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Evaluating Cognitive–Linguistic Deficits Postconcussion in Adults

Contributions of Self-Report and Standardized Measures

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Purpose: We sought to document the cognitive–linguistic challenges experienced by 3 adults with concussion at varying lengths postinjury. **Method:** A multiple case study design utilized motivational interviewing techniques, 4 self-report measurement tools, and 5 standardized neurocognitive tests. The 1 female and 2 male participants were 1, 21, and 37 months postconcussion. **Results:** All participants self-reported cognitive and linguistic challenges significantly impacting daily functioning and quality of life. Cognitively, participants demonstrated deficits in independence, metacognition, and cognitive flexibility. Linguistically, participants demonstrated deficits in verbal memory, verbal fluency, and reading. The participant 1-month postconcussion demonstrated deficits on multiple standardized measures; however, participants in the chronic phase of recovery demonstrated substantially more self-reported deficits than were noted on standardized testing. **Discussion:** Evaluation of cognitive–linguistic deficits postconcussion requires both self-report and standardized measurement; however, limitations of both tools exist. We discuss clinical implications for professionals selecting testing measures for use in this population. **Key words:** *assessment*, *chronic deficits*, *cognition*, *communication*, *self-report*, *standardized tests*

CONCUSSION IN ADULTS

Neurologic changes and symptoms vary on an individual basis following mild traumatic brain injury (mTBI; also referred to as concussion). Many factors can lead to generalized prolonged symptoms (Ponsford et al., 2000) such as impact location (Crisco et al., 2010), younger age (Pellman, Lovell, Viano, & Casson, 2006), female gender (Kutcher & Eckner, 2010; Musille, 2016), history of prior concussion (Covassin, Stearne, & Elbin, 2008), presence of mood disorders (Matuszak, McVige, McPherson, Willer, & Leddy, 2016), and learning disability (Collins et al., 1999). Such factors also further influence the type and severity of persistent symptomatology. Without correct evaluation and treatment, a potential subset of individuals with concussion experience persistent deficits that substantially impact task performance and return to daily activities. This is confirmed by researchers who have established that up to 30% of individuals with mild brain injury are still below full levels of functioning at 1-year postinjury (McMahon et al., 2014). The term *mild* continues to be a misnomer and undervalues the

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need for in-depth evaluation of deficits. Consequently, severe deficits exist postconcussion that may warrant rehabilitation efforts as symptoms negatively influence independent daily task completion (e.g., work and school; Kashluba, Hanks, Casey, & Millis, 2008).

COGNITIVE AND LINGUISTIC DEFICITS

The presence of both cognitive and linguistic deficits following concussion is routinely documented in the literature. For individuals with concussion, commonly experienced cognitive deficits include declines in working, verbal, and visual memory; information processing speed; impulse control; sustained and selective attention; and executive function (e.g., reasoning, problem solving, initiation; Covassin et al., 2008; Guskiewicz et al., 2003; Macciocchi, Barth, Alves, Rimel, & Jane, 1996). The intrinsic connection between cognition and language often results in linguistic deficits stemming from underlying cognitive processes (e.g., attention, memory, and executive functions); these deficits are consistently termed cognitive–communication disorders within the literature (Togher, McDonald, Coelho, & Byom, 2013). Research relative to cognitive and linguistic impairments following mTBI highlights frequent limitations in rapid naming (Galetta et al., 2011), verbal fluency, verbal memory (Allen & Gfeller, 2011) and reading abilities (Garden & Sullivan, 2010). However, research examining the extent to which these difficulties persist beyond the acute stage of recovery and negatively impact daily functioning is lacking. One reason for the lack of research in this area may be that assessments currently utilized by speech–language pathologists to assess cognitive and linguistic deficits following mTBI lack the sensitivity to detect subtle impairments (Duff, Proctor, & Haley, 2002). Therefore, referral and follow-up procedures are not initiated. Assessing both cognition and language in isolation as well as concurrent neurological processes thus requires a holistic approach.

APPROACHES TO COGNITIVE–LINGUISTIC ASSESSMENT

As with other aspects of concussion management (e.g., treatment, education), there are no evidence-based guidelines to inform the selection of cognitive and linguistic testing measures (Duff et al., 2002; Krug & Turkstra, 2015) for use in the general population. Relying on one assessment in isolation to effectively document such impairments postinjury is futile and understanding the contribution of various testing methods to the determination of patient deficits is a crucial step in the rehabilitation process. It should be noted that ideally assessment practices utilized by clinicians would include a multidisciplinary approach and incorporate additional testing such as balance, vestibular, and oculomotor functioning and that use of comprehensive, interdisciplinary assessment may elucidate therapeutic targets following mTBI (Kontos et al., 2018). Such practices are emerging across disciplines and settings; however, distinct protocols endorsed and utilized consistently are not yet available at this time.

Self-report measures

Many professionals rely primarily on patient self-report measures to diagnose and determine symptomatology because standard neuroimaging results (e.g., computed tomography [CT]) are often normal following mTBI (McCrory et al., 2013). Consequently, injuries may not be documented until an individual attempts to return to daily activities (e.g., vocational or academic tasks) and acknowledges difficulty performing at previous levels of functioning.

Suggested models from the World Health Organization encourage rehabilitation professionals to collect information from the perspective of individuals themselves, as well as from other sources. Self-report elicited through patient interviews is increasingly recognized as the best, or perhaps only, way to estimate brain injury incidence and prevalence of persistent symptoms (Dams-O'Connor et al., 2014).

