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Research Article

An Evaluation of Reading Comprehension of Expository Text in Adults With Traumatic Brain Injury

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Purpose: This project was conducted to obtain information about reading problems of adults with traumatic brain injury (TBI) with mild-to-moderate cognitive impairments and to investigate how these readers respond to reading comprehension strategy prompts integrated into digital versions of text.
Method: Participants from 2 groups, adults with TBI (n = 15) and matched controls (n = 15), read 4 different 500-word expository science passages linked to either a strategy prompt condition or a no-strategy prompt condition. The participants' reading comprehension was evaluated using sentence verification and free recall tasks.
Results: The TBI and control groups exhibited significant differences on 2 of the 5 reading comprehension measures: paraphrase statements on a sentence verification task and communication units on a free recall task. Unexpected group differences were noted on the participants' prerequisite reading skills. For the within-group comparison, participants showed significantly higher reading comprehension scores on 2 free recall measures: words per communication unit and type–token ratio. There were no significant interactions.
Conclusion: The results help to elucidate the nature of reading comprehension in adults with TBI with mild-to-moderate cognitive impairments and endorse further evaluation of reading comprehension strategies as a potential intervention option for these individuals. Future research is needed to better understand how individual differences influence a person's reading and response to intervention.

Key Words: traumatic brain injury, cognition, reading, adults, education, assessment, dyslexia

Adult survivors of traumatic brain injury (TBI) often enroll in postsecondary or professional education after their injuries in order to establish, resume, or change career paths (Ackerman, DiRamio, & Mitchell, 2009; Kennedy, Krause, & Turkstra, 2008). Evidence shows that adults with TBI who are enrolled in postsecondary education programs struggle academically compared to their uninjured peers (Radford & Wun, 2009; Todis, Glang, Bullis, Ettel, & Hood, 2011). A growing number of these adults face educational failure as a result of problems with academic reading activities (Kennedy, Krause, et al., 2008; Sohlberg, Fickas, & Griffiths, 2011). These problems are compounded in the workplace; advanced reading demands along with other complex skills are increasing across job sectors, compelling young, middle-age, and older employees—with or without TBI—to enroll in higher education courses (Mitchell, Kemp, Benito-Leon, & Reuber, 2010; Murnane, Sawhill, & Snow, 2012).

Problems with academic reading difficulties are particularly concerning given increasing numbers of individuals with combat-acquired and sports-related TBIs (Cook & Kim, 2009; Guskiewicz et al., 2003). A 2008 study by the RAND Corporation estimated that 320,000 service members probably experienced a brain injury during deployment (Tanielian & Jaycox, 2008). In 2007–2008, an estimated 60,000 to 90,000 veterans enrolled in postsecondary education were coping with cognitive impairments that could impact their reading comprehension abilities and ultimately compromise their academic as well as vocational success (Belanger, Kretzmer, Yoash-Gantz, Pickett, & Tupler, 2009; Hoge et al., 2008; Radford & Wun, 2009). Estimates for sports-related concussions have increased by 62% from 2001 to 2009 and range from 248,000 to 300,000 per year (Faul, Xu, Wald, & Coronado, 2010; Schatz & Moser, 2011). Although most of these individuals report that symptoms resolve within hours or days, a history of concussion is associated with increased risk for repeated concussions and persistent neuropsychological symptoms that can impact

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their academic performance (Guskiewicz et al., 2003; Moser, Schatz, & Jordan, 2005).

Given the diversity in ages of adults with TBI and in mechanisms of injury, the skill and impairment profiles of these individuals are diverse. In this study, we targeted adults with TBI who reported problems with reading comprehension that were not explained by (a) premorbid reading challenges, (b) visual deficits, or (c) frank acquired linguistic impairments. The target population often report that they can still read for most purposes but have problems understanding and/or remembering ideas when reading connected text (Lezak, Howieson, & Loring, 2012; Mann, 2006; Salmen, 2004).

