. J., Darling, S. R., Shucard, J., Makdissi, M., & Willer, B. S. (2016). Gender differences in recovery from sports-related concussion in adolescents. *Clinical pediatrics, 55*(8), 771-775.

Barak, A., & English, N. (2002). Prospects and limitations of psychological testing on the Internet. *Journal of Technology in Human Services, 19*(2-3), 65-89.

Barlow, D. H., Ellard, K. K., Sauer-Zavala, S., Bullis, J. R., & Carl, J. R. (2014). The origins of neuroticism. *Perspectives on Psychological Science, 9*, 481–496.

Barlow, D. H., Sauer-Zavala, S., Carl, J. R., Bullis, J. R., & Ellard, K. K. (2013). The nature, diagnosis, and treatment of neuroticism: Back to the future. *Clinical Psychological Science, 2*(3), 344-365. doi:10.1177/2167702613505532

Barnes, M. A., Dennis, M., & Wilkinson, M. (1999). Reading after closed head injury in childhood: Effects on accuracy, fluency, and comprehension. *Developmental Neuropsychology, 15*(1), 1-24.

Bauman, S., Ray, M., & Joseph, P. P. (2017). Gender differences in clinical presentation and recovery of sports related concussion. *Br J Sports Med, 51*(11), A35-A35.

Bazarian, J. J., Zhong, J., Blyth, B., Zhu, T., Kavcic, V., & Peterson, D. (2007). Diffusion tensor imaging detects clinically important axonal damage after mild traumatic brain injury: A pilot study. *Journal of neurotrauma, 24*(9), 1447-1459.

Beauchamp, M. H., & Anderson, V. (2010). SOCIAL: an integrative framework for the development of social skills. *Psychological Bulletin, 136*(1), 39.

Beauchamp, M. H., Landry-Roy, C., Gravel, J., Beaudoin, C., & Bernier, A. (2017). Should young children with TBI be compared to community or orthopedic control participants? *Journal of neurotrauma*(ja).

Belanger, H. G., Curtiss, G., Demery, J. A., Lebowitz, B. K., & Vanderploeg, R. D. (2005). Factors moderating neuropsychological outcomes following mild traumatic brain injury: A meta-analysis. *Journal of the International Neuropsychological Society, 11*(03), 215-227.

Belanger, H. G., & Vanderploeg, R. D. (2005). The neuropsychological impact of sports-related concussion: a meta-analysis. *Journal of the International Neuropsychological Society, 11*(04), 345-357.

Berisha, V., Wang, S., LaCross, A., Liss, J., & Garcia-Filion, P. (2017). Longitudinal changes in linguistic complexity among professional football players. *Brain and Language, 169*, 57-63.

Bernard, C. O., Ponsford, J. L., McKinlay, A., McKenzie, D., & Krieser, D. (2017). Do Concussive Symptoms Really Resolve in Young Children? *The Journal of head trauma rehabilitation*.

Bernstein, D. M. (2002). Information processing difficulty long after self-reported concussion. *Journal of the International Neuropsychological Society, 8*(5), 673-682.

Bethune, A., da Costa, L., van Niftrik, C., & Feinstein, A. (2016). Suicidal Ideation after Mild Traumatic Brain Injury: A Consecutive Canadian Sample. *Archives of Suicide Research*.

Bialunska, A., & Salvatore, A. (2017). What's Going on With Auditory Comprehension After Sport-Related Concussion? *Archives of Physical Medicine and Rehabilitation, 98*(10), e22.

Biddle, K. R., McCabe, A., & Bliss, L. S. (1996). Narrative skills following traumatic brain injury in children and adults. *Journal of Communication Disorders, 29*(6), 447-469.

Blanchet, S., Paradis-Giroux, A.-A., Pépin, M., & Mckerral, M. (2009). Impact of divided attention during verbal learning in young adults following mild traumatic brain injury. *Brain Injury, 23*(2), 111-122.

Boersma, G. J., Benthem, L., van Beek, A. P., van Dijk, G., & Scheurink, A. J. (2011). Personality, a key factor in personalized medicine? *Eur J Pharmacol, 667*(1), 23-25.

Bohnen, N., Jolles, J., & Twijnstra, A. (1992). Neuropsychological deficits in patients with persistent symptoms six months after mild head injury. *Neurosurgery, 30*(5), 692-696.

Borgaro, S. R., Prigatano, G. P., Kwasnica, C., & Rexer, J. L. (2003). Cognitive and affective sequelae in complicated and uncomplicated mild traumatic brain injury. *Brain Injury, 17*(3), 189-198.

Brickman, A. L., Yount, S. E., Blaney, N. T., Rothberg, S. T., & De-Nour, A. K. (1996). Personality traits and long-term health: Status the influence of neuroticism and conscientiousness on renal deterioration in type-1 diabetes. *Psychosomatics, 37*(5), 459-468.

Bridge, J. A., McBee-Strayer, S. M., Cannon, E. A., Sheftall, A. H., Reynolds, B., Campo, J. V., . . . Brent, D. A. (2012). Impaired decision making in adolescent suicide attempters. *Journal of the American Academy of Child & Adolescent Psychiatry, 51*(4), 394-403.

Brooks, B. L., Kadoura, B., Turley, B., Crawford, S., Mikrogianakis, A., & Barlow, K. M. (2014). Perception of recovery after pediatric mild traumatic brain injury is influenced by the "good old days" bias: tangible implications for clinical practice and outcomes research. *Archives of Clinical Neuropsychology, 29*(2), 186-193.

Brooks, B. L., Mrazik, M., Barlow, K. M., McKay, C. D., Meeuwisse, W. H., & Emery, C. A. (2014). Absence of differences between male and female adolescents with prior sport concussion. *The Journal of head trauma rehabilitation, 29*(3), 257-264.

Brookshire, B. L., Chapman, S. B., Song, J., & Levin, H. S. (2000). Cognitive and linguistic correlates of children's discourse after closed head injury: A three-year follow-up. *Journal of the International Neuropsychological Society, 6*(7), 741-751.

Bruwer, B., Emsley, R., Kidd, M., Lochner, C., & Seedat, S. (2008). Psychometric properties of the Multidimensional Scale of Perceived Social Support in youth. *Comprehensive Psychiatry, 49*(2), 195-201.

Buchanan, T., Johnson, J. A., & Goldberg, L. R. (2005). Implementing a five-factor personality inventory for use on the internet. *European Journal of Psychological Assessment, 21*(2), 115-127.

Buske-Kirschbaum, A., Geiben, A., & Hellhammer, D. (2001). Psychobiological aspects of atopic dermatitis: an overview. *Psychotherapy and Psychosomatics, 70*(1), 6-16.

Buss, K. A., Davidson, R. J., Kalin, N. H., & Goldsmith, H. H. (2004). Context-specific freezing and associated physiological reactivity as a dysregulated fear response. *Developmental Psychology, 40*(4), 583-594. doi:10.1037/0012-1649.40.4.583

Buss, K. A., Goldsmith, H. H., & Davidson, R. J. (2005). Cardiac reactivity is associated with changes in negative emotion in 24-month-olds. *Developmental Psychobiology, 46*(2), 118-132.

Carman, A. J., Ferguson, R., Cantu, R., Comstock, R. D., Dacks, P. A., DeKosky, S. T., . . . Gioia, G. (2015). Expert consensus document: mind the gaps [mdash] advancing research into short-term and long-term neuropsychological outcomes of youth sports-related concussions. *Nature Reviews Neurology, 11*(4), 230-244.

Carroll, L. J., Cassidy, J. D., Cancelliere, C., Côté, P., Hincapié, C. A., Kristman, V. L., . . . Hartvigsen, J. (2014). Systematic review of the prognosis after mild traumatic brain injury in adults: cognitive, psychiatric, and mortality outcomes: results of the International Collaboration on Mild Traumatic Brain Injury Prognosis. *Archives of Physical Medicine and Rehabilitation, 95*(3), S152-S173.

