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The Intensive Cognitive-Communication Rehabilitation (ICCR) Program for Young Adults with

Acquired Brain Injury (ABI)

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Abstract

Purpose: This study investigated the effects of an intensive cognitive-communication rehabilitation (ICCR) program for young individuals with chronic Acquired Brain Injury (ABI).

Methods: ICCR included classroom lectures; metacognitive instruction, modeling, and application; technology skills training; and individual cognitive-linguistic therapy. Four individuals participated in the intensive program (6 hours with 1 hour lunch break x 4 days x 12-weeks of treatment); three participants completed three consecutive semesters; the fourth completed one. Two controls did not receive treatment and completed assessments before and after the 12-week treatment interval only.

Results: All four experimental participants demonstrated significant improvements on at least one standardized cognitive-linguistic measure, whereas controls did not. Furthermore, timepoint significantly predicted participants' scores on two of the four standardized outcome measures, indicating that as duration in ICCR increased, scores increased. Participants who completed multiple semesters of ICCR also showed gains in their therapy and personal goals, classroom behavior, life participation, and QOL.

Conclusion: After ICCR, participants showed gains in their cognitive-linguistic functioning, classroom participation, and individual therapy. They also demonstrated improvements outside of the classroom and in their overall well-being. There is a gap between the large population of young adults with ABI who wish to return to higher education and a lack of rehabilitation programs supporting re-entry into academic environments; ICCR is a first step in reducing that gap.

Background

Individuals with Acquired Brain Injury (ABI) as a result of traumatic brain injury (TBI) or stroke (CVA) typically experience cognitive and/or language deficits that persist for years post-onset (Chapey, 2008; Cicerone et al., 2011; Kennedy, Coelho, et al., 2008; Sohlberg & Mateer, 1989).¹ Young adults are a frequently affected and growing population (i.e., age 18-36) within ABI (“TBI: Get the Facts,” 2017; “Young Stroke Survivors,” 2016).

Unfortunately, when a young adult has a brain injury during high school or college, essential aspects of the college experience (e.g., following a schedule, taking notes, studying, writing papers, giving presentations) become challenging due to deficits in executive function, attention, memory, and language skills. Post-secondary education may be challenging for individuals with ABI, but has the potential to be quite valuable for them as it would tax their problem-solving skills; provide opportunities to interact with peers (Cicerone, 2004; Lyon, 1992); and build independence (Kennedy, O’Brien, & Krause, 2012). Regrettably, individuals with ABI are typically offered transition services that prepare them for employment or independent living rather than a college/university setting (Todis & Glang, 2008). When individuals with ABI do pursue post-secondary education, they often do not seek out available support services (e.g., note-takers, counselors; Kennedy, Krause, & Turkstra, 2008). Not

¹ Although individuals with brain injury due to TBI and CVA do not present with exactly the same deficit profiles and needs, there is considerable overlap. For example, it is common for both groups to experience deficits in attention, memory, language, and executive function (Bonini & Radanovic, 2015; Rao & Lyketsos, 2000); mood and anxiety disorders (Mukherjee, Sifton, & Heller, 2006); and fatigue (Colle, Bonan, Gellez Leman, Bradai, & Yelnik, 2006).

surprisingly then, degree completion is rare for this population; and requires extensive support and extraordinary personal motivation (Todis & Glang, 2008).

Currently, Cognitive Rehabilitation (CR; Cicerone et al., 2000) is the gold standard treatment for individuals with ABI. Most CR can be organized into two broad categories: *impairment-based* therapy (e.g., Attention Process Training (APT); Sohlberg, McLaughlin, Pavese, Heidrich, & Posner, 2000) and *functional* therapy (e.g., training on the use of external memory aids, Promoting Aphasics' Communicative Effectiveness (PACE); Cicerone et al., 2011; Davis, 2005). Ideally, a comprehensive CR program would employ a holistic approach: targeting the body structure/function, or impairment level, and the activity/participation, or functional level (World Health Organization, 2002). Furthermore, it would consider psychosocial, environmental, and personal factors (Bayley et al., 2014; Cicerone et al., 2011; Corrigan & Hammond, 2013; Kennedy, Coelho, et al., 2008; Kennedy & Coelho, 2005; Scottish Intercollegiate Guidelines Network (SIGN), 2013). One could further argue that CR service delivery models for young individuals with ABI should include academic instruction, vocational counseling/rehabilitation, opportunities for community re-entry with typical peers, and/or programming for age-appropriate social and leisure activities. Yet, few programs currently exist for young individuals with ABI who wish to enroll in college that include all of these components.

There is a wealth of literature demonstrating that individuals with ABI respond variably to rehabilitation (e.g., Brady, Kelly, Godwin, Enderby, & Campbell, 2016; Cicerone et al., 2011). One individual may respond well to a particular treatment, but then, that same treatment approach may be less effective for another individual, despite similar clinical profiles (Coelho, DeRuyter, & Stein, 1996; Holland, Fromm, DeRuyter, & Stein, 1996). Many behavioral,

neurological, and psychosocial factors influence treatment recovery in ABI (Bonilha, Gleichgerrcht, Nesland, Rorden, & Fridriksson, 2016; Leininger, Strong, & Donders, 2014). Thus, one underlying driver of rehabilitation is how the brain reorganizes as a response to specific training (i.e., experience-dependent neural plasticity; (Kerr, Cheng, & Jones, 2011; Kleim, 2011; Kleim & Jones, 2008; Power & Schlaggar, 2017; Warraich & Kleim, 2010). Based on this research, brain reorganization occurs according to behavioral, sensory, and cognitive experiences that encourage specific skill use, and repetitive, intensive practice. These tenets have since been implemented in effective rehabilitation techniques for neurogenic populations (e.g., constraint induced language therapy (CILT); Pulvermüller et al., 2001).

The following principles of neural plasticity are particularly relevant to CR for young individuals with ABI interested in pursuing higher education: age (i.e., Younger brains may change more and faster than aging brains, although both are responsive to experience); intensity (i.e., increased length and frequency of treatment); salience (i.e. stimuli must be sufficiently interesting and engaging); and repetition (i.e., skill is elicited a sufficient number of times for learning). However, to our knowledge, no CR programs to date incorporate all of these principles into one design to optimize the potential for neural plasticity. The following sections detail programs that incorporate some, but not all of these principles.

Currently, most CR is provided in a hospital or clinic setting (e.g., TBI Model System Centers). While this intervention may include academic support and training, it may not be formal and is unlikely to involve real-time clinician support in the classroom setting.

In recent years, Intensive Comprehensive Aphasia Programs (ICAPs) have also become a popular option for individuals with aphasia as a result of ABI. ICAPs are efficacious treatments that are generally hosted at an aphasia center, or in a university clinic (Babbitt, Cherney, &

Worrall, 2016; Hoover, Caplan, Waters, & Carney, 2017; Persad, Wozniak, & Kostopoulos, 2013; Rodriguez et al., 2013; Rose, Cherney, & Worrall, 2013; Winans-Mitrik et al., 2014).

While these treatment programs were built using principles of neural plasticity (e.g., intensity, salience) and target both the impairment and activity/participation levels, they do not appear to be the most appropriate CR choice for young individuals with ABI interested in enrolling in higher education for a number of reasons. First, although younger individuals have participated in ICAPs, they were primarily surrounded by much older individuals (Mean (M) =53; Range 16-86; Persad et al., 2013). Second, most ICAP participants have already graduated from college and/or worked in professional careers (Persad et al. 2013). Third, caregivers are heavily involved in ICAPs, which is at odds with typical goals for college-age individuals (i.e., to increase their independence from their guardians). Most importantly, while ICAPs provide intensive treatment (≥ 3 hours of daily therapy, 2-4.5 weeks; Rose, Cherney, & Worrall, 2013), cognitive-linguistic skills are not specifically targeted in an academic context.