A common problem following TBI with the potential to impact an individual's reading comprehension is cognitive impairment (Lezak, 1995; Sohlberg & Mateer, 2001). Cognitive impairment after TBI is known to affect other high-level academic learning and cognitive–communicative activities. For example, many students with TBI have reported difficulty following instructions for assignments, remembering new content, and writing essays (Hall & DePompei, 1986; Kennedy, Krause, et al., 2008). Cognitive impairments include problems with attention, working memory, and executive functions (Lezak et al., 2012; Sohlberg & Turkstra, 2011). These key cognitive functions are critical in the selection and organization of incoming information; the retrieval and transfer of information to and from long-term memory; and the active manipulation, integration, and construction of information (Ericcson & Kintsch, 1995; Kintsch, 1988).

Despite the growing problem of cognitive impairment following TBI, the research regarding reading comprehension after TBI is severely limited. In order to address the gaps in the research literature, we conducted this study with two objectives. The first objective was to obtain information about the nature of reading comprehension problems after TBI by comparing the reading comprehension performance of adults with TBI to controls matched for age, gender, and education. The second objective was to investigate whether reading comprehension performance in adults with TBI changes when participants are prompted to use reading strategies. In the following section, we describe the theoretical model of reading comprehension that we used as a framework for this study, followed by a discussion of the development of the strategy prompt intervention used in the study.

Interactive Activation (IA) Model of Reading Comprehension

The reading literature offers a number of validated models that depict reading comprehension in unimpaired populations (e.g., Gernsbacher, 1997; Kintsch, 1988; Rumelhart, 2004; Verhoeven & Perfetti, 2008). Different models focus on different aspects of the reading process; however, a common thread is the conceptualization that reading is an iterative and integrative function involving ongoing and simultaneous processing of information from the text and prior knowledge.

The IA model addresses how cognitive factors might disrupt an individual's reading comprehension (Perfetti, 1985; Verhoeven & Perfetti, 2008). In the IA model, reading comprehension is conceptualized as a system of component processes, with each component serving particular functions. The two main components in the IA model of reading comprehension are word identification and comprehension (Verhoeven & Perfetti, 2008).

The function of the word identification component is to automatically activate and retrieve word meaning. At the word identification level, orthographic and phonological processes occur more or less simultaneously to lead to word retrieval; both processes interact with high-level processes to resolve ambiguities (Verhoeven & Perfetti, 2008). For skilled readers, word identification is an automatic process and is generally preserved after TBI (Lezak, 1995; Lezak et al., 2012).

Of primary interest in this study is the comprehension component of the IA model. Comprehension is conceptualized as a process of constructing mental representations of what is being read at three different levels: (a) the surface, or verbatim, level; (b) the propositional, or paraphrase, level; and (c) the situational, or inference, level (Verhoeven & Perfetti, 2008). Different processes contribute to the formulation of these different types of mental representations (Verhoeven & Perfetti, 2008; Zwann & Radvansky, 1998).

At the *surface* level, readers hold a verbatim representation of the sentence—essentially a snapshot of the sentence that is retained just long enough for syntactic processing to establish relationships between activated word meanings. As the meaning of the sentence unfolds, readers construct the *propositional* level of mental representation. At this level, readers comprehend the sentence as a whole and can typically demonstrate this understanding by paraphrasing the sentence. As readers continue to read, they construct the next level of mental representation—the *situational* level. At the situational level, readers integrate meaning within the text to relevant background knowledge in order to create an integrated understanding of the content they are reading (Verhoeven & Perfetti, 2008). Situational-level understanding requires higher level comprehension skills that include inferencing, comprehension monitoring, and sensitivity to discourse structure (Zwann & Radvansky, 1998).

The three levels of comprehension conceptualized in the IA model provided a useful framework for investigating how an individual's reading comprehension after TBI might differ from that of controls and suggested possible targets for reading comprehension intervention (Perfetti & Matron, 1996). The very limited research pertaining to reading comprehension and cognition in adults with TBI provided a basis for anticipating how cognitive impairments might differentially impact different levels of reading comprehension ability as conceptualized by the IA model.

A study by Schmitter-Edgecombe and Bales (2005) compared the narrative reading performance of adults with a severe closed head injury (CHI) to that of uninjured controls. A think-aloud protocol was used in which participants verbalized what they were thinking after reading each sentence of a narrative, and then those productions were analyzed using a coding scheme that distinguished between inferential comments, including explanations, elaborations, and associations, and noninferential comments, including repetitions and paraphrases. Compared to controls, the readers with a CHI were more likely to produce repetitions and paraphrases; that is, the readers with a CHI were more likely to be restricted to the content of the recently read sentence. From the perspective of the IA model, the readers with a CHI focused on the surface and propositional levels of comprehension. These readers did not demonstrate integration of ideas across the narrative as would be expected as the situational level of understanding is constructed. Schmitter-Edgecombe and Bales (2005) hypothesized that differences in the readers' working memory contributed to the differences in performance.