Of concern, however, is the fact that many symptoms experienced postconcussion are not unique to brain injury and may be experienced by individuals with other diagnoses or by those in the general public (Smith-Seemiller, Fow, Kant, & Franzen, 2003). Furthermore, many tools utilized for self-report of symptoms postinjury were not developed using rigorous, scientific methods (Alla, Sullivan, Hale, & McCrory, 2009). These issues combined with the potential for individuals to experience impaired self-awareness or hypersensitivity of deficits (Dirette & Plaisier, 2007; Ettenhofer & Abeles, 2009; Tsanadis et al., 2008) following injury can complicate interpretation of patterns of symptoms resulting in questionable validity of self-report measures when used in isolation. This under or overestimation of symptoms reported during assessment may also delay appropriate treatment or strategy development posing threats to independence, given that successful task completion and performance regulation rely heavily on one's understanding of limitations (Kennedy & Coelho, 2005; Sherer, Hart, & Nick, 2003). Thus, relying on patient self-report to evaluate symptomology and plan treatment protocols is insufficient in isolation; however, self-reports are necessary components of a holistic testing process.

Standardized neurocognitive measures

Professionals traditionally rely on standardized test administration because these assessments allow for objective deficit measurements (Eslinger, Zappala, Chakara, & Barrett, 2011). Despite efforts, standardized tests provide inconsistent identification of dysfunction in individuals across the brain injury severity spectrum (Wood & Liossi, 2006). For individuals with mTBI, inconsistent impairment identification is primarily due to individuals demonstrating varying outcomes dependent on the measurement tool used. For example, when using standardized assessment measures, 40% of individuals with mTBI may show evidence of objective cognitive impairment despite self-reports of being symptom-free (Broglio, Macciocchi, & Ferrara, 2007). However, relying solely on standardized measures is unrealistic, given that many tests demonstrate low test–retest reliability (Iverson, Lovell, & Collins, 2003; Schatz, 2010), include the potential for practice effects (Rosenbaum, Arnett, Bailey, & Echemendia, 2006), and lack sensitivity (Silverberg et al., 2015). Further complicating this matter is the fact that individuals with mTBI perform relatively well, given structure and routine (e.g., standardized tests) but may perform poorly during novel functional tasks.

CURRENT STUDY

The purpose of this study was to document and compare outcomes of self-report and standardized cognitive and linguistic assessments administered to individuals with mTBI. The multiple case studies presented herein highlight the unique profiles of three individuals with concussion at various time points postinjury. The inclusion of both self-report and standardized measures allowed for an in-depth exploration into the cognitive and linguistic deficits experienced by these individuals and provided a means of summarizing data sources. The research methodology utilized in this study included primarily quantitative data; however, we included a motivational interview component (Hettema, Steele, & Miller, 2005; Medley & Powell, 2010), given the widely accepted use of person-centered interview in clinical practice and research (Brookshire, 2007; Sohlberg & Mateer, 2001). Selection of a multiple case study design allowed us to develop a more in-depth understanding of the comparison between self-report and standardized measures of functioning post-mTBI than could be explored using only a single case design (Chmiliar, 2012).

METHODS

Participants

Participants included two males and one female with history of at least one concussion. We defined concussion as a type of traumatic brain injury caused by a 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 (Centers for Disease Control and Prevention, 2016). Furthermore, participants could not experience a loss of consciousness over 30 min, exhibit evidence of posttraumatic amnesia greater than 24 hr, and/or have a Glosgow Coma Scale rating of less than 13 following the injury (Kay et al., 1993). Participants ranged in age from 21 to 57 years ($M = 35.66$, $SD = 18.90$) and all participants were white. Participants reported completing between 12 and 16 years of education ($M = 14.00$, $SD = 2.00$) and were 1, 21, and 37 months post their most recent concussion at the time of study completion ($M = 19.66$, $SD = 18.03$). No participants were involved in litigation relative to their injuries at any point in the recovery process leading up to participation in the current study. Participants completed the symbol cancellation subtest of the Cognitive Linguistic Quick Test (Helm-Estabrooks, 2001), with 100% accuracy to ensure adequate vision to perform experimental tasks. Participants accurately responded to 1,000, 2,000, and 4,000 Hz tones presented at 40 dB to ensure adequate hearing.

In addition, all participants completed the Brain Injury Screening Questionnaire (BISQ; Dams-O'Connor et al., 2014). The BISQ served to quantify participants' symptoms, document past medical history, and screen for and document history related to traumatic brain injury. The inventory includes 100 possible cognitive, physical, emotional, and behavioral symptoms. Information about each individual participant's health and social history as well as postconcussion symptomatology is discussed later. Institutional review board approval was obtained at both universities before commencing all research activities. We present information later regarding each participant using pseudonyms to retain confidentiality.

Gloria

Gloria is a 29-year-old woman who reports completing a bachelor's degree as her highest level of education. At the time of injury, Gloria worked as a pediatric intensive care unit nurse and lived with her spouse. She reported no significant medical or developmental history; however, she reported taking medication to relieve symptoms associated with anxiety. She reported no previous difficulty with academic or vocational roles prior to the current injury.