In addition to the efficacy of ICAPs, recent work in CR for TBI has investigated its effect on military service members. Although differences in TBI etiology and their subsequent sequelae exist between civilians and service members,² a brief discussion of the approaches used in a few of these studies is relevant to the present study. As veterans often pursue academic goals upon deployment, MacLennan & MacLennan, (2008) investigated the readiness of three veterans with

² The primary cause of TBI in the military population is blasts, blasts plus motor vehicle accidents (MVA), MVAs, and gunshot wounds. TBI in civilians is often caused by falls, MVAs, being hit with something, and/or assault. TBIs in veterans may result in different symptoms that require additional intervention than those needed by civilians with ABI (i.e., post-concussive symptoms for longer periods of time, post-traumatic stress disorder (PTSD), chronic pain, substance abuse, other medical injuries; Summerrall, 2017).

TBI to enter the post-secondary setting via a simulated college experience. The intervention involved sixteen 60-minute sessions and consisted of twelve lectures, seven of which focused on the effects of brain injury (e.g., Pathophysiology of Brain Injury) and five on study skills (e.g., Study Skills: Reading College Textbooks). The benefit of compensatory strategies (i.e., note takers, extra time for tests, video-recorded lectures, and audio-recorded textbooks) were assessed for each student. They were quizzed using short-answer, multiple-choice, and true/false questions to capture both their recall and recognition memory function. Following the intervention, two students decided not to enroll in school due to the severity of their impairments, and the third student was similarly encouraged to pursue vocation rather than school. Although referred to as a simulated college experience, this program was used primarily as an assessment. It did not provide students with academic content, nor did it provide support for those who wanted to return to school, but did not possess the necessary skills.

Additionally, the Study of Cognitive Rehabilitation Effectiveness (SCORE; Cooper et al., 2017), consisting of four treatment arms: (1) psychoeducation, (2) computer-based CR, (3) therapist-directed CR, and (4) integrated therapist-directed CR, combined with cognitive-behavioral psychotherapy (CBT), was recently completed. The fourth arm was the most comprehensive, holistic, and intensive, providing 10 hours total of individual CR, metacognitive group therapy, psychoeducational counseling, and computerized therapy, and thus would be hypothesized to be the most effective. Yet, all four arms resulted in significant cognitive, psychological, and behavioral improvements, suggesting that no particular treatment arm was significantly more effective than any other arm. Furthermore, the SCORE program was tested with individuals with mild TBI only and did not focus on transition to an academic environment.

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Some treatments have in fact been developed to support individuals with TBI in the academic environment, but these are offered to students who are already actively enrolled. The College Program for Students with Brain Injury (Kennedy & Krause, 2011), at the University of Minnesota, is one such opportunity (eligibility criteria: completed rehabilitation, accepted to a two or four-year college, and need to have return to college as a “realistic” goal). While providing a valuable service to students with ABI in the academic setting, such programs are not available to individuals who have not yet been accepted to a university due to the severity of their cognitive-linguistic impairments. Furthermore, this program teaches strategies to cope in the classroom, not the academic material. Some community colleges also provide opportunities for individuals with ABI (e.g., Coastline Community College’s Acquired Brain Injury (ABI) program), although the efficacy of these programs has not been established through experimental means.

While some of the aforementioned programs incorporated intensity (e.g., SCORE, ICAPs) and others implemented specificity of training (e.g., MacLennan & MacLennan, 2008), age (e.g., College Program for Students with Brain Injury), and/or repetition (e.g., TBI Model Systems of Care), none of them included all the key principles of neural plasticity in one program (i.e., repetition, salience, specificity of training, intensity, age). Given this literature, it appears rare for individuals with ABI to receive post-acute CR that focuses directly on the necessary skills for a successful transition to higher education (Masel & DeWitt, 2010). Therefore, in the present study, we developed a comprehensive CR program, entitled Intensive Cognitive-Communication Rehabilitation (ICCR), to address the rehabilitation needs of young individuals with ABI interested in enrolling in higher education with full inclusion. To determine the initial efficacy of this novel treatment approach, we investigated the following research questions (RQs):

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1. *Do participants demonstrate changes in cognitive-linguistic skills as a result of this novel intervention program?*

Hypothesis: ICCR incorporated key aspects of evidence-based cognitive rehabilitation (i.e., targeting impairment, function, and psychosocial aspects of ABI within individual and group settings) and principles of experience-dependent neural plasticity (i.e., age, repetition, salience, and intensity). Therefore, we hypothesized that participants with chronic ABI would improve in their cognitive-linguistic skills as measured by standardized outcome measures after treatment.

2. *Do participants improve in their classroom participation over time?*

Hypothesis: In this program, participants were provided instructional material at a reduced pace with repetition and instructed to use metacognitive strategies in the academic context. Given this design, we hypothesized that they would answer questions, make comments, and ask questions at an increased frequency and with greater accuracy and appropriateness over the course of treatment.

3. *Do participants progress toward therapy and personal goals over the course of treatment?*

Hypothesis: Participants received intensive speech-language and cognitive therapy (one - four times/week), targeting both therapy (e.g., improve auditory comprehension of complex questions) and personal goals (e.g., self-transportation) throughout the program. Therefore, we hypothesized that they would show improvements in these areas.

4. *Do participants demonstrate changes at the activity and participation levels, as well as changes to their quality of life, as a result of this program?*

Hypothesis: Individuals in ICCR participated in a semester-long academic program within a real university setting. They engaged in a college experience with a cohort of age-matched peers and

used academic facilities with other university students. They became part of the college milieu, an opportunity otherwise unavailable to them because of the severity of their brain injuries. We hypothesized that treatment in the group setting, in a college environment, would increase not only their life participation, but also their quality of life, as assessed via standardized measures and subjective reports.

Methods

Participants

Six individuals with ABI (Male = 4) as the result of a TBI ($n = 4$) or CVA were recruited from the New England region of the US through referral from physicians, speech-language pathologists, neuropsychologists, and word of mouth. Recruitment materials were emailed to professionals (e.g., physicians, speech-language pathologists) working with this population in the greater Boston area and nationally (e.g., hospitals, rehabilitation clinics, community colleges). Fliers were also posted on various academic and clinical listservs. Interested individuals who were not within commuting distance of Boston University temporarily relocated to participate in the program, as dormitory housing was not available.

Participants ranged in age from 21-34 years ($M = 27.17$, $SD = 4.99$), months post onset (MPO) from 38-97 months ($M = 68.17$, $SD = 24.38$), and education from 12-16 years ($M = 13.5$, $SD = 1.76$). The study utilized a quasi-experimental design, with treatment administered to four experimental participants (P1, P2, P3, and P4) and deferred for two control participants (C1 and C2). It should be noted that P1, P2, and P3 participated in three consecutive semesters, C1 participated in the first two semesters, and P4 and C2 participated in the spring semester only (displayed in Figure 1).