Several studies evaluating other high-level cognitive–communicative functions in the TBI population, such as listening comprehension and discourse production, provide further empirical support for predicting breakdowns at different levels of reading comprehension (e.g., Chapman et al., 1992; Coelho, 2002; Coelho et al., 2013; Moran & Gillon, 2005; Moran, Kirk, & Powell, 2012; Tompkins, Bloise, Timko, & Baumgaertner, 1994). Ferstl, Walther, Guthke, and Von Cramon (2005) compared the narrative listening comprehension abilities of four groups: adults with left-hemispheric brain damage ($n = 18$), adults with right-hemispheric brain damage ($n = 12$), adults with traumatic brain damage ($n = 34$), and uninjured controls ($n = 49$). Across all three groups with brain damage, implicit questions were more difficult to answer than explicit questions. Similarly, Moran and Gillon (2005) showed that adolescents with poor working memory due to TBI performed worse than controls on inference measures that were completed after listening to narratives. However, when working memory demands were controlled, inference comprehension for the TBI group was no different than that for the controls (Moran & Gillon, 2005). These findings are pertinent given that inferencing is a critical skill for the situational level of understanding (Verhoeven & Perfetti, 2008; Zwann & Radvansky, 1998).

Discourse production deficits have been linked to executive function and working memory impairments (Chapman et al., 1992; Douglas, 2010; Lê, Coelho, Mozeiko, Krueger, & Grafman, 2012). For example, in story retell tasks, adults with TBI produced less relevant content and fewer organizational elements compared to uninjured adults (Coelho, Ylvisaker, & Turkstra, 2005).

The connection between other cognitive deficits and breakdowns in reading comprehension also comes from studies of reading comprehension in other populations with specific cognitive impairments (Carreti, Cornolid, DeBeni, & Romano, 2005; Samuelson, Lundberg, & Herkner, 2004; Stine-Morrow, Miller, Ganage, & Hertzgog, 2008). For example, readers with attention deficit and hyperactivity disorder showed reduced performance on inferencing tasks compared to unninjured readers (Samuelson et al., 2004). As another example, when young adult readers were compared to older adult readers, differences in working memory between the groups impacted comprehension at both the propositional and situational levels of understanding. These differences were mitigated by the readers' self-regulation abilities (Stine-Morrow et al., 2008).

Strategy Prompts to Improve Reading

The fledgling treatment research identifying methods for managing impairments in reading comprehension following TBI has focused on the evaluation of reading strategies to help readers compensate for cognitive impairments (Griffiths, Sohlberg, Samples, Close, & Dixon, 2010; Mann, 2006). Reading strategy intervention is based on the executive function literature that offers support for training adults with TBI to use metacognitive strategies to compensate for a wide range of cognitively based impairments (Kennedy & Coelho, 2005; Kennedy, Coelho, et al., 2008). Performance is enhanced by teaching clients to systematically follow a series of steps that facilitate the self-monitoring of understanding when they are engaged in other learning activities (Kennedy, Coelho, et al., 2008). For example, strategies that facilitate mental imagery and elaborated rehearsal have been shown to enhance an individual's learning and recall of verbal material (Sohlberg & Turkstra, 2011). Metacognitive strategy instruction practice guidelines emphasize the efficacy of training domain-specific strategies to facilitate improvement in targeted areas (Kennedy, Coelho, et al., 2008).

To date, no research is available that has validated the use of specific reading comprehension strategies with adults with TBI. The largest reading strategy literature base comes from the regular and special education fields for children and adolescents. Recent meta-analyses provide compelling evidence for the use of reading strategy instruction to improve comprehension with related populations (Berkeley, Scruggs, & Mastropieri, 2009; Gajiria, Jitendra, Sood, & Sacks, 2007). The most scrutinized and supported components of reading strategy intervention include (a) helping activate background knowledge or anticipate content before readers begin their reading, (b) facilitating active manipulation of the content during the reading process, and (c) helping readers integrate information with prior knowledge for later recall (Berkeley et al., 2009; Gajiria et al., 2007). The effectiveness of these strategies is supported by evidence showing a benefit to adolescent and adult readers with other learning disabilities. By supporting the active processing of content and self-monitoring of understanding, individuals have shown improvements in reading comprehension performance, including higher level skills such as inferencing and content integration, at the situational level of understanding (Manset-Williamson, Dunn, Hinshaw, & Nelson, 2008; Mastropieri et al., 1996; McNamara, 2004; Palinscar & Brown, 1984; Souvignier & Mokhlesgerami, 2006).

Speech-language pathologists have reported favorable outcomes from training clients to use reading comprehension strategies such as SQ3R: Survey, Question, Read, Recite, Review; and PQRST: Preview Question, Read, Summarize, and Test to address deficits in reading comprehension (Griffiths et al., 2010; Mann, 2006). In an unpublished dissertation, students with acquired brain injury (ABI) who were enrolled in a 16-week remedial reading course were taught general information about the process of reading and goal setting (Mann, 2006). The students were also taught to use the K-W-L metacognitive strategy, which prompts the reader to think about "What do I *k*now?" before reading, "What do I *w*ant to know?" while reading, and "What did I *l*earn?" after reading (Ogle, 1986). Mastery of the strategy was reinforced through practice in the daily reading labs. Students' postintervention scores on the Nelson-Denny Reading Test (Brown, Fischo, & Hanna, 1993; Mann, 2006) were higher compared with pre-intervention scores; whether these results represented a significant change is unknown because no statistical comparison of results was reported. Although the authors of these studies suggested that reading strategy intervention in the brain injury population has the potential to improve reading comprehension, generalization is limited by the descriptive methodology, and there continues to be a lack of experimental evaluation.

Development of Strategies for Improving Reading

In the current study, we developed a reading comprehension intervention called *Strategies for Improving Reading* (STIR) that integrated what is known about metacognitive strategy instruction in the TBI population with what is known about reading comprehension strategy use in other populations of struggling readers. The nascent TBI intervention literature plus cross-population research supported the use of prompting to cue reading comprehension during three phases of the reading process: (a) prereading, (b) active reading, and (c) review (Berkeley et al., 2009; Gajiria et al., 2007). To ensure consistency of delivery, we decided to deliver strategy prompts electronically via a computer program interface that integrated the prompts into the text passages used in the study. Strategy prompts delivered in the prereading phase guided readers to preview headings in order to activate background knowledge before reading the actual passage. After previewing, readers moved to the active reading phase. Strategy prompts in the active reading phase instructed readers to select and organize key ideas into an outline in order to facilitate active manipulation of the content. During the review phase, strategy prompts led readers through three tasks to help them integrate information for later recall. These tasks included typing summaries based on key ideas listed in readers' outlines, categorizing key ideas, and practicing recall of key ideas through a flash card–type activity.

Study Purpose

The purpose of this study was twofold. The first aim was to investigate the nature of reading comprehension impairments in the population with TBI by comparing their performance on reading comprehension measures to that of uninjured controls. The second aim was to evaluate whether reading strategy prompts improve the reading comprehension performance in adult readers, and in particular, readers with a history of TBI. The two primary research questions guiding this study are listed below with our associated hypotheses.

- Do adult readers with a history of TBI perform differently on measures of reading comprehension of expository texts when compared to uninjured controls matched for age, gender, and education? If so, is the difference between the two groups more pronounced on measures that reflect situational-level understanding versus measures that reflect propositional-level understanding ? We hypothesized that the TBI group would be less accurate on the sentence verification task (SVT) and would produce less content in the free recall task compared to the control group. We also predicted that the difference in scores would be greater between the two groups when comparing inference statements on the SVT.
- Will adult readers with TBI perform better on reading comprehension measures in the strategy prompt condition compared to the no-strategy prompt condition? If so, is the benefit different on measures that reflect situational-level understanding versus propositional-level understanding? We hypothesized that accuracy scores on the SVT and content recalled on the free recall task would be higher in the strategy prompt condition compared to the no-strategy prompt condition. We also predicted that the effect of the strategy prompt condition would be greatest for inference statements in the SVT.

Method

Participants

Two groups of participants completed this study: 15 adults with TBI and 15 uninjured control participants matched for age, gender, and education. All of the participants were recruited via flyers posted at area colleges, universities, and health clinics, and via local web bulletin boards, and all participants were compensated monetarily. Initial screening required the participants to be (a) between 18 and 55 years of age; (b) medically and psychiatrically stable (i.e., no hospitalizations or medication changes in prior 6 months; no active substance abuse issues); (c) able to read for daily needs (e.g., newspaper, street signs), with no reported history of reading or learning problems prior to TBI; (d) able to see 12-point font and scan lined text without apparent vision deficits; (e) familiar with basic computer navigation skills; and (f) native English speakers. Recruitment was open to participants with a history of TBI or nontraumatic ABI. However, only two individuals with nontraumatic ABI participated in the study; their results are not reported. Participants in the TBI group met the following additional requirements: history of traumatic head injury occurring after 17 years of age, at least 1 year post injury, and no more than moderate impairments on a cognitive screening battery. All of the participants with TBI reported closed-head injuries. Participants in the control group were matched to the participants with TBI based on age (±10 years), gender, and education level, and were required to demonstrate cognitive function within normal limits on a cognitive screening battery.

To identify potentially significant differences between the TBI group and the control group on age and education variables, we conducted independent-samples t tests with Bonferroni correction for multiple comparisons ($\alpha = .05/2 = .025$). No significant differences were detected for age ($t = 0.76$, $p = .46$; TBI: $M = 32$ years, $SD = 6$ years; control: $M = 30$ years, $SD = 8$ years) or education ($t = 0.46$, $p = .65$; TBI: $M = 14$ years, $SD = 1$ year; control: $M = 14$ years, $SD = 1$ year). Both groups included 12 males and three females.

Cognitive skills screen. Both groups were required to complete a cognitive screening battery in order to verify eligibility based on the inclusion and exclusion criteria. Although individuals with TBI frequently have impaired cognition compared to their prior levels of function, the literature highlights the lack of sensitivity of neuropsychological measures for detecting high-level impairments (Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Coelho et al., 2005). Therefore, participants in the TBI group were not required to meet a minimum cognitive impairment level but were excluded if they presented with more than a moderate cognitive impairment. Control participants were required to score within the normal cognitive ability range in order to be included in the study.

Eligibility for the study was established using selected standardized scores from three cognitive measures: the Conners' Continuous Performance Test II (CPT II; Conners & Staff, 2000a, 2000b), the Paced Auditory Serial Addition Test (PASAT; Gronwall, 1977), and the California Verbal Learning Test—Second Edition (CVLT–2; Delis, Kramer, Kaplan, & Ober, 2000). For attention, the commission and omission standard scores from the CPT II were selected. For working memory, the composite standard score from the PASAT was used. Finally, for verbal learning and recall, trial 1–5 and trial B scores from the CVLT–2 were used.

Prerequisite reading skills screen. A reading screen was conducted to verify that the participants had sufficient vocabulary knowledge and word identification skills considered prerequisite for reading comprehension (Biancarosa & Snow, 2004). Given that the text passages used in the study were rated to be at a 12th-grade level, participants were required to have a raw score of 198 on the Peabody Picture Vocabulary Test—Fourth Edition (PPVT–4; Dunn & Dunn, 2007), which is considered equivalent to a 12th grade–level vocabulary. To evaluate word identification skills, we used an oral reading fluency (ORF) task. The ORF task is well established in education and is used as a proximal measure of word identification skills (Fuchs, Fuchs, Hosp, & Jenkins, 2001). Participants were required to read a short passage at a rate considered to be fluent (135–165 words per minute; Fuchs et al., 2001). Individuals are expected to achieve this level of fluency by the eighth grade; fluency does not substantially change after this point (Fuchs et al., 2001).

Procedure

Reading materials. Four 500-word expository text passages were used for this study. To ensure that the materials represented the actual texts encountered in introductory college coursework, we selected text passages from Connexions, which is a nonprofit website that serves as a repository and access point for free educational content (Connexions, 2009). Reading assessment researchers have identified characteristics of reading material known to contribute to comprehension that, for this study, could confound performance differences due to strategy prompts (Biancarosa & Snow, 2004; Lee & Spratley, 2010; RAND Reading Study Group, 2002). For example, differences in structure, organization, and cohesion of text, as well as discipline-specific writing conventions, