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FEASIBILITY AND ACCEPTABILITY OF ADMINISTERING A FUNCTIONAL COGNITIVE-COMMUNICATION ASSESSMENT TO INDIVIDUALS WITH SELF-REPORTED CONCUSSION

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Feasibility and Acceptability of Administering a Functional Cognitive-Communication Assessment to Individuals with Self-Reported Concussion

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Purpose: Individuals who experience ongoing symptoms after sustaining a mTBI may not receive the help they need because the deficits they endorse on self-report measures are not identified on current standardized cognitive assessments. The purpose of the current investigation is to determine how to better document ongoing cognitive-communication deficits and to characterize the nature of how these deficits impact daily life and communicative participation, using a multidimensional assessment protocol.
Method: A multiple case study design was selected to comprehensively document the cognitive-linguistic functioning of multiple individuals with concussion. Five participants completed one session over a telehealth platform that included four self-report measures and four standardized cognitive assessments. All participants then completed a second session which included a planning portion for in-person and at-home tasks followed by execution of in-person tasks. The participants completed the at-home tasks for the 10 subsequent days following the planning phase.
Results: All five participants successfully participated in all portions of the protocol being implemented. Participant self-report measures indicated a variety of cognitive deficits not identified during the standardized cognitive measures. Many of the cognitive deficits endorsed on the self-report measures were observed during the participant's execution of functional cognitive tasks.
Conclusion: Detecting cognitive-communication deficits in individuals with concussion/mTBI using a standardized assessment continues to pose as a challenge for rehabilitation professionals given the gap between performance on standardized assessments and symptoms endorsed on self-report measures. Further research and adaptations of this multidimensional protocol may be beneficial to the development of a functional standardized assessment.

INTRODUCTION

Traumatic brain injuries (TBI) are the leading cause of death and disability worldwide out of all trauma-related injuries (Dewan et al., 2019). In 2020, there were over 64,000 deaths related to TBI in the United States which averages out to approximately 176 deaths per day (CDC, 2022). The most common type of TBI is a mild traumatic brain injury (mTBI), often referred to as a concussion (McInnes et al., 2017). It is estimated that worldwide, approximately 69 million individuals will suffer from a TBI each year and of those 69 million individuals, approximately 81% of them will be classified as mild (Dewan et al., 2019). Mild TBI has a substantial economic impact, accounting for about 44% of the 56-billion-dollar annual cost of the TBI in the United States (Belanger et al., 2004, p. 215). Thus, in the United States alone, approximately 611,200 to 1.9 million people are diagnosed with mTBI each year, and of those who are clinically diagnosed, approximately 15% of brain injury survivors will experience post-concussion syndrome (PCS) even if this is their first mTBI (McInnes et al., 2017).

According to the Mild Traumatic Brain Injury Committee of the American Congress of Rehabilitation Medicine, mTBI is described as “a mild insult to the head that results in a brief period of unconsciousness followed by impaired cognitive function” (McInnes et al., 2017, p. 2). However, the American Congress of Rehabilitation Medicine has been working with an expert panel to update the original definition created in 1993, and from their most recent discussion, a period of a loss of consciousness was not a critical component in diagnosing an mTBI (Silverberg & Iverson, 2021). Mild TBI, also sometimes referred to as concussion, presents with symptoms including, but not limited to, cognitive impairments including reduced processing speed, impaired memory, impaired attention and concentration, and executive functions. Physical symptoms can include dizziness, headache, fatigue, and nausea. According to Hadanny and

Efrati (2016), most mTBI are due to falls, motor vehicle accidents, sports and blast-related injuries, typically seen in the military setting. In typical mTBI cases, symptoms last two to four weeks, but when a person experiences post-concussion syndrome (PCS), symptoms on average last 3.35 years (Rees & Bellon, 2007). The criteria in the DSM-V diagnoses PCS as a mild to major neurocognitive disorder and according to Rees and Bellon (2007), typical symptoms of PCS include physical and cognitive fatigue, depressive behaviors, sensitivity to noise, social withdrawal and irritability. Kim & Pfiefer (2020) reported similar symptoms to Rees and Bellon (2007) with the addition of concentration and problem-solving difficulties, loss of libido, and impaired decision-making abilities. While PCS presents with many symptoms, it often goes underreported (Prince & Bruhns, 2017). For this study, PCS will refer to any cognitive deficits occurring after a mTBI/concussion that have been self-identified by the participant.

PCS is common in athletes and veterans, but also occurs in people who have sustained recreational mTBIs and who have been involved in motor vehicle accidents. Sports-related concussions are traumatic events that affect up to 3.8 million athletes per year (Hadanny & Efrati, 2016, p. 1). Athletes are typically less likely to report persisting symptoms as this may interfere with their ability to compete in their sport, and organizations like the National Football League (NFL) have previously discredited the research indicating that a concussion can lead to persisting problems. Athletes, specifically those who play contact sports such as hockey, football, or lacrosse are at a higher risk than the average population of those experiencing a mTBI. The other group that is highly affected by post-concussion syndrome is war veterans. Hoge, Goldberg and Castro (2009), reported that the post-deployment screening process that they developed reported that at least 40% of the service members who had a concussion also had persistent symptoms. Military members stationed in high-risk zones are at a higher exposure to combat hazards which impact mTBI, but can also be affected by other types of mTBI factors such as falls and motor vehicle crashes, which leads to a higher percentage of military personnel reporting persistent concussive symptoms than the average population. Hoge (2009) also found that there is a correlation between post-traumatic stress disorder (PTSD) and depression in soldiers who have sustained a mTBI while deployed. Persistent symptoms resulting from concussion can have a significant impact on daily life, and the current standardized cognitive assessments used to define deficits do not appear to be sensitive enough to identify deficits endorsed by individuals on self-report measures.

Return to Daily Life

Patients who experience PCS are often referred to as "the walking wounded" or the "miserable minority" because of the deficits they experience that are hidden from the naked eye (Prince & Bruhns, 2017; Habanny & Efrati, 2016). The cognitive domains that are negatively impacted by mTBI include attention, processing speed, executive functions, and memory. Deficits in attention regulation, executive functioning, and memory are often present in people presumed to have PCS (Prince & Bruhns, 2017). These cognitive functions are crucial for return to school or the workplace. Without the ability to regulate attention or control memory, students struggle to take notes in lecture halls and employees struggle to complete work-related tasks. In 2016, Brown and Hux found that there was significant variability in the planning and execution behaviors of nine participants with mTBI. While this small sample cannot be generalized to the larger population, use of ecologically-valid assessment tools should be used to help identify challenges individuals experience during daily functional cognition tasks. Cognitive deficits in planning, problem solving, self-awareness, and memory may negatively affect performance of activities of daily living (ADLs), return to employment, and social competencies.

A majority of individuals who experience mTBI are displaced from work for a short period of time, but those who experience PCS due to a mTBI may return to work before they are cognitively ready (Losoi et al., 2016). Returning to work or school can be negatively impacted when cognitive deficits are still present, but deciding to wait to return can also have negative consequences on activities of daily living and overall quality of life. For example, Losoi et al. (2016) conducted a study to help describe recovery in individuals with mTBI who had no pre-existing health conditions. The researchers reported that 50 out of 74 participants (67.5%) returned to work within one month of their mTBI. Of the 50 participants who returned to work, 6% of them had a mild cognitive impairment identified through self-report measures, 26% presented with mild PCS, and 2% presented with moderate PCS as identified by the one-month follow-up. A person who experiences a mTBI typically returns to work within two to four weeks as represented by this study, yet those with PCS have deficits, specifically cognitive deficits, that make returning to work more difficult. Losoi et al., (2016) found that 36.4% of participants demonstrated symptoms of PCS, including cognitive impairments at 1-month, 14.5% of participants showed symptoms at the 6-month follow up, and 5% of participants still had persisting symptoms at the 12-month follow up. The authors concluded that while patients with no pre-existing health conditions who reportedly experienced chronic mild PCS were able to functionally recover, many continued to be dissatisfied and distressed psychologically. These findings suggest that many people return to work or school with persisting cognitive deficits that negatively impact school and work-related duties.

Current Protocol and Testing for Post-Concussion Syndrome

The current protocol for PCS diagnosis and treatment lacks efficacy and effectiveness as evidenced by the inadequacy of evidenced-based diagnosis and intervention options for patients who meet the PCS criteria (Kim & Pfiefer, 2020). Commonly used concussion assessments include the *Post-Concussion Symptom Scale* (PCSS; Pardini et al., 2004), *Standard Assessment of Concussion* (SAC; McCrea, Kelly & Randolph, 2000), S*ports Concussion Assessment Tool V* (SCAT5; Davis et al., 2017), the *Immediate Post-Concussion Assessment and Cognitive Testing* (ImPACT; Iverson, Lovell & Collins, 2003) and the *Vestibular/Ocular Motor Screening* (VOMS; Mucha et al., 2014). A newer form of concussion management that is used to enhance care of athletes is *SWAY* (Amick et al., 2015). This FDA approved app tracks an individual's balance, cognitive function, and self-reported symptoms. It is a convenient way for athletic trainers, coaches, and healthcare providers to better track a person's abilities post-concussion. Unfortunately, *SWAY* requires baseline data in order to determine accurate results. The PCSS and the SCAT5 are currently the only two assessments that are commonly used to help determine if someone has PCS. The PCSS is a self-report scale that has multiple questions addressing balance, vision, cognition, physical symptoms and emotional regulation. Each question has a 0- to 6-point scale that the patient uses to rate their symptoms. This tool provides beneficial information about physical symptoms as well as changes in cognitive-function, but the questions about cognitive functioning are quite vague and only address some of the cognitive domains such as executive functioning and attention. The SCAT5 is a tool typically used to diagnose the presence of concussion-related symptoms at time of injury, but can be used to help with a PCS diagnosis because it includes self-report measures. The SCAT5 is composed of eight subtests which include the *Glascow Coma Scale* (GCS; Teasdale et al., 2014), *Maddocks Score*

(Maddocks, Dicker & Saling, 1995), *Post-Concussion Symptom Scale* (PCSS), *Standard Assessment of Concussion* (SAC), *Modified Balance Error Scoring System* (mBESS; Guskiewicz, 2011), coordination exam, and SAC delayed recall. Of all eight subtests, only the SAC and PCSS address a person's cognitive deficits. Although these two assessments can help with the diagnosis of PCS, there is currently no formal assessment that definitively tests for PCS. All of these tests are standardized and have moderate test-retest reliability, but they do not assess functional cognition and are typically only used for assessing the presence or absence of concussion, not for documenting and tracking persistent symptoms during treatment and ongoing rehabilitation. While all of these assessments provide valuable information into deficits, most of these assessments require baseline data for accurate interpretation of deficits. Also, these standardized assessments are typically not sensitive enough to identify many of the cognitive deficits people experience during novel daily tasks of which are often endorsed on self-report measures.

Patient-reported outcome measures (PROMS) and self-report questionnaires are most commonly used to assess ongoing/persisting symptoms of mTBI/concussion (Hadanny & Efrati, 2016). While patients who have experienced severe traumatic brain injury routinely undergo extensive neuropsychological evaluation and neurocognitive rehabilitation, this is not typically the case for individuals with mTBI (Willer & Leddy, 2006). A group of professionals including clinicians that represented emergency medicine, family medicine, sports medicine, neurology, and physical medicine and rehabilitation, met in 2015 to conduct a systematic review and to update the current clinical practice guidelines for mTBI and persisting symptoms (McInnes et al., 2017). One of these guidelines directly addresses the need for neuropsychological assessment for individuals with persisting symptoms, "Patients who have cognitive symptoms that are not resolving and continue to interfere in daily functioning (e.g., school, work) should be considered for referral for neuropsychological assessment" (Marshall et al., 2015, p. 695). While further neuropsychological assessments may be warranted, given a shortage in physicians, it may take multiple weeks or more for someone to complete further testing ultimately prolonging time before treatment initiation. To gather a more holistic understanding of a person's symptoms, including self-report measures, standardized cognitive assessments, and a functional assessment of novel daily tasks may prove to be most beneficial in the care of a person who is experiencing persistent symptoms.

Improving the Assessment of PCS

While current research focuses on understanding the effectiveness of assessment and treatment of a variety of symptoms including sleep/wake disturbances, fatigue, vision dysfunction, and post-traumatic headache, cognitive deficits are infrequently addressed (Marshall et al., 2015). Improving the assessment of cognitive domains and functional cognition may improve the development of effective and efficacious interventions for individuals with persisting symptoms of mTBI. Self-report and standardized neurocognitive measures are currently being used to help determine if someone presents with persistent concussion symptoms, but no evidenced based assessment protocols exist that test cognitive skills in a natural environment (i.e., functional cognition).

The *Multiple Errands Test Revised* (MET-R, Shallice & Burgess, 1991), measures how impairments in executive performance affect cognitive functioning in natural contexts. By testing functional cognition, researchers and clinicians can increase ecological validity, and attempt to better detect the subtle, yet complex group of cognitive impairments. Individuals with mTBI typically perform relatively well when given standardized tests that follow a specific structure and routine, but perform poorly when completing functional tasks (Brown & Knollman-Porter, 2019). It is possible to have full cognitive impairment recovery, but awareness of the deficit must be achieved to help with recovery. Therefore, functional testing in natural environments can enhance awareness of deficits. Brown and Hux (2016) began adapting a modified *Multiple Errands Test (MET-R)* to assess task planning and execution followed by immediate execution of modified *MET* tasks on a college campus in the Midwest. They conducted a study to determine the feasibility of using ecologically-valid procedures to assess planning and execution of daily tasks by individuals with an acquired brain injury. The researchers were able to obtain information regarding the feasibility of completing a functional assessment with the assistance of nine participants who had sustained a mTBI. Throughout their research, they identified different ways to adapt the assessment procedure to enhance feasibility. They collected data for each participant including attempts made to complete tasks, accurate completion of tasks, rules violated, and strategies used. The researchers described that an individual with TBI may perform well in a structured or routine situation, such as a standardized assessment in a clinical setting, but they may struggle with tasks in a more natural environment. They found this to be true as exhibited by the participants' behaviors which ultimately lead to poor overall performance and rule violations. The authors concluded that creating adaptations of their current modified MET protocol may help rehabilitation professionals evaluate the strengths and weakness of an individual who has sustained a mTBI. Using the basic concepts of the protocol developed by the researchers allows for simple changes to be made for each unique environment in order to make this functional assessment extremely adaptable.

In 2017, Brown and Hux published a subsequent study including nine participants with acquired brain injury. Instead of asking participants to complete tasks in a specified environment like the modified MET-R used in their 2016 study, tasks for this study were completed in the participants' home. Brown and Hux (2017) also incorporated participants without TBI to identify variability that may be related to cognitive deficits resulting from the acquired TBI. All participants completed a planning phase and then were allotted ten days to complete eight different functional tasks in their home environment. The researchers collected data on task execution and strategies used. It took the participants anywhere from 3 minutes to 37 minutes to complete the task planning portion of the assessment. Participants with TBI completed on average 3.11 of the 8 tasks required while participants without TBI completed on average 6.67 of the 8 tasks. The researchers found that while participants with and without TBI did not differ significantly in the time they required for planning; however, participants with TBI completed substantially fewer tasks than those who did not have a TBI. Brown and Hux concluded that the measures developed in their study were more indicative in identifying cognitive deficits that impact successful completion of functional tasks in a real-world setting. While current standardized neurocognitive measures provide valuable information, a functional assessment, like that developed by Brown and Hux, may provide more insight into the subtle cognitive changes a person experiences in daily life post-concussion.

In 2019, Brown and Knollman-Porter conducted a study to evaluate the contribution of self-report measures and standardized measures in identifying deficits in individuals who have experienced a concussion. The researchers completed case studies on three participants who had a history of at least one concussion. Each participant completed the *Brain Injury Screening Questionnaire (BISQ)* to quantify symptoms, document past medical history, and identify history related to traumatic brain injury. After the participants completed the *BISQ* and a motivational interview, they then participated in four self-report measures and six standardized neurocognitive assessments. They found that all three participants endorsed experiencing at least 10 of the 100 *BISQ* items daily or several times, and from the self-report measures, the researchers identified challenges that were common within all three participants which included, independence, emotional well-being, and metacognition. While the participant's scores on self-report measures were similar, their performance on the standardized neurocognitive assessments were variable. However, patterns emerged between the three participants on their self-report measures and their performance on standardized assessments which the authors attributed to time postinjury. The researchers concluded that there is a clinical concern for the lack of sensitivity standardized assessments have in identifying subtle cognitive changes that are endorsed on self-report measures and motivational interviews. Therefore, indicating the need for a functional assessment that can identify the subtle cognitive changes recorded on self-report measures.

While it is evident that many people with mTBI experience long term cognitive effects of concussion, they are not getting needed cognitive-communication interventions to support return to school/work (Brown & Knollman-Porter, 2020). A disconnect exists between results stemming from standardized assessments and self-reports from the individuals with persisting symptoms. Brown and colleagues have continued to conduct research implementing protocols similar to the MET-R while continuing to utilize information obtained through standardized neurocognitive assessments and self-report measures to develop a functional multidimensional assessment to capture the cognitive-linguistic deficits of post-concussion syndrome. Speech-language pathologists and associated healthcare providers (e.g., athletic training) are ideally suited to assess and treat these persistent symptoms (Brown et al., 2019; Dachtyl & Morales, 2017).

The current study is an extension and adaptation of the three studies completed by Brown and colleagues (2016; 2017; 2019) mentioned above. The purpose of the current investigation is to determine how to better document ongoing cognitive-communication deficits and to characterize the nature of how these deficits impact daily life and communicative participation. Better documenting these persistent ongoing cognitive-communication deficits has the potential to improve implementation of effective interventions. This project explored the feasibility and acceptability of conducting a multi-dimensional assessment tool for individuals with concussion that integrates standardized cognitive assessment, self-report of cognitive communication symptoms, and ecologically valid functional assessment that is administered in natural contexts. The following research questions will be addressed:

1) Can the multi-dimensional assessment tool identify persisting symptoms of concussion and associated cognitive communication deficits in people with mTBI?
2) Is it feasible to administer to this multi-dimensional assessment tool to students, veterans, and community members using telehealth and COVID-19 pandemic adaptations in Montana?
3) What are some of the challenges that arise concerning the feasibility of administering this assessment?

METHODS

Research Design

This Phase I project aimed to investigate the feasibility and acceptability of administering a telehealth-delivered multidimensional evaluation of cognitive performance (MECP) to individuals who have incurred a concussion and who have persisting cognitive symptoms (PCS). This novel assessment protocol was designed to do the following: (1) target multiple cognitive domains simultaneously, (2) provide ecologically-valid insight into real-world participation, and (3) objectively document subtle deficits not indicated by other testing measures. The purpose of the MECP protocol is to facilitate the simultaneous use of interactive tasks, self-report, and standardized neurocognitive measures to explore the real-world deficits experienced by individuals with post-concussion syndrome.

A multiple case study design was selected to comprehensively document the cognitive-linguistic functioning of multiple individuals with concussion. This study design was adapted from studies completed by Brown and Knollman-Porter (2019) and Brown and Hux (2016; 2017). The multidimensional evaluation of cognitive performance (MECP) procedures occurred across a one- to two-week period for each participant; however, no more than three weeks passed between initial testing and completion. Total study time per participant did not exceed four hours and included: (1) one or two telehealth-based sessions (i.e., self-report measures, standardized assessments), (2) interactive campus-based task completion (with the researcher observing at a distance), and one independent task phase (i.e., task execution in the home setting). The order of task completion was not controlled during this feasibility/acceptability phase of the research.

Participants

Participants with mild traumatic brain injury/concussion were recruited through word of mouth, self-referral, or referrals from healthcare professionals (e.g., athletic trainers, speech-language pathologists, physical therapists, neurologists, physicians). Recruitment included email distribution lists, list serves, social media, and snowball emails that reached: (1) mTBI and concussion-related healthcare professionals; (2) University of Montana (UM) campus affiliates including but not limited to the Neural Injury Center, College of Health clinics (e.g., DeWit RiteCare Center, Athletic Training, Pharmacy, Physical Therapy, Social Work), the Veteran's Office; (3) regional researchers who regularly investigate mTBI/concussion; and (4) regional brain injury advocacy and education groups (e.g., Montana Brain Injury Alliance). Participants who contacted the researchers were provided with information about the study via email. Those who remained interested were scheduled for a telehealth-based meeting (via Zoom for Health Care) to discuss the project and consent documents. All procedures were approved by the University of Montana Institutional Review Board (UM IRB #4-21).

Following the guidelines used in Brown and Knollman-Porter (2019) which were adapted from the Centers for Disease Control and Prevention, a concussion was defined as any "bump, blow, or jolt to the head or by a hit to the body that caused the head and brain to move rapidly back and forth" (p.242). Participants with brain injury were in the post-acute stage – at least 30 days post self-reported injury. Inclusion criteria included: 18-50 years of age; spoke English as a primary language; and reported no history of a previous neurological condition (e.g., stroke, seizures), psychiatric history requiring hospitalization, or current chronic substance abuse. All participants completed the *Brain Injury Screening Questionnaire (BISQ;* Dams-O'Connor et al., 2014*)* prior to experiment completion to document TBI history, symptoms, and other health conditions. The BISQ rules out alternative explanations for symptoms and inferences can be made regarding the extent to which symptoms are specifically attributable to TBI. All mTBIs accounted for in this study were self-reported by each participant. No formal concussion diagnosis by a healthcare provider was made.

Fifteen people initially inquired about this study. Nine of those fifteen participated in a consent meeting, all of whom completed the consent documents. Five of these nine participants scheduled a session to complete the study with the researchers and attended all subsequent sessions. The five participants enrolled in this study included two females and three males. Each participant reported a history of at least one concussion. Participants ranged in age from 21 years old to 45 years old (M= 31.2, SD= 8.67). All participants completed some higher education and all but one lived within the city limits of a city with a population of over 50,000 people. See Table 1 for a summary of participant demographic and concussion information.

Table 1

Participant Demographic and Concussion Information

Participant ID	Age	Race	Level of Education	# of self-reported mTBIs	Most Recent mTBI
TBI-001	30	Caucasian	Some College	5	2020
TBI-002	29	African-Russian	Some College	11	2021
TBI-003	31	Caucasian	Bachelor’s	21	2021
TBI-004	45	African-American	Associate’s	10	2018
TBI-005	21	Caucasian	Associate’s	50	2021

Participant 1

Participant 1 is a 30-year-old Caucasian female. She lives with other people within the city limits of a town with a population greater than 50,000 people. She reported completing some graduate classes, but did not obtain a degree. Per her BISQ, she has no outstanding health history, but has been hospitalized due to multiple bone fractures from 1997 through 2020. At the time of this study, Participant 1 reported moving to a new city to start a new job, but cognitive deficits stemming from her concussions were negatively impacting everyday activities. Participant 1 reported that she had cognitive deficits prior to her most recent concussion and that the most recent concussion exacerbated the deficits.

Participant 1 experienced her first two concussions in 2012, resulting from falls during biking/rollerblading/skateboarding and skiing/snowboarding, respectively. She reported no loss of consciousness for either injury, but did experience periods of confusion lasting 1 to 10 minutes and 11 to 20 minutes following the injuries, respectively. Participant 1 experienced a third concussion in 2014 with a period of confusion lasting less than one minute, that was the result of her, as a pedestrian, being hit by a vehicle. In 2017 and 2020, Participant 1 experienced two more concussions occurring from falls while biking/rollerblading/skateboarding. After both of these concussions, Participant 1 reported a period of confusion lasting 11 to 20 minutes. From 2012 to 2020, Participant 1 experienced five concussions with the most recent occurring in 2020.

As documented in the BISQ, Participant 1 reported on the daily difficulties she has experienced over the past month and the frequency of their occurrence. Most of her difficulties were experienced one to two times within the month. These difficulties included physical changes like clumsiness, dropping or tripping over things, losing balance, headaches, and feeling cold. Difficulties related to cognition that Participant 1 experienced included thinking and learning slowly, difficulty concentrating or paying attention, losing her train of thought, difficulty solving problems, difficulty learning new skills or information, and difficulties with speed and retention when reading. Participant 1 also reported experiencing socioemotional symptoms of which included not listening when being talked to, feeling impatient or irritable, having repeated thoughts and feeling sad. Participant 1 selected 15 of the possible 100 symptoms on the BISQ as experiencing them one to two times within the month, and 1 of the possible 100 experiencing that symptom "several times in the past month."

Participant 2

Participant 2 is a 29-year-old African-Russian male. He lives alone within the city limits of a town with a population greater than 50,000 people. He is currently a university student of sophomore standing. He has completed some college but has not yet obtained a degree. Per his BISQ, he has no outstanding health history, but has been hospitalized due to high fever/seizures during which he experienced a period of confusion lasting 21 to 30 minutes in 2011. Participant 2 reported moving to the United States as a child and experiencing multiple episodes of physical violence while residing in his home country.

Participant 2 experienced his first two concussions in 2002, both of which were the result of assault. During one of these concussions, he reported losing consciousness for less than one minute, followed by a period of confusion lasting 11 to 20 minutes. He reported his third concussion with a period of confusion lasting 1 to 10 minutes occurring in 2003. This concussion was the result of physical abuse. In 2007, Participant 2 was hit by a falling object on three separate occasions, two of which resulted in a loss of consciousness lasting less than a minute, followed by five periods of confusion lasting a range of one day to one week. When Participant 2 moved to the United States he participated in organized sports which resulted in his next three concussions during the year 2009. One of these concussions resulted in a loss of consciousness for less than a minute and a period of confusion lasting up to one week. In 2014, Participant 2 reported a concussion due to a drug or alcohol blackout which included a period of confusion of

1 to 10 minutes. Participant 2's most recent concussion occurred in 2021 and was the result of a fall while skiing/snowboarding. He reported feeling confused for less than a minute after this concussion. Overall, Participant 2 has experienced eleven concussions from the years 2002 to 2021.

As documented in the BISQ, Participant 2 reported on the daily difficulties he has experienced over the past month and the frequency of their occurrence. He reported difficulties with physical changes including trouble falling or staying asleep, difficulty waking up, nightmares, blacking out or seizures, clumsiness, double or blurred vision, little or no appetite, and headaches. Difficulties with cognition which Participant 2 reported experiencing included difficulty concentrating, being easily distracted, losing his train of thought, forgetting to eat, do chores, homework or household work, forgetting well-known phone numbers and addresses, losing track of time and being disorganized, and difficulties with making decisions. Participant 2 reported many difficulties in regards to rate at which he learned new information. Socioemotional symptoms that Participant 2 reported having difficulties with included constructs of a conversation, feeling frustrated, angry, sad, lonely, impatient, hopeless, and not confident. Participant 2 reported feeling impulsive and having difficulty coping with unexpected change. Participant 2 rated 44 of the 100 possible symptoms as things he experiences "daily or almost daily", 13 out of the 100 possible symptoms as things he experiences "several" times a day and 11 out of the 100 possible symptoms as things he experiences "1 to 2 times a month".

Participant 3

Participant 3 is a 31-year-old Caucasian male. He lives alone, 60 miles outside of the closest city with a population of 25,000 or greater. He reported obtaining a Bachelor's degree and is not currently a student. Per his BISQ report, he was diagnosed with a personality disorder at age 21 and hypertension at age 31. He was hospitalized in 2009 due to a concussion resulting from a blast injury while in combat.

Participant 3 experienced his first concussion followed by multiple others as the result of physical abuse during the 1990s. He experienced more concussions from physical abuse in 2007, 2008 and 2009. In 2008, Participant 3 experienced three concussions from assault, with one resulting in a period of confusion lasting less than a minute. Participant 3 reported verbally that his most significant concussion occurred from a blast injury he experienced during combat in 2009 at which time he lost consciousness for an unknown amount of time followed by a period of confusion. This verbal report was supported by his BISQ report. From 2009 to present day, Participant 3 has experienced approximately ten concussions from motor vehicle accidents, two concussions from being hit by equipment, and one concussion from biking/rollerblading/skateboarding. He reported undisclosed number of concussions from sports and falling object that have occurred during his adult life.

As documented in the BISQ, Participant 3 reported on the daily difficulties he has experienced over the past month and the frequency of their occurrence. He reported difficulties with physical changes including trouble falling or staying asleep, trouble staying awake, clumsiness, losing his balance, feeling cold, feeling dizzy, ringing in his ear or difficulty with hearing, double or blurred vision, little or no appetite, feeling tired, moving slowly, increased or decreased sexual desire or behavior, and headaches. Difficulties with cognition which Participant 3 reported experiencing included thinking slowly, difficulty concentrating, being confused in a familiar place, being easily distracted, losing his train of thought, forgetting well-known phone numbers, addresses, and names of common objects, losing track of time and being disorganized, and difficulties with making decisions and following instructions. Participant 3 reported difficulties with his rate of reading and his retention of information read. Difficulties with unexplained changes at work or school were among some of the symptoms experienced by Participant 3. Socioemotional symptoms that Participant 3 reported having difficulties with included constructs of a conversation, difficulties with social constructs such as understanding jokes and making inappropriate comments. Participant 3 reported feeling frustrated, angry, bored yet restless, hopeless, and having difficulty coping with unexpected change. Participant 3 rated 7 of the 100 possible symptoms as things he experiences "daily or almost daily", 12 out of the 100 possible symptoms as things he experiences "several" times a day and 53 out of the 100 possible symptoms as things he experiences "1 to 2 times a month".

Participant 4

Participant 4 is a 45-year-old African-American female. She lives alone within the city limits of a town with a population greater than 50,000 people. She reported completing her Associate's degree and is currently a university student of senior standing. Per her BISQ report, she was diagnosed with a thyroid disorder at age 30, anxiety at age 31, muscle/bone problems at age 32, and chronic pain at age 36. She reported no hospitalizations.

Participant 4 experienced her first concussion when she hit her head on the inside of an enclosed water slide that led to a period of confusion for up to a week in 2007. In 2009, Participant 4 sustained a second concussion that included a loss of consciousness for up to 23 hours followed by a period of confusion that lasted up to a week from physical abuse. Also in 2009, Participant 4 was assaulted which led to a concussion resulting in a loss of consciousness for up to 23 hours followed by a period of confusion lasting over a month. Participant 4 reported four concussions in 2012 from different falling incidents, two of which resulted in a loss of consciousness for up to 23 hours, and one period of confusion lasting up to a week. During 2014, Participant 4 sustained a concussion after being assaulted. After this incident she reported a loss of consciousness for up to 23 hours followed by a period of confusion lasting over a month. Participant 4 experienced her two most recent concussions in 2018, both results of motor vehicle accidents one of which was followed by a loss of consciousness for less than a minute and a period of confusion lasting up to a week. From 2007 to 2018, Participant 4 experienced ten concussions.

As documented in the BISQ, Participant 4 reported on the daily difficulties she has experienced over the past month and the frequency of their occurrence. She reported difficulties with physical changes including trouble falling or staying asleep, trouble staying awake, difficulty waking up, nightmares, clumsiness, losing her balance, feeling cold, feeling dizzy, ringing in his ear or difficulty with hearing, double or blurred vision, little or no appetite, food not tasting right, feeling tired, moving slowly, increased or decreased sexual desire or behavior, and headaches. Difficulties with cognition which Participant 4 reported experiencing included thinking slowly, difficulty concentrating, being easily distracted, losing her train of thought, forgetting what she said, forgetting names of people and names of common objects, misplacing items, being disorganized, and difficulties with making decisions and following instructions. Participant 4 reported difficulties with cognitive functions which impact her academics including writing slowly, poor handwriting, spelling mistakes, reading slowly and understanding what she read. Socioemotional symptoms that Participant 4 reported included having difficulties with constructs of a conversation, avoiding family and friends, feeling uncomfortable around others, and difficulty starting things. Participant 4 rated 9 of the 100 possible symptoms as things he experiences “daily or almost daily”, 18 out of the 100 possible symptoms as things he experiences “several” times a day and 31 out of the 100 possible symptoms as things he experiences “1 to 2 times a month”.

Participant 5

Participant 5 is a 21-year-old Caucasian male. He lives with other people within the city limits of a town with a population greater than 50,000 people. He reported obtaining his Associate’s degree and is currently a university student with junior standing. Per his BISQ report, he was diagnosed with a behavioral disorder at age 5, major depressive episodes at age 13, respiratory disorder at age 14, anxiety at age 17, muscle/bone problems at age 18, and bipolar/manic disorder, substance abuse and ADD/ADHD at age 20. He has been hospitalized in 2010 and 2015 for concussions and high fevers/seizures resulting in a loss of consciousness for 1 to 10 minutes followed by confusion for up to one week. He also reported being hospitalized for multiple broken bones and an injury involving his kidneys. Participant 5 completed all portions of this study using a telehealth modality.

Participant 5 experienced his first concussion in 2010 from a fall while skiing/snowboarding. He also reported sustaining a concussion from skiing/snowboarding in 2014 and 2017. In 2010, 2015, and 2018, Participant 5 experienced approximately 15 concussions while playing sports, three of which resulted in a loss of consciousness for 1 to 10 minutes followed by a period of confusion lasting up to one week. Participant 5 experienced two concussions in 2013 due to physical abuse. From 2015 to 2019, Participant 5 sustained approximately 20 mTBIs from being hit by a falling object and two concussions from being hit by equipment. Of those concussions, two resulted in a loss of consciousness, and approximately ten resulted in periods of confusion lasting up to a week. Participant 5 experienced one concussion in 2017 due to a motorcycle/ATV accident. Participant 5 experienced his two most recent concussions in 2021, one was sustained while falling from a high place which resulted in a loss of consciousness for up to a week followed by confusion and the other was sustained from a fall while he was “blacked out from drugs or alcohol” resulting in a loss of consciousness for up to 23 hours, followed by confusion. From 2010 to 2021, Participant 5 has experienced over approximately 50 concussions.

As documented in the BISQ, Participant 5 reported on the daily difficulties he has experienced over the past month and the frequency of their occurrence. He reported difficulties with physical changes including trouble falling or staying asleep, trouble staying awake, difficulty waking up, nightmares, clumsiness, losing her balance, feeling cold, feeling dizzy, ringing in his ear or difficulty with hearing, double or blurred vision, eating too much, food not tasting right, moving slowly, and increased or decreased sexual desire or behavior. Difficulties with cognition which Participant 5 reported included thinking slowly, difficulty concentrating, being easily distracted, losing his train of thought, forgetting what he said and recent events, forgetting names of people and names of common objects, misplacing items, and difficulties with making decisions and following instructions. Participant 5 reported difficulties with cognitive functions which impact his academic performance including learning slowly, poor handwriting, spelling mistakes, reading slowly and difficulty with reading, writing and math. Socioemotional symptoms that Participant 5 reported included having difficulties with constructs of a conversation, rapid mood changes, repeated thoughts, inappropriate comments and behaviors, crying easily or for an unknown reason, feeling lonely, sad, misunderstood, impulsive, and difficulties with coping with change. Participant 5 rated 24 of the 100 possible symptoms as things he experiences “daily or almost daily”, 29 out of the 100 possible symptoms as things he experiences “several” times a day and 22 out of the 100 possible symptoms as things he experiences “1 to 2 times a month”.

Procedures

Participants with a mild traumatic brain injury completed the following study procedures across 3-5 sessions, at the convenience of the participant. These procedures occurred across a one- to two-week period for each participant; however, no more than three weeks passed between initial screening and completion of the protocol.

Asynchronous Remote Screening

Following enrollment, consent procedures, and study information consultation, participants were instructed to asynchronously complete the *Brain Injury Screening Questionnaire (BISQ)* via an online Qualtrics survey to document the presence or absence of brain injury. The link and instructions to completing this Qualtrics-based measure were emailed to the participant.

Synchronous Remote Telehealth Assessment

During the initial telehealth session (via Zoom for Healthcare), the researcher(s) asked participants several screening questions about vision, hearing, and reading to ensure adequate abilities to participate in experimental tasks. After initial screening and BISQ completion, participants completed four cognitive assessments (usual care cognitive measures) and four self-report measures (NIH toolbox, evidence-based) during a telehealth session. All assessments and self-report measures were completed during one telehealth session.

Participants completed the following self-report measures (via Qualtrics) while logged into Zoom for Healthcare:

1. **Behavior Rating Inventory of Executive Functioning – Adults (BRIEF-A; Roth, Isquith & Gioia, 2005).** This 10-minute, 75-item measure included 9 scales (inhibition, self-monitoring, planning/organization, shifting, initiation, task monitoring, emotional control, working memory, organization) and created 3 scores: Behavioral Regulation, Global Executive Composite, Metacognition. This measure has a moderate inter-rater reliability but a high internal consistency and test-retest reliability. The score range for this measure was 75 – 225 with higher scores indicating symptoms having a more severe impact on daily function.
2. **Quality of Life after Brain Injury (QOLIBRI; von Steinbuchel et al., 2010).** This 10-minute, 37 item measure covered 6 quality of life dimensions – cognition, self, daily life & autonomy, social relations, emotions, and physical problems – as well a total score. Questions were coded as *satisfaction* or *feeling bothered* items and were queried using a 5-point Likert type scale. This measure has good internal consistency and test-retest reliability. The score range for this measure was 37 – 185 with higher scores indicating a lower quality of life satisfaction.
3. **Neuro-QOL Cognitive Function Measure (Gershon et al., 2012)**. This 5 minute, 28-question measure queried individuals about current difficulties with cognitive functions as well as difficulties experienced over the previous 7-day period. Respondents indicated frequency using a 5-point Likert type scale. This measure has good construct validity and

interrater reliability. The score range for this measure was 28 – 140 with higher scores indicating experiencing difficulties with cognitive function more frequently over a 7-day period.

4. **PROMIS Cognitive Function Measure (Becker et al., 2014)**. This 5 minute, 32-question measure queries individuals about cognitive function across the previous 7-day period using a 5-point Likert type scale. This measure is highly reliable and valid. The score range for this measure was 32 – 160 with higher scores indicating poor satisfaction of their cognitive function over the past 7 days.

Participants were administered the following standardized cognitive assessments (with instructions provided orally and via PowerPoint) while being logged into Zoom for Healthcare:

1. **Weschler Adult Intelligence Scale IV – Digit Span; Sequencing (Weschler, 1955):** This 6-minute measure assessed attention and working memory. This assessment has high interrater agreement, test-retest and internal reliability, as well as concurrent and construct validity. The score range for this assessment was 0 – 16 for both the forward portion and the backward portion. Higher scores indicated better attention and working memory skills.
2. **Hopkins Verbal Learning Test-Revised (Brandt & Benedict, 2001).** This 5-10-minute measure assessed new learning ability. This assessment has a high test-retest reliability and was determined a valid assessment with normative data. The score range for this assessment was 0 – 12 for both the immediate and delayed recall portions. Higher scores indicated a higher ability for learning new material.
3. **Controlled Oral Word Association Test – F, A, S, Animals (Ruff et al., 1996):** This 6-minute measure assessed flexibility of thought by assessing verbal fluency. This assessment

has excellent interrater and test-retest reliability. There was no defined score range for this assessment. Individuals who score higher on this assessment demonstrate greater verbal fluency and flexibility skills.

4. **Delis-Kaplan Executive Function System Color-Word Interference (Delis, Kaplan & Kramer, 2001):** This 5-minute measure assessed attention and inhabitation. This assessment is both a reliable and valid source for identifying cognitive changes specifically for individuals with moderate to severe cognitive dysfunction. The score range for this assessment is 0 – 100 for all three separate trials. Individuals who score higher on this assessment, specifically on the third trial, demonstrate greater attention and inhibition skills.

Functional, Integrative Measures in Naturalistic Environments

Integrative cognitive tasks focused on task planning and execution in natural settings. This assessment occurred in two contexts. First, participants planned for and executed tasks in the presence of the researcher within a natural environment (i.e., university campus). Second, participants planned for and executed tasks independently in their home environment.

Task Execution in the Presence of the Researcher.

Participants created a plan using only a provided 12-item task list and 10 rules to determine task execution. This task was based on the *Multiple Errands Test,* a measure used by rehabilitation professionals that allows for adaptation to a testing site (Brown, & Hux, 2016; Brown & Hux, 2017). A version for the University of Montana campus was created that was appropriate for Missoula's recommendations for COVID-19 safety and mitigation. As specified by the *Multiple Errands Test,* six tasks required the retrieval of items, one task required meeting the examiner 15 minutes after starting, and the final task required the participants to state when they have finished (by texting or phoning the researcher). Task rules required participants to complete all tasks in any order of their choosing. Participants were not allowed to enter any personal office space, go back to a location which they had already been, or enter a location for a reason other than task completion. Participants were not allowed to speak to the researcher unless part of the exercise. Using Zoom for Healthcare, the participant was asked to show the researcher that they had the following items: paper/writing tool, a smart phone/tablet OR a watch, Griz Card, a map of the UM campus (PDF, link, or via UM app), a face mask, and portable hand sanitizer.

The researcher then reviewed the **Task List** and **Rule List** with the participant by sharing their screen on Zoom for HealthCare (see Appendix A). The researcher instructed the participant to read the Task List and the Rule List. Once the participant had read these, they were asked to develop a plan for task completion using a paper and a writing tool. The researcher told the participant that the Task List and Rule List would not be available following planning; however, the participant could retain or had access to all other materials for task completion (i.e., personal planning document, watch/phone, and map). No time limit was imposed on the length of planning. During planning, the researcher performed "momentary time sampling" at two-minute intervals to record the participant's strategies and behaviors (observable via Zoom). Additional data collected during the planning time included: (1) total time spent planning, and (2) number of information units recorded during self-generated planning notes.

Once the participant indicated that their plan was complete, task execution commenced. The researcher met the participant at the Oval/Bear on the UM Campus and followed the participant at an approximate distance of 6-15 feet and recorded percent of attempted tasks

(X/12), percent of accurately completed tasks, number and frequency of rule violations (X/10), and strategy use. At no time were the participant and researcher closer than 6 feet apart. Participants and researchers were required to wear masks.

Independent Task Execution in Home Environment.

During a Zoom for Healthcare meeting, participants were asked to plan for home environment tasks. Participants were asked to have paper, a writing tool, and a calendar. The researcher reviewed the **Task Menu** document and the **Task Rules** document with the participant by sharing their screen. The **Task Menu** included 25 potential activities for a participant to complete over the subsequent 10-day period (see Appendix B). Each task required participants to create a permanent product as a record of task completion. Participants selected five personally motivating tasks to complete over the 10-day period according to a set of six pre-determined rules (e.g., participants cannot begin until the next day and tasks must be completed over 10 days).

During planning efforts, the researcher performed momentary time sampling at two-minute intervals to record strategy use and behaviors. Each participant completed their self-selected tasks across 10-days using only their planning document, **Task Rules** document, and calendar, as desired. Participants also completed a **Task Completion** document to help the researcher identify strategies used for completion. Adherence to rules was monitored based on the permanent products received following task completion. For example, researchers were aware of rule violations stating that a participant cannot complete more than one task per day when permanent products of more than one task were received (e.g., receipt of phone call and email on same day). Dependent variables included percent of attempted tasks (X/5), percent of successfully completed tasks (X/5), and number and frequency of rule violations.

Data Collection and Analysis

Data was collected from three different sources: (1) self-report measures, (2) standardized cognitive measures, and (3) functional, integrative measures. We analyzed all standardized cognitive assessments and self-report measures according to the assessment manuals and/or published normative data. We then identified a mean score accompanied by a standard deviation for each standardized assessment. Data derived from the standardized assessments was calculated using the test manuals for each respective test including the *Hopkins Verbal Learning Test – Revised*, *Weschler Adult Intelligence Scale – 4th Edition*, and *Delis-Kaplan Executive Function System Color-Word Interference (STROOP Test)*. Scores were calculated for each individual trial of *Controlled Oral Word Association Tests* and then a mean score was calculated and interpreted using the revised Heaton norms (M = scaled score of 10, SD = scaled score of 3; Heaton, Milller, Taylor, & Grant, 2004). Data interpretation for the self-report measures was adapted from a model used by Brown and Knollman-Porter (2019). This interpretation utilized an affiliated scoring system from the NIH Toolbox, the *BRIEF-A* testing manual, and *QOLIBRI* publications. Means and standard deviations for the self-report measures were adapted from participant responses.

The functional assessment portion of the test battery was analyzed using both qualitative and quantitative measures. Quantitative data was collected in the form of the number of tasks attempted, the number of tasks accurately completed, the number of rules violated, the frequency of rule violations, the time to complete all tasks, and the amount of time to complete task planning for both in-person and at-home tasks. Qualitative observations were completed throughout the duration of the functional assessment portion of this study. The researchers noted any questions asked during the task planning portion for both in-person and at-home tasks, reason for failure of task completion, strategies used to execute in-person MET tasks, and tasks chosen for at-home execution. To help interpret feasibility and acceptability of using a functional multidimensional assessment, data was collected to identify portions of assessment that increased ease of administration and deficits in the assessment process.

RESULTS

The following sections highlight a summary of participant data followed by individual data derived from standardized cognitive assessments, self-report measures, and functional integrative measures. Providing information in this format allowed us to feature the unique profiles of each participant in a multiple case study format. Raw scores for each participant's self-report measures are located in Table 2, raw scores for each participant's standardized scores are located in Tables 3a and 3b, and quantitative information and strategies derived from the functional integrative measures are located in Tables 4 and 5. On almost all of the standardized neurocognitive assessments, participants scored within normal limits. Performance of less than one to two standard deviations from the mean on the standardized neurocognitive assessments is indicated in Table 3a.

Table 2

Raw Scores for Self-Report Measures

Participant ID	*BRIEF-A* (R: 75 - 225)	*QOLIBRI* (R: 37 – 185)	*NEURO-QOL* (R: 28 - 140)	*PROMIS* (R: 32 - 160)
TBI-001	77	47	32	37

TBI-002	147	137	113	137
TBI-003	122	117	62	85
TBI-004	127	109	58	87
TBI-005	154	113	86	109

R = Range of possible scores

Table 3a

Raw Scores for Standardized Cognitive Assessments

Participant ID	*HVLT Immediate Recall* (max = 12)	*HVLT Delayed Recall* (max = 12)	*COWAT Letter*	*COWAT Category*
TBI-001	8*	9	12.34	21.5
TBI-002	6*	7*	13.67	20
TBI-003	8*	10	13.33	22.5
TBI-004	6.33*	7*	14.67	20.5
TBI-005	7.33*	6*	10	20.5

* Indicates scores 1-2 SD below normal limits

Table 3b

Raw Scores for Standardized Cognitive Assessments

Participant ID	*DigitSpan* (Forward) (max = 16)	*DigitSpan* (Backward) (max = 16)	*Stroop* (Colors) (max = 100)	*Stroop* (Words) (max = 100)	*Stroop* (Blocks) (max = 100)
TBI-001	10	11	92	100	65
TBI-002	11	10	76	74	49

TBI-003	8	12	34	100	25
TBI-004	8	11	68	100	48
TBI-005	8	11	78	80	62

Table 4

MET Information

Participant ID	Planning Time	Completion Time	Tasks Attempted	Tasks Completed	Rules Violated
TBI-001	21 mn 24 sec	30 mn 38 sec	12/12 (100%)	6/12 (50%)	1
TBI-002	15 mn 57 sec	60 mn 42 sec	10/12 (83%)	5/12 (41%)	1
TBI-003	5 mn 45 sec	49 mn 23 sec	9/12 (75%)	5/12 (41%)	1
TBI-004	13 mn 7 sec	48 mn 0 sec	11/12 (91%)	10/12 (83%)	0
TBI-005	10 mn 5 sec	55 mn 0 sec	12/12 (100%)	11/12 (91%)	0

Table 5

Strategies Used by Participants to Complete MET

Participant ID	Self-talk	Environmental Resources	Provided Resources	Personal Resources	Multi-tasking
TBI-001	X	X	X		
TBI-002			X	X	
TBI-003	X		X	X	
TBI-004	X	X	X		
TBI-005					X

Three males and two females completed all portions of this study. Three participants were Caucasian, one participant was African-American, and one participant was African-Russian. All participants were 21-years old or older (M= 31.2, SD= 8.67, Range= 21-45). As reported on the BISQ, each participant had sustained at least one concussion at least 36 months prior to the study, but all but one participant had experienced more than ten concussions in their lifetime. The total number of concussions participants had experienced in their lifetime ranged from five to approximately fifty (M= 19.4, SD= 18.1, Range 5-50). All participants completed some higher-level education with two participants obtaining and Associate's degree and one participant obtaining a Bachelor's degree. All participant with the exception of Participant 3 lived within the city limits of a town larger than 50,000 people. Participant 1and Participant 2 reported no outstanding health information. Participant 3 reported being diagnosed with personality disorder at 21-years-old and hypertension at 31-years-old. Participant 4 reported being diagnosed with thyroid disorder at age 30, anxiety at age 31, muscle/bone problems at age 32, and chronic pain at age 36. Lastly, Participant 5 reported seven medical diagnoses from age 5 to age 20, including ADD/ADHD, substance abuse, Bipolar/Manic disorder and anxiety. As reported on the BISQ, all participants endorsed difficulties with socioemotional symptoms, some physical symptoms including clumsiness and cognitive deficits including slowed thinking, difficulty learning new information and distractibility. Participant demographic and concussion information can be found in Table 1.

The first portion of the assessment protocol included the standardized cognitive assessments and self-report measures. On average, it took the participants approximately 55 minutes to complete this portion of the assessment protocol (M=54.48, SD=9.98 Range= 50.04-71.41). Average scores for the standardized cognitive assessments included *Hopkins Verbal Learning Test Immediate Recall* (M=7.13, SD= 0.93, Range= 6-8), *Hopkins Verbal Learning Test Delayed Recall* (M=7.8, SD= 1.64, Range= 6-10), *Controlled Oral Word Association Test Letters* (M=12.8, SD= 1.77, Range= 10-14.67), *Controlled Oral Word Association Test*

Categories (M=21, SD= 1, Range= 20-22.5), D*igitSpan Forward* (M=9, SD= 1.4, Range= 8-11), *DigitSpan Backwards* (M=11, SD= 0.71, Range= 10-12), *Color-Word Interference Blocks* (M=69.6, SD= 21.7, Range= 34-92), *Color-Word Interference Color Names* (M=90.8, SD= 12.77, Range= 74-100), *Color-Word Interference Colored Blocks* (M=49.8, SD=15.8, Range= 25-65).

All four of the self-report measures (*BRIEF-A*, *QOLIBRI*, *PROMIS*, and *NEURO-QOL*) were scored using a numerical system which correlated to a verbal phrase (i.e., 1= never, 2 = rarely, 3 = sometimes, 4 = often, 5 = always). For the *QOLIBRI*, participants had an overall average score of approximately 104, which indicated participants mostly rated answers of a 2 or a 3 which for this assessment indicated they experienced certain symptoms “slightly” or “moderately” (Overall M= 104.6, Overall SD= 33.95, Individual Rating M= 2.8, Range= 47-137). For the *Neuro-QOL*, participants had an overall average score of approximately 70, which indicated participants mostly rated answers of a 2 or a 3 which for this assessment indicated they experienced certain symptoms “a little” or “somewhat” (Overall M= 70.2, Overall SD= 30.65, Individual Rating M= 2.51, Range= 32-113). For the PROMIS, participants had an overall average score of 91, which indicated participants mostly rated answers of a 2 or a 3 which for this assessment indicated they experienced certain symptoms “rarely” or “sometimes” (Overall M= 91, Overall SD= 36.77, Individual Rating M= 2.84, Range= 37-137). For the BRIEF-A, participants had an overall average score of approximately 125, which indicated participants mostly rated answers of a 1 or a 2 which for this assessment indicated they experienced certain symptoms “never” or “sometimes” (Overall M= 125.4, Overall SD= 30.17, Individual Rating M= 1.67, Range= 77-154). Collectively, the multidimensional portion of this assessment, the MET, took the participants approximately 49 minutes to complete (M= 48.74, SD=11.3, Range=

30.63-55). The average number of tasks attempted by participants was approximately 11 (M=10.8, SD= 1.3, Range= 9-12) while the average number of tasks completed was around 7 (M=7.4, SD= 2.88, Range= 5-11). A summary of the scores for the self-report measures and standardized cognitive assessments can be found in Table 6 and Table 7.

Table 6

Summary of Self-Report Measure Scores

Assessment	Mean	Standard Deviation	Individual Rating	Range
BRIEF-A	125.4	30.17	1.67	77-154
NEURO-QOL	70.2	30.65	2.51	32-113
PROMIS	91	36.77	2.84	37-137
QOLIBRI	104.6	33.95	2.8	47-137

Table 7

Summary of Standardized Cognitive Assessment Scores

Assessment	Mean	Standard Deviation	Range
HVLT (Immediate Recall)	7.13	0.93	6-8
HVLT (Delayed Recall)	7.8	1.64	6-10
COWAT (Letters)	12.8	1.77	10-14.67
COWAT (Categories)	21	1	20-22.5
DigitSpan (Forward)	9	1.4	8-11
DigitSpan (Backward)	11	0.71	10-12
Stroop (Colors)	69.6	21.7	34-92
Stroop (Words)	90.8	12.77	74-100
Stroop (Blocks)	49.8	15.8	25-65

Participant 1

Cognitive Assessments and Self-Report Measures

Participant 1 is a 30-year-old Caucasian female with a total of five concussions and her most recent concussion occurring in 2020. The first portion of the study lasted 50 minutes and four seconds for Participant 1. While completing the COWAT, Participant 1 required a break after finishing the second letter due to a distraction in her home environment. After she relocated her computer, she was able to continue on with testing without further distraction. After the entirety of the COWAT portion of the assessment, Participant 1 asked for a short break and was ready to resume testing after approximately 3 minutes. Participant 1 scored a 77 on the *BRIEF-A*, 32 on the *NEURO-QOL*, 37 on the *PROMIS*, and 47 on the *QOLIBRI*. Participant 1's scores on the self-report measures indicated difficulty with concentration, metacognitive behaviors, mental math and reading, and feelings of loneliness and anxiety. Participant 1 scored almost two standard deviations below the mean on all self-report measures. Participant 1 scored an average of 8 on the three trials for immediate recall and 9 on the delayed recall for the *HVLT*. On the *COWAT,* Participant 1 scored a 12.34 for average letter generation and a 21.5 for average categorical generation. Participant 1 scored a 10 on the forward *DigitSpan* and an 11 on the backwards *DigitSpan.* Finally, Participant 1 scored a 92 on the *Color-Word Interference Blocks*, a 100 on the *Color-Word Interference Color Names,* and a 65 on the *Color-Word Interference Colored Blocks.* Despite reporting some deficits on the self-report measures, Participant 1 demonstrated typical cognitive behavior for all standardized cognitive assessments except one scoring at or above the mean by two standard deviations. Individual scores for all cognitive assessments and self-report measures are located in Table 8a and 8b.

Table 8a

Participant 1 Self-Report Measure Scores

Brief-A	*QOLIBRI*	*NEURO-QOL*	*PROMIS*
77	47	32	37

Table 8b

Participant 1 Standardized Cognitive Assessment Scores

HVLT Immediate Recall	*HVLT Delayed Recall*	*COWAT Letter*	*COWAT Category*	*DigitSpan Forward*	*DigitSpan Backward*	*Stroop Colors*	*Stroop Words*	*Stroop Blocks*
8	9	12.34	21.5	10	11	92	100	65

Modified Multiple Errands Task

Participant 1 completed the planning portion for the MET in 21 minutes and 24 seconds. Throughout the planning phase, Participant 1 asked six questions to clarify how the tasks had to be executed, location and name of specific buildings, and if there were any restrictions on campus given that she was not currently a student. She utilized self-talk throughout her planning process. After meeting the researchers on campus, Participant 1 completed the MET in 30 minutes and 38 seconds. Of the 12 possible tasks, Participant 1 attempted all 12 tasks but only successfully completed 6 of them. Participant 1 had one rule violation occurrence. During the MET, Participant 1 utilized environmental resources and provided resources as well as multi-tasking for task execution. Participant 1 successfully completed all tasks for the at-home portion of the MET and sent her document explaining how she executed the at-home tasks after the 10-days had expired. Information on Participant 1's MET completion is located in Table 8c.

Table 8c

Participant 1 MET Completion

Planning Time	Completion Time	Tasks Attempted	Tasks Successfully Completed	Number of Rule Violations	At-home Tasks Successfully Completed
21mn 24 sec	30 mn 38 sec	12/12 (100%)	6/12 (50%)	1	5/5

Participant 2

Cognitive Assessments and Self-Report Measures

Participant 2 is a 29-year-old African-Russian male with a total of eleven concussions and his most recent concussion occurring in 2021. Participant 2 required 1 hour, 11 minutes and 41 seconds to complete the first portion of the study. Participant 2 demonstrated some difficulty with following directions for navigating the telehealth platform when initially starting the cognitive assessment portion which he reported was due to his lack of experience using "Zoom". After completing the delayed recall portion of the assessment, Participant 2 asked for a break that lasted approximately 2 minutes. Participant 2 reported substantial deficits related to his brain injury that have decreased his quality of life and ability to complete daily activities. During the self-report measures, he indicated difficulty with physical performance, conversating with others, decision making, remembering new and old information, concentration, and metacognitive behaviors. Participant 2 scored a 147 on the *BRIEF-A,* 113 on the *NEURO-QOL*, 137 on the *PROMIS,* and 137 on the *QOLIBRI*. Participant 2 scored at least one standard deviation above the mean on all self-report measures. Participant 2 scored an average of 6 on the three trials for immediate recall and a 7 on the delayed recall for the *HVLT*. On the *COWAT,* Participant 2 scored a 13.67 for average letter generation and a 20 for average categorical generation. Participant 2 scored an 11 on the forward *DigitSpan* and a 10 on the backwards *DigitSpan.* Finally, Participant 2 scored a 76 on the *Color-Word Interference Blocks*, a 74 on the *Color-Word Interference Color Names*, and a 49 on the *Color-Word Interference Colored Blocks.* Despite reports of significant deficits on the self-report measures, Participant 2 scored within normal limits on all but two subtests. Participant 2 demonstrated deficits in the delayed and immediate recall portions of the *Hopkins Verbal Learning Test,* scoring one to two standard deviations below the mean. Individual scores for all cognitive assessments and self-report measures are located in Table 9a and 9b.

Table 9a

Participant 2 Self-Report Measure Scores

Brief-A	*QOLIBRI*	*NEURO-QOL*	*PROMIS*
147	137	113	137

Table 9b

Participant 2 Standardized Cognitive Assessment Scores

HVLT Immediate Recall	*HVLT Delayed Recall*	*COWAT Letter*	*COWAT Category*	*DigitSpan Forward*	*DigitSpan Backward*	*Stroop Colors*	*Stroop Words*	*Stroop Blocks*
6	7	13.67	20	11	10	76	74	49

Modified Multiple Errands Task

Participant 2 completed the planning portion for the MET in approximately 16 minutes. Participant 2 asked if he was allowed to take a picture of the tasks. After the researcher told him this was not allowed, he did not ask any other clarifying questions. No other observations were made during the planning portion. After meeting the researchers on campus, Participant 2 completed the MET in approximately 1 hour. Of the 12 possible tasks, Participant 1 attempted 10 tasks but only successfully completed 5 of them. Participant 2 had one rule violation occurrence. During the MET, Participant 2 utilized personal resources and provided resources as well as technology. Participant 2 successfully completed all tasks for the at-home portion of the MET, but did not send the researcher his final document reporting how he completed the at-home tasks. Information on Participant 2's MET completion is located in Table 9c.

Table 9c

Participant 2 MET Completion

Planning Time	Completion Time	Tasks Attempted	Tasks Successfully Completed	Number of Rule Violations	At-home Tasks Successfully Completed
15 mn 57 sec	60 mn 42 sec	10/12 (83%)	5/12 (41%)	1	5/5

Participant 3

Cognitive Assessments and Self-Report Measures

Participant 3 is a 31-year-old Caucasian male with a total of twenty-one reported concussions and his most recent concussion occurring in 2021. Participant 3 completed the first portion of the study in 51 minutes and 32 seconds. Participant 3 actively took notes during the assessment, recording the names of the assessments and surveys he was completing and stated "he had a habit of taking notes". Participant 3 did not require any breaks for the duration of the first portion of the study. Before the *Color-Word Interference Test*, Participant 3 reported he was green/orange colorblind, but it did not impact his ability to complete the task. Participant 3 scored a 122 on the *BRIEF-A*, 62 on the *NEURO-QOL*, 85 on the *PROMIS*, and 117 on the *QOLIBRI*. Participant 3's scores on the self-report measures indicated difficulty with conversating with others and fluent speech, decreased processing speed, concentration, decreased self-esteem or self-perception, decreased life participation, managing relationships and creating new ones, regulating emotions, and forming thoughts. Participant 3 scored within one standard deviation of the average on all self-report measures. Although Participant 3 reported difficulty with cognition, he scored within normal limits on all standardized cognitive assessments except for one. Participant 3 scored an average of 8 on the three trials for immediate recall and a 10 on the delayed recall for the *HVLT*. On the *COWAT*, Participant 3 scored a 13.33 for average letter generation and a 22.5 for average categorical generation. Participant 3 scored an 8 on the forward *DigitSpan* and a 12 on the backwards *DigitSpan.* Finally, Participant 5 scored a 34 on the *Color-Word Interference Blocks,* a 100 on the *Color-Word Interference Color Names,* and a 25 on the *Color-Word Interference Colored Blocks.* He scored between one to two standard deviations below the average on the immediate recall on the Hopkins Verbal Learning test. Individual scores for all cognitive assessments and self-report measures are located in Table 10a and 10b.

Table 10a

Participant 3 Self-Report Measure Scores

Brief-A	*QOLIBRI*	*NEURO-QOL*	*PROMIS*
122	117	62	85

Table 10b

Participant 3 Standardized Cognitive Assessment Scores

HVLT Immediate Recall	*HVLT Delayed Recall*	*COWAT Letter*	*COWAT Category*	*DigitSpan Forward*	*DigitSpan Backward*	*Stroop Colors*	*Stroop Words*	*Stroop Blocks*
8	10	13.33	22.5	8	12	34	100	25

Modified Multiple Errands Task

Participant 3 completed the planning portion for the MET in approximately 6 minutes. Participant 3 asked clarifying questions about task execution and location of tasks. He utilized self-talk while writing down each of the tasks. After meeting the researchers on campus, Participant 3 completed the MET in approximately 50 minutes. Of the 12 possible tasks, Participant 3 attempted 9 tasks but only successfully completed 5 of them. Participant 3 had one rule violation occurrence. During the MET, Participant 3 utilized personal resources and provided resources as well as technology. Participant 3 successfully completed 4 out of 5 tasks for the at-home portion of the MET, and he did not send researcher his final document reporting how he completed the at-home tasks. Information on Participant 3's MET completion is located in Table 10c.

Table 10c

Participant 3 MET Completion

Planning Time	Completion Time	Tasks Attempted	Tasks Successfully Completed	Number of Rule Violations	At-home Tasks Successfully Completed
5 mn 45 sec	49 mn 23 sec	9/12 (75%)	5/12 (41%)	1	4/5

Participant 4

Cognitive Assessments and Self-Report Measures

Participant 4 is a 45-year-old African-American female with a total of ten concussions and her most recent concussion occurring in 2018. The first portion of the study lasted 54 minutes and 21 seconds. for Participant 4. Throughout the duration of the assessment, Participant 4 was easily distracted by background noise and would frequently make unsolicited comments about what she was thinking. Participant 4 required three breaks throughout the duration of the first portion of the study, all lasting approximately one to two minutes. Participant 4 scored a 127 on the *BRIEF-A,* 58 on the *NEURO-QOL*, 87 on the *PROMIS*, and 109 on the *QOLIBRI*. Participant 4 reported difficulty with concentration, metacognitive behaviors, processing speed, multi-tasking, physical performance, emotional regulation, task initiation, completing everyday tasks, and remembering new and old information. Participant 4 scored within one standard deviation of the mean on all self-report measures. Participant 4 scored an average of 6.33 on the three trials for immediate recall and a 7 on the delayed recall for the *HVLT*. On the *COWAT*, Participant 4 scored a 14.67 for average letter generation and a 20.5 for average categorical generation. Participant 4 scored an 8 on the forward *DigitSpan* and an 11 on the backwards *DigitSpan.* Finally, Participant 4 scored a 68 on the *Color-Word Interference Blocks*, a 100 on the *Color-Word Interference Color Names*, and a 48 on the *Color-Word Interference Colored Blocks.* Participant 4 demonstrated typical cognitive behavior for all standardized cognitive assessments except for two of the standardized subtests. Participant 4 scored one standard deviation below the mean on the immediate recall and delayed recall tasks for the *Hopkins Verbal Learning Tes*t. Individual scores for all cognitive assessments and self-report measures are located in Table 11a and 11b.

Table 11a

Participant 4 Self-Report Measure Scores

Brief-A	*QOLIBRI*	*NEURO-QOL*	*PROMIS*
127	109	58	87

Table 11b

Participant 4 Standardized Cognitive Assessment Scores

HVLT Immediate Recall	*HVLT Delayed Recall*	*COWAT Letter*	*COWAT Category*	*DigitSpan Forward*	*DigitSpan Backward*	*Stroop Colors*	*Stroop Words*	*Stroop Blocks*
6.33	7	14.67	20.5	8	11	68	100	48

Modified Multiple Errands Task

Participant 4 completed the planning portion for the MET in approximately 13 minutes. Throughout the planning phase, Participant 4 asked three questions to clarify how the tasks had to be executed, location of tasks, and if she was to use the same phone number for each task. She utilized self-talk throughout her planning process and double checked all of her notes before indicating she was ready to meet the researchers on campus. After meeting the researchers on campus, Participant 4 completed the MET in approximately 48 minutes. Of the 12 possible tasks, Participant 4 attempted 11 tasks but only successfully completed 10 of them. Participant 4 did not have any rule violations while completing the MET. During the MET, Participant 4 utilized environmental resources and provided resources for task execution. Participant 4 successfully completed 4 out of 5 tasks for the at-home portion of the MET, and she did not send researcher her final document reporting how she completed the at-home tasks. Information on Participant 4's MET completion is located in Table 11c.

Table 11c

Participant 4 MET Completion

Planning Time	Completion Time	Tasks Attempted	Tasks Successfully Completed	Number of Rule Violations	At-home Tasks Successfully Completed
13 mn 7 sec	48 mn 0 sec	11/12 (91%)	10/12 (83%)	0	4/5

Participant 5

Cognitive Assessments and Self-Report Measures

Participant 5 is a 21-year-old Caucasian male with a total of approximately 50 concussions and his most recent concussion occurring in 2021. Participant 5 completed the first portion of this study in 45 minutes and 44 seconds. Before completing the *Color-Word Interference Test*, Participant 5 reported he completed this task as part of his vision therapy that he completes with his optometrist. Participant 5 required a break lasting approximately two minutes after completing the delayed recall portion of the assessment. Participant 5 reported substantial deficits related to his brain injuries that have decreased his quality of life and ability to complete daily activities. Participant 5 scored a 154 on the *BRIEF-A*, 86 on the *NEURO-QOL*, 109 on the *PROMIS*, and 113 on the *QOLIBRI*. Participant 5 reported scores on the self-report measures which indicated difficulty with metacognitive behaviors, concentration, slowed processing time, remembering new and old information, multi-tasking, self-esteem, emotional regulation, impulsivity, time management, and conversing with others. concentration, metacognitive behaviors, mental math and reading, and feelings of loneliness and anxiety. Participant 5 scored at or above one standard deviations above the mean on all self-report measures. Despite reporting significant deficits on the self-report measures, Participant 5 demonstrated typical cognitive behavior for all standardized cognitive assessments except for two of the standardized subtests. Participant 5 scored an average of 7.33 on the three trials for immediate recall and a 6 on the delayed recall for the *HVLT*. On the *COWAT*, Participant 5 scored a 10 for average letter generation and a 20.5 for average categorical generation. Participant 5 scored an 8 on the forward *DigitSpan* and an 11 on the backwards *DigitSpan.* Finally, Participant 5 scored a 78 on the *Color-Word Interference Blocks*, an 80 on the *Color-Word Interference Color Names*, and a 62 on the *Color-Word Interference Colored Blocks.* Participant 5 scored within one to two standard deviations below the mean on both the immediate recall and delayed recall portions of the *Hopkins Verbal Learning Test.* Individual scores for all cognitive assessments and self-report measures are located in Table 12a and 12b.

Table 12a

Participant 5 Self-Report Measure Scores

Brief-A	*QOLIBRI*	*NEURO-QOL*	*PROMIS*

154	113	86	109

Table 12b

Participant 5 Standardized Cognitive Assessment Scores

HVLT Immediate Recall	*HVLT Delayed Recall*	*COWAT Letter*	*COWAT Category*	*DigitSpan Forward*	*DigitSpan Backward*	*Stroop Colors*	*Stroop Words*	*Stroop Blocks*
7.33	6	10	20.5	8	11	78	80	62

Modified Multiple Errands Task

Participant 5 completed the planning portion for the MET in approximately 10 minutes. Throughout the planning phase, Participant 5 asked one question to clarify if he was allowed to drive down the same street since he was completing all of his tasks remotely. Participant 5 double checked all of his notes before indicating that he was ready to start. After completing the planning portion, Participant 5 took a short break and then called the researchers using the telehealth platform Zoom on his cell phone to indicate he was ready to start completing tasks. Participant 5 completed the MET in approximately 55 minutes. While Participant 5 was driving to different locations he would place his phone in the cupholder of his car to allow the researchers the opportunity to observe his behavior between tasks. While completing tasks, Participant 5 carried the phone with him to allow the researchers the opportunity to observe techniques for tasks execution and completion of all tasks. Of the 12 possible tasks, Participant 5 attempted all 12 tasks but only successfully completed 11 of them. Participant 5 did not have any rule violations while completing the MET. During the MET, Participant 5 utilized multi-tasking and wrote down the time he started completing tasks to help with task execution. Participant 5 did not complete any of the at-home portion and did not send the researchers his document reporting how he completed the at-home tasks. After the 10-day period for at-home task execution had expired, the researcher emailed the participant twice asking for his documents, but none were ever received. Information on Participant 5's MET completion is located in Table 12c.

Table 12c

Participant 5 MET Completion

Planning Time	Completion Time	Tasks Attempted	Tasks Successfully Completed	Number of Rule Violations	At-home Tasks Successfully Completed
10 mn 5 sec	55 mn 0 sec	12/12 (100%)	11/12 (91%)	0	0/5

DISCUSSION

Access to healthcare has posed a challenge to individuals in both urban and rural communities due to physical access, shortage of physicians, and cost. Therefore, when individuals experience symptoms that cannot be identified on a current standardized assessment, a more comprehensive evaluation may be required by a different professional, and it can take up to months for the individual to make a preliminary appointment. Without an objective assessment to help identify deficits, providers are unable to provide adequate services. While many different rehabilitation professionals provide assessments, the process and focus of the assessments is variable depending on the professional's domain. In order for rehabilitation professionals to implement appropriate services, document outcomes, and determine an individual's susceptibility to persistent deficits, an effective evaluation of both cognitive and linguistic deficits post-concussion is necessary (Brown & Knollman-Porter, 2019; Brown et al 2020).

Typical testing methods for individuals with concussion currently include completion of self-report measures and standardized cognitive assessments as well as domain specific objective assessments. We set out to explore both quantitative and qualitative evaluations of various cognitive and linguistic deficits in five individuals who had self-reported persisting symptoms following concussion. Similar to the study completed by Brown and Knollman-Porter (2019), our results highlighted individual differences in the type and severity of deficits exhibited, while also identifying general themes. All participants with the exception of Participant 1, reported at least 15 out of the possible 100 symptoms on the BISQ as experienced either daily or several times within the past month prior to testing. On self-report measures, all five participants endorsed challenges with metacognitive behaviors, concentration, emotional well-being and additional cognitive and psychosocial changes that have impacted daily functioning. Scores on the standardized cognitive measures varied slightly, but all five participants scored within two standard deviations of the norm indicating no clinical significance in performance. MET completion varied by each participant, but gave the researchers the opportunity to observe cognitive deficits and skills in a functional, natural environment. Many of the deficits described on the participant's self-report measures were also observed during the MET. When completing the MET, all of the participants utilized some form of a strategy to help make task completion easier, yet specific strategy use was not an indicator for accurate task completion. The following sections will detail potential interpretations for these results, rationale for the feasibility and acceptability of implementing a multidimensional assessment, and discuss clinical implications for assessment and treatment for adults who have persisting symptoms of concussion/mTBI.

Testing Methods and Clinical Implications

The purpose of this multiple case study was to investigate the feasibility and acceptability of administering a hybrid in person and telehealth-delivered multidimensional evaluation of cognitive performance (MECP) to individuals who had persisting symptoms following concussion. The primary finding from this study was that administering this multi-dimensional assessment using a hybrid approach appears to be feasible. The longest duration of testing, including the MET planning phase, lasted approximately two hours and the shortest duration for testing was 53 minutes. All task planning was completed through the platform Zoom making this an accessible assessment procedure for anyone with a computer, smart phone, or tablet. Participant 5 completed the entire study protocol, including the MET tasks using the Zoom platform, providing evidence of the feasibility of administering this functional assessment from remote locations.

The success of administering the MET portion of the study protocol demonstrates that it can be adapted for any environment. During this study, the researchers adapted the task list for the MET twice in order for the functional portion of the study to be completed in two different environments. The original task list included activities that could all be completed on the University of Montana campus. Tasks that were adapted for Participant 5's completion included writing the time and date on a piece of paper and leaving it on his kitchen counter instead of retrieving an envelope and delivering it to a specific building as well as driving to different businesses rather than walking to different buildings on campus. These two adaptations of the MET tasks can be visualized in Appendix A. Guidelines for deciding on different tasks should be established to ensure the cognitive-linguistic functions required for task execution are consistent regardless of location. Brown and Knollman-Porter (2019) reported a reason for clinical concern when using measures that are more sensitive that identify cognitive deficits is the lack of baseline data available to clinicians. Test adaptability will increase the locations and frequency at which this assessment can be administered thereby leading to the potential to increase baseline data acquisition. Because all portions of this study were able to be provided both in-person and through the telehealth platform, it not only increases the accessibility to people in more rural communities who may not have close access to providers, but it also enhances opportunities for further research to help determine baseline data.

Brown and Knollman-Porter (2019) discussed issues regarding the discrepancy between standardized assessments and self-report measures and reported that the data they collected was consistent with this discrepancy. Similar to Brown and Knollman-Porter, the researchers of the current study also discovered a mismatch between cognitive-linguistic performance on standardized assessment and symptoms endorsed by participants on self-report measures. Although limited data was collected due to sample size, the multidimensional functional portion of the study, the MET, allowed the researchers to determine cognitive deficits not indicated on the standardized assessments. Cognitive deficits identified by Brown and Hux (2017) in their study using the MET included, deficits in speed and planning as well as failing to attend to instructions and inadequate selection and implementation of strategies. In the current study, similar cognitive deficits reported by the participants that were also observed during the MET included, attention, working memory, and executive functioning including but not limited to planning, organizing, and problem solving. While identifying these deficits is of utmost importance, the MET also allowed the researchers the opportunity to observe strategies the participants used independently. Different strategies to decrease cognitive deficits used by the participants included engagement in self-talk and the use of personal, environmental, and provided resources. Both studies by Brown and Knollman-Porter (2019) and Brown and Hux (2017) emphasized the importance of obtaining objective data to identify cognitive deficits because current standardized measures are not sensitive enough to identify subtle changes in cognitive behaviors. The current study also found that obtaining objective data regarding discrete cognitive-linguistic deficits and strategies independently used by individuals' post-concussion provides guidance for clinicians when identifying post-concussion syndrome and developing treatment plans to assist the individual for successful return to vocational activities.

Limitations and Future Directions

This multiple case study provided an opportunity for in-depth exploration into five individuals with a history of concussion who were in varying stages of the recovery spectrum. The current study is not without limitations. The proceeding following limitations will guide our recommendations for future directions.

First, as with any analysis regarding symptom reports, the researchers assumed the participants endorsed honest and accurate information when completing all baseline and post-concussion symptom reports. Due to reduced accessibility to participant health information, the current study did not verify the reported information to confirm brain injuries. While this information is not essential, it may be beneficial for future research to have a more comprehensive medical history for each participant.

Second, the small sample size provides information about individuals who are in the recovery process anywhere from three months to two years post-concussion. While this small sample size allows the researchers to identify individual deficits unique to each participant, applying the interpreted results to a larger population is limited due to demographic and injury-related variables. Since this study was focusing primarily on feasibility of administering a multidimensional protocol, prior medical history was not taken into consideration when selecting participants. While other disorders or injuries may have impacted the overall outcomes and performance during the study, they did not decrease the feasibility of completing all of the portions of this study. Past medical history or other underlying disorders should be considered in future studies to determine deficits strictly associated with post-concussion syndrome. Evaluation of a larger sample size with increased control of participant characteristics (e.g., concussion history) could provide insight into general themes that emerge in individuals experiencing cognitive and linguistic deficits post-concussion.

Additionally, all concussions documented by participants were self-reported; formal diagnosis of a mTBI was not required for this study. While this study reports a comprehensive history of potential concussions each participant experienced, the possible reasons for variability in performance are not controlled. For future studies, inclusionary criteria must include a formal diagnosis of concussion/mTBI at least four weeks prior to beginning the study. The number of concussions should also be controlled for future research to accurately identify deficits associated with post-concussion syndrome.

Third, although all five participants completed each portion of the study, variability of instruction delivery may have impacted participant performance. While multiple sessions were scheduled to reduce fatigue when completing tasks, many participants required rescheduling of sessions. Also, due to COVID-19 restrictions, some portions of the study were to be completed fully online while other portions of the study were allowed to be completed in person with specific guidelines (e.g., the researcher may not follow the participant closer than 6 feet, both the researchers and participants will wear a mask at all times, and the researcher will carry hand sanitizer throughout the duration of the in-person portion of the study). While all portions of the study were successfully completed, delivery of instructions through the telehealth platform may have reduced participant's carry-over of instructions. To provide clarity about the impact of service delivery model on study completion, future research should consider providing two options for study completion, one group that completes all portions of the study in-person, and one group that completes all portions of the study through the telehealth platform. All sessions should be scheduled upon initial meeting and each session should occur within 3 to 5 days of each other to reduce scheduling conflicts. Evaluating the two service delivery models (i.e., in person vs. telehealth) directly could help to decrease variability and to identify the effectiveness and efficiency for each delivery method. This comparison could add additional insight into better understanding participant compliance with all required tasks.

Finally, the duration of time it took each participant to complete the MET was not realistic for an efficient clinical environment. While the researchers attempted to emulate the tasks proposed in the study completed by Brown and Hux (2016), the size of the University of Montana campus was not conducive for efficiency. Future research should identify a smaller geographic area and plan tasks within that region to reduce the time required to walk between tasks. The participant's familiarity with the university's campus may have also impacted the overall time to complete the tasks. Familiarity is likely secondary to geographical size when concerning task completion time. By creating tasks that are located more closely together, future researchers will be able to better identify the application of a functional multidimensional assessment within a clinical setting. Table 13 outlines recommendations for completing future studies.

Table 13

Recommendations for Future Studies

Changes to Current Protocol	Continuation of Current Protocol
Conduct full protocol with one group in person	Use Qualtrics for completion of all self-report measures

Conduct full protocol with one group using only the telehealth platform	Schedule participants for both sessions during first meeting
Include healthy controls to determine variability of individuals with typical cognitive function	Reduce the number of cognitive evaluations, but keep *Hopkins Verbal Learning Test* and *BRIEF-A*.
Include individuals who have only sustained one medically-documented concussion	
Change tasks to be completed in a smaller geographical area of the University campus	
Vary order in which cognitive tests and self-report measures are given	
Reduce number of cognitive assessments and self-report measures to those which provide the most valuable information based	

CONCLUSION

All participants in the current study endorsed changes in their cognitive function following concussion that negatively impacted their occupational or academic performance. Each participant reported frustration with the cognitive changes that occurred following their concussion. Speech-language pathologists are one of the few providers who have the skills necessary to determine changes in cognitive-linguistic abilities and to provide rehabilitation services that address functional cognition. While this study only included researchers from the speech-language pathology discipline, including researchers from occupational therapy and athletic training would allow for more complete assessment of function. However, detecting cognitive and linguistic deficits in individuals with concussion/mTBI using a standardized assessment continues to pose as a challenge for rehabilitation professionals given the gap between performance on standardized assessments and symptoms endorsed on self-report measures.

Results of this study revealed that the commonly administered standardized cognitive assessments may not be sensitive enough to identify subtle changes in cognitive-linguistic functioning. While some standardized cognitive assessments provided some insight into deficits that may be present in individuals who have experienced a mTBI, all of the assessments in this study may not be necessary for clinical application. All of the self-report measures included in this study also provided good insight into the deficits experienced by the participants, but some of the measures quantified similar deficits, indicating that reducing the number of self-report measures administering may be warranted. A larger study utilizing the standardized cognitive assessments and self-report measures used in this study is first needed to better understand which assessments and measures would provide the most sensitive information regarding deficits. Due to the difficulty of identifying cognitive and linguistic deficits using one type of standardized assessment, it is crucial that clinicians utilize multiple measures to understand how a person performs during functional tasks to help individuals who have experienced a concussion successfully return to daily activities.

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Appendix A

TASK LIST

Complete the following three tasks:

1. You should do the following six things:
    a. Retrieve an envelope from the Oval/Bear labeled "UM Concussion Project" and deliver it to the box at the University (Main) Hall outside of the president's office.
    b. Retrieve a magazine from the library and give it to the researcher at the end of the tasks.
    c. Enter Rec Center and ask front desk worker, "How much is a non-student rate for a semester?" and take a picture of the sign for the Guide Policies.
    d. Take a picture of the menu for Doc's in the UC and text it to the researcher using the BRAIN Lab phone at (406)214-6872.
    e. In the lobby of Curry Health Center, pick up a small hand sanitizer. Keep this with you to show the researcher at the end of the tasks.
    f. Call Mackenzie, using the BRAIN Lab phone number (406)214-6872 and tell her who you are, where you are, and what time it is. If she is not there, you may leave a message.
2. You should obtain the following information and write it down:
    a. When was Craig Hall Built?
    b. How many handicapped/QuickStop parking spaces are in front of the theater and Adams Center?
    c. What is the daily menu at the Food Zoo?
    d. How many double-door entrances/exits are there on the main floor of the Phyllis J. Washington Education Center?
3. Be at the Oval/Bear about fifteen minutes after you have started the exercise.

Text or phone the person observing when you are done.

RULES LIST

1. Require participants to complete all tasks in order of their choosing.
2. Participants cannot enter any personal office or space.
3. Participants cannot go back to a location which they have already been.
4. Participants cannot enter a location for a reason other than task completion.
5. Participants cannot speak to the researcher unless part of exercise.

Appendix B

Task Menu

Email activities *Send an email between 8-9am with:* • One paragraph about an activity completed that day • A picture of yourself with written sentences about your strengths • One paragraph about a place you would like to travel to • One paragraph stating one famous person you would like to have dinner with and why you choose them • A picture of your favorite animal with three facts about the animal	**Phone activities (messages)** *Call between 7-8pm and leave a message about:* • The current weather and a forecast for the next day • All of the chores you have completed thus far that week • The last television show you watched • What you are going to do over the weekend • The last thing you had to eat	**Interactive activities** *Complete activity and bring it to the Speech Language Hearing and Occupational Sciences Department and leave in UM Concussion Project box, located in the basement of Curry Health Center* • Bring a restaurant take-out menu • Complete a word search • Complete a sudoku • Print out a picture of yourself and on the back write three words that describe you • Print out a picture of your favorite movie and on the back write three sentences to describe the movie
Google/Word document activities • Write about a personal goal • Upload a city map and mark your favorite area • Paste a link to a recipe you would like to make and include the price of three ingredients • Write out the rules to your favorite board/card game • Upload a map of your favorite amusement park or national park and write about your favorite thing to do in the park	**Phone activities (texting)** • Three sentences about your favorite sport • Three sentences about your favorite board/card game • Three sentences about your favorite book • Three sentences about your favorite hobby • A verse from your favorite song translated into Spanish, German, or Arabic	*use (406)214-6872 for calling and texting activities *send your google document via email to researcher after completed

<u>At-Home Task Rules</u>

1. You may not begin tasks until the day after completing Zoom task planning session.
2. You must complete all 5 tasks within 10-days.
3. You may not complete more than one task per day.
4. You may complete tasks in any order of their choosing.
5. You must fill out task completion document during the 10-day period.
6. You must email task completion document to researcher at the end of the 10-day period.

Task Completion Document

DESCRIPTION OF TASK COMPLETED	DATE/TIME OF TASK COMPLETION	METHOD FOR RECALL OF TASK	PROCEDURES TAKEN FOR TASK COMPLETION
1.	1.	1.	1.
2.	2.	2.	2.
3.	3.	3.	3.
4.	4.	4.	4.
5.	5.	5.	5.