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Participants met several inclusion criteria: (a) between the ages of 18 and 36; (b) ABI after the onset of adolescence (age 13 or older)³; (c) interest in post-secondary education; (d) cognitive and/or linguistic deficits that precluded enrollment in post-secondary education; and (e) adequate vision and hearing for functional reading and conversation. Participants with cognitive and/or linguistic deficits solely as the result of a congenital or developmental disorder and/or concomitant neurological disease were excluded. Participants consented in writing before any assessments were administered in accordance with the Boston University Institutional Review Board protocol.

The diagnosis of cognitive-linguistic impairment was made using the battery of standardized assessments reviewed below. Medical records were also reviewed to determine the nature and etiology of their ABI. See Table 1 for relevant demographic information and treatment assignment. Notably, P4 had severe language deficits and mild-to-moderate cognitive deficits secondary to TBI. As we hypothesized that young individuals with any severity of ABI would improve in their cognitive-linguistic skills as a function of ICCR and he met the selection criteria for the study, he was not excluded based on his initial test scores, but rather was enrolled with support in the classroom to augment his auditory comprehension (i.e., supported communication techniques).

³ Individuals with language and cognitive deficits as a result of stroke and/or traumatic brain injury were included in this study as the primary inclusion criteria was that participants were young and interested in enrolling in college, but could not due to the severity of their cognitive-linguistic profile.

Standardized Assessments

The following assessments were administered: (a) Western Aphasia Battery - Revised (WAB-R; Kertesz, 2006) to assess broad language function, (b) Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 2012) to measure cognitive function, (c) Scales of Cognitive and Communicative Ability for Neurorehabilitation (SCCAN; Holland & Milman, 2012) to evaluate cognitive and linguistic skills, (d) Discourse Comprehension Test (DCT; Brookshire & Nicholas, 1993) to examine listening and reading comprehension at the narrative level, (e) Child and Adolescent Scale of Participation (CASP; McDougall, Bedell, & Wright, 2013) to assess participation at home, school, and in the community, and (f) subtests of the TBI Quality-of-Life (QOL) (Tulsky et al., 2016) or Neurologic Quality of Life (Neuro-QOL) (Gershon et al., 2012; i.e., communication, anxiety, depression, positive affect and well-being, and cognitive function), depending on etiology, to evaluate health-related QOL.⁴ Goal Attainment Scaling (GAS; King, McDougall, Palisano, Gritzan, & Tucker, 2000) was also incorporated to allow patients to develop personal goals for the semester. All participants were assessed with this battery both before and after each semester of the intervention. For all individuals who participated in multiple semesters of ICCR, the post-intervention scores from the first semester were used as the pre-intervention scores for the next semester. Figure 1 depicts the schedule of assessments for each participant.

Treatment

⁴ Both patient-reported outcome (PRO) measures developed according to the PROMIS standards, the Neuro-QOL has good internal consistency, test-retest reliability and responsiveness to change, and the TBI-QOL has good construct validity and internal consistency (Tulsky et al. 2016).

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Similar to a typical undergraduate student, ICCR students took four classes per semester; were administered weekly quizzes and final exams; prepared presentations and wrote papers; asked and answered questions requiring both memorization and critical thinking; discussed course content with the lecture facilitator and their peers; accessed course content online (i.e., video lectures to review later and class notes); asked the lecture facilitator to meet with them to review course content outside of class as needed; traveled from one classroom to another; took certain courses on one day and others on a different day; and stayed in an apartment near campus and/or commuted from home. One possible difference from a traditional liberal arts education was that students in ICCR reviewed video-recorded lectures, which were facilitated by an SLP. However, online courses have increased in prevalence in the last twenty years (Miller et al., 2013), and therefore, watching lectures on a screen may actually be reflective of some typical students' experiences. ICCR further diverged from a typical college environment in that students were not regularly expected to complete assignments outside of class and were reminded of assignments/course topics by the clinician as opposed to having to follow a syllabus only.

According to the principle of intensity, each treatment phase consisted of a 12-week semester, during which participants received treatment four days per week, six hours per day with a one hour lunch break. The only restriction for control subjects was that they not engage in other intensive rehabilitation during the deferred treatment phase. In each day of ICCR, students participated in academic classes and metacognitive therapy, individual speech-language-cognitive therapy, and technology skill training. Lecture content was repeated throughout the day and the schedule of activities did not vary, which allowed for specificity and repetition of training. Each of these elements is described below.

Academic coursework consisted of open source academic material (e.g., “Khan Academy,” 2017); Open Yale Courses, Bloom, 2012) spanning subjects from psychology to personal finance. Each semester was designed to simulate a liberal arts curriculum, thus comprising the functional component of ICCR, wherein students applied discretely trained skills in the relevant, salient classroom environment. Academic content was presented through video-recorded lectures moderated by a trained research assistant (RA) or clinical fellow in speech-language pathology (CF-SLP) (e.g., stopping the lecture to ask discussion questions, review information). Classes included lecture material, academic projects, and training and application of strategies. Course subjects were selected based on the complexity of the material and with consideration of participants’ interests to align with the principle of salience. The reader is referred to Appendix 1 for more details on the academic component of ICCR.

Speech-language-cognitive therapy served as the impairment-based complement to the functional classroom. Short- and long-term goals were developed according to the participants’ individual profiles, as determined from case histories, client and caregiver report, and formal testing, which also supported salience. Therapy could address the following goal areas: attention, memory, executive functioning, auditory comprehension, verbal expression, reading comprehension, written expression, motor speech, social-pragmatics, and/or augmentative-alternative communication (AAC). Metacognitive strategy training and supported practice were provided at the individual and group levels.

Participants targeted their cognitive-linguistic functioning during a technology-skills session, which included various programs (e.g., ICCR website, Microsoft Office, Google Suite, Constant Therapy). During this time, they could access previously-watched lectures to review content about which they were confused; enter information into Google sheets related to a class

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activity; write a paragraph/essay/paper for a class assignment; work on a presentation for finance or public speaking and/or target impairment-based cognitive-linguistic skills using application-based therapy.

In terms of the clinician's role, during class, the clinician targeted ICCR students' attention (e.g., redirected students during lecture preview), memory (e.g., asked students to recall lecture content immediately and after a delay), problem-solving (e.g., during moments of confusion, irritability, hypersensitivity, and within academic tasks), executive function skills (e.g., promoted students to self-monitor, self-correct, self-advocate), auditory comprehension (e.g., repeated information on request), verbal expression (e.g., facilitated lexical retrieval with semantic, phonologic, orthographic cueing and/or encouraged self-cueing), reading (e.g., supported students' oral reading), writing (e.g., assisted students' note writing), metacognitive (e.g., provided strategy instruction and modeling; facilitated application in a natural context), and pragmatic skills (e.g., targeted appropriateness, such as turn taking, topic, and timing; extinguished negative behaviors; increased social communication). The clinician was also responsible for creating the weekly quizzes and lecture notes and keeping the website current for students. During the technology skills training, the clinician supported students with application-based therapy as indicated, encouraged students to maintain attention to the tasks, and provided assistance to students reviewing classroom material, as needed.

Treatment Data

Classroom performance

Students' classroom behavioral performance was measured by on-line tracking of the frequency of "positive" behaviors (i.e., answering questions accurately (i.e., cued and uncued), asking appropriate questions, and making appropriate comments) and "negative" behaviors (i.e.,

answering questions inaccurately, asking inappropriate questions, making inappropriate comments) exhibited during coursework on a daily basis. The instructor would tally each time the participants performed one of the previously described behaviors on a paper datasheet, which was then entered into Research Electronic Data Capture (REDCap) (Harris et al., 2009) for later analysis. The reader is referred to Appendix 2 for more information regarding the classroom performance data collection process. Progress in SLP sessions was measured across different cognitive-linguistic domains (e.g., attention, auditory comprehension, etc.) with specific metrics for the task at hand (e.g., accuracy, duration, frequency).

Weekly Quizzes

Participants were administered quizzes in two courses each week. Quizzes consisted of five questions (i.e., four multiple-choice and 1 true/false) pertaining to academic content that had been repeated multiple times during the lecture and was provided in supplemental lecture notes. Quizzes were administered to 1) hold the students accountable for the material they were learning each day, 2) provide a context for them to apply metacognitive strategies; and 3) facilitate retention of information in line with the testing effect (i.e., more likely to recall information later when you have been tested on it; Batsell, Perry, Hanley, & Hostetter, 2017).

Data Analysis

First, a group level analysis was performed using logistic mixed-effect regression models to determine if timepoint significantly predicted item score on the standardized measures. Fixed effects included timepoint as a numerical predictor (Pre="0", Post1="1", Post2="2", Post3="3"). Random effects included random intercepts for subjects and items with by-subject random slopes for timepoint.

Second, to supplement the group level analysis, data from four experimental patients and two controls were analyzed on an individual basis. McNemar's tests were performed comparing

item-level accuracy between different time periods: 1) before treatment/no-treatment to the final treatment/no-treatment timepoint (P1-P3: Pre to Post3; P4 and C2: Pre to Post1; C1: Pre to Post2); and 2) between each treatment/no-treatment timepoint (i.e., P1-P3 and C2: Post1 to Post2; P1-P3: Post2 to Post3) to assess for statistical improvements on standardized measures (i.e., WAB-R, RBANS, SCCAN, and DCT). For items with gradient scoring (e.g., WAB-R object naming scores range 0 – 3), responses that received full credit were assigned a 1; responses below this threshold were assigned a 0. This type of analysis summed all of the incorrect responses (0) and correct responses (1), then, compared the proportion to see if there were significantly more positive or negative responses at between two timepoints.

Linear mixed-effects regression models were used to analyze classroom participation (i.e., summed frequency of classroom behaviors) as the dependent variable and time (i.e., weeks), behavior type (i.e., positive/negative), and their interaction as independent variables. These data were collected for each semester. However, only the data for semester three could be analyzed because the same coding system was employed throughout the entire semester by the same clinician, which was not the case for the other two semesters.

While gains in individual speech-language-cognitive therapy were measured during each therapy session by the treating clinician, qualitative improvements were noted through inspection for changes in the complexity of short-term goals across the duration of the program, which are available in Table 6.

Improvements in participation and quality of life were determined by visual inspection for increases in T-scores on the TBI- and Neuro-QOLs and CASP summary and domain scores, which are available in Table 2.

Results

Standardized Assessments

Logistic mixed-effects regression analyses accounting for differences in baseline performance across participants/items and different rates of improvement showed a positive effect of treatment on cognitive-linguistic functioning. Timepoint significantly predicted participants' scores on the WAB ($\beta=.45$, $SE=.12$, $t=3.88$, $p < .001$) and the SCCAN ($\beta=.44$, $SE=.16$, $t=2.74$, $p=.01$), indicating that participants' scores increased as the number of semesters they spent in ICCR increased, as depicted in Figure 2.

Follow-up analyses conducted at the individual participant level support the results reported above. All four experimental participants made statistically significant gains on at least one standardized assessment by the third semester of intervention. The reader is referred to Table 2 for subtest and total scores on these measures and Table 3 for statistical results of the McNemar's tests. On the WAB, P1 made statistically significant gains from the second to third timepoint (i.e., semester) and from pre-treatment to the final semester; P2 showed statistically significant gains from the first to the second semester and from pre-treatment to the final semester; and P3 demonstrated statistically significant gains from pre-treatment to the first semester and from pre-treatment to the final semester. On the RBANS, P1 made statistically significant improvements from the second to the third semester and from pre-treatment to the final semester. On the SCCAN, P1 exhibited statistically significant gains after the first semester and from pre-treatment to the final semester; and P2 showed statistically significant increases from the second to third semester and from pre-treatment to the final semester. On the DCT, only P4 demonstrated statistically significant improvements from pre-treatment to the final semester. Importantly, none of the control participants exhibited statistically significant gains on any of the standardized assessments after a period without intervention, suggesting that the gains seen in the

experimental group were not due to practice effects. Furthermore, the experimental participants did not demonstrate steady gains on each subtest each semester, as would have been if their improvements were due to repeated exposure to the tests.

Classroom Performance

Attendance

Overall, participants who committed to the program (i.e., P1, P2, P3, P4) attended consistently (see Table 4). In the first semester, P1 and P3 attended ICCR very regularly, as evidenced by attendance records of 98% and 95%, respectively. P2 committed at the start of the first semester to a less intensive schedule (i.e., three days/week), thus he attended 68% of the four-day week. Of note, he attended 86% of his 3-day week schedule. In the Spring Semester, attendance ranged from 93 – 98% for all four participants. In the Summer Semester, attendance ranged from 93 – 100%.

In-class participation

To capture changes in the classroom over time, participation (i.e., summed frequency of tracked behaviors) for each week of the third semester served as the dependent variable in a linear mixed-effects model. Fixed effects in this model included time (i.e., weeks), behavior type (i.e., positive/negative), and their interaction. To account for individual variability, participant was used as a random effect in the model. The first finding was a main effect of time ($F_{(1, 51)} = 37.75, p < 0.001$), suggesting that classroom behavior increased significantly as the third semester progressed. Secondly, and more importantly, as depicted in Figure 3, there was a significant time-by-behavior type interaction effect, ($F_{(1, 51)} = 11.249, p = 0.002$), such that the effect of time was significantly less for negative behaviors than positive behaviors ($\beta = -5.850, SE = 1.744, t(1,51) = -3.34, p = 0.002$). In other words, the frequency of positive behaviors (e.g., asking appropriate questions) increased at a greater rate over time than negative behaviors (e.g.,

asking inappropriate questions), suggesting that participants' were more positively engaged in the classroom with the duration of the third semester. It is important to note that while these results reflect the data that was collected in the third semester, they may have been influenced by the classroom experience of previous semesters. Furthermore, reliability checks could not be completed for the classroom data. Thus, these findings should be interpreted with caution.

Quiz performance

Participants demonstrated variable accuracy on the weekly quizzes, as reflected in Table 5. Anecdotally, P1 consistently studied for his quizzes across all semesters; P2 started consistently studying for quizzes in the Spring semester; and P3 did not regularly study for quizzes outside of ICCR, as he needs support to do so and that was not available through his group home. These observations are relatively consistent with their performance. Notably, one may not expect to see a linear upward trend in accuracy on the quizzes across the semester(s) as the complexity of the test varied each week.

SLP Performance

Three to five impairment-level cognitive-linguistic goals per semester were generated for each participant and targeted during individual SLP sessions via drills and structured exercises. Participants' performance in these goal areas was regularly monitored, and once the established criterion was achieved, the goal was revised. All participants who committed to at least one full semester of ICCR targeted more complex goals in their SLP sessions at the end of the treatment than at baseline.

At the time of enrollment, P1 exhibited moderate-severe cognitive deficits, moderate anomic aphasia, and mild-moderate apraxia of speech (AOS). After three semesters, he demonstrated improvements across goal areas, and now exhibits moderate impairments. P2

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initially exhibited mild-moderate anomic aphasia, and mild cognitive deficits, particularly in executive function. P2 also demonstrated broad gains across goal areas, ultimately presenting with only mild cognitive-linguistic deficits. Furthermore, after completing his third semester, P2 discharged from ICCR and re-enrolled at a local community college to finish his Associate's Degree, a goal he had abandoned prior to ICCR. P3 initially was classified as having moderate-to-severe cognitive-linguistic deficits, particularly in attention and memory, as well as a severe spastic dysarthria. At the end of Semester 3, he continued to demonstrate moderate-to-severe cognitive-communication deficits, though he demonstrated incremental gains across goal areas. Finally, P4 demonstrated Broca's aphasia, mild-to-moderate cognitive deficits of attention and executive function, and moderate AOS. Following his one semester of treatment, his profile also remained generally stable, though incremental progress was noted in his goals as well.

GAS was used to allow participants to generate specific goals that they wanted to prioritize in therapy. P1 improved in his immediate/delayed memory in the first semester (+ 20) and ability to navigate a city in the third semester (+ 3.10). P2 was interested in securing alternative transportation (i.e., wanted to begin driving lessons, take public transportation, etc.) and made gains on that goal in the third semester (+30). P3 made gains in reducing his use of a maladaptive speech intelligibility strategy (i.e., reduce finger occlusion of nose) and ability to make a daily schedule in the Fall (+ 10) and Spring (+ 12.40) semesters. P4 was interested in obtaining employment and did not make gains toward that goal, which may not be surprising given that ICCR is focused on furthering academic versus vocational goals specifically. These results are also available in Table 2.

Participation and Quality of Life

In order to measure participation, CASP responses from pre-treatment and the final available time-point were compared. All experimental participants transitioned from a score of 0 (“unable to participate”) in the School domain to a score of 65 or greater. P1, P2, and P4 all exhibited increases in their total CASP scores (+17.5, +2.9, +5.7), as did C1 (+5.0), though P3 exhibited a decrease (-12.7).

Responses from the TBI- and Neuro-QOL were compared for all patients who completed the measure more than once (i.e., P1, P2, and P3). All values refer to t-scores, with the exception of Communication on the Neuro-QOL, which does not provide a t-score so raw scores were used. P1 demonstrated an improvement in Cognitive Function (+0.8), Depression (-7.3; lower scores indicate fewer symptoms of depression), and Positive Affect and Well-Being (+4.7). He also showed an increase in Anxiety (+2.7; higher scores indicate more symptoms of anxiety). Positively, P2 demonstrated a reduction in his anxiety levels (i.e., Anxiety: -5.8), but slight decreases in the remaining QOL domains (Cognitive Function = -1; Communication = -1; Depression = +1.5; Positive Affect and Well-Being = -1). Finally, P3 demonstrated improved Anxiety levels (-5.2); decreased Cognitive Function (-8.7) and Communication (-9.9); and stable report in the remaining domains.

Treatment Fidelity

A speech-language pathologist on the project who was not directly involved in the day-to-day treatment administration documented observation of approximately 10% of the classroom instruction across the Fall, Spring, and Summer semesters. No gross deviations from the treatment protocol (see Appendix 1) were noted during those times. Treatment protocols detailing procedures for different aspects of the project were written before the start of the semester for the speech-language pathologist and/or classroom facilitators to follow.

Discussion

The results of this study provide initial evidence that an intensive cognitive-communication rehabilitation (ICCR) program resulted in improved cognitive-linguistic skills for young adults with chronic ABI. Following ICCR, all four experimental participants demonstrated statistically significant gains on at least one standardized measure of cognitive-linguistic functioning, while control participants did not. Furthermore, there was a significant linear effect of timepoint for the WAB and SCCAN, such that as the number of semesters students were in the program increased, their assessment scores increased. Extending those results, all three participants who completed multiple semesters of ICCR demonstrated significantly more positive classroom behaviors than negative behaviors over time; more complex individual SLP goals; and made gains on their personal (GAS) goals across at least one semester. Finally, those same three participants improved in their school participation and on at least one aspect of their health-related quality of life.

This study's findings support growing evidence that principles of experience-dependent neural plasticity are indeed advantageous for rehabilitation (Persad et al. 2013). ICCR deliberately incorporated many of these principles into its design (i.e., age, intensity, repetition, specificity of training, and salience). The benefits of CR for individuals with ABI are well-known, and during ICCR, the classroom setting provided a much-needed context for learning and generalization four days a week (Peach, Nathan, & Beck, 2017; i.e., intensity, repetition, age). Behaviors and metacognitive strategies targeted during individual therapy, group therapy, and technology-skills training could be immediately applied within the functional setting of the classroom, as also seen by Kennedy and Krause (2011) with their coaching intervention. These results indicate that a systematic, structured, and intensive rehabilitation program that includes both impairment and activity-level components in its treatment approach has the potential to

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improve functional skills in young adults with chronic TBI. While the key component of ICCR cannot be determined without future carefully-designed research, it is likely that the intensive, repetitive training of discrete skills, while providing a natural context for their application, is driving the improvements seen in ICCR students.

By participating in ICCR, students also became aware of strategies and accommodations that were specifically beneficial to them. Of note, P2 has returned to community college to complete an Associate's Degree and is an excellent example of a student utilizing the skills and services promoted in ICCR. He and his family met with disability services prior to re-enrolling, they utilized SLP progress notes to ensure appropriate accommodations, and they petitioned for one ICCR class to fill an educational maintenance requirement during his absence from school.

Outside of cognitive gains, students also expressed changes in their participation, social engagement, and well-being after the program. It would seem that ICCR supported the students' ability to increase their involvement in activities in their home (e.g., caregivers reported anecdotally that one participant initiated more conversation over the weekends with family), school (e.g., all students asked/answered more questions, and made more comments in class), and community (e.g., one student invited another to go to an amusement park together to celebrate their birthday). Social communication was encouraged in the program (i.e., Clinicians suggested that students eat lunch together), but not targeted directly to allow conversation and friendships to develop organically. In the future, this aspect of the program will be investigated objectively to determine the advantages/disadvantages of this approach.

The above-described reports are supported objectively in that three out of four experimental participants made gains on the CASP total participation scale by their final semester. These improvements may be partly attributable to the cognitive-communication gains

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they made in the program, which may have allowed them to engage more frequently and successfully in their homes and communities. Additionally, as ICCR courses took place in Sargent College of Rehabilitation Sciences, ICCR students attended classes on the same semester schedule as BU students and thus, had the opportunity to observe and interact with them on a regular basis in the building. The positive effects of this environment on ICCR students' psychosocial gains cannot be understated, particularly given the propensity for individuals with ABI to experience social isolation post-injury (McLean, Jarus, Hubley, & Jongbloed, 2012; Northcott & Hilari, 2011).

Gains in quality of life were expected as a result of ICCR for both individuals with cognitive-linguistic impairments secondary to TBI and/or stroke. According to the literature, social integration, a key component of ICCR, has been shown to be related to better QOL in both of these populations (Hilari, Cruice, Sorin-Peters, & Worrall, 2016; Johnston & Miklos, 2002). Furthermore, in PWA, participation in ICAPs and group therapy, have also been associated with gains in QOL, again suggesting that QOL should improve with ICCR. Interestingly, post-ICCR, participants who had completed multiple semesters of ICCR reported improvements in at least one domain, as well as decreases in at least one domain. The decreases are likely attributable to two factors: 1) increased insight into deficits; and 2) response shift, a change in self-evaluation due to improved understanding of QOL on follow-up test administration (Megari, 2013).