Gloria reported a history of two concussions across the life span. Gloria's first concussion occurred in 2011 when she experienced a fall from a horse; she reported requiring approximately 6 weeks to fully recover from this injury. The most recent injury occurred 28 days prior to initiation of experimental procedures and resulted from a fall in the shower. Gloria reported hitting her head directly on a solid surface in the bathroom as a result of the fall; however, she reported no loss of consciousness or physical injuries and both CT and magnetic resonance imaging (MRI) reports were negative. Following injury, Gloria attempted to return to work without seeking any medical attention and completed three successive work shifts. However, during her third shift, she was unable to fully perform her occupational duties (e.g., decreased processing speed, short-term memory deficits, inability to shift between tasks) and returned home. She sought medical attention from a concussion specialist and was immediately placed on family and medical leave. The physician directed Gloria to not operate a motor vehicle; driving was not yet recommended at the time of study completion. In addition, medications were prescribed as needed to assist with Gloria's postinjury symptoms: nausea, dizziness, migraines, and digestion. Following her initial medical visit, Gloria commenced biweekly appointments with the physician and was referred for physical therapy and speech–language pathology services. Gloria received physical therapy services for approximately 3 weeks before independently deciding to end treatment. She received speech–language therapy services for 7 weeks following completion of the experiment. The weekly, hour-long speech–language therapy sessions focused both on restorative and compensatory approaches across three main cognitive and linguistic domains (i.e., processing speed, alternating attention, and short-term memory).

Gloria selected 39 out of 100 possible symptoms on the BISQ as experiencing either "daily or almost daily" or "several times in the past month." She reported the most symptoms relative to physiological deficits ($n = 12$; e.g., losing balance, headaches, difficulty sleeping). This was followed by 11 socioemotional symptoms (e.g., feeling bored, feeling frustrated, difficulty dealing with people), nine cognitive symptoms (e.g., thinking slowly, difficulty concentrating, losing train of thought), and seven linguistic symptoms (e.g., reading slowly or having difficulty reading, trouble understanding conversation, or difficulty pronouncing words).

Patrick

Patrick is a 57-year-old man who completed a high school degree as his highest level of education. Prior to the initial injury, he worked full time as a regional park manager and held a second part-time job in law enforcement. Patrick had multiple supervisory and managerial responsibilities that required multitasking, flexibility, and problem solving. Patrick stated that his medical history included sleep apnea, congestive heart failure, hyperlipidemia, diabetes mellitus, and migraines.

Patrick reported a history of two concussions. The first occurred in 1976 secondary to falling from a ladder. Patrick was unable to recall postinjury symptoms or outcomes of this event. The most recent concussion occurred 21 months prior to the initiation of this study secondary to a restrained motor vehicle accident. Patrick reported experiencing loss of consciousness for less than 1 min and walked away from the accident independently with no other injuries, medical care, or hospitalization. However, over the course of the subsequent 5 days, he experienced increased light sensitivity, difficulty concentrating, balance disturbances, and decreased self-regulation. An MRI completed 5 days postinjury was negative. Following the injury, Patrick attempted to return to work but postinjury symptoms prevented him from successfully completing job requirements (e.g., decreased ability to perform multiple tasks simultaneously, fatigue, inattention) and, therefore, he was placed on medical leave.

At 6 months postinjury, Patrick enrolled for disability classification secondary to persistent postconcussive symptoms. His physician also prescribed medications to regulate his postinjury symptoms of depression and decreased attention. Over the course of the next 18 months, Patrick received physical therapy, occupational therapy, chiropractic services, and counseling. He also completed a neuropsychological evaluation, which he reported performing at above-average levels. He relayed not experiencing improvement from these services and self-reported that his cognitive symptoms continued to persist. In addition, his physician recommended that he restrict driving to only within his community. At the time of study completion, he was employed part-time doing maintenance work.

Completion of the BISQ revealed that Patrick endorsed 49 out of a possible 100 symptoms as experienced either daily or several times within the month prior to testing. The most frequently endorsed category was cognitive deficits ($n = 18$; e.g., missing or being late for appointments, being disorganized, difficulty planning future events). He also endorsed 15 socioemotional symptoms (e.g., feeling impatient or irritable, arguing, feeling misunderstood) and eight symptoms in both physiological (e.g., having trouble staying awake, ringing in the ears, moving slowly) and linguistic (e.g., reading very slowly, difficulty following oral directions) categories.

Thomas

Thomas is a 21-year-old man who completed high school as his highest level of education. Prior to injury, Thomas reported being an above-average student in high ability classes. He had no previous medical diagnoses or concerns.

Thomas reported a history of three previous concussions. The first occurred in 2008 (11 years of age) when he was riding on a sled tied behind an all-terrain vehicle. He reported that the vehicle turned rapidly resulting in a "whip" effect with no direct trauma or injury other than concussion. He reported moments of unconsciousness but could not recall any other symptoms immediately after the injury. Both CT and MRI results were negative. When Thomas returned to school, he could no longer perform at his previous level academically secondary to increased fatigue, decreased concentration, and decreased recall. He reported missing many school days secondary to persistent symptoms, causing his grades to suffer. This continued throughout middle school. The second concussion occurred in 2011 during a soccer game when Thomas headed a ball. He experienced increased dizziness, fatigue, and brain fog. Academic work became even more challenging to the point that he dropped out of school, took online classes, and completed his high school degree in 5 years. During this time, he received vision therapy, which he found was not helpful. Finally, 37 months prior to testing, he fell off of a wakeboard being pulled by a boat. Following the event, he experienced decreased recall of events before, during, and immediately after the injury. However, he reported no other symptoms. At the time of study completion, Thomas was attending college at a reduced load of nine credit hours. He continued to experience persistent postconcussion symptoms and received academic accommodations (i.e., increased time to take tests and complete assignments; testing in a quiet, distraction-free environment). He did not report taking any prescribed medications.

Thomas selected 16 out of a possible 100 symptoms when completing the BISQ as occurring either daily or several times monthly. He selected the most symptoms in the cognitive category ($n = 7$; e.g., poor span of attention, being easily distracted, losing train of thought). This was followed by physiological ($n = 4$; e.g., feeling tired, having trouble waking up), socioemotional ($n = 3$; e.g., feeling uncomfortable around others, experiencing difficulties in crowds), and linguistic symptoms ($n = 2$; i.e., reading slowly, forgetting what you just read).

Stimuli

Research stimuli included four self-report and six standardized neurocognitive measures relative to cognition and language. Each testing component is described later. Additional materials included digital video/audio recorders to capture testing and interviews.

Self-report measures

Selected measures served to gather participant-reported information regarding postinjury symptomatology, the functional impact of concussion in daily life, and quality of life. Each self-report tool incorporated both cognitive and linguistic factors and is described later.

The Behavior Rating Inventory of Executive Function—Adult Version

The Behavior Rating Inventory of Executive Function—Adult Version (BRIEF-A; Roth, Isquith, & Gioia, 2005) is a 75-item self-rating scale that captures executive functions and self-regulation in everyday environments. The BRIEF-A includes nine nonoverlapping scales (i.e., inhibition, self-monitoring, planning, shifting, initiation, task monitoring, emotional control, working memory, and organization). Three scores are derived from this measure, that is, behavioral regulation, metacognition, and the global executive composite. Higher raw scores, *T*-scores, and percentile ranks indicate a greater degree of executive dysfunction (Roth et al., 2005). *T*-scores of 65 or greater are considered clinically significant.

The Quality of Life in Neurological Disorders

The Quality of Life in Neurological Disorders (Neuro-QOL Item Bank v2.0-Cognitive Function; National Institute of Neurological Disorders and Stroke, 2015) is a paper-based 28-item questionnaire that queries individuals regarding current difficulties with cognitive functions as well as difficulties experienced over the previous 7-day period. Questions are formed in a manner to provide example activities relative to distinct cognitive functions (e.g., "How much difficulty do you currently have keeping track of time [e.g., using a clock]?). Participants are tasked with responding on a 5-point Likert-type scale indicating frequency with which a symptom occurs such from very often (1) to never (5). Lower raw scores indicate a greater degree of dysfunction. We used the HealthMeasures Assessment Center Scoring Service and user manual, as endorsed by the National Institutes of Health (NIH), to analyze participant scores on this measure (Cella, Gershon, Bass, & Rothrock, 2017; https://www.assessmentcenter.net/ac_scoringservice). An average *T*-score of 50 (*SD* = 10) was developed using normative data from individuals without a history of neurological disorders.

The Patient-Reported Outcomes Measurement Information System

The Patient-Reported Outcomes Measurement Information System (PROMIS) Item Bank v2.0-Cognitive Function (Health Measures, 2018) includes 32 questions and queries individuals regarding cognitive function across the previous 7-day period using a 5-point Likert-type scale. The PROMIS differs from the Neuro-QOL in that it does not provide contextual examples of cognitive deficits but rather explicitly queries respondents regarding particular domains. Lower raw scores indicate a higher degree of dysfunction. We also used the HealthMeasures Assessment Center Scoring Service to analyze participant scores on this measure. An average *T*-score of 50 (*SD* = 10) was developed using normative data from individuals without a history of neurological disorders.

The Quality of Life After Brain Injury

The Quality of Life after Brain Injury (QOLIBRI; von Steinbüchel et al., 2010a, 2010b) includes 37 items covering six health-related dimensions of quality of life following traumatic brain injury—cognition, self, daily life and autonomy, social relations, emotions, and physical problems. The questionnaire provides a profile of quality of life through a total score value and a score in each of the six domains. Each domain is scored out of a possible 100 points with a score of zero indicating very poor quality of life and a score of 100 indicating very high quality of life. Questions are coded as satisfaction or feeling bothered items and use a 5-point scale (i.e., "How satisfied are you . . . ." and "How bothered are you . . . ."). For satisfaction items, scores range from not at all satisfied (1) to very satisfied (5). Scores for the bothered items range from very bothered (1) to not at all bothered (5).

Standardized neurocognitive measures

We selected the cognitive and linguistic assessments based on a variety of factors: (1) past research indicating the use of these particular standardized measures for individuals with brain injury (e.g., Busch, McBride, Curtiss, & Vanderploeg, 2005; Mueller & Dollaghan, 2013; O'Neil-Pirozzi, Goldstein, Strangman, & Glenn, 2012; Spencer et al., 2013; Sugarman & Axelrod, 2015), (2) NIH Toolbox assessment recommendations (Weintraub et al., 2013; Weintraub et al., 2014; Zelazo et al., 2013), and (3) availability of normed data. Table 1 indicates the assessment measure, estimated completion time, and targeted cognitive or linguistic domain(s).

Procedures

We utilized a multiple case study approach to examine fully the cognitive and linguistic deficits of three unique individuals with history of one or more mTBIs. Our holistic assessment approach included a motivational interview, self-report measurement tools, and standardized neurocognitive tests or subtests. Primarily, we focused on quantitative data as a means of classifying deficits and symptoms for each of the participants. Inclusion of motivational interview techniques, producing qualitative data, was desirable, given the common use of patient interview with individuals with acquired brain injury (e.g., D'Cruz, Howie, & Lentin, 2016; Ponsford et al., 2016). We utilized information derived from participant interviews as a means of identifying each participant's primary concerns postinjury and overall goals. Detailed information regarding all assessment procedures appears later.

Table 1. Standardized testing procedures

Assessment	Targeted Domain(s)	Approximate Time (min)
Montreal Cognitive Assessment	Orientation Attention Memory Delayed recall Abstract reasoning Visuospatial/executive skills Naming Language	10
Delis Kaplan Executive Function System Color–Word Interference Tests	Inhibition Cognitive flexibility	5
Trail Making A & B	Attention Cognitive flexibility Processing speed Executive functioning	5
Hopkins Verbal Learning Test	Working memory Delayed recall Verbal fluency New learning	10
Controlled Oral Word Association Test (i.e., FAS + animals)	Verbal fluency Cognitive flexibility	3
Digit Span subtest of the Wechsler Adult Intelligence Scale—4th Edition	Attention Working memory Cognitive flexibility	8

Motivational interview

Before completing any testing, all individuals participated in a motivational interview. Interviews lasted between 15 and 30 min (M = 21.67 min, SD = 7.64). Motivational interview techniques (Hettema et al., 2005; Medley & Powell, 2010) combined a supportive and empathic counseling style with a conscious, directive method for patient self-analysis. Interviews emphasized and honored patient autonomy through clinician and patient coconstruction of challenges and needs. Techniques involved the clinician beginning with an open-ended question. The clinician then followed with open-ended, directive prompts; reflected on patient responses; and summarized/synthesized patient remarks. The two authors of this article performed all motivational interviews. We digitally recorded interviews with both audio and video data for later transcription.

Testing

Participants completed all self-report and standardized testing in unique random orders. Two participants completed all testing within one session, whereas the remaining participant required two sessions to complete testing (Patrick). The testing protocol required fewer than 3 hr to complete. Participants received breaks as requested during testing. All assessments were conducted by a clinically certified, trained speech–language pathologist.

Data analysis

We analyzed all self-report and standardized testing data according to assessment manuals and/or published normative data. As such, we converted raw scores to either scaled scores or *T*-scores as appropriate. We also calculated percentile rankings as appropriate. Data for interpretation of self-report measures came from the NIH Toolbox affiliated scoring system (Cella et al., 2017), the BRIEF-A testing manual (Roth et al., 2005), and QOLIBRI publications (e.g., von Steinbuchel et al., 2010a, 2010b). For standardized assessments, evaluative data from the Hopkins Verbal Learning Test—Revised (HVLT-R; Brandt & Benedict, 2001), Wechsler Adult Intelligence Scale—4th Edition (WAIS-IV; Wechsler, 2008), and Delis-Kaplan Executive Function System Color–Word Interference (D-KEFS; Delis, Kaplan, & Kramer, 2001) tests came from the respective test manuals. We derived interpretive data for the Trails A and B test and Controlled Oral Word Association Test (COWAT; i.e., F-A-S + animals) from the revised Heaton norms (M = scaled score of 10, SD = scaled score of 3; Heaton, Miller, Taylor, & Grant, 2004).

All motivational interviews were transcribed verbatim by trained research assistants. Subsequently, the lead author reviewed each transcript to identify primary areas of concern since onset of the most recent injury endorsed by each participant as well as short- and/or long-term recovery goals. The second author of the article then reviewed the transcripts to determine agreement and identify areas of discrepancy with the first author. Both researchers then collectively agreed on each participant's expressed areas of concern and primary goals. Both authors then selected participant quotes exemplifying these concerns and goals.

RESULTS

The following sections highlight individual data across interviews, self-report forms, and standardized testing measures. We opted to present participant data individually and in chronological format from the most recently occurring injury to the most chronic. This allowed us to highlight the unique profiles of individuals in a multiple case study format. Raw scores on self-report measures for each participant appear in Table 2; raw scores on standardized tests and subtests for each participant appear in Table 3.

Participant 1: Gloria

Motivational interview

Gloria's interview lasted approximately 20 min. Gloria discussed that her chief complaints at the time of interview related to dizziness (*I can't drive because I get very dizzy*; *Just a constant . . . I feel like I'm in motion.*), visual processing deficits (*So, honestly, just walking and moving takes a lot of focus.*), word-finding difficulties (*I could not pull out the word for anything and it's a word I should be able to pull out no matter what*; *I know it's a d-word and I know what the word means, but I couldn't get the word.*), and challenges in performing daily chores and work-related activities (*Being organized enough to take care of two ICU [intensive care unit] patients who are side-by-side and sometimes they're very similar situations*; *I do some light housework and I'm like "oh I feel like crap"*; *Going to Target, favorite store! It was like too much.*). At the time of interview, Gloria reported that her goal was to be at prebaseline status within the subsequent 4-week period; however, she did acknowledge that return to baseline may not be feasible (*But even if that means a new baseline that I can work with and grow with.*).

Self-report measures of cognitive and linguistic functioning

Gloria's scores on self-report measures indicated difficulty with independent completion of daily tasks, emotional regulation, and metacognition behaviors. Gloria performed almost two standard deviations below the mean on the PROMIS measure and scored within the 85th percentile for Metacognition Index on the BRIEF-A; although neither of these scores were clinically or statistically significant. Performance on the Neuro-QOL and additional BRIEF-A indexes was also within

Table 2. Raw scores on self-report measures for each participant[a]

Measure	Gloria	Patrick	Thomas
NIH Toolbox			
PROMIS—Cognitive Function (__/160)	67	56	132
Neuro-QOL—Cognitive Function (__/140)	28	**13**	23
BRIEF-A			
Behavioral regulation index (__/90)	43	**60**	41
Metacognition index (__/120)	76	**86**	**79**
Global executive composite (__/210)	119	**146**	120
QOLIBRI			
Thinking abilities	42.86	32.00	53.57
Emotions/view of oneself	25	42.85	46.42
Independence/ADLs	3.57	25	39.28
Social relationships	58.33	16.66	45.83
Feelings	30	80	55
Physical problems	40	15	70
Total (__/100)	32.50	34.45	50.67

Note. ADLs = Activities of Daily Living; BRIEF-A = Behavior Rating Inventory of Executive Function—Adult Version; Neuro-QOL = Quality of Life in Neurological Disorders; NIH = National Institutes of Health; PROMIS = Patient-Reported Outcomes Measurement Information System; QOLIBRI = Quality of Life after Brain Injury.
[a]Values shaded and in boldface indicate clinically or statistically significant deficits as designated by assessment manuals. Interpretation of clinical or statistical significance is not available for QOLIBRI scores.

Table 3. Raw scores on standardized tests and subtests for each participant[a]

Measure	Gloria	Patrick	Thomas
Montreal Cognitive Assessment (__/30)	30	28	30
Color–Word Interference Test			
Color Naming Time	**96 s**		**49 s**
Word Reading Time	**59 s**		**36 s**
Inhibition Time	**129 s**		**67 s**
Trail Making A Time	**47 s**	38 s	21 s
Trail Making B Time	**135 s**	93 s	39 s
Hopkins Verbal Learning Test			
Immediate Recall Score (__/36)	23	30	30
Delayed Recall Score (__/12)	9	**0**	**7**
Recognition Discrimination Index Score	11	**7**	12
COWAT			
F-A-S score	27	33	36
Animals score	**16**	14	22
WAIS-IV Digit Span			
Forward (__/16)	8		13
Backward (__/16)	5		13
Sequencing (__/16)	5		9
Total (__/48)	**18**		35

Note. COWAT = Controlled Oral Word Association Test; WAIS-IV = Wechsler Adult Intelligence Scale—4th Edition.
[a]Values shaded and in boldface indicate clinically or statistically significant deficits as designated by assessment manuals; Patrick did not complete Color–Word Inference Testing because of color blindness.

normal range. On the QOLIBRI, Gloria self-assessed quality of life below 50/100 points for all but one of six domains (exception: social relationships) and indicated a total quality-of-life score of 32.50 (out of 100).

Standardized assessments of cognitive and linguistic functioning

Gloria completed standardized testing 28 days postinjury. Gloria demonstrated significant impairments on assessments relative to verbal fluency (COWAT animal subtest), cognitive flexibility (Trails A & B, WAIS-IV Digit Span), and inhibition (D-KEFS Color–Word Interference subtests). She scored within normal limits on the Montreal Cognitive Assessment (MoCA) and HVLT-R subtests.

Participant 2: Patrick

Motivational interview

Patrick's interview lasted approximately 30 min. He relayed chief concerns relating to dizziness (*The last two days I was here for orientation. I took a hiking stick with me because I'm not old enough for a cane.*), problem solving (*I had difficulty adding and subtracting numbers),* time management (*Procrastination is a big one*), emotional regulation (*I'm more impatient something I'd never had before*), reading (*The absorption of the material, so I may have to read something again, um, after reading for a little bit .... For some reason reading just has become difficult*), and attention (*And um it's like I can't pay attention enough from all the everything coming in*). Overall, Patrick expressed frustration regarding his current level of function (*I'm forced to be that way so now having to cope with the new me, is what I call it. So coming to terms with the new me with, with reduced open expectations for improvement .... And what I tell people is I'm 57 but I feel like I'm 77*).

Self-report measures of cognitive and linguistic functioning

Patrick self-reported substantial deficits and decreased quality of life according to self-report measures. Overall, Patrick indicated deficits in physical performance and function, maintaining social relationships, and behavioral regulation. Patrick performed two or more standard deviations below the mean on the Neuro-QOL NIH Toolbox measure. Furthermore, his scores on all of the BRIEF-A domains were clinically significant. Patrick reported quality of life less than 50/100 possible points on all but one domain on the QOLIBRI scale (exception: feelings) and reported a total quality of life score of 34.25.

Standardized assessments of cognitive and linguistic functioning

Patrick completed standardized testing 21 months postinjury and required 2 hr. Despite reporting deficits according to self-report measures, Patrick performed within normal limits for all but two standardized subtests demonstrating significant deficits on the delayed recall and recognition discrimination index portions of the Hopkins Verbal Learning Test were revealed. Patrick did not complete the D-KEFS Color–Word Interference Test as he is color-blind and did not complete WAIS-IV Digit Span testing.

Participant 3: Thomas

Motivational interview

Thomas' interview lasted approximately 20 min. During the interview, Thomas verbalized difficulty with attention (*... So it's like- in class when I'm having listened to the teacher I couldn't listen to the teacher. I could be focused on the teacher, um but my mind be wondering somewhere else and thinking about something else so I couldn't pay attention and all that*), mental fogginess (*Brain fog has been a huge problem of mine ... it's like a fog like over my senses at least for attention and pertaining information*), fatigue (*I don't feel restful. I don't think I feel rested, like rarely, like over the past-literally years, 2011, 7 years, I uh I probably have felt restful after sleeping like three to- between three and ten times*), and time management (*I am on a reduced academic load but sometimes*

I can't get to class. Like Monday, I missed two classes). Thomas voiced optimism about completing college.

Self-report measures of cognitive and linguistic functioning

Completion of the self-report measures revealed Thomas' self-perceived difficulties in independence and metacognition. Results from both NIH Toolbox measures revealed that Thomas self-reported difficulties in cognitive functioning at or slightly below the mean. Results of the BRIEF-A indicated greater degrees of difficulty, such that challenges in metacognition were considered clinically significant. Thomas reported quality of life below 50 out of 100 possible points on three domains (i.e., emotions, independence, and social relationships), yielding a total quality-of-life score of 50.67.

Standardized assessments of cognitive and linguistic functioning

Thomas completed standardized testing 37 months after his most recent mTBI. Testing required approximately 2 hr to complete. Thomas demonstrated significant impairments in the areas of delayed recall (HVLT-R) as well as cognitive flexibility and inhibition (D-KEFS Color–Word Interference subtests). Thomas scored at or above the normal range of functioning in all other testing domains.

DISCUSSION

Effective evaluation of both cognitive and linguistic deficits postconcussion is necessary for rehabilitation professionals to document outcomes, implement appropriate supports, and determine individuals who may or may not be susceptible to persistent deficits. Preliminary evidence exists to document factors that may contribute to persistent postconcussion deficits. However, these data have typically been collected with heterogeneous, small samples and primarily utilized survey and chart reviews (e.g., Minen et al., 2017; Sveen, Ostensjo, Laxe, & Soberg, 2013). Regardless, ample evidence exists to suggest that a relatively large subset of individuals will exhibit persistent deficits and thus may benefit from effective, early assessment and perhaps, initiation of targeted treatment (McCrory et al., 2017).

Current methods of assessment vary across professional domain, practice settings, and age at onset of injury (e.g., assessment varies by professional domain as a physical therapist may focus on cervical spine and vestibular function whereas a physician may focus on ocular function; Duff et al., 2002; Krug & Turkstra, 2015). However, testing methods are likely to include both self-report and completion of standardized, objective testing measures. We sought to explore both the objective and subjective evaluation of discrete cognitive and linguistic deficits in three individuals postinjury. Results highlighted individual differences in the type and severity of exhibited deficits; however, general themes emerged. All three participants endorsed 10 out of the possible 100 symptoms on the BISQ as experienced either daily or several times within the month prior to testing. Results of self-report measures consistently indicated challenges with independence, emotional well-being, and metacognition. However, scores differed on standardized neurocognitive tests as varying patterns emerged regarding the relation between testing and self-report measures. Early evidence indicates that this may be related to time postinjury. In the following sections, we provide potential interpretations for these results and discuss clinical implications for assessment and treatment of adults postinjury.

Testing methods and clinical implications

The potential lack of sensitivity for capturing subtle cognitive changes postconcussion through use of standardized assessment is of important clinical concern (Silverberg et al., 2015). Measuring cognitive functioning following brain injury has been deemed particularly difficult by rehabilitation professionals and researchers as these tests may provide inconsistent identification of dysfunction (Wood & Liossi, 2006). Specifically, challenges with test sensitivity when used in isolation (Lau, Collins, & Lovell, 2011), exacerbation of high-level cognitive deficits when basic cognition is impaired (Arciniegas, Held, & Wagner, 2002), and ecological validity of testing measures have been cited (Chaytor, Schmitter-Edgecombe, & Burr, 2006). Some researchers extend these concerns further citing that no neuropsychological tests have met criteria to support clinical application at this time (Randolph, McCrea, & Barr, 2005) and that long-term cognitive deficits may be undetectable by traditional postconcussion assessment (Broglio, Ferrara, Piland, & Anderson, 2006).

Concerns about the sensitivity of these measures are supported by clinicians such that a recent study exploring speech–language pathologists' perceptions of available cognitive–linguistic assessments revealed that 80% of clinicians report less than complete satisfaction and/or dissatisfaction with available tools across cognitive domains (Brown, 2018). When providing rationales, clinicians reported that 32% of the 467 reported challenges with the functional, realistic nature of assessments.

Another reason for these challenges may be the lack of baseline data available to clinicians during testing. The most sensitive standardized assessments postconcussion are enhanced by the presence of cognitive baseline performance (e.g., ImPACT; ImPACT Applications Inc., 2016); however, the availability of such information is lacking for individuals outside of athletics. Issues regarding a potential mismatch between standardized measures of cognition and language along with interview and self-report data were consistent with the participants in the current study—particularly for the two individuals who exhibited persistent postinjury symptoms. For Patrick and Thomas, significant reports of changes in functioning were noted on self-report symptom and quality-of-life measures. However, performance in all but one standardized testing domain (the delayed recall portion of the Hopkins Verbal Learning Test) was within the normal range of functioning for age, gender, and education. Functionally, both of these participants discussed cognitive challenges significantly interfering with daily roles and responsibilities and return to preinjury status (e.g., return to work, academic tasks, reliance on others to complete daily tasks).

A differing performance pattern emerged for Gloria; an individual still within 1 month of injury occurrence. In this case, it appeared that performance on standardized cognitive testing more closely related to self-report measurements such that Gloria demonstrated difficulty on assessments in verbal fluency and cognitive flexibility—domains in which she self-reported difficulties. It stands to reason that the contribution of standardized cognitive testing measures to evaluation of overall functioning in this population may be related to recovery status. However, more information is needed to understand how self-report and standardized measures relate to functional, real-world outcomes and predict long-term recovery.

Despite these challenges, the potential value of standardized assessment protocols should not be overlooked. In fact, garnering objective data regarding performance on discrete cognitive domains may serve to elucidate areas of cognition that are particularly challenging for individuals postconcussion and thus provide guidance for rehabilitation professionals developing plans regarding return to activity and direct treatment options. Results from our motivational interviews—open-ended interview methodology—revealed that each participant in the current study perceived substantial impacts on daily functioning resulting from cognitive and linguistic impairments. Despite limitations in self-report measurements following brain injury (e.g., hypersensitivity to deficits, decreased awareness), interview methods that focus on patient perspectives prove crucial to the evaluative process.

Limitations and future directions

A multiple case study approach provided opportunity for in-depth exploration into three individuals with history of concussion across the recovery spectrum. Although some individual and group conclusions can be derived from these data, we discuss future directions as they relate to study limitations.

First, the small sample size provides information about individuals at 1 month, 21 months, and 37 months postconcussion highlighting potentially the unique cognitive and linguistic deficits noted by these particular individuals at various stages in the recovery process. However, confounding demographic and injury-related variables (e.g., varying age ranges, history of previous concussion) limit interpretations of results, which apply to a broader audience. Evaluating larger sample sizes of individuals across the recovery spectrum would provide insight into both the cognitive and linguistic deficits experienced postinjury. Future research should include both modifiable (e.g., number of previous concussions, loss of consciousness) and nonmodifiable (e.g., age, gender) demographic characteristics and incorporate time postonset as critical factors in deficit modeling. Understanding for whom cognitive and linguistic deficits might persist has vital implications for deficit assessment and treatment across rehabilitation specialties and settings.

Various theoretical models exist describing the relationship between cognition and language (Steel, Ferguson, Spencer, & Togher, 2015). Whereas some scholars argue that language is a precursor to cognitive development (linguistic determinism), others argue that cognition must be fully intact for efficient language use to occur (cognitive determinism; de Villiers & deVilliers, 2000). Nonetheless, completion of daily tasks requires more than one neurological domain or subdomain to be working simultaneously and often in collaboration with one another (Constantinidou, Wertheimer, Tsanadis, Evans, & Paul, 2012). Specifically, many individuals report issues with verbal memory, verbal fluency, and reading, as was confirmed by participants in the current study. At this time, however, clinicians lack evaluative tools to objectively and efficiently capture the discriminant and overlapping functions of cognition and language impaired following concussion in both structured and functional contexts. Future research should consider the overlap between cognitive and linguistic domains when an individual performs naturalistic tasks requiring both communicative and cognitive functions and seeks to evaluate how these two domains work together to inhibit or enhance task performance. Inclusion of single- and dual-task paradigms in assessment protocols may assist with determining the overlapping and discrete functions of cognitive and linguistic domains postinjury (Howell, Kirkwood, Provance, Iverson, & Meehan, 2018). Development of such tools will provide information that will direct the development of individualized therapeutic approaches to effectively manage the postinjury symptoms experienced postinjury.

Finally, relying solely on participant self-report and completion of standardized assessments may be limiting when attempting to document holistic, functional deficits postconcussion. Taken from behavioral scientists, models of in-depth assessment at the functional level should include informant methods (self-report), objective measurements (standardized tests), and empirical observations (observation of functioning in real-world environments; Watson & Skinner, 2001). Our decision to include only two of these measurement techniques limits the application of testing findings to understanding real-world performance. From a clinical standpoint, effective assessment techniques will garner information that is useful for selecting and implementing person-centered treatment approaches. This brings to question whether rehabilitation professionals should focus on particular subdomains using isolated assessment methods, or alternatively, whether concussion assessment should include evaluation of personally relevant, real-world tasks in naturalistic contexts.

CONCLUSION

All of the participants in the current study relayed changes in cognitive–linguistic function following concussion, which negatively influenced their ability to perform occupational and academic responsibilities previously completed with ease. Because of these changes, all three verbalized frustration regarding their current level of function and independence. Speech–language pathologists have the skills required to discern the subtle and persistent cognitive and linguistic changes often experienced by individuals postinjury. However, at this time, there is no single assessment measure or battery of tests that is sensitive in objectively documenting these self-perceived changes. In fact, results of this study revealed that commonly administered standardized assessments of cognitive-linguistic functioning may not be sensitive enough to detect subtle changes in functioning—particularly for the two participants with persistent deficits. Because of this, use of multiple measures (including self-report and/or observational assessment of patients' performance during functional tasks in real-word environments) is of crucial importance if clinicians are to truly help individuals with concussion return to activities and responsibilities successfully.

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