Carroll, L. J., Cassidy, J. D., Peloso, P., Borg, J., Von Holst, H., Holm, L., . . . Pépin, M. (2004). Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine, 36*(0), 84-105.

Caspi, A., Roberts, B. W., & Shiner, R. L. (2005). Personality development: Stability and change. *Annual Review of Psychology, 56*(1), 453-484. doi:doi:10.1146/annurev.psych.55.090902.141913

Cassidy, J. D., Carroll, L., Peloso, P., Borg, J., Von Holst, H., Holm, L., . . . Coronado, V. (2004). Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *Journal of Rehabilitation Medicine, 36*(0), 28-60.

Catale, C., Marique, P., Closset, A., & Meulemans, T. (2009). Attentional and executive functioning following mild traumatic brain injury in children using the Test for

Attentional Performance (TAP) battery. *Journal of Clinical and Experimental Neuropsychology, 31*(3), 331-338.

Catroppa, C., Hearps, S., Crossley, L., Yeates, K., Beauchamp, M., Fusella, J., & Anderson, V. (2016). Social and Behavioral Outcomes following Childhood Traumatic Brain Injury: What Predicts Outcome at 12 Months Post-Insult? *Journal of neurotrauma*.

Chapman, B. P., Roberts, B., & Duberstein, P. (2011). Personality and longevity: Knowns, unknowns, and implications for public health and personalized medicine. *Journal of aging research, 2011*.

Chapman, S. B., Culhane, K. A., Levin, H. S., Harward, H., Mendelsohn, D., Ewing-Cobbs, L., . . . Bruce, D. (1992). Narrative discourse after closed head injury in children and adolescents. *Brain and Language, 43*(1), 42-65.

Chrisman, S. P., & Richardson, L. P. (2014). Prevalence of diagnosed depression in adolescents with history of concussion. *Journal of Adolescent Health, 54*(5), 582-586.

Chuah, S. C., Drasgow, F., & Roberts, B. W. (2006). Personality assessment: Does the medium matter? No. *Journal of Research in Personality, 40*(4), 359-376.

Clauss, J. A., & Blackford, J. U. (2012). Behavioral inhibition and risk for developing social anxiety disorder: A meta-analytic study. *Journal of the American Academy of Child and Adolescent Psychiatry, 51*(10), 1066-1075

Cleveland, H. H., Koss, M. P., & Lyons, J. (1999). Rape tactics from the survivors' perspective: Contextual dependence and within-event independence. *Journal of Interpersonal Violence, 14*(5), 532-547.

Cochran, W., & Cox, G. (1957). Experimental designs John Wiley and Sons Inc. *New York*.

Coelho, C. A. (2002). Story Narratives of Adults With Closed Head Injury and Non-Brain-Injured AdultsInfluence of Socioeconomic Status, Elicitation Task, and Executive Functioning. *Journal of Speech, Language, and Hearing Research, 45*(6), 1232-1248.

Coelho, C. A., Grela, B., Corso, M., Gamble, A., & Feinn, R. (2005). Microlinguistic deficits in the narrative discourse of adults with traumatic brain injury. *Brain Injury, 19*(13), 1139-1145.

Coelho, C. A., Liles, B. Z., & Duffy, R. J. (1995). Impairments of discourse abilities and executive functions in traumatically brain-injured adults. *Brain Injury, 9*(5), 471-477.

Cohn, M. A., Mehl, M. R., & Pennebaker, J. W. (2004). Linguistic markers of psychological change surrounding September 11, 2001. *Psychological Science, 15*(10), 687-693.

Cole, W. R., & Bailie, J. M. (2016). Neurocognitive and psychiatric symptoms following mild traumatic brain injury.

Collins, M. W., Lovell, M. R., Iverson, G. L., Ide, T., & Maroon, J. (2006). Examining concussion rates and return to play in high school football players wearing newer helmet technology: a three-year prospective cohort study. *Neurosurgery, 58*(2), 275-286.

Cook, K. J. (2008). *The effects of auditory distraction on discourse retell tasks in traumatic brain injury.* (Master of Speech and Language Therapy Master's thesis), University of Canterbury, Collections: Science: Theses and Dissertations.

Corwin, D. J., Zonfrillo, M. R., Master, C. L., Arbogast, K. B., Grady, M. F., Robinson, R. L., . . . Wiebe, D. J. (2014). Characteristics of prolonged concussion recovery in a pediatric subspecialty referral population. *The Journal of pediatrics, 165*(6), 1207-1215.

Courchesne, E. (1978). Neurophysiological correlates of cognitive development: changes in long-latency event-related potentials from childhood to adulthood. *Electroencephalography and Clinical Neurophysiology, 45*(4), 468-482.

Cuijpers, P., Smit, F., Penninx, B. W., de Graaf, R., ten Have, M., & Beekman, A. T. (2010). Economic costs of neuroticism: a population-based study. *Archives of General Psychiatry, 67*(10), 1086-1093. doi:10.1001/archgenpsychiatry.2010.130

Cummings, J. L., & Masterman, D. L. (1999). Depression in patients with Parkinson's disease. *International Journal of Geriatric Psychiatry, 14*(9), 711-718.

Currie, S. R., & Wang, J. (2005). More data on major depression as an antecedent risk factor for first onset of chronic back pain. *Psychological Medicine, 35*(09), 1275-1282.

Dall'Acqua, P., Mica, L., Simmen, H.-P., Glaab, R., Fandino, J., Schwendinger, M., . . . Baetschmann, H. (2017). Functional and Structural Network Recovery after Mild Traumatic Brain Injury: A 1-Year Longitudinal Study. *Frontiers in Human Neuroscience, 11*, 280.

Dashnaw, M. L., Petraglia, A. L., & Bailes, J. E. (2012). An overview of the basic science of concussion and subconcussion: where we are and where we are going. *Neurosurgical focus, 33*(6), E5.

Deary, I. J., Weiss, A., & Batty, G. D. (2010). Intelligence and personality as predictors of illness and death how researchers in differential psychology and chronic disease epidemiology are collaborating to understand and address health inequalities. *Psychological Science in the Public Interest, 11*(2), 53-79.

Dennis, M., & Barnes, M. A. (2000). Speech acts after mild or severe childhood head injury. *Aphasiology, 14*(4), 391-405.

Dexheimer, J. W., Kurowski, B. G., Anders, S. H., McClanahan, N., Wade, S. L., & Babcock, L. (2017). Usability evaluation of the SMART application for youth with mTBI. *International journal of medical informatics, 97*, 163-170.

Di Gallo, A. (2003). While my sister went to the disco, I went to hospital and met the doctors: Narrative as a measure of the psychological integration of the experience of cancer in childhood and adolescence. *Clinical Child Psychology and Psychiatry, 8*(4), 489-502.

Didehbani, N., Munro Cullum, C., Mansinghani, S., Conover, H., & Hart, J. (2013). Depressive symptoms and concussions in aging retired NFL players. *Archives of Clinical Neuropsychology, 28*(5), 418-424.

Dougan, B. K., Horswill, M. S., & Geffen, G. M. (2014). Athletes' age, sex, and years of education moderate the acute neuropsychological impact of sports-related concussion: A meta-analysis. *Journal of the International Neuropsychological Society, 20*(01), 64-80.

Eichstaedt, J. C., Schwartz, H. A., Kern, M. L., Park, G., Labarthe, D. R., Merchant, R. M., . . . Sap, M. (2015). Psychological language on twitter predicts county-level heart disease mortality. *Psychological Science, 26*(2), 159-169.

Elman, J. L., Bates, E. A., Johnson, M. H., Karmiloff-Smith, A., Parisi, D., & Plunkett, K. (1998). *Rethinking innateness: A connectionist perspective on development*. Cambridge, MA: MIT press.

Evans, J. L., & Craig, H. K. (1992). Language sample collection and analysis: Interview compared to freeplay assessment contexts. *Journal of Speech, Language, and Hearing Research, 35*(2), 343-353.

Ewing-Cobbs, L., & Barnes, M. A. (2002). Linguistic outcomes following traumatic brain injury in children. *Seminars in Pediatric Neurology, 9*(3), 209-217.

Ewing-Cobbs, L., Brookshire, B., Scott, M. A., & Fletcher, J. M. (1998). Children's narratives following traumatic brain injury: Linguistic structure, cohesion, and thematic recall. *Brain and Language, 61*(3), 395-419.

Ewing-Cobbs, L., Fletcher, J. M., Levin, H. S., Francis, D. J., Davidson, K., & Miner, M. E. (1997). Longitudinal neuropsychological outcome in infants and preschoolers with traumatic brain injury. *Journal of the International Neuropsychological Society, 3*(06), 581-591.

Ewing-Cobbs, L., Levin, H. S., Eisenberg, H. M., & Fletcher, J. M. (1987). Language functions following closed-head injury in children and adolescents. *Journal of Clinical and Experimental Neuropsychology, 9*(5), 575-592.

Fann, J. R., Burington, B., Leonetti, A., Jaffe, K., Katon, W. J., & Thompson, R. S. (2004). Psychiatric illness following traumatic brain injury in an adult healthMaintenance organization population. *Archives of General Psychiatry, 61*(1), 53-61.

Faul, M., Xu, L., Wald, M. M., & Coronado, V. (2010). Traumatic Brain Injury in the United States. *Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control*.

Fay, T. B., Yeates, K. O., Taylor, H. G., Bangert, B., Dietrich, A., Nuss, K. E., . . . Wright, M. (2010). Cognitive reserve as a moderator of postconcussive symptoms in children with complicated and uncomplicated mild traumatic brain injury. *Journal of the International Neuropsychological Society, 16*(1), 94-105.

Field, M., Collins, M. W., Lovell, M. R., & Maroon, J. (2003). Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes. *The Journal of pediatrics, 142*(5), 546-553.

Fletcher, J. M., Ewing-Cobbs, L., Miner, M. E., Levin, H. S., & Eisenberg, H. M. (1990). Behavioral changes after closed head injury in children. *Journal of Consulting and Clinical Psychology, 58*(1), 93.

Fox, A. S., & Kalin, N. H. (2014). A translational neuroscience approach to understanding the development of social anxiety disorder and its pathophysiology. *American Journal of Psychiatry, 171*(11), 1162-1173.

Fox, N. A., Henderson, H. A., Marshall, P. J., Nichols, K. E., & Ghera, M. M. (2005). Behavioral inhibition: Linking biology and behavior within a developmental framework. *Annual Review of Psychology, 56*, 235-262. doi:10.1146/annurev.psych.55.090902.141532

Fromm, D., MacWhinney, B., Forbes, M., & Holland, A. (2011). Is the Cinderella Task Biased for Age or Gender? *Montréal, Canada: Academy of Aphasia*.

Fueger, C. (2017). *Visually-Guided Reaching Under Varying Cognitive and Motor Demand in Young Adult Females with a History of Concussions.* The University of Wisconsin-Milwaukee,

Gagnon, I., Swaine, B., Friedman, D., & Forget, R. (2004). Visuomotor response time in children with a mild traumatic brain injury. *The Journal of head trauma rehabilitation, 19*(5), 391-404.

Galetto, V., Andreetta, S., Zettin, M., & Marini, A. (2013). Patterns of impairment of narrative language in mild traumatic brain injury. *Journal of Neurolinguistics, 26*(6), 649-661.

Gan, C., Campbell, K. A., Gemeinhardt, M., & McFadden, G. T. (2006). Predictors of family system functioning after brain injury. *Brain Injury, 20*(6), 587-600.

Ganguly, K., & Poo, M.-m. (2013). Activity-dependent neural plasticity from bench to bedside. *Neuron, 80*(3), 729-741.

Ge, Y., Patel, M. B., Chen, Q., Grossman, E. J., Zhang, K., Miles, L., . . . Grossman, R. I. (2009). Assessment of thalamic perfusion in patients with mild traumatic brain injury by true FISP arterial spin labelling MR imaging at 3T. *Brain Injury, 23*(7-8), 666-674.

Gentilini, M., Nichelli, P., Schoenhuber, R., Bortolotti, P., Tonelli, L., Falasca, A., & Merli, G. A. (1985). Neuropsychological evaluation of mild head injury. *Journal of Neurology, Neurosurgery & Psychiatry, 48*(2), 137-140.

Giza, C. C., & Hovda, D. A. (2014). The new neurometabolic cascade of concussion. *Neurosurgery, 75*(0 4), S24.

Giza, C. C., Kutcher, J. S., Ashwal, S., Barth, J., Getchius, T. S., Gioia, G. A., . . . Manley, G. (2013). Summary of evidence-based guideline update: Evaluation and management of concussion in sports Report of the Guideline Development Subcommittee of the American Academy of Neurology. *Neurology, 80*(24), 2250-2257.

Glosser, G., & Deser, T. (1992). A comparison of changes in macrolinguistic and microlinguistic aspects of discourse production in normal aging. *Journal of Gerontology, 47*(4), P266-P272.

Goddings, A.-L., Mills, K. L., Clasen, L. S., Giedd, J. N., Viner, R. M., & Blakemore, S.-J. (2014). The influence of puberty on subcortical brain development. *NeuroImage, 88*, 242-251.

Goldstein, B. L., & Klein, D. N. (2014). A review of selected candidate endophenotypes for depression. *Clinical Psychology Review, 34*(5), 417-427. doi:10.1016/j.cpr.2014.06.003

Goldstein, T. R., Bridge, J. A., & Brent, D. A. (2008). Sleep disturbance preceding completed suicide in adolescents. *Journal of Consulting and Clinical Psychology, 76*(1), 84.

Green, S. L., Keightley, M. L., Lobaugh, N. J., Dawson, D. R., & Mihailidis, A. (2018). Changes in working memory performance in youth following concussion. *Brain Injury, 32*(2), 182-190.

Gronwall, D. (1989). Cumulative and persisting effects of concussion on attention and cognition. *Mild head injury*, 153-162.

Gunstad, J., & Suhr, J. A. (2001). " Expectation as etiology" versus" the good old days": Postconcussion syndrome symptom reporting in athletes, headache sufferers, and depressed individuals. *Journal of the International Neuropsychological Society, 7*(3), 323-333.

Guskiewicz, K. M., Marshall, S. W., Bailes, J., McCrea, M., Harding, H. P., Matthews, A., . . . Cantu, R. C. (2007). Recurrent concussion and risk of depression in retired professional football players. *Medicine and Science in Sports and Exercise, 39*(6), 903.

Guskiewicz, K. M., & McLeod, T. C. V. (2011). Pediatric sports-related concussion. *PM&R, 3*(4), 353-364.

Hakstian, A. R., Roed, J. C., & Lind, J. C. (1979). Two-sample T–2 procedure and the assumption of homogeneous covariance matrices. *Psychological Bulletin, 86*(6), 1255.

Halliday, M. A. K., & Hasan, R. (1976). *Cohesion in english*. London, UK: Longman.

Harvey, J. (2016). Narrative Discourse in Female Collegiate Athletes Pre-and Post-Concussion.

Heilmann, J., Miller, J. F., & Nockerts, A. (2010). Using language sample databases. *Language, Speech, and Hearing Services in Schools, 41*(1), 84-95.

Heilmann, J., Nockerts, A., & Miller, J. F. (2010). Language sampling: Does the length of the transcript matter? *Language, Speech, and Hearing Services in Schools, 41*(4), 393-404.

Heitger, M. H., Jones, R. D., Dalrymple-Alford, J. C., Frampton, C. M., Ardagh, M. W., & Anderson, T. J. (2006). Motor deficits and recovery during the first year following mild closed head injury. *Brain Injury, 20*(8), 807-824.

Hellstrom, T., Westlye, L., Sigurdardottir, S., Brunborg, C., Soberg, H., Holthe, Ø., . . . Andelic, N. (2017). Longitudinal changes in brain morphology from 4 weeks to 12 months after mild traumatic brain injury: associations with cognitive functions and clinical variables. *Brain Injury*, 1-12.

Hengartner, M. P., Kawohl, W., Haker, H., Rössler, W., & Ajdacic-Gross, V. (2016). Big Five personality traits may inform public health policy and preventive medicine: Evidence from a cross-sectional and a prospective longitudinal epidemiologic study in a Swiss community. *Journal of Psychosomatic Research, 84*, 44-51.

Hessen, E., Nestvold, K., & Anderson, V. (2007). Neuropsychological function 23 years after mild traumatic brain injury: a comparison of outcome after paediatric and adult head injuries. *Brain Injury, 21*(9), 963-979.

Hill, N. M., & Schneider, W. (2006). Brain changes in the development of expertise: Neuroanatomical and neurophysiological evidence about skill-based adaptations. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 653-682). New York, NY: Cambridge University Press.

Hintsanen, M., Puttonen, S., Smith, K., Törnroos, M., Jokela, M., Pulkki-Råback, L., . . . Raitakari, O. T. (2014). Five-factor personality traits and sleep: Evidence from two population-based cohort studies. *Health Psychology, 33*(10), 1214.

Howell, D. R., O'Brien, M. J., Beasley, M. A., Mannix, R. C., & Meehan, W. P. (2016). Initial somatic symptoms are associated with prolonged symptom duration following concussion in adolescents. *Acta Paediatrica*.

Howell, D. R., Osternig, L. R., & Chou, L.-S. (2018). Detection of Acute and Long-Term Effects of Concussion: Dual-Task Gait Balance Control Versus Computerized Neurocognitive Test. *Archives of Physical Medicine and Rehabilitation*.

Hudson, J. A., & Shapiro, L. R. (1991). From knowing to telling: The development of children's scripts, stories, and personal narratives. *Developing narrative structure*, 89-136.

Illingworth, A. J., Morelli, N. A., Scott, J. C., & Boyd, S. L. (2015). Internet-based, unproctored assessments on mobile and non-mobile devices: Usage, measurement equivalence, and outcomes. *Journal of Business and Psychology, 30*(2), 325-343.

Inglese, M., Makani, S., Johnson, G., Cohen, B. A., Silver, J. A., Gonen, O., & Grossman, R. I. (2005). Diffuse axonal injury in mild traumatic brain injury: a diffusion tensor imaging study. *Journal of neurosurgery, 103*(2), 298-303.

Iverson, G. L., Gardner, A. J., Terry, D. P., Ponsford, J. L., Sills, A. K., Broshek, D. K., & Solomon, G. S. (2017). Predictors of clinical recovery from concussion: a systematic review. *Br J Sports Med, 51*(12), 941-948.

Iverson, G. L., & Lange, R. T. (2003). Examination of" postconcussion-like" symptoms in a healthy sample. *Applied Neuropsychology, 10*(3), 137-144.

Iverson, G. L., Lange, R. T., Brooks, B. L., & Lynn Ashton Rennison, V. (2010). "Good old days" bias following mild traumatic brain injury. *The Clinical Neuropsychologist, 24*(1), 17-37.

James, S., Brumfitt, S., & Cowell, P. (2009). The influence of communication situation on self-report in people who stutter. *International Journal of Speech-Language Pathology, 11*(1), 34-44.

Kagan, J. (1964). Mediation processes and the acquisition of linguistic structure: Formal discussion. *Monographs of the Society for Research in Child Development, 29*, 169-173.

Kagan, J., Reznick, J. S., & Snidman, N. (1988). Biological bases of childhood shyness. *Science, 240*(4849), 167-171.

Karr, J. E., Areshenkoff, C. N., & Garcia-Barrera, M. A. (2014). The neuropsychological outcomes of concussion: A systematic review of meta-analyses on the cognitive sequelae of mild traumatic brain injury. *Neuropsychology, 28*(3), 321.

Keilp, J. G., Sackeim, H. A., Brodsky, B. S., Oquendo, M. A., Malone, K. M., & Mann, J. J. (2001). Neuropsychological dysfunction in depressed suicide attempters. *American Journal of Psychiatry, 158*(5), 735-741.

Kendler, K. S., & Gardner, C. O. (2014). Sex differences in the pathways to major depression: A study of opposite-sex twin pairs. *American Journal of Psychiatry, 171*(4), 426-435. doi:10.1176/appi.ajp.2013.13101375

King, K. A., Hough, M. S., Walker, M. M., Rastatter, M., & Holbert, D. (2006). Mild traumatic brain injury: Effects on naming in word retrieval and discourse. *Brain Injury, 20*(7), 725-732.

King, N., Crawford, S., Wenden, F., Moss, N., & Wade, D. (1995). The Rivermead Post Concussion Symptoms Questionnaire: a measure of symptoms commonly experienced after head injury and its reliability. *Journal of Neurology, 242*(9), 587-592.

Klee, T., & Fitzgerald, M. D. (1985). The relation between grammatical development and mean length of utterance in morphemes. *Journal of Child Language, 12*(2), 251-269.
Kolb, B., Pellis, S., & Robinson, T. E. (2004). Plasticity and functions of the orbital frontal cortex. *Brain and Cognition, 55*(1), 104-115.
Kosslyn, S. M., Cacioppo, J. T., Davidson, R. J., Hugdahl, K., Lovallo, W. R., Spiegel, D., & Rose, R. (2002). Bridging psychology and biology: the analysis of individuals in groups. *American Psychologist, 57*(5), 341.
Kotov, R., Gamez, W., Schmidt, F., & Watson, D. (2010). Linking "big" personality traits to anxiety, depressive, and substance use disorders: A meta-analysis. *Psychological Bulletin, 136*(5), 768-821. doi:10.1037/a0020327
Kovach, S. E. (2015). *Narrative discourse in male athletes pre-and post-concussion.* University of Colorado at Boulder,
Labov, W., & Waletzky, J. (2003). *Narrative analysis: Oral versions of personal experience*: University of Washington Press.
Lahey, B. B. (2009). Public health significance of neuroticism. *The American psychologist, 64*(4), 241-256. doi:10.1037/a0015309
Lange, R. T., Iverson, G. L., Brooks, B. L., & Ashton Rennison, V. L. (2010). Influence of poor effort on self-reported symptoms and neurocognitive test performance following mild traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology, 32*(9), 961-972.
Langlois, J. A., Rutland-Brown, W., & Thomas, K. E. (2005). The incidence of traumatic brain injury among children in the United States: Differences by race. *The Journal of head trauma rehabilitation, 20*(3), 229-238.
Lê, K., Coelho, C. A., Mozeiko, J., Krueger, F., & Grafman, J. (2011). Measuring goodness of story narratives: Implications for traumatic brain injury. *Aphasiology, 25*(6-7), 748-760.
Lee, L. L. (1974). *Developmental sentence analysis: A grammatical assessment procedure for speech and language clinicians*. Evanston, IL: Northwestern University Press.
Leininger, B. E., Gramling, S. E., Farrell, A. D., Kreutzer, J. S., & Peck, E. A. (1990). Neuropsychological deficits in symptomatic minor head injury patients after concussion and mild concussion. *Journal of Neurology, Neurosurgery & Psychiatry, 53*(4), 293-296.
Leon-Carrion, J., Martin-Rodriguez, J. F., Damas-Lopez, J., Barroso y Martin, J. M., & Dominguez-Morales, M. R. (2009). Delta–alpha ratio correlates with level of recovery after neurorehabilitation in patients with acquired brain injury. *Clinical Neurophysiology, 120*(6), 1039-1045.
Levin, H. S., Hanten, G., Zhang, L., Swank, P. R., & Hunter, J. (2004). Selective impairment of inhibition after TBI in children. *Journal of Clinical and Experimental Neuropsychology, 26*(5), 589-597.
Lewandowski, L., Rieger, B., Smyth, J., Perry, L., & Gathje, R. (2009). Measuring post-concussion symptoms in adolescents: feasibility of ecological momentary assessment. *Archives of Clinical Neuropsychology, 24*(8), 791-796.
Lieberman, S. A., Oberoi, A. L., Gilkison, C. R., Masel, B. E., & Urban, R. J. (2001). Prevalence of neuroendocrine dysfunction in patients recovering from traumatic

brain injury. *The Journal of Clinical Endocrinology & Metabolism, 86*(6), 2752-2756.
Liles, B. Z., & Coelho, C. A. (1998). Cohesion Analysis. In L. R. Cherney, C. A. Coelho, & B. B. Shadden (Eds.), *Analyzing discourse in communicatively impaired adults* (pp. 65-83). Gaithersburg, MD: Aspen Publishers.
Lloyd, J., Wilson, M. L., Tenovuo, O., & Saarijärvi, S. (2015). Outcomes from mild and moderate traumatic brain injuries among children and adolescents: A systematic review of studies from 2008–2013. *Brain Injury, 29*(5), 539-549.
Long, C., Childs, A., Ellois, V., Smith, J., Bertisch, H., Lui, Y., & Rath, J. F. (2016). Gender Differences in Neuropsychological Functioning Following Mild Traumatic Brain Injury: Implications for Assessment and Rehabilitation. *Archives of Physical Medicine and Rehabilitation, 97*(10), e94.
Luna, B., Paulsen, D. J., Padmanabhan, A., & Geier, C. (2013). The teenage brain cognitive control and motivation. *Current Directions in Psychological Science, 22*(2), 94-100.
Lund, N. J., & Duchan, J. F. (1993). *Assessing Children's Language in Naturalistic Contexts* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.
MacFlynn, G., Montgomery, E., Fenton, G., & Rutherford, W. (1984). Measurement of reaction time following minor head injury. *Journal of Neurology, Neurosurgery & Psychiatry, 47*(12), 1326-1331.
MacWhinney, B. (2000). The CHILDES project: Tools for analyzing talk: Volume I: Transcription format and programs, volume II: The database. In: MIT Press.
Marini, A., Galetto, V., Zampieri, E., Vorano, L., Zettin, M., & Carlomagno, S. (2011). Narrative language in traumatic brain injury. *Neuropsychologia, 49*(10), 2904-2910. doi:10.1016/j.neuropsychologia.2011.06.017
Mathias, J., Dennington, V., Bowden, S., & Bigler, E. (2013). Community versus orthopaedic controls in traumatic brain injury research: How comparable are they? *Brain Injury, 27*(7-8), 887-895.
Max, J. E., Pardo, D., Hanten, G., Schachar, R. J., Saunders, A. E., Ewing-Cobbs, L., . . . Bigler, E. D. (2013). Psychiatric disorders in children and adolescents six-to-twelve months after mild traumatic brain injury. *The Journal of neuropsychiatry and clinical neurosciences, 25*(4), 272-282.
Mayr, U., Awh, E., & Laurey, P. (2003). Conflict adaptation effects in the absence of executive control. *Nature Neuroscience, 6*(5), 450-452.
McAllister, T. (2011). Neurobiological consequences of traumatic brain injury. *Dialogues in Clinical Neuroscience, 13*(3), 287.
McCauley, S. R., Wilde, E. A., Barnes, A., Hanten, G., Hunter, J. V., Levin, H. S., & Smith, D. H. (2014). Patterns of early emotional and neuropsychological sequelae after mild traumatic brain injury. *Journal of neurotrauma, 31*(10), 914-925.
McCrea, M. (2001). Standardized mental status testing on the sideline after sport-related concussion. *J Athl Train, 36*(3), 274.
McCrea, M., Kelly, J. P., Randolph, C., Kluge, J., Bartolic, E., Finn, G., & Baxter, B. (1998). Standardized assessment of concussion (SAC): on-site mental status evaluation of the athlete. *The Journal of head trauma rehabilitation, 13*(2), 27-35.
McCrea, M., Meier, T., Huber, D., Ptito, A., Bigler, E., Debert, C. T., . . . Wall, R. (2017). Role of advanced neuroimaging, fluid biomarkers and genetic testing in

the assessment of sport-related concussion: a systematic review. *Br J Sports Med*, bjsports-2016-097447.

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, B., Dvořák, J., Echemendia, R. J., . . . Raftery, M. (2013a). Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *British Journal of Sports Medicine, 47*(5), 250-258.

McCrory, P., Meeuwisse, W. H., Aubry, M., Cantu, R. C., Dvořák, J., Echemendia, R. J., . . . Raftery, M. (2013b). Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport, Zurich, November 2012. *J Athl Train, 48*(4), 554-575.

McInnes, K., Friesen, C. L., MacKenzie, D. E., Westwood, D. A., & Boe, S. G. (2017). Mild Traumatic Brain Injury (mTBI) and chronic cognitive impairment: A scoping review. *PLoS ONE, 12*(4), e0174847.

Meier, T. B., Bellgowan, P. S., Singh, R., Kuplicki, R., Polanski, D. W., & Mayer, A. R. (2015). Recovery of cerebral blood flow following sports-related concussion. *JAMA neurology, 72*(5), 530-538.

Menza, M. A., Robertson-Hoffman, D. E., & Bonapace, A. S. (1993). Parkinson's disease and anxiety: comorbidity with depression. *Biological Psychiatry, 34*(7), 465-470.

Miller, J. F., & Chapman, R. S. (1981). The relation between age and mean length of utterance in morphemes. *Journal of Speech, Language, and Hearing Research, 24*(2), 154-161.

Miller, J. F., & Leadholm, B. (1992). *Language Sample Analysis Guide: The Wisconsin Guide for the Identification and Description of Language Impairment in Children*: Wisconsin Department of Public Instruction.

Moffitt, T. E., Poulton, R., & Caspi, A. (2013). Lifelong impact of early self-control. *American Scientist, 101*(5), 352-359.

Moore, R. D., Lepine, J., & Ellemberg, D. (2017). The independent influence of concussive and sub-concussive impacts on soccer players' neurophysiological and neuropsychological function. *International Journal of Psychophysiology, 112*, 22-30.

Mozeiko, J., Le, K., Coelho, C. A., Krueger, F., & Grafman, J. (2011). The relationship of story grammar and executive function following TBI. *Aphasiology, 25*(6-7), 826-835.

National Research Council Committee on Sports-Related Concussions in Youth. (2014). *Sports-related concussions in youth: improving the science, changing the culture*: National Academies Press.

Ng, L. C., Ahishakiye, N., Miller, D. E., & Meyerowitz, B. E. (2015). Narrative characteristics of genocide testimonies predict posttraumatic stress disorder symptoms years later. *Psychological Trauma: Theory, Research, Practice, and Policy, 7*(3), 303.

Nielsen, A., Mortensen, P., O'Callaghan, E., Mors, O., & Ewald, H. (2002). Is head injury a risk factor for schizophrenia? *Schizophrenia Research, 55*(1), 93-98.

Nishiguchi, S., Yamada, M., Fukutani, N., Adachi, D., Tashiro, Y., Hotta, T., . . . Tsuboyama, T. (2015). Spot the Difference for Cognitive Decline: A quick memory and attention test for screening cognitive decline. *Journal of Clinical Gerontology and Geriatrics, 6*(1), 9-14.

Norbury, C. F., & Bishop, D. V. (2003). Narrative skills of children with communication impairments. *International Journal of Language & Communication Disorders, 38*(3), 287-313.

Nuti, A., Ceravolo, R., Piccinni, A., Dell'Agnello, G., Bellini, G., Gambaccini, G., . . . Bonuccelli, U. (2004). Psychiatric comorbidity in a population of Parkinson's disease patients. *European Journal of Neurology, 11*(5), 315-320.

Ormel, J., Jeronimus, B. F., Kotov, R., Riese, H., Bos, E. H., Hankin, B., . . . Oldehinkel, A. J. (2013). Neuroticism and common mental disorders: Meaning and utility of a complex relationship. *Clinical Psychology Review, 33*(5), 686-697. doi:10.1016/j.cpr.2013.04.003

Ozen, L. J., & Fernandes, M. A. (2011). Effects of "diagnosis threat" on cognitive and affective functioning long after mild head injury. *Journal of the International Neuropsychological Society, 17*(02), 219-229.

Panayiotou, A., Jackson, M., & Crowe, S. F. (2010). A meta-analytic review of the emotional symptoms associated with mild traumatic brain injury. *Journal of Clinical and Experimental Neuropsychology, 32*(5), 463-473.

Pasternak, O., Koerte, I. K., Bouix, S., Fredman, E., Sasaki, T., Mayinger, M., . . . Forwell, L. A. (2014). Hockey Concussion Education Project, Part 2. Microstructural white matter alterations in acutely concussed ice hockey players: a longitudinal free-water MRI study: Clinical article. *Journal of neurosurgery, 120*(4), 873-881.

Pedersen, S. S., & Denollet, J. (2006). Is Type D personality here to stay? Emerging evidence across cardiovascular disease patient groups. *Current Cardiology Reviews, 2*(3), 205-213.

Pennebaker, J. W., Mehl, M. R., & Niederhoffer, K. G. (2003). Psychological aspects of natural language use: Our words, our selves. *Annual Review of Psychology, 54*(1), 547-577.

Peper, J. S., & Dahl, R. E. (2013). The teenage brain surging hormones—brain-behavior interactions during puberty. *Current Directions in Psychological Science, 22*(2), 134-139.

Petley, L., Bardouille, T., Chiasson, D., Froese, P., Patterson, S., Newman, A., . . . Beyea, S. (2018). Attentional dysfunction and recovery in concussion: effects on the P300m and contingent magnetic variation. *Brain Injury*, 1-10.

Phillips, A. C., Batty, G. D., Weiss, A., Deary, I., Gale, C. R., Thomas, G. N., & Carroll, D. (2010). Neuroticism, cognitive ability, and the metabolic syndrome: The Vietnam Experience Study. *Journal of Psychosomatic Research, 69*(2), 193-201.

Ponsford, J., Cameron, P., Fitzgerald, M., Grant, M., Mikocka-Walus, A., & Schönberger, M. (2012). Predictors of postconcussive symptoms 3 months after mild traumatic brain injury. *Neuropsychology, 26*(3), 304.

Ponsford, J., Willmott, C., Rothwell, A., Cameron, P., Ayton, G., Nelms, R., . . . Ng, K. (1999). Cognitive and behavioral outcome following mild traumatic head injury in children. *The Journal of head trauma rehabilitation, 14*(4), 360-372.

Ponsford, J., Willmott, C., Rothwell, A., Cameron, P., Ayton, G., Nelms, R., . . . Ng, K. (2001). Impact of early intervention on outcome after mild traumatic brain injury in children. *Pediatrics, 108*(6), 1297-1303.

Powell, K. (2006). Neurodevelopment: how does the teenage brain work? *Nature, 442*(7105), 865-867.
Preece, A. (1987). The range of narrative forms conversationally produced by young children. *Journal of Child Language, 14*(02), 353-373.
Putukian, M., Aubry, M., & McCrory, P. (2009). Return to play after sports concussion in elite and non-elite athletes? *British Journal of Sports Medicine, 43*(Suppl 1), i28-i31.
Rabinowitz, A. R., & Levin, H. S. (2014). Cognitive sequelae of traumatic brain injury. *Psychiatric Clinics of North America, 37*(1), 1-11.
Ramsden, S., Richardson, F. M., Josse, G., Thomas, M. S., Ellis, C., Shakeshaft, C., . . . Price, C. J. (2011). Verbal and non-verbal intelligence changes in the teenage brain. *Nature, 479*(7371), 113-116.
Ratner, N. B., & MacWhinney, B. (2016). *Your laptop to the rescue: Using the Child Language Data Exchange System archive and CLAN utilities to improve child language sample analysis.* Paper presented at the Seminars in speech and language.
Roberts, B. W., & DelVecchio, W. F. (2000). The rank-order consistency of personality traits from childhood to old age: a quantitative review of longitudinal studies. *Psychological Bulletin, 126*(1), 3.
Roberts, B. W., Kuncel, N. R., Shiner, R., Caspi, A., & Goldberg, L. R. (2007). The power of personality: The comparative validity of personality traits, socioeconomic status, and cognitive ability for predicting important life outcomes. *Perspectives on Psychological Science, 2*, 313-345.
Robles, T. F., Glaser, R., & Kiecolt-Glaser, J. K. (2005). Out of balance a new look at chronic stress, depression, and immunity. *Current Directions in Psychological Science, 14*(2), 111-115.
Rosenthal, R. (1994). Parametric measures of effect size. *The handbook of research synthesis*, 231-244.
Roth, F. P., & Spekman, N. J. (1986). Narrative discourse: Spontaneously generated stories of learning-disabled and normally achieving students. *Journal of Speech and Hearing Disorders, 51*(1), 8-23.
Rothschild, L., Maerlender, A., Caze, T., & Higgins, K. (2016). Mood and Anxiety in Concussion and Mild Traumatic Brain Injury (mTBI): A Systematic Review. *Critical Reviews™ in Physical and Rehabilitation Medicine*.
Rude, S., Gortner, E.-M., & Pennebaker, J. (2004). Language use of depressed and depression-vulnerable college students. *Cognition & Emotion, 18*(8), 1121-1133.
Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1997). The psychological construct of word fluency. *Brain and Language, 57*(3), 394-405.
Russo, J., Katon, W., Lin, E., Von Korff, M., Bush, T., Simon, G., & Walker, E. (1997). Neuroticism and extraversion as predictors of health outcomes in depressed primary care patients. *Psychosomatics, 38*(4), 339-348.
Sagarkar, S., Bhamburkar, T., Shelkar, G., Choudhary, A., Kokare, D. M., & Sakharkar, A. J. (2017). Minimal traumatic brain injury causes persistent changes in DNA methylation at BDNF gene promoters in rat amygdala: A possible role in anxiety-like behaviors. *Neurobiology of Disease, 106*, 101-109.

Sanger, D. D., Hux, K., & Belau, D. (1997). Oral language skills of female juvenile delinquents. *American Journal of Speech-Language Pathology, 6*(1), 70-76.
Satterthwaite, F. E. (1946). An approximate distribution of estimates of variance components. *Biometrics Bulletin, 2*(6), 110-114.
Schmidt, J. D., Rizzone, K., Hoffman, N. L., Weber, M. L., Jones, C., Bazarian, J., . . . McAllister, T. W. (2018). Age at First Concussion Influences Number of Subsequent Concussions. *Pediatric neurology*.
Schwarz, A. (2013). The selling of attention deficit disorder. *New York Times, 14*.
Seignourel, P. J., Kunik, M. E., Snow, L., Wilson, N., & Stanley, M. (2008). Anxiety in dementia: a critical review. *Clinical Psychology Review, 28*(7), 1071-1082.
Shackman, A. J., Fox, A. S., Oler, J. A., Shelton, S. E., Davidson, R. J., & Kalin, N. H. (2013). Neural mechanisms underlying heterogeneity in the presentation of anxious temperament. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 6145-6150. doi:1214364110 [pii]
10.1073/pnas.1214364110
Shackman, A. J., Tromp, D. P., Stockbridge, M. D., Kaplan, C. M., Tillman, R. M., & Fox, A. S. (2016). Dispositional negativity: An integrative psychological and neurobiological perspective. *Psychological Bulletin, 142*(12), 1275.
Shaffer, D., Bijur, P., Oliver, F., & Rutter, M. L. (1980). Head injury and later reading disability. *Journal of the American Academy of Child Psychiatry, 19*(4), 592-610.
Shahar, G., Henrich, C. C., Reiner, I. C., & Little, T. D. (2003). Development and initial validation of the brief adolescent life event scale (BALES). *Anxiety, Stress & Coping, 16*(1), 119-128.
Sheehan, D. V., Lecrubier, Y., Sheehan, K. H., Amorim, P., Janavs, J., Weiller, E., . . . Dunbar, G. C. (1998). The Mini-International Neuropsychiatric Interview (MINI): The development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. *Journal of Clinical Psychiatry, 59*, 22-33.
Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annu. Rev. Clin. Psychol., 4*, 1-32.
Shiner, R. L., & Masten, A. S. (2012). Childhood personality as a harbinger of competence and resilience in adulthood. *Development and Psychopathology, 24*(2), 507-528.
Silver, J. M., McAllister, T. W., & Yudofsky, S. C. (2011). *Textbook of traumatic brain injury*: American Psychiatric Pub.
Silverberg, N. D., Gardner, A. J., Brubacher, J. R., Panenka, W. J., Li, J. J., & Iverson, G. L. (2015). Systematic review of multivariable prognostic models for mild traumatic brain injury. *Journal of neurotrauma, 32*(8), 517-526.
Silverberg, N. D., & Iverson, G. L. (2013). Is rest after concussion "the best medicine?": recommendations for activity resumption following concussion in athletes, civilians, and military service members. *The Journal of head trauma rehabilitation, 28*(4), 250-259.
Sizonenko, P., & Aubert, M. (1986). Neuroendocrine changes characteristic of sexual maturation. *Journal of neural transmission. Supplementum, 21*, 159-181.
Skehan, P., & Foster, P. (1999). The influence of task structure and processing conditions on narrative retellings. *Language learning, 49*(1), 93-120.

Slomine, B. S., Gerring, J. P., Grados, M. A., Vasa, R., Brady, K. D., Christensen, J. R., & Denckla, M. B. (2002). Performance on measures of executive function following pediatric traumatic brain injury. *Brain Injury, 16*(9), 759-772.

Smith, T. W., & MacKenzie, J. (2006). Personality and risk of physical illness. *Annu. Rev. Clin. Psychol., 2*, 435-467.

Snow, P. C., & Powell, M. B. (2004). Developmental language disorders and adolescent risk: A public-health advocacy role for speech pathologists? *International Journal of Speech-Language Pathology, 6*(4), 221-229.

Snow, P. C., & Powell, M. B. (2005). What's the story? An exploration of narrative language abilities in male juvenile offenders. *Psychology, Crime & Law, 11*(3), 239-253.

Snow, P. C., & Powell, M. B. (2012). Youth (in) justice: Oral language competence in early life and risk for engagement in antisocial behaviour in adolescence. *Trends & Issues in Crime and Criminal Justice, 435*.

Soto, C. J., & John, O. P. (2016). The Next Big Five Inventory (BFI-2): Developing and Assessing a Hierarchical Model With 15 Facets to Enhance Bandwidth, Fidelity, and Predictive Power.

Soto, C. J., & John, O. P. (2017). The next Big Five Inventory (BFI-2): Developing and assessing a hierarchical model with 15 facets to enhance bandwidth, fidelity, and predictive power. *Journal of Personality and Social Psychology, 113*(1), 117.

Spencer, R. J., Drag, L. L., Walker, S. J., & Bieliauskas, L. A. (2010). Self-reported cognitive symptoms following mild traumatic brain injury are poorly associated with neuropsychological performance in OIF/OEF veterans. *J Rehabil Res Dev, 47*(6), 521-530.

Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, G. A. (1983). *Manual for the State-Trait Anxiety Inventory.* Palo Alto, CA: Consulting Psychologists Press.

Stark, J. A. (2010). Content analysis of the fairy tale Cinderella–A longitudinal single-case study of narrative production:"From rags to riches". *Aphasiology, 24*(6-8), 709-724.

Stazyk, K., DeMatteo, C., Moll, S., & Missiuna, C. (2017). Depression in youth recovering from concussion: correlates and predictors. *Brain Injury*, 1-8.

Stein, D. G., & Hoffman, S. W. (2003). Concepts of CNS plasticity in the context of brain damage and repair. *The Journal of head trauma rehabilitation, 18*(4), 317-341.

Stephens, J. A., Salorio, C. F., Barber, A. D., Risen, S. R., Mostofsky, S. H., & Suskauer, S. J. (2017). Preliminary findings of altered functional connectivity of the default mode network linked to functional outcomes one year after pediatric traumatic brain injury. *Developmental Neurorehabilitation*, 1-8.

Stillman, A., Madigan, N., & Alexander, M. (2016). Factors Associated with Prolonged, Subjective Post-Concussive Symptoms (P3. 325). *Neurology, 86*(16 Supplement), P3. 325.

Stockbridge, M. D., Doran, A., King, K., & Newman, R. S. (2018). The effects of concussion on rapid picture naming in children. *Brain Injury, 32*(4), 506-514.

Stockbridge, M. D., & Newman, R. S. (2017). Translating neurodevelopmental findings into predicted outcomes and treatment recommendations for language skills in

children and young adults with brain injury. *Translational Issues in Psychological Science, 3*(1), 104.
Stockbridge, M. D., Newman, R. S., Zukowski, A., Slawson, K. K., Doran, A., & Bernstein-Ratner, N. (under review). Language Phenotyping in Young Children with Concussion *Journal of Head Trauma Rehabilitation*.
Stoet, G. (2016). PsyToolkit: A novel web-based method for running online questionnaires and reaction-time experiments. *Teaching of Psychology*.
Strain, J., Didehbani, N., Cullum, C. M., Mansinghani, S., Conover, H., Kraut, M. A., . . . Womack, K. B. (2013). Depressive symptoms and white matter dysfunction in retired NFL players with concussion history. *Neurology, 81*(1), 25-32.
Strekas, A., Ratner, N. B., Berl, M., & Gaillard, W. D. (2013). Narrative abilities of children with epilepsy. *International Journal of Language & Communication Disorders, 48*(2), 207-219.
Suhr, J. A., & Gunstad, J. (2002). "Diagnosis threat": The effect of negative expectations on cognitive performance in head injury. *Journal of Clinical and Experimental Neuropsychology, 24*(4), 448-457.
Suls, J., & Bunde, J. (2005). Anger, anxiety, and depression as risk factors for cardiovascular disease: the problems and implications of overlapping affective dispositions. *Psychological Bulletin, 131*(2), 260.
Sussman, D., da Costa, L., Chakravarty, M. M., Pang, E. W., Taylor, M. J., & Dunkley, B. T. (2017). Concussion induces focal and widespread neuromorphological changes. *Neuroscience Letters*.
Taylor, S. J., Barker, L. A., Heavey, L., & McHale, S. (2013). The typical developmental trajectory of social and executive functions in late adolescence and early adulthood. *Developmental Psychology, 49*(7), 1253.
Teasdale, T. W., & Engberg, A. W. (2001). Suicide after traumatic brain injury: a population study. *Journal of Neurology, Neurosurgery & Psychiatry, 71*(4), 436-440.
Templer, K. J., & Lange, S. R. (2008). Internet testing: Equivalence between proctored lab and unproctored field conditions. *Computers in Human Behavior, 24*(3), 1216-1228.
Thompson, E. C., Krizman, J., White-Schwoch, T., Nicol, T., LaBella, C. R., & Kraus, N. (2018). Difficulty hearing in noise: a sequela of concussion in children. *Brain Injury*, 1-7.
Thordardottir, E., & Weismer, S. E. (2001). High‐frequency verbs and verb diversity in the spontaneous speech of school‐age children with specific language impairment. *International Journal of Language & Communication Disorders, 36*(2), 221-244.
Tlustos, S. J., Peter Chiu, C., Walz, N. C., & Wade, S. L. (2015). Neural substrates of inhibitory and emotional processing in adolescents with traumatic brain injury. *Journal of pediatric rehabilitation medicine, 8*(4), 321-333.
Tofighi, D., & MacKinnon, D. P. (2011). RMediation: An R package for mediation analysis confidence intervals. *Behavior Research Methods, 43*(3), 692-700.
Tromp, E., & Mulder, T. (1991). Slowness of information processing after traumatic head injury. *Journal of Clinical and Experimental Neuropsychology, 13*(6), 821-830.

Tucker, F. M., & Hanlon, R. E. (1998). Effects of mild traumatic brain injury on narrative discourse production. *Brain Injury, 12*(9), 783-792.

Turgeon, C., Champoux, F., Lepore, F., Leclerc, S., & Ellemberg, D. (2011). Auditory processing after sport-related concussions. *Ear and Hearing, 32*(5), 667-670.

Turner, S., Langdon, J., Shaver, G., Graham, V., Naugle, K., & Buckley, T. (2017). Comparison of psychological response between concussion and musculoskeletal injury in collegiate athletes. *Sport, exercise, and performance psychology, 6*(3), 277.

Uliaszek, A. A., Hauner, K. K., Zinbarg, R. E., Craske, M. G., Mineka, S., Griffith, J. W., & Rose, R. D. (2009). An examination of content overlap and disorder-specific predictions in the associations of neuroticism with anxiety and depression. *Journal of Research in Personality, 43*(5), 785-794.

Underwood, B. J. (1975). Individual differences as a crucible in theory construction. *American Psychologist, 30*, 128-134.

Vaidyanathan, U., Patrick, C. J., & Cuthbert, B. N. (2009). Linking dimensional models of internalizing psychopathology to neurobiological systems: Affect-modulated startle as an indicator of fear and distress disorders and affiliated traits. *Psychological Bulletin, 135*(6), 909-942. doi:10.1037/a0017222

van Donkelaar, P., Langan, J., Rodriguez, E., Drew, A., Halterman, C., Osternig, L., & Chou, L.-S. (2005). Attentional deficits in concussion. *Brain Injury, 19*(12), 1031-1039.

Vander Werff, K. R., & Rieger, B. (2017). Brainstem evoked potential indices of subcortical auditory processing after mild traumatic brain injury. *Ear and Hearing, 38*(4), e200-e214.

Vargas, G., Rabinowitz, A., Meyer, J., & Arnett, P. A. (2015). Predictors and prevalence of postconcussion depression symptoms in collegiate athletes. *J Athl Train, 50*(3), 250-255.

Wäljas, M., Lange, R. T., Hakulinen, U., Huhtala, H., Dastidar, P., Hartikainen, K., . . . Iverson, G. L. (2014). Biopsychosocial outcome after uncomplicated mild traumatic brain injury. *Journal of neurotrauma, 31*(1), 108-124.

Walsh, A., & Ellis, L. (2007). Psychosocial theories: Individual traits and criminal behavior. In A. Walsh & L. Ellis (Eds.), *Criminology: An interdisciplinary approach.* (pp. 169-198). Thousand Oaks, CA: Sage.

Wang, Y., West, J. D., Bailey, J. N., Westfall, D. R., Xiao, H., Arnold, T. W., . . . McDonald, B. C. (2015). Decreased cerebral blood flow in chronic pediatric mild TBI: an MRI perfusion study. *Developmental Neuropsychology, 40*(1), 40-44.

Warriner, E. M., & Velikonja, D. (2006). Psychiatric disturbances after traumatic brain injury: Neurobehavioral and personality changes. *Current Psychiatry Reports, 8*(1), 73-80.

Watson, D., & Clark, L. A. (1984). Negative affectivity: The disposition to experience aversive emotional states. *Psychological Bulletin, 96*(3), 465-490.

Watson, D., Clark, L. A., McIntyre, C. W., & Hamaker, S. (1992). Affect, personality, and social activity. *Journal of Personality and Social Psychology, 63*(6), 1011-1025.

Watson, D., & Naragon-Gainey, K. (2014). Personality, emotions, and the emotional disorders. *Clinical Psychological Science, 2*, 422-442.

Weston, S. J., Hill, P. L., & Jackson, J. J. (2014). Personality traits predict the onset of disease. *Social Psychological and Personality Science, 26*. doi:10.1177/1948550614553248

Whelan, B.-M., & Murdoch, B. E. (2006). The impact of mild traumatic brain injury (mTBI) on language function: More than meets the eye? *Brain and Language, 99*(1-2), 183-184.

Whelan, B.-M., Murdoch, B. E., & Bellamy, N. (2007). Delineating communication impairments associated with mild traumatic brain injury: A case report. *The Journal of head trauma rehabilitation, 22*(3), 192-197.

Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R., & Roper, B. (2016). Verbal fluency: language or executive function measure? *Applied Neuropsychology: Adult, 23*(1), 29-34.

Wolfson, A. R., & Carskadon, M. A. (1998). Sleep schedules and daytime functioning in adolescents. *Child Development, 69*(4), 875-887.

Wong, M. M., Brower, K. J., & Zucker, R. A. (2011). Sleep problems, suicidal ideation, and self-harm behaviors in adolescence. *Journal of Psychiatric Research, 45*(4), 505-511.

Wong, M. N., Murdoch, B., & Whelan, B.-M. (2010). Language disorders subsequent to mild traumatic brain injury (MTBI): Evidence from four cases. *Aphasiology, 24*(10), 1155-1169.

Wrightson, P., McGinn, V., & Gronwall, D. (1995). Mild head injury in preschool children: Evidence that it can be associated with a persisting cognitive defect. *Journal of Neurology, Neurosurgery & Psychiatry, 59*(4), 375-380.

Xiong, K., Zhu, Y., Zhang, Y., Yin, Z., Zhang, J., Qiu, M., & Zhang, W. (2014). White matter integrity and cognition in mild traumatic brain injury following motor vehicle accident. *Brain Research, 1591*, 86-92.

Yan, H., Sun, C., Wang, X., & Bai, L. (2017). *Deteriorating neural connectivity of the hippocampal episodic memory network in mTBI patients: A cohort study.* Paper presented at the Neural Networks (IJCNN), 2017 International Joint Conference on.

Yeates, K. O., Taylor, H. G., Drotar, D., Wade, S. L., Klein, S., Stancin, T., & Schatschneider, C. (1997). Preinjury family environment as a determinant of recovery from traumatic brain injuries in school-age children. *Journal of the International Neuropsychological Society, 3*(06), 617-630.

Ylvisaker, M. (1986). Language and communication disorders following pediatric head injury. *The Journal of head trauma rehabilitation, 1*(4), 48-56.

Zhao, J., Huynh, J., Hylin, M. J., O'Malley, J. J., Perez, A., Moore, A. N., & Dash, P. K. (2017). Mild traumatic brain injury reduces spine density of projection neurons in the medial prefrontal cortex and impairs extinction of contextual fear memory. *Journal of neurotrauma*.

Zimet, G. D., Powell, S. S., Farley, G. K., Werkman, S., & Berkoff, K. A. (1990). Psychometric characteristics of the multidimensional scale of perceived social support. *Journal of Personality Assessment, 55*(3-4), 610-617.