Although ICCR resulted in consistent positive gains on standardized assessment measures for participants who enrolled in consecutive semesters, not all participants responded similarly to the treatment. This responsiveness primarily appeared to be due to severity, insight, and motivation, which will be described in some detail below. P4 had high levels of family/caregiver support and initial motivation to attend, and so he was enrolled with accommodations for his

language impairments. Despite these adaptations, he struggled to attend, comprehend, and participate. While he demonstrated the smallest objective gains in ICCR, he did initiate use of total communication in the classroom, which was a therapy goal for him. Nonetheless, he elected to seek vocational employment upon completion of one semester, which in certain cases may be more appropriate for some young individuals with ABI (MacLennan & MacLennan, 2008).

In regards to the control subjects, both C1 and C2 were invited to enroll as experimental participants after deferring for one semester. However, neither decided to do so after re-evaluating their current levels of functioning and/or educational goals. C2 agreed to continue as a control subject for one additional semester. Notably, neither C1 nor C2 demonstrated statistically significant gains during their involvement in the study.

There are many ongoing and future avenues available for ICCR's improvement. First, although this study demonstrated preliminary evidence of efficacy, it needs to be studied with a larger, more diverse patient sample. Thus, these results, as well as any limitations, should be interpreted with caution, especially given the small sample size. Second, time post onset (i.e., All participants were in the chronic phase of recovery; Moss & Nicholas, 2006) and etiology (i.e., Participants with TBI and stroke significantly improved) did not appear to influence treatment outcome. Yet, severity did seem to play a role (i.e., P1 and P2: less severe; robust treatment responses; P3 and P4: more severe; less favorable treatment responses). Thus, ICCR does look to be a better fit for individuals with chronic ABI with deficits in the mild and moderate range. Third, it would be ideal if ICCR could be scaled to other colleges and rehabilitation clinics and partnerships with the local community and state may be useful in meeting that goal. Fourth, it may also be beneficial to explore the effects of neuromodulation (e.g., TDCS) concurrent with behavioral intervention to enhance ongoing treatment. Finally, although no participants thus far

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have been safe to undergo magnetic resonance imaging (MRI), we hope to explore the effects of ICCR on brain reorganization (i.e. functional near-infrared spectroscopy (fNIRS); electroencephalography (EEG); functional MRI (fMRI); diffusion tensor imaging (DTI)) if possible.

Conclusion

Currently, there exists a gap in rehabilitation services for young individuals with chronic ABI, who want to continue their education but are not yet able to do so. ICCR is a first step in filling that gap. This program was designed using principles of experience-dependent neural plasticity and cognitive rehabilitation to support young adults with ABI to build the skills necessary to enroll in post-secondary education. Following ICCR, participants demonstrated improved cognitive-linguistic skills, more appropriate classroom behavior, and increased complexity of targeted SLP goals. Beyond these improvements, participants reported increased life participation and QOL. They enjoyed ICCR and found it beneficial; they learned from one another, supported each other, and even became friends. Overall, these findings demonstrate initial effectiveness of the ICCR program and support its use with this population.

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Figure captions:

Figure 1. Schedule of standardized assessment testing for experimental participants and controls

Figure 2. Number of correct responses on each standardized test for experimental participants at each timepoint. Timepoint significantly predicted participants' scores on the WAB and SCCAN, indicating that as the number of semesters in ICCR increased, participants' scores on those tests increased. *Note:* * indicates that timepoint was a significant predictor of score

Figure 3. Results of linear mixed effects regression revealed that time (i.e., weeks) had a significantly greater effect on the positive classroom behaviors (solid line) than the negative classroom behaviors (dotted line), supporting that ICCR students demonstrated more accurate and appropriate classroom participation with the duration of the third semester.

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Appendix 1: ICCR Treatment Protocol

Semester 1 classes: Psychology, Economics, US History, Personal Finance, Public Speaking

Semester 2 classes: Biology, Psychology, US History, Finance, Communications

Semester 3 classes: Biology, Psychology, Finance, US History

Pre-semester preparation

- Determine semester schedule
- Decide on courses from content available on Khan Academy, Open Yale Courses, other on-line sources and students' interests
- Choose units/sub-topic videos with 30-40 minutes lecture content/hour
- Administer pre-treatment test battery unless student is returning for a consecutive semester, in which case use previous post-treatment scores
- Create the following documents for each class
- Semester Tracker - plan and track completion of video lectures
- Syllabus – instructor information, class description, dates/schedules, lecture topics, and grading rubric
- Weekly PowerPoints – presentations with linked videos for core and elective classes
- Generate materials for individual treatment sessions to target:
- Impairment-based cognitive-linguistic goals based on pre-testing for 1:1 sessions and classroom
- Functional GAS goal(s) developed with clients in pre-testing

During the semester

Classes

Core classes: "Preview, Review/Discuss, Quiz Review" Model

- First hour (preview): watch lecture with no distractions, pause only for student questions.
- Second hour (review/discussion): re-watch content presented in the first hour; introduce metacognitive strategies (e.g., RITA: Rehearse, Imagine, Take Time, Activate; STEP BACK: Self-care, Take Breaks, Exercise, Pace yourself, Be open to help, Avoid interruptions, Cut distractions, Keep it simple) and mnemonics while providing rationale for their use; provide visual aids, written support, and repetition to support memory and auditory comprehension; facilitate conversation between the students to recap what they have learned and generate connections between new and old content.
- Third hour (quiz review): answer sample quiz questions that have been prepared by the clinician and apply metacognitive strategies they learned in the previous hour to encode salient information from the lecture that they may be quizzed on later in the week

Elective classes:

- Option 1

- 60 minutes (discussion): watch the lecture and clinician stops it and asks students to recall salient information that was just presented taxing their immediate recall. Then, they discuss the meaning/significance/relevance and relate it to current events and their environment
- Option 2
 - Find an article relevant to the subject
 - Read as a group with participants taking turns
 - Discuss main ideas following each paragraph/section
 - Generate a slide presentation as a group to be presented by students on final day of article discussion

ICCR Website

- Student “Lecture notes” – Clinician posts notes in basic outline format on academic content in CORE subject
- Research Assistants (RAs) create these outside of class
- Videos – post lecture content for all classes at the end of each day

Individual sessions

- 60 minute cognitive-linguistic therapy

Technology Time

- 60 minutes of Constant Therapy, individual or supported lecture review, or classroom assignment completion (i.e., may involve use of internet, Google Docs, Microsoft Word)
- RA provides ICCR students support during this hour

Testing

- Quizzes – 5 question multiple choice (1 True/False) questions regarding content from that week’s lecture material
- Administered Mondays/Tuesdays prior to lecture in CORE classes ONLY
- Hand back to students for guided self-correction during “Quiz Review” hour
- Final exam – compilation of quizzes; CORE classes ONLY

Appendix 2: Additional details regarding classroom data

Operational definitions used for coding classroom participation behaviors:

- **Accurately answered question:** Student gave an accurate response reflecting comprehension of the material
- **Accurately answered question cued:** Clinician provided support for the student to answer the question accurately (i.e., choices, phonemic (first sound of the word), semantic (related word), orthographic (wrote part of the word)) or, if the clinician asked the student to elaborate.
- **Inaccurately answered question:** Clinician explicitly stated that the student was incorrect and asked them to try again, or asked another student to answer. Also, relevant if the student replied “I don’t know” when asked a question
- **Appropriate question:** Student generated a question that was on topic, relevant, and added value to the conversation (e.g. While discussing addictive food product, a student asked if cigarettes have similar addictive properties? Although class is currently discussing food, student connected addictive properties to another known source).

Inappropriate question: When the student produced questions that were directed at discontinuing a productive academic activity such as, “Why do we have to do this?” or questions that were irrelevant to the current topic?, “Did you know last summer I scraped my knee and got a bruise?”

- **Appropriate comment:** When the student’s response was relevant to the current topic, and/or added value to the subject, or when students made comments that related information in the current class to information they were learning in another class.
- **Inappropriate comment:** Student produced a comment that was not irrelevant to the current topic, was distracting to other students, or included information that should be discussed individually (if at all) and not with the group during class

Sample datasheet used to collect classroom participation data

Classes

Date

Clinician

ICCR Day

	P1		P2		P3	
Answered Question						
Asked Question						
Made Comment						
Notes						

Key: accurate/appropriate = +, accurate/appropriate cued = (+), inaccurate/inappropriate = -

Table 1. Demographic Information

	P1	P2	P3	P4	C1	C2
Etiology	TBI	CVA	TBI	TBI	CVA	TBI
Age	21	29	25	34	31	23
Sex	M	M	M	M	F	F
Education (years)	12	15	12	16	14	12
Months Post Onset	49	70	96	97	59	38
Cognitive-Linguistic Profile	Moderate-severe cognitive deficits, moderate aphasia, mild-moderate AOS	Mild-moderate aphasia, mild cognitive deficits	Severe cognitive deficits, severe spastic dysarthria	Severe Broca's aphasia, mild-to-moderate cognitive deficits, moderate AOS	Mild aphasia, mild AOS	Moderate cognitive deficits, moderate-to-severe hypokinetic dysarthria

Note: TBI – Traumatic Brain Injury; CVA – Cerebrovascular Accident; M - Male; F - Female; AOS – Apraxia of speech

Table 2. Standardized tests scores at each time point for each participant

		P1				P2				P3				P4		C1			C2	
		Pre	Post1	Post2	Post3	Pre	Post1	Post2	Post3	Pre	Post1	Post2	Post3	Pre	Post	Pre	Post1	Post2	Pre	Post
WAB-R	Language Quotient	56.8	60.4	65.9	64.5	72.5	80.3	82.4	85.3	69.9	78.9	81.0	82.8	24.1	25.1	85.0	84.5	87.0	90.6	91.3
	Cortical Quotient	65.2	66.5	73.9	73.2	76.4	81.8	86.3	89.1	71.6	81.0	83.6	84.8	34.0	32.9	88.0	89.4	91.0	90.3	89.8
	Aphasia Quotient	61.9	66.6	78.3	74.9	78.8	85.8	88.1	93.3	62.5	76.3	83.0	83.0	18.8	17.5	84.3	91.0	91.8	91.3	92.8
RBANS	Imm. Mem.	44.0	44.0	44.0	61.0	69.0	76.0	83.0	73.0	44.0	40.0	40.0	44.0	40.0	40.0	73.0	76.0	73.0	69.0	87.0
	V/C	69.0	72.0	72.0	69.0	72.0	87.0	87.0	100.0	66.0	75.0	69.0	72.0	96.0	84.0	84.0	92.0	84.0	60.0	53.0
	Language	40.0	44.0	40.0	47.0	82.0	87.0	78.0	74.0	47.0	74.0	47.0	74.0	40.0	40.0	87.0	78.0	54.0	74.0	85.0
	Attention	43.0	49.0	40.0	43.0	40.0	40.0	43.0	46.0	53.0	64.0	53.0	43.0	43.0	46.0	49.0	40.0	56.0	56.0	43.0
	Del. Mem.	44.0	44.0	48.0	52.0	94.0	88.0	97.0	94.0	40.0	44.0	44.0	40.0	40.0	40.0	94.0	83.0	97.0	44.0	44.0
	Total	45.0	46.0	45.0	49.0	64.0	69.0	72.0	71.0	46.0	52.0	46.0	49.0	47.0	46.0	71.0	67.0	66.0	52.0	54.0
	SCCAN	Oral Expr.	42.1	47.4	57.9	57.9	78.9	78.9	73.7	89.5	47.4	47.4	57.9	52.6	15.8	5.3	89.5	84.2	94.7	100.0
	Orient.	58.3	83.3	91.7	100.0	100.0	100.0	100.0	100.0	58.3	91.7	66.7	66.7	50.0	91.7	100.0	100.0	100.0	100.0	83.3
	Memory	42.1	36.8	47.4	57.9	42.1	52.6	84.2	84.2	21.1	26.3	31.6	42.1	21.1	21.1	57.9	68.4	89.5	31.6	26.3
	Speech	61.5	69.2	69.2	69.2	69.2	100.0	92.3	100.0	84.6	100.0	92.3	100.0	30.8	46.2	76.9	100.0	92.3	100.0	92.3
	Reading Comp.	33.3	83.3	66.7	83.3	83.3	83.3	83.3	91.7	58.3	66.7	58.3	41.7	66.7	33.3	83.3	91.7	83.3	75.0	66.7
	Writing	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	85.7	71.4	85.7	85.7	42.9	42.9	57.1	71.4	57.1	71.4	71.4
	Attention	43.8	56.3	62.5	81.3	75.0	75.0	81.3	93.8	43.8	50.0	56.3	50.0	50.0	56.3	87.5	100.0	93.8	68.8	75.0
	Prob. Solv.	47.8	69.6	82.6	87.0	87.0	82.6	78.3	100.0	56.5	52.2	56.5	56.5	47.8	60.9	95.7	95.7	91.3	69.6	82.6
	Total	46.0	60.0	63.0	71.0	70.0	75.0	80.0	86.0	54.0	59.0	58.0	58.0	37.0	41.0	64.0	68.0	72.0	63.0	55.0
DCT	List. + Read. Total	45.0	51.0	54.0	48.0	60.0	53.0	60.0	57.0	38.0	41.0	43.0	46.0	0.0	40.0	64.0	68.0	72.0	63.0	55.0
CASP	Home	79.2	100.0	79.2	100.0	91.7	83.3	87.5	83.3	87.5	83.3	79.2	79.2	79.2	70.8	91.7	100.0	100.0		87.5
	Neigh. and Comm.	50.0	68.8	50.0	81.3	75.0	62.5	75.0	93.8	81.3	75.0	68.8	75.0	68.8	68.8	93.8	93.8	100.0		100.0
	School	0.0	75.0	80.0	90.0	0.0	85.0	85.0	85.0	0.0	75.0	75.0	85.0	0.0	65.0	0.0	0.0	0.0		100.0
	Home and Comm.	100.0	50.0	58.3	95.0	80.0	68.8	68.8	85.0	81.3	62.5	62.5	45.0	37.5	75.0	100.0	100.0	100.0		87.5
	Total	75.0	76.3	69.4	92.5	83.3	76.3	80.3	86.3	83.9	75.0	72.4	71.3	64.3	70.0	95.0	98.3	100.0		93.8
NEURO- and TBI- QOL	Anxiety			41.2	43.9			54.2	48.4			41.2	36		49.4			42.1		52.0
	Cog. Fxn.			43.0	43.8			43.9	42.9			32.8	24.1		47.5			44.9		38.2
	Communication			45.4	45.4			20.0	19.0			57.5	47.6		40.3			19		49.9
	Depression			68.3	61.0			45.3	46.8			38.3	38.3		70.5			36.9		63.0
	Pos. Aff.			33.7	38.4			57.8	56.8			67.8	67.8		43.1			68.0		41.5
GAS	Change		20.0	0.0	3.1		0.0	0.0	30.0		10.0	12.4	0.0							

