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Assessing Classroom Readiness Post-Concussion in College Student-Athletes: Comparing the ImPACT to Standardized Cognitive Assessments

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Abstract

The ImPACT (Immediate Post-Concussion Assessment and Cognitive Test) is a commonly used computerized neurocognitive test for concussion management in college student-athletes (Lovell, 2020). This assessment is heavily relied upon by athletic trainers to make decisions regarding timing of return-to-play and return-to-classroom for college student-athletes. Predicting when students are ready to return-to-learn is imperative for their success in the classroom. However, the current evidence shows that the validity and reliability of the ImPACT may be lacking. As of ten years ago, a single study had yet to demonstrate the validity of the ImPACT by comparing the scores to traditional neurocognitive testing (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). Traumatic Brain Injuries (TBIs) are within the scope of practice for speech-language pathologists (SLPs) and they utilize traditional cognitive test batteries to assess their clients (Traumatic Brain Injury in Adults, n.d.). Because this area of research is still in its infancy, this study compared ImPACT scores to standardized cognitive assessments used by SLPs for assessing cognition post-concussion. The topic was further explored by gathering qualitative data post-concussion via surveys. The information gathered suggests that the ImPACT should be interpreted cautiously as some cognitive deficits may go undetected. In addition, among the traditional assessments of cognition employed in this study, clock drawing and phonemic verbal fluency tasks appear to be the most sensitive measures for cognitive evaluation of mild traumatic brain injuries.

Introduction

Concussions have been a growing area of scientific interest in recent years due to the lack of complete knowledge of their effects, in addition to the commonality of their occurrence in student-athletes. This type of trauma can have multiple and varying consequences including disturbances in the classroom which can be especially problematic for college student-athletes who are attempting to balance their athletic and academic schedules. Currently, computerized testing is employed by athletic trainers as one of the primary ways of making return-to-learn decisions. However, there is evidence that computerized testing may be inadequate in this area. While student athletes are frequently supported by athletic trainers as they gradually return to play post-injury, there are often no specific professionals available to guide students in their return to classroom. Speech-language pathologists are trained to assess and treat traumatic brain injuries as part of a multidisciplinary team. They utilize traditional cognitive assessments and are equipped to assist student athletes in their transition back to the classroom. Despite this, they are rarely called on to be a part of a concussion management team (Ketcham et al., 2017). In order to explore this topic and assess whether the ImPACT can predict student's readiness to return to classroom post-concussion, standardized cognitive assessments commonly used by SLPs will be compared to ImPACT scores.

Concussion

A concussion is a mild traumatic brain injury (mTBI) which is the product of outside trauma often without accompanying outside visual evidence (Ragnarsson, 2018). Trauma can include, but is not limited to, an assault to the head or body which accelerates the head and brain to move in such a way that the brain bounces, twists, and/or stretches. This can harm brain cells as well as change the brain chemically (What is a Concussion?, n.d.). With an estimated 1.6 to 3.8 million concussions occurring annually in the United States, there has been a growing

concern and interest around concussions, especially sports-related concussions (SRC), in recent years (Fenden, 2016).

Concussions can be diagnosed by a variety of factors. These factors include losing consciousness for up to 30 minutes, amnesia for up to 24 hours after injury, or a difference in mental state post-injury (I.e. disorientation, confusion, etc.) (Ragnarsson, 2018). If the injury persists past these barriers (ex. Losing consciousness for 60 minutes, amnesia past 24 hours, etc.) it is not ruled as a concussion or mTBI. Instead, the injury is diagnosed as a traumatic brain injury, contusion, brain hemorrhage, etc. (Ragnarsson, 2018). Immediate symptoms of a concussion commonly also include headaches, dizziness, and cognitive defects (Constantin et al., 2018). Individuals may lose consciousness, but is not necessary for a concussion diagnosis (What is a Concussion?, n.d.). Usually a rapid and complete recovery happens within a few days or weeks of injury, although some individuals may require more time (Nelson, Janecek, & McCrea, 2013).

Beyond the diagnosis and early injury symptomology, concussions can have longer lasting cognitive effects. For example, after becoming concussed there is the possibility for second impact syndrome, post-concussion syndrome, and chronic traumatic encephalopathy (Fenden, 2016). There is a growing concern for multiple SRCs as they have shown to have long term consequences including early onset of dementia, depression, mild cognitive impairment, and chronic neurodegeneration. (Nelson, Janecek, & McCrea, 2014, Constantin et al., 2018). In addition, despite some conflicting studies, the current research shows that athletes with multiple concussions demonstrate lower levels of cognitive function compared to non-concussed athletes (Collie, McCrory, & Makdissi, 2006). Because of the possibility for long-term consequences, it

is imperative that health professionals have the best assessment tools possible in order to assess and properly treat concussed student-athletes.

SRC Effects on College Student-Athletes

In addition to the long-term effects of concussions, the short-term symptoms of an mTBI can be problematic for anyone, but especially for college student-athletes who are battling pressures to perform both in the classroom and on the field. SRCs can affect student athletes in multiple and varying ways in the classroom. Physical and behavioral concussion symptoms can initially cause issues when returning-to-learn, but cognitive symptoms can be longer lasting and harder to detect, making them especially detrimental to student's performance in the classroom. Additionally, college-student athletes are often juggling classes, practice, and sporting events. Therefore, they may have less time to spend on their studies than their peers. Thus, it is imperative that they be at the top of their game cognitively in addition to physically and behaviorally.

There are multiple ways that physical and behavioral symptoms can affect students' learning in the classroom. Physically, students can experience headaches, nausea, vomiting, visual disturbance, dizziness, balance issues, light/noise sensitivity, fatigue, and insomnia (Fenden, 2016). Headaches can distract from concentration in the classroom and insomnia can negatively impact memory (Fenden, 2016; Hall, 2017). Physical symptoms may also cause students athletes to miss class time. Parsons, Bay, and Valovich-McLeod (2013) found that almost 30% of the high schoolers in their study missed school due to a concussion. Behaviorally students have also reported that their emotions are increased, feeling sad, depressed, anxious, or irritable (Fenden, 2016). These emotions could understandably impact students' motivation to

succeed in the classroom. Thus, both physical and behavioral symptoms can affect students' academic success.

In addition to physical and behavioral symptoms, there are multiple concerning cognitive effects of SRCs. These effects can include memory problems, difficulty concentrating, mental fogginess, feeling "slow," and feeling confused (Fenden, 2016). One study found that teenagers who had been concussed performed significantly lower on working memory tasks (Keightley et al., 2014). Another found that those who had sustained a concussion had issues with auditory processing tasks (Białuńska & Salvatore, 2017). In addition, physical symptoms have been found to be linked to cognitive symptoms, with headaches being significantly related to cognitive impairment, memory, and processing speed challenges. Furthermore, insomnia is correlated with memory issues (Guty and Arnett, 2018). All these cognitive symptoms can negatively impact students in the classroom in many ways. It may be difficult to learn new tasks, apply previously learned information, focus in the classroom, and take tests with these symptoms (Hall, 2017). Cognitive symptoms from concussion can have multiple detrimental effects on student's performance in the classroom.

In general, student-athletes' performance in the classroom can be greatly compromised by a SRC. Student-athletes often prioritize their sport and education equally or may even prioritize their sport over their education. A concussion can greatly affect their carefully balanced priorities and schedules which can cause anxiety and detriment to their overall quality of life (Ketcham et al., 2017). It can be difficult for students to catch up on their academic requirements after sustaining a SRC, especially if they are experiencing cognitive symptoms which, unlike physical symptoms, may often go unnoticed. Thus, because of academic concerns,

it is extremely important that health professional have ways of accurately assessing concussion symptoms.

Current Concussion Management Practices

Because of the challenges that concussed student-athletes may experience in the classroom and the potential for long term cognitive impairment, both of which affect quality of life, it is imperative that the best practices are in place for assessment and treatment of SRC. Assessment can be difficult due to the invisible nature of concussions. Often, evaluation is performed using a computerized assessment program. Treatment commonly includes rest and gradual return to full activities. Since there is great variance in symptoms, there is not a set treatment plan for concussions, each one must be managed individually (Constantin et al., 2018). While this protocol for assessment and treatment of concussions is considered to be best practice, research in this area is growing and there may be room for improvement.

Management of SRC at the college level starts with the athletic training staff who are the first responders to concussions. According to the National Athletic Trainers Association (NATA) and their position statement on the management of SRCs, all student-athletes should receive baseline assessment in the areas of physical, neurocognitive, and motor control. These baseline tests can then be re-administered in the case of a concussion to assess their symptoms (Broglio et al., 2014). Baseline testing can be done in a variety of ways, but most commonly it includes a self-report symptom assessment, the Balance Error Scoring System (BESS), and a computerized test for neurocognitive symptoms. The information gained from these assessments, both initially and during a re-evaluation post-concussion, can be used by the athletic training staff to determine if the student-athlete is ready to begin their gradual return to sports and school (Broglio et al., 2014).

After diagnosis of a concussion by the athletic training staff or other health professional, student-athletes are advised to have a period of rest. They are instructed to avoid physical and cognitive activity as too much of either could exacerbate concussion symptoms. Once initial symptoms (headache, nausea, etc.) have subsided, the baseline assessments should be repeated and compared to the original scores. It is common for students who no longer have concussion symptoms to demonstrate the same abilities on these tests that they did post injury. However, it should be noted that 40% of patients who do not have concussion symptoms have continued cognitive declines despite being "asymptomatic" (Broglio et al., 2014). Additionally, there is great variance on how long it takes to return to pre-injury levels of performance on the assessment. Typically, young males may recover within two weeks while females may take over 14 days. Any decline lasting longer than 30 days may cause the student to be diagnosed with post-concussive syndrome. After returning to pre-injury performance on assessments, students are given the clearance to gradually return to the classroom and physical activity. If the gradual return causes symptoms or a decline in performance, activity is ceased and restarted 24 hours later (Broglio et al., 2014).

Computerized Testing and ImPACT

For assessment of SRC in college athletes, computerized testing is heavily relied upon for a concussion diagnosis (Hall, 2017). The Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) is the most commonly used and scientifically supported computerized post-concussion assessment. It is used by over a thousand colleges/universities to assess cognitive deficits in student-athletes and, as of 2018, has been administered over 16 million times (ImPACT Applications, 2020.). The test is employed by gathering a baseline pre-concussion and comparing post-concussive scores to determine the presence and severity of cognitive symptoms

post-injury. ImPACT providers state that, “Neurocognitive testing is the cornerstone of modern concussion management” and that it, “aids in tracking recovery for safe return to activity" (ImPACT Applications, 2020). This statement has some credibility. According to a recent study, the ImPACT has been found to be a reliable test for post-concussion assessment (Nakayama, Covassin, Schatz, Nogle, & Kovan, 2014). However, while the ImPACT is a widely used tool for assessing concussions, is it truly effective or is it merely the best we have?

Current research on the ImPACT challenges its ability to inform cognitive concussion management. For example, one study concluded that the current research does not support the test’s ability to accurately predict readiness of return (Mayers & Redick, 2012). Another study found the reliability of the ImPACT to be variable especially for the verbal and visual memory sections (Resch et al., 2013). Investigators in another study which evaluated a multitude of common concussion assessment tools including the ImPACT, drew similar conclusions. They came to the verdict that while the ImPACT performed better than other means of concussion assessment, it did not meet an acceptable level for use by professionals (Broglio, Katz, Zhao, Mccrea, & Mcallister, 2017). Additionally, in a study that compared the Computerized Revised Token Test, a test of auditory language processing, to the ImPACT it was concluded that the ImPACT did not accurately demonstrate the period of time it took to gain back auditory comprehension skills. The researchers in this study recommended that neurocognitive testing of multisensory processing may be better at predicting recovery than the ImPACT which only uses the visual modality (Białuńska & Salvatore, 2017). A fifth study which compared the ImPACT to many traditional neuropsychological measures found that while the test displayed validity in most cognitive areas, it failed to accurately identify the abilities of sustained attention and auditory working memory (Maerlender et al., 2010). Upon reviewing the evidence for the utility

of the ImPACT in making clinical decisions, there is much evidence contradicting the validity and reliability of the assessment.

Another issue that arises when using the ImPACT to determine the readiness of student-athletes to return to the classroom is known as sandbagging. Sandbagging is when student-athletes are coached or otherwise decide to give less than their best effort on their initial baseline of the ImPACT in order to bypass detection of deficits in the case of a concussion (Schatz & Glatts, 2013). This may seem counterintuitive, except for the fact that in doing so student-athletes are putting themselves in a position where they may be able to return to their sport more quickly than if they had given their best effort on the assessment. The ImPACT does include a validity indicator making it more difficult for athletes to intentionally lower their performance on the ImPACT. However, one study found that 30-35% of sandbagging athletes were able to avoid detection (Schatz & Glats, 2013). Despite the presence of sandbagging, another study found that only half of athletic trainers take the time to check baseline tests for validity. This oversight could result in athletes returning to play and to the classroom sooner than is appropriate (Covassin, Elbin, Stiller-Ostrowski, & Kontos, 2009). Sandbagging is a concerning issue in the use of the ImPACT for concussion management.

Speech-Language Pathologists and Concussions

Traumatic brain injury and concussion is listed as an area within the scope of practice for Speech-Language Pathologists (SLPs) (American Speech-Language-Hearing Association, 2016). Their role for concussion management is to work with other professionals in assessment and treatment of concussions (Ramanathan, 2018). They are especially valuable in the possible cognitive-linguistic impairments that persist after injury (Ramanathan, 2018). Cognitive-linguistic symptoms that persist past the usual 1-2 weeks of recovery time should be assessed

and treated by an SLP with individualized therapy in addition to collaborating with an interdisciplinary team (Ramanathan, 2018). SLPs have a variety of tools they use to diagnose and treat mTBI including the Ross Information Processing Assessment (RIPA), Boston Diagnostic Aphasia Battery (BDAE), Boston Naming Test (BNT), and Scales for Cognitive Assessment of TBI (SCATBI) (Duff, Proctor & Haley, 2002). Thus, SLPs are equipped with skills and tools to assess and treat traumatic brain injuries.

Currently, it is uncommon for SLP's to be members of concussion management team despite their value in the treatment of traumatic brain injuries (Ketcham et at, 2017.). Ketcham et al. (2017) argued that SLPs should be available to students as they begin to return to the classroom post-concussion as SLPs can provide students with useful strategies regarding attention, focus, and cognitive processing. SLPs may deliver ongoing rehabilitation services to student athletes to ease their transition back to the classroom. Athletes who experience post-concussive syndrome are often referred to neuropsychologists or another concussion health expert, but the referral can take a significant amount of time. In the meantime, students are often trying to resume classroom duties in varying capacities. SLP's can provide immediate strategies and intervention to support students as they combat cognitive symptoms while pursuing their academic endeavors. Providing this service can positively impact students academically, shorten recovery time, and improve overall quality of life (Ketcham et al., 2017). Therefore, SLPs possess knowledge and skills that can support students and add value to a concussion management team.

Summary

The current research shows that SRCs can affect student athletes in the classroom in multiple and varying ways, including cognitively. While current concussion management

practices are supported by research, there is also conflicting data which demonstrates that the ImPACT may not show appropriate levels of validity and reliability. Also, there is the issue of student-athletes sandbagging during the baseline assessment. The purpose of the study is to assess classroom readiness post-concussion in college student-athletes. Because SLPs are equipped to assess and treat brain injuries and because the research comparing ImPACT measures to traditional cognitive tests is lacking, ImPACT scores will be compared to cognitive tests used by SLP's. Additionally, qualitative data will be gathered via surveys. It is hypothesized that the ImPACT may not be a sensitive enough measure of classroom readiness and that traditional cognitive assessments may detect areas which are lacking in the ImPACT.

Research Design & Methodology

Athletic trainers at Fontbonne University, as the first responders to SRC injuries, agreed to be liaisons between student-athletes who sustained an SRC and the primary investigator (PI). Individuals were recruited for the study by word of mouth, e-mails to head coaches, and flyers around campus. These means of recruitment instructed individuals who had sustained an SRC to speak with their athletic trainer who would then send their contact information to the PI. From there, the PI would contact potential subjects and set up a time to meet with them as soon as possible after passing the ImPACT.

A variety of tools were chosen to assess individuals post completion of the ImPACT. Two assessments were selected: The Cognitive Linguistic Quick Test (CLQT) by Mary Helms Estabrook and the Test of Information Processing Skills (TIPS) by Raymond E. Webster. Despite some minor overlap, two assessments were selected to measure broader range of cognitive functioning necessary for successful classroom performance. For example, the CLQT contains a variety of subtests designed to assess various cognitive domains including attention,

language, and problem solving. On the other hand, the TIPS is organized to focus on memory and information processing among other aspects of cognition. Both assessments are paper and pencil tests which can be administered by SLPs. In addition to these two assessments, three surveys were given to the participants. One survey, the Pre-Testing Survey, was given at the time of the post-ImPACT assessment session with the PI. The following two surveys, Post-Testing Survey 1 & 2, were identical and given to the participant two and four-weeks post assessment. This was done in order to collect longitudinal data on possible persistent symptoms post-clearance from athletic training staff via the ImPACT. The variety of tools chosen allowed multiple types of data to be gathered, thus giving insight into the accuracy of the ImPACT in predicting classroom readiness.

The CLQT was chosen for this study for a few reasons. According to the testing manual, the CLQT was developed for individuals with acquired neurological dysfunction, which includes stroke, traumatic brain injury, or dementia from the ages of 19-89, making it an appropriate cognitive assessment for college students with mTBI (Helm-Estabrooks, 2001). In addition, it is a pencil/paper test whereas the ImPACT is a computerized test which allows for further comparison. The CLQT was created to evaluate five domains of cognition including attention, memory, language, executive function, and visuospatial skills (Helm-Estabrooks, 2001). These tasks provide insight into one's cognitive processes and can assist in evaluating classroom readiness in college student-athletes. Additionally, this assessment provides scores in the ranks of *within normal limits, mild, moderate, and severe*. Assessments that did not have a *within normal limits* level were not chosen because it would be unclear whether the individual was performing in the normal or impaired range. Therefore, the assessment is appropriate for the nature of this study due to the norms, tasks, and scoring system.

The assessment is composed of ten subtests including personal facts, symbol cancellation, confrontational naming, clock drawing, story retelling, symbol trails, generative naming, design memory, mazes, and design generation. For the first task, the individual is asked to recall personal facts (ex. date of birth, place of birth, address etc.) to appraise episodic memory, orientation, word recall, and verbal communication. In the second section, the individual is shown a symbol and asked to cross out all the examples of the original icon on a page with a variety of images. This determines the presence of visual attention as well as visuospatial and visual perceptual skills. Confrontational naming is evaluated by asking the individual to name ten line drawn pictures to assess semantic and phonological language. Afterwards, the subject is directed to draw a clock with the hands pointing to ten minutes after eleven. The clock drawing task gauges a multitude of cognitive domains including sustained attention, working memory, executive functions, language, and visuospatial skills. For the story retelling subtest, the individual listens to a story, then summarizes the story aloud to measure the following areas: attention, verbal working memory, language comprehension, and verbal production. Next, the individual is instructed to create trails by connecting symbols according to directions given by the investigator. This evaluates the domains of attention, executive functioning, and visuospatial skills. Verbal fluency or generative naming is assessed both by providing the individual with the category of "animals" and asking them to name as many as possible in 60 seconds. The task is repeated, this time giving the individual the letter "M" as a cue. Both trials are designed to assess working memory, verbal language skills, and executive functions. In the eighth subtest, the individual is shown two designs and asked to identify the originals when presented with six models to examine the domains of visual attention, visual memory, and visuospatial skills. For the next task, the individual is provided mazes to complete

in two minutes. Finally, the individual is asked to generate as many designs as possible in 3 minutes after a model provided by the investigator. The final two tasks are designed to appraise attention, executive function, and visuospatial skills. By assessing attention, memory, language, executive function, and visuospatial skills, these tasks provide insight into cognitive functioning and thus can aid in assessment of classroom readiness.

The TIPS also possess several qualifications making it suitable for this study. This 2009 assessment was normed on 3,300 persons between the ages of 5 and 97. According the manual, the test is designed to measure, "a number of information processing skills (in children and adults) that relates directly to acquiring, organizing, retrieving, using and managing what is seen and/or heard" (Webster, 2009, p.9). These information processing skills that the assessment purports to measure are: "short-term memory acquisition, working memory capacity, serial vs. unordered recall in two capacities, delayed recall, word fluency, acoustic intrusion effects, and proactive interference effects" (Webster, 2009, p.5). These abilities are vital to college students' performances in the classroom, especially student-athletes who often have less time to spend on their studies due to rigorous practice schedules. Thus, there is value in the assessment of these skills. Like the CLQT, the TIPS provides scores in the *significant*, *mild*, or *no impairment* ranges based on percentile rank. The *no impairment* range is important to this study for reasons stated above. Due to the norms, measured skills, and scoring range, this assessment was found to be appropriate for this study.

TIPS is composed of four subtests, visual modality, auditory modality, delayed recall, and word fluency. The visual modality scores demonstrate the individual's ability to learn visual information presented for free recall. The auditory modality displays the same information, but in an auditory modality (Webster, 2009). More specifically, these first two

subtests assess short-term memory acquisition, working memory capacity, and serial vs. unordered recall. They are carried out by providing the individual with strings of letters, both visually and audibly. The individual must recall as many letters as possible from the string, in the original order if possible. First, the individual must repeat the letters back to the investigator immediately after being presented with the string (Short term – ST). Next, the individual is asked to perform a counting task, then, say the string again (Working Memory 1 – WM1). Afterwards, the individual is asked to repeat a sentence after the investigator, then, produce the string one last time before moving on to the next string (Working Memory 2 – WM2). Strings increase in length until the individual makes two consecutive mistakes on the ST task, or until they reach the end of the visual and auditory sections which both contain a string of 9 letters. The third task, which evaluates delayed recall, requires the subject to remember animal and fruit terms which were embedded within sentences in the first and second sections when the individual was asked to repeat a sentence as a distractor task. The final subtest appraises verbal fluency and asks the individual to generate as many words as possible given a single letter in 60 seconds. There are four trials of this subtest. In the first two trials, the words are produced verbally by the subject given a single letter cue. Next, in the final two trials the words are written given new single letter cues (Webster, 2009). These tasks provide insight into cognitive functions needed to perform well in the classroom and therefore are appropriate for this study.

The surveys given can be found in Appendix A and were used to gather qualitative data from the subject. The pre-testing survey was utilized to inquire about the subject's concussion history including number, dates, and severity of past mTBIs, in addition to past and current symptoms. The individual was also asked to note if they had any kind of pre-existing learning disability or other diagnosis which may affect the results of the assessment. The pre-testing

survey also queried about the individual's attitudes towards the level of support the current concussion management system provided in their return to the classroom. Additionally, it was inquired whether the athlete put forth their best effort on the ImPACT and whether they had ever been counseled to give less than their best effort. The post-testing surveys, given two and four weeks after the assessment session, were designed to evaluate the student's symptoms and attitudes as the length of time since clearance by the athletic training staff via the ImPACT increased. Overall, the surveys were designed to gather data that may not be visible in the formal assessments.

It should be noted that since the surveys inquired about the current symptoms that the athlete was experiencing, the PI stressed to the individual during their meeting that all information reported would be completely confidential. This was done because a student-athlete admitting that they are still experiencing concussion symptoms, for example a headache, would jeopardize their cleared to play status. Thus, to ensure that the information reported was as accurate as possible, reassurance was given to the subject.

The information collected by the CLQT, TIPS, and surveys was to be compared to the ImPACT. The ImPACT is a computerized neurocognitive test specifically created for professionals to evaluate and manage concussions. The test was standardized on 16,566 individuals and is appropriate for individuals from the ages 12-59 (Lovell, 2020). The ImPACT manual stresses that the assessment alone is not enough to make a clinical diagnosis of an mTBI and that other assessments should be used in conjunction with the ImPACT. The test recommends gathering a baseline score of all individuals to compare to post-injury scores in order to assess cognitive functioning. The assessment measures four main areas: sequencing/attention, word memory, visual memory, and reaction time (Lovell, 2020).

The ImPACT is composed of six subtests which include word memory, design memory, X's and O's, symbol match, color match, and three letters in addition to a self-report of concussion symptoms. The first subtest presents the subject with 12 words twice. Individuals are then asked to choose the original 12 words given 24 words. Next, for the second subtest, the individual is provided 12 designs to remember. As in the last subtest, the subject must correctly identify the 12 original designs out of 24 given designs. Both tasks evaluate attention and visual recognition memory. For the third subtest, the individual is asked to remember the location of yellow X's and O's presented on the screen while performing a distractor task in between presentation and recall to measure working memory and visual processing/visual motor speed. Afterwards, in the next subtest, the individual is presented with the numbers 1-9 which are each paired with a symbol. When a symbol flashes onscreen, the individual is asked to identify the number that the symbol goes with. Next, the individual is asked to recall as many number-symbol pairings as possible. This task assesses visual processing speed, learning and memory. For the fifth subtest, the individual is presented with color words ("blue," "green," etc.) in varying text colors. The individual is asked to click on the word only if the word matches the text color, thus gauging impulse control/response inhibition. During the final task, the subject is asked to recall a string of 6 consonants presented initially after being given a distractor task: clicking on numbers 25-1 in descending order presented in a random cluster. This last task measures working memory and visual-motor response speed. After the tasks are completed, individual is asked to respond to a symptom report checklist to note which, if any, symptoms they are experiencing at the time of testing. The scores on these tasks are to be compared pre- and post-injury to give information as to whether students are ready to return to play and the classroom (Lovell, 2020).

Between the ImPACT and the CLQT/TIPS combination, there are many similarities in the cognitive domains assessed, but also some key differences. Both the ImPACT and the CLQT/TIPS assess the areas of attention, memory, learning, and visual processing skills. However, unlike the CLQT/TIPS, the ImPACT explores the area of visual motor speed. Furthermore, the CLQT/TIPS include sections assessing language skills whereas the ImPACT does not. Overall, while there are multiple common areas for comparison between these assessments, each includes areas that are not contained in the other.

Description of Subject

The individual who agreed to participate in this study will be referred to as "Abby" to preserve privacy. Abby was a 20 year and 9-month-old female college student at the time of assessment. She was a sophomore biology major with a 3.5 GPA and played soccer at the NCAA Division III level. She had a history of concussions. She reports that her first concussion, sustained in 2012, was mild. In addition, she suffered a severe concussion in 2016. Both concussions were diagnosed by a medical professional and reports no suspected undiagnosed concussions. She cannot recall the exact date of the most recent sustained concussion, but reports that it was sometime during the end of October or beginning of November in 2019. The individual reports the most recent concussion to be mild. The SRC was sustained during a soccer game when she went up to head a ball. She states that she did lose consciousness very briefly, but was still able to recall her location, the score of the game, and the date after regaining her awareness. Afterwards, she reports refusing to come off the field and continuing to play. Yet, she expresses being unable to remember the rest of the game at the time of the testing session with the PI. For a few weeks after the injury, Abby denied the existence of concussion symptoms to her athletic trainers and coach, until the season ended in mid-November

when she finally admitted her symptoms and began receiving treatment. The symptoms experienced by the individual after this most recent concussion were occasional attention difficulties, occasional concentration difficulties, frequent headaches, and some insomnia. She reported that she did not have any difficulty processing written information, memory difficulties, time management difficulties, nausea, dizziness, depression, or anxiety after her most recent concussion. The individual passed the ImPACT on November 22nd and was assessed by the PI on December 4th, thus, eleven days apart. At the time of testing the individual denied any common concussion symptoms.

Collection of Data

Before collecting data, the individual was informed about the study and asked to sign the informed consent form if she desired to participate. The assessment session took place in a small therapy room at a table. After signing, data was collected via the pre-testing survey which gathered information detailing history of past concussions, current concussion symptoms, and questions about ImPACT performance. After this survey, Abby was given the CLQT and then the TIPS with a one minute break in between. The individual was offered a longer break, but desired to bypass the interruption and continue the session. The session did not exceed an hour and a half. After the session, the individual was informed that she would be e-mailed two surveys by the PI at two and four week intervals. She was asked to return them within a few days of them being sent out. After post-testing surveys were filled out two and four weeks later, the assessment portion of this study was completed.

Results

For the ImPACT taken on November 22nd, 2019, because Abby scored within 95% of her original score, the recommended pass rate by the National Athletic Training Association according to athletic trainers at Fontbonne University, she was deemed cleared to play and learn. It can be noted that the subject scored the same or higher on all the initial ImPACT subtests, except for the design memory subtest on which she scored three points lower than previously (11 vs. 8). When it came to her domain scores, the individual displayed improved verbal memory (91 vs. 99) and visual memory (73 vs. 77) totals. Her impulse control remained the same as previous scores (5 vs. 5). Additionally, her reaction time was longer than before by 0.02 seconds and visual motor composite score was slightly lower than it was previously (41.63 vs. 38.45). It can also be noted that her symptom score is lower as the individual reported 2 symptoms of trouble falling asleep and sleeping less than usual on her original assessment but did not report these symptoms at the later testing date. Data is represented in tables 1 and 2.

ImPACT Subtest Scores		
Subtest	*8/16/2017*	*11/22/2019*
Word Memory	12	12
Design Memory	11	8
X's and O's	7	9
Symbol Match	27	27
Color Match	9	9
Three Letters	5	5

Table 1. ImPACT Subtest Scores

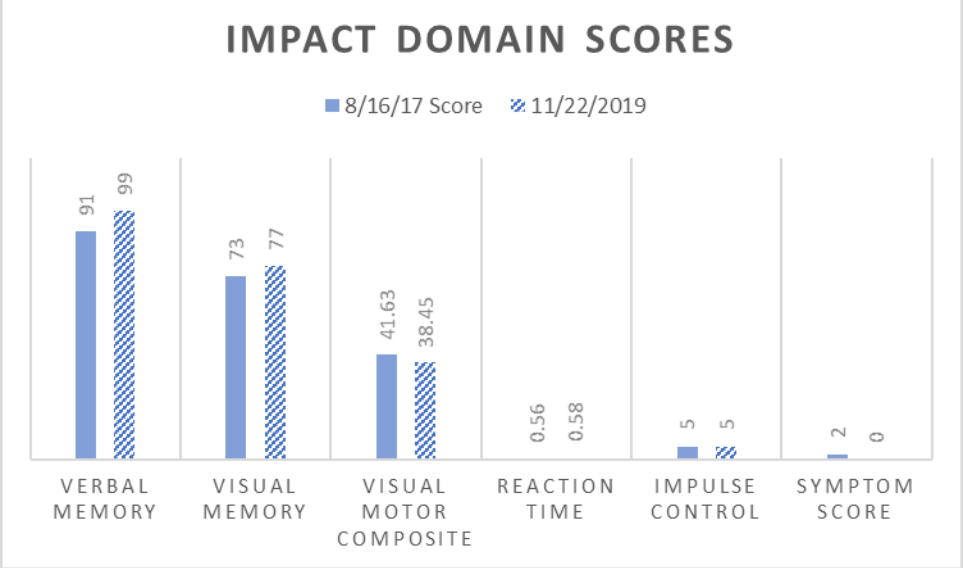

Table 2. ImPACT Domain Scores

For the CLQT, the individual scored within normal limits for the domains of attention, memory, executive, functions, language, and visuospatial skills. The test of clock drawing was scored as mild, with a score of 11/13. The individual was asked to set the hands to "ten minutes after eleven." While the individual had no issues organizing and representing a clock, the time shown on the clock appears to be approximately 10:57. Despite this error, overall, the individual scored within normal limits. Data is represented in Figure 3 and 4.

Domain	Score	CLQT Severity Rating
Attention	206	WNL 215-180
Memory	164	WNL 185-155
Executive Functions	34	WNL 40-24
Language	31	WNL 37-29
Visuospatial Skills	102	WNL 105-82
Clock Drawing	11	MILD 11-10

Figure 3. Individual's scores on the Cognitive Linguistic Quick Test

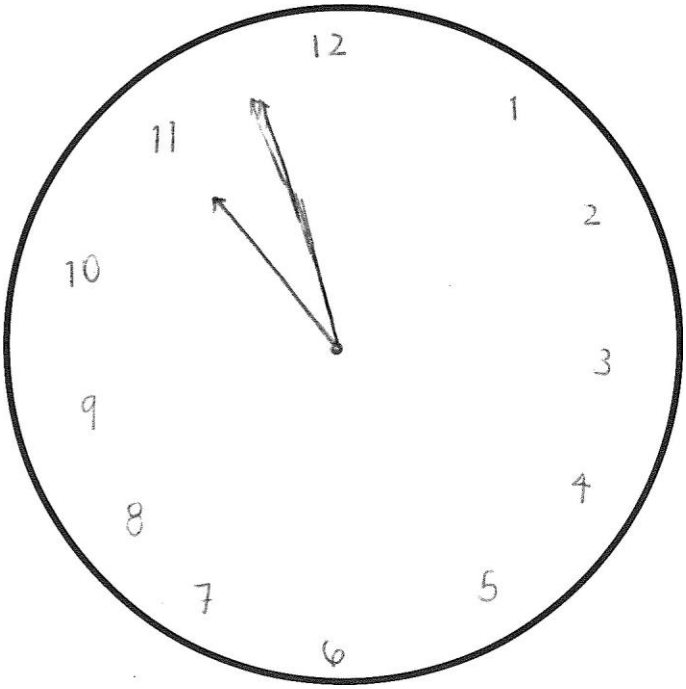

Figure 4. The individual's clock drawing for the Cognitive Linguistic Quick Test. Instructions were to: "Set the clock to 10 minutes after 11."

The participant scored in the average or above average range for all areas of the TIPS except oral word fluency. She showed no difficulty with processing and recalling strings of letters in either the visual or auditory modalities. Yet, it can be noted that on average her scores for the auditory modality were lower than her scores for the visual modality, scoring in the 63rd percentile for the auditory modality and the 79th percentile for the visual modality. The subject scored in the average range for delayed recall with scores ranking in the 50th percentile. Her overall score for word fluency put her in the 16th percentile which is the borderline score between *no impairment* and *mild impairment.* Within word fluency, it can be noted that she received a lower score for the oral section than for the written section. Scores are visually represented in Figure 5.

	TIPS SUBTEST SCALED SCORES														
	Ordered						***Unordered***								
	Visual			**Auditory**			**Visual**			**Auditory**			**Delayed Recall**	**Word Fluency**	
	ST	*WM1*	*WM2*	*ST*	*WM1*	*WM2*	*ST*	*WM1*	*WM2*	*ST*	*WM1*	*WM2*	*DR*	*Oral*	*Written*
19															
18															
17															
16															
15															
15															
13			X	X					X						
12	X	X					X	X							
11					X					X	X	X			
10						X							X		
9															
8															X
7															
6														X	
5															
4															
3															
2															
1															

Figure 5. Test of Information Processing scaled scores. Scores WNL are represented by the gray section.

In the data collected via surveys, the subject denies any common concussion symptoms since being cleared to return to play. In all three surveys (Pre-testing, Post-testing 1, and Post-testing 2) she responded "Never" when asked if she had experienced the following symptoms since being cleared to play: difficulty processing auditory verbal information, difficulty processing written information, attention difficulties, concentration difficulties, memory difficulties, time management, headaches, nausea, dizziness, depression, and anxiety. The subject states in all three surveys that her most recent concussion has not affected her daily life nor academic life since being cleared to play or taking the last survey. She selected "Yes" when asked if she felt equally confident in her academic abilities pre- and post-concussion. In

addition, she notes that when given the "return to play status" she also felt prepared to "return to learn." Yet, the subject maintains in all three surveys that extra supports (further evaluation/testing, cognitive therapy, academic supports etc.) would have been would have been "important" in her clearance to return to the classroom. In addition, the subject responded that she presented her best effort on her initial ImPACT, thus denying sandbagging. She also denies ever being instructed by a teammate, coach, or other individual related to her athletic career to not give her best effort on the baseline ImPACT.

Discussion of results

Overall, the results appear to support the ImPACT as a means for predicting student-athletes readiness to return to the classroom. However, there were also two areas where the individual fell below the typical scores, suggesting that there may be deficits that go undetected by the ImPACT and thus requiring a more sensitive measure as hypothesized. These areas are the clock drawing task on the CLQT and oral verbal fluency on the TIPS. It is noted that the individuals scores were only mildly impaired in both areas area, falling in the borderline 16th percentile in verbal fluency and scoring 11/13 on the clock drawing task, thus earning a mild diagnosis. Despite the mildness of impairments, it is worth examining why the individual may have achieved these scores.

Tasks regarding word fluency assess one's ability to generate words. The task appears simple, however, there are many executive functions that are necessary with this action. The skills needed to perform such a task include attention, the ability to choose appropriate information stored in the semantic and lexical memory, using one or both phonemic and lexical information given to produce words appropriate to the task, and selecting information from the verbal declarative memory (Webster, 2009). In addition, immediate attention and sustained

attention must be functioning properly, as well as concentration, psychomotor speed, and memory. Specifically, working memory is very important for this task because one must monitor their answers to ensure that they are appropriate (ex. not using proper nouns in the task as instructed) (Webster, 2009).

The research on verbal fluency demonstrates that it is a common impairment with traumatic brain injury and has been shown to predict academic success. Low rates of word-fluency have been found in multiple diagnoses including traumatic brain injury (Gruen, et al., 1990). Moreover, challenges with word fluency have been demonstrated to have a relationship to deficits in the left prefrontal cortex (Warkentin, Risberg, Nilsson, Karlson, & Graae, 1991). One study which assessed the relationship between verbal fluency and academic achievements in second and third graders concluded that the verbal fluency is highly correlated with academic success (Aksamovic, Djordjevic, Malaec & Memisevic, 2019). Another study reported that those with severe TBI showed impairments on tests of verbal fluency whereas those with mild TBI received scores within normal limits. Interestingly, this study also found that many individuals provided fewer answers to phonemic verbal fluency tasks than semantic verbal fluency tasks as was the case with this study and will be addressed below (Woods, Wyma, Herron, & Yund, 2016).

It must be noted that the individual scored in the normal range for the semantic and phonemic verbal fluency subtest of the CLQT. In addition, she also performed within normal limits for the written verbal fluency assessment in the TIPS. Nonetheless, there are some key differences in these assessments. The CLQT was given first in the assessment session, and the TIPS was given second. The verbal fluency assessment is given at the end of the TIPS, so it is possible that fatigue played a role in the impaired scores. However, the oral verbal fluency

section (impaired score) was given before the written verbal fluency section (within normal limits), so it is unclear whether fatigue played a role. In addition, the CLQT asks the individual to name animals and then words that begin with "m" in two separate trials whereas the TIPS asks the individual to preform 4 trials with phonemic cues. Two trials involve producing the words aloud and in the other two sets the individual is instructed to write the words. For the CLQT, the individual named 18 animals, but only 12 words with "m." Her performance on the semantic section (animals) appears to even out her performance on the phonemic section ("m"). When it came to the TIPS, the individual produced only 7 and 12 words on the oral section, and 9 and 11 words in the written section which resulted in the borderline 16th percentile ranking. The results show that semantic verbal fluency may be less impaired than phonemic verbal fluency.

Research supports the idea that phonemic verbal fluency, versus semantic verbal fluency, may be a more sensitive measure when assessing traumatic brain injured patients due to frontal lobe impairments. One study with individuals who suffered mTBI compared performance on semantic and phonemic verbal fluency tasks to a control group. It was found that those with mTBIs performed lower on both tasks compared to the control. However, differences between groups were larger for phonemic verbal fluency (Cralidis & Lundgren, 2014). Another study found that patients who had a moderate to severe TBI and had challenges completing a functional task, such as grocery shopping, also had challenges with phonemic verbal fluency, but not with semantic fluency (Cralidis & Salley, 2017). When comparing phonemic and semantic verbal fluency, another study found that phonemic verbal fluency was more sensitive in the assessment of TBI than the Wisconsin Card Sorting Test, a common neuropsychological test of abstract reasoning (Henry & Crawford, 2004). While it appears that phonemic verbal fluency rather than semantic verbal fluency is more commonly impaired in individuals with TBI, the

opposite is true for individuals with Alzheimer's and age-related cognitive decline (Cradilis & Lundgren, 2014; Capitani, Rosci, Saetti, & Laiacona, 2009). This difference in verbal fluency scores is thought to be due to frontal lobe commonly being affected by TBI and having a strong effect on phonemic verbal fluency, whereas semantic verbal fluency relies more so upon the temporal lobe (Cradilis & Lundren, 2014; Capitani et al., 2009).

The error in the clock drawing is to be addressed. The task of drawing and setting a clock requires multiple cognitive skills making it a sensitive measure. These skills include language, visuospatial planning skills, and conceptualization of time in addition to sustained attention, memory, and executive functions (Helm-Estabrooks, 2001). The most common error made is setting the hands to the wrong time which is the error made by the individual in this study (Helm-Estabrooks, 2001).

This error can have multiple cognitive implications. For example, the error may have been made because of a language deficit. It is possible that the individual may have not comprehended the language of the verbal directions. Another possibility is that the individual's memory, specifically short-term and working memory, could not hold the information long enough to accurately draw the clock. The individual may have been challenged by sustained attention and executive functions in order to notice her mistake and correct it. A final option is the individual may have lacked the ability to understand and/or calculate the correct time.

Other studies reinforce the idea that the clock drawing task is a sensitive measure for assessing cognitive impairment with those who have traumatic brain injury. One study by Writer, Schillerstorm, Regwan, and Harlan (2010) examined the correlation between performance on a five-minute clock drawing task and functional cognitive status on fifteen veterans with mTBI and comorbid PTSD. They concluded that the clock drawing task, similar to

the one utilized in this study, was sensitive to assessing functional status, regardless of anxiety or depression caused by PTSD. Another study which focused on the detection of overlooked symptoms of mTBI, assessed 223 participants in an outpatient TBI clinic. The outcomes indicated that the clock drawing test was is a highly effective screening tool for cognition for those in the TBI population (Hazan, Zhang, Brenkel, Shulman, & Feinstein, 2017). Yet another study compared various performances of individuals with varying severities of TBIs on multiple cognitive tests including the clock drawing test and the Mini-Mental State Examination. The results displayed that the combination of the clock drawing and the trail making test had a strong potential for early assessment of TBI patients (de Guise, Gosselin, LeBlanc, Champoux, Couturier, Lamoureux,... & Feyz, 2011). Thus, the task of clock drawing is a sensitive research supported task for cognitive assessment post-TBI.

Limitations

While there is a lack of research in this area, it only adds to the importance and urgency of the current study. Even in this single-case study, significant discrepancies were shown between ImPACT testing and other cognitive tests. Thus, there is a further need to continue this research with a greater number of participants

Future directions

This study can be repeated with more individuals to determine whether the ImPACT predicts classroom readiness. Additionally, with more individuals the traditional assessments utilized can be counterbalanced throughout the study. Another study may be designed by comparing the ImPACT to a screening composed of phonemic verbal fluency and clock drawing tasks. Screening may be done immediately after passing the ImPACT post-concussion or, a

chosen amount of time after clearance. Students may also be followed over time to assess their GPA, noting whether possible undetected concussion symptoms have effects on GPA. In addition to gathering quantitative data, students may be surveyed about how they feel a concussion may have affected them in the classroom and if they are aware of resources and health professionals they can turn to if needed.

Clinical Implications

This study has several clinical implications for assessment of SRCs and ensuring that student athletes are supported cognitively post-concussion. For example, this study maintains the current idea that concussion assessment should be a multi-faceted process. Furthermore, the clock drawing task may be included in this process as a short, precise screening tool. As with the ImPACT, it cannot be used by itself to assess complete cognitive functioning, but this study and other research suggest that it is a highly sensitive short task. In addition, it appears that verbal fluency may also be a useful screening task for mild traumatic brain injuries. More specifically, a verbal fluency task given a phonemic cue appears to be the most perceptive, especially when there is frontal lobe involvement. Multi-faceted cognitive assessment, possibly including clock drawing and phonemic verbal fluency tasks, is a research supported means of concussion management.

Clinical implications for SLPs include being aware of deficits that can often go undetected by the ImPACT. Additionally, SLPs should be aware of their value in a concussion management team. Despite being rarely called upon to be a part of this process, SLPs can play an important role in this type of assessment if needed. Furthermore, SLPs can assist with immediate strategies and resources to support student-athletes as they assume their classroom requirements in varying capacities.

In addition to SLPs, there are clinical implications for other health and educational professionals. For athletic trainers and professors, it may be important to note that no test is perfect. Thus, despite clearance to return to the classroom, if one notices that a student is struggling academically to a higher degree than they had been prior to injury, it is important to make a referral to another professional (ex. SLP, academic tutor, neuropsychologist, etc.).

Conclusion

It can be concluded that the ImPACT results should be interpreted cautiously due to some cognitive impairments possibly going undetected. The hypothesis that the ImPACT may not be sensitive to mild cognitive impairments was upheld. This reinforces the idea that concussion assessment should be multi-faceted, and one measure should not be solely relied upon to make a diagnosis. Furthermore, clock drawing and verbal fluency tasks given a letter cue may be valid and sensitive screening tools for individuals with SRC. In addition, SLP's should advocate for their abilities to assist in providing cognitive assessment and treatment to individuals with concussions when needed.

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APPENDIX A

Pre-testing Survey

Please fill out accurately. This information will only be shared in a completely confidential manner. Your answers will not affect the fact that you are currently cleared to play.

Name:
Sex: (circle) M F
Sport:
Most recent concussion date:
Date of most recently being cleared by athletic training staff from concussion:
Severity of most recent concussion (Mild, moderate, severe)_____

Which of the following symptoms did you experience BETWEEN your most recent concussion and your subsequent cleared status:

Difficulty processing written information

Never Occasionally Sometimes Frequently Constantly

Attention Difficulties

Never Occasionally Sometimes Frequently Constantly

Concentration difficulties

Never Occasionally Sometimes Frequently Constantly

Memory difficulties

Never Occasionally Sometimes Frequently Constantly

Time management

Never Occasionally Sometimes Frequently Constantly

Headaches

Never Occasionally Sometimes Frequently Constantly

Nausea

Never Occasionally Sometimes Frequently Constantly

Dizziness

Never Occasionally Sometimes Frequently Constantly

Depression

Never Occasionally Sometimes Frequently Constantly

Anxiety

Never Occasionally Sometimes Frequently Constantly

Insomnia/Sleeping Problems

Never Occasionally Sometimes Frequently Constantly

How many TOTAL diagnosed concussions in your lifetime? _____

Approximate date of diagnosed concussions:
_____

Severity of diagnosed concussions: (mild, moderate, severe)
_____

Sports related? (Circle) Yes No

How many OTHER suspected undiagnosed concussion(s):_____

Approximate date of suspected undiagnosed concussion(s):_____

Suspected severity of possible undiagnosed concussions: (mild, moderate, severe)_____

Sports related? (Circle) Yes No

Have you been diagnosed with any of the following: (circle) ADD ADHD Learning Disability

What medications are you taking if any?
_____

What concussion-related symptoms are you CURRENTLY experiencing (if any)? (Remember this information will not be shared with your coaches or athletic trainer and will only be reported in an anonymous manner so please answer as accurately as possible).

Difficulty processing auditory verbal information

Never Occasionally Sometimes Frequently Constantly

Difficultly processing written information

Never Occasionally Sometimes Frequently Constantly

Attention difficulties

Never Occasionally Sometimes Frequently Constantly

Concentration difficulties

Never Occasionally Sometimes Frequently Constantly

Memory difficulties

Never Occasionally Sometimes Frequently Constantly

Time management difficulties

Never Occasionally Sometimes Frequently Constantly

Headaches

Never Occasionally Sometimes Frequently Constantly

Nausea

Never Occasionally Sometimes Frequently Constantly

Dizziness

Never Occasionally Sometimes Frequently Constantly

Depression

Never Occasionally Sometimes Frequently Constantly

Anxiety

Never Occasionally Sometimes Frequently Constantly

Do you feel that your concussion has affected you in your daily life since you have been "cleared" to play?

(circle) Yes No

Explain_____

_____

_____

Do you feel that your concussion has affected you in your academic life since you have been cleared to play?

(circle) Yes No

Explain

_____

_____

_____

Overall, would you say that when you were given the "return to play" status you also felt prepared to "return to learn?"

(circle) Yes No

Why or why not

_____

_____

_____

I currently feel that extra supports (further evaluation/testing, cognitive therapy, academic supports ect.) would have been _____ in my clearance to return to the classroom

Very important Important Moderately important Of little importance Not important

When taking the baseline ImPACT test (the first time you took it) at Fontbonne University, did you give your best effort?

(circle) Yes No

Have you ever been instructed by a teammate, coach, or other individual related to your athletic career to NOT give your best effort on the baseline ImPACT test?

(circle) Yes No

Post-testing Survey #1 & #2

Please fill out accurately. This information will only be shared in a completely confidential manner. Your answers will not affect the fact that you are currently cleared to play.

Name:
Sex: (circle) M F
Sport:
Most recent concussion date:
Date of most recently being cleared by athletic training staff from concussion:

What concussion-related symptoms are you CURRENTLY experiencing (if any)? (Remember this information will not be shared with your coaches or athletic trainer so please answer to the best of your knowledge).

Difficulty processing auditory verbal information

Never Occasionally Sometimes Frequently Constantly

Difficulty processing written information

Never Occasionally Sometimes Frequently Constantly

Attention Difficulties

Never Occasionally Sometimes Frequently Constantly

Concentration difficulties

Never Occasionally Sometimes Frequently Constantly

Memory difficulties

Never Occasionally Sometimes Frequently Constantly

Time management

Never Occasionally Sometimes Frequently Constantly

Headaches

Never Occasionally Sometimes Frequently Constantly

Nausea

Never Occasionally Sometimes Frequently Constantly

Dizziness

Never Occasionally Sometimes Frequently Constantly

Depression

Never Occasionally Sometimes Frequently Constantly

Anxiety

Never Occasionally Sometimes Frequently Constantly

Do you feel that your concussion has affected you in your daily life since the last survey?

(circle) Yes No

Explain_____

_____

_____

Do you feel that your concussion has affected you in your academic life since the last survey?

(circle) Yes No

Explain

_____

_____

_____

Overall, would you say that you currently feel equally as confident in your academic skills pre- and post-concussion?

(circle) Yes No

Explain

_____

_____

_____

I currently feel that extra supports (further evaluation/testing, cognitive therapy, academic supports ect.) would have been _____ in my clearance to return to the classroom. (Circle)

Very important Important Moderately important Of little importance Not important