Note Western Aphasia Battery- Revised (WAB-R; Kertesz, 2006); Repeatable Battery for the Assessment of Neuropsychological Status Update (RBANS Update; Randolph, 2012); Scales of Cognitive and Communicative Ability for Neurorehabilitation (SCCAN; Holland & Milman, 2012); Discourse Comprehension Test (Brookshire & Nicholas, 1993); Child and Adolescent Scale of Participation (CASP) (McDougall et al., 2013); TBI Quality-Of-Life (QOL; Tulsky et al., 2016), or Neurologic Quality Of Life (Neuro-QOL; Gershon et al., 2012); Goal Attainment

Scaling (GAS; King et al., 2000); Imm. Mem. = Immediate Memory; V/C = Visuospatial Constructional; Del. Mem. = Delayed Memory; Oral Expr. = Oral Expression; Orient. = Orientation; Prob. Solv. = Problem Solving; List. + Read. Total = Listening And Reading; Neigh. and Comm. = Neighborhood and Community, Home and Comm. = Home and Community Living Cog. Fxn. = Cognitive Function; Pos. Aff. = Positive Affect and Well-Being;

Table 3. Statistical results of McNemar’s tests used to test for item-level gains in standardized measures after each assessment timepoint

Time point	P1				P2				P3				P4	C1			C2
	Pre-Post1	Post1-Post2	Post2-Post3	Pre-Post3	Pre-Post1	Post1-Post2	Post2-Post3	Pre-Post3	Pre-Post1	Post1-Post2	Post2-Post3	Pre-Post3	Pre-Post1	Pre-Post1	Post1-Post2	Pre-Post2	Pre-Post1
WAB-R			$\chi^2 :5.0;$ $p=.025$	$\chi^2 :10.1;$ $p=.001$		$\chi^2 :15.6;$ $p <.001$		$\chi^2 :8.0;$ $p <.01$	$p=.007$				$\chi^2 :9.6;$ $p <.01$				
RBANS			$\chi^2 : 8.5;$ $p=0.004$	$\chi^2 :18.3;$ $p <.001$													
SCCAN	$p <.001$			$\chi^2 :19.9;$ $p <.001$			$p=.031$	$p <.01$									
DCT													$\chi^2 :38.0;$ $p <.01$				

Note: Blank cell = Change was non-significant; Bold value = Gains were statistically significant, according to McNemar’s Test, $p < 0.05$; Timepoint: Pre = Baseline testing, Post1 = Semester 1, Post2=Semester 2, Post3 = Semester 3/final timepoint; Western Aphasia Battery- Revised (WAB-R; Kertesz, 2006); Repeatable Battery for the Assessment of Neuropsychological Status Update (RBANS Update; Randolph, 2012); Scales of Cognitive and Communicative Ability for Neurorehabilitation (SCCAN; Holland & Milman, 2012); Discourse Comprehension Test

Table 4. ICCR Attendance (% of days attended)

	Semester		
	Fall	Spring	Summer
P1	98.0	95.0	100.0
P2	68.0	98.0	100.0
P3	95.0	98.0	95
P4	n/a	93.0	n/a

Note: P2 elected to attend only 3/4 days of ICCR for his first semester. He attended 86 % of the days that he committed to attending the first semester of ICCR.

Table 5. Participant's quiz data (i.e., Proportion of correct items/total items represented as a percent correct)

Quiz #	P1						P2						P3						P4					
	Fall		Spring		Summer		Fall		Spring		Summer		Fall		Spring		Summer		Fall		Spring		Summer	
	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6
1	80	60	80	60	60	60	n/a	80	100	100	80	80	20	40	60	80	40	40	n/a	n/a	60	60	n/a	n/a
2	40	40	80	100	100	100	60	20	100	100	40	60	60	60	80	80	60	60	n/a	n/a	80	n/a	n/a	n/a
3	50	100	60	100	40	40	100	100	100	100	40	80	83	40	100	100	40	40	n/a	n/a	60	60	n/a	n/a
4	40	40	100	100	80	80	60	60	80	80	40	100	40	60	80	100	40	40	n/a	n/a	20	20	n/a	n/a
5	80	40	60	40	60	60	80	80	100	100	20	100	40	60	80	100	60	60	n/a	n/a	60	40	n/a	n/a
6	80	69	80	40	60	60	100	31	80	40	80	80	40	38	80	60	20	20	n/a	n/a	80	60	n/a	n/a
7	100	60	60	80	80	80	80	80	100	60	60	60	80	60	100	80	60	60	n/a	n/a	60	80	n/a	n/a
8	80	80	80	80	40	40	60	80	100	80	40	60	40	80	100	60	20	20	n/a	n/a	80	20	n/a	n/a
9	100	100			0	0	100	100			80	40	80	80			20	20						
10	80				60	60	80				60	40	100				60	60						

Note: C1=Psychology I, C2=Economics I, C3=Psychology II, C4=Biology I, C5=Psychology III, C6=Biology II All quizzes were 5 questions (i.e., 4 multiple-choice and 1 True/False), with the exception of Quiz 6 in C2, which was out of 16 points.

Table 6. SLP treatment goal areas

	Initial Goal Areas	Final Goal Areas
P1 (August 2016 - August 2017)	<ul style="list-style-type: none"> • Selective attention in a non-distracting environment with minimal cues • Concrete problem solving with moderate cues and extra time • 1-paragraph auditory comprehension 	<ul style="list-style-type: none"> • Alternating/divided attention in a mildly distracting environment with minimal cues • Mixed concrete-abstract problem solving with minimal-moderate cues and extra time • Word-to-phrase level reading and writing
P2 (August 2016 - August 2017)	<ul style="list-style-type: none"> • 1-2 paragraph auditory comprehension with moderate cues and extra time • Concrete problem solving • Organization and cognitive flexibility in concrete, discrete scenarios with maximal cues 	<ul style="list-style-type: none"> • Multi-step functional problem solving with moderate cues • Organization and cognitive flexibility in functional situations with moderate-maximal cues
P3 (August 2016 - August 2017)	<ul style="list-style-type: none"> • 1-5 minute sustained attention in a minimally distracting environment with moderate-maximal cues • Basic concrete problem solving with maximal cues and extra time • <15 automatic utterances per session with maximum cues 	<ul style="list-style-type: none"> • 10 minute sustained and selective attention in a classroom environment with minimal cues • Minimally-moderately complex concrete problem solving with moderate-maximal cues and extra time • <10 automatic, inappropriate utterances per session with minimal cues
P4 (January - May 2016)	<ul style="list-style-type: none"> • Use total communication on 3 occasions to repair breakdowns given maximal cues • Identify basic familiar pictures by name from a field of 3 	<ul style="list-style-type: none"> • Use total communication on 4-5 occasions to repair breakdowns given moderate cues • Identify basic familiar pictures by name from a field of 4

Note: P = Participant; Date ranges refer to the time periods during which the participant was enrolled in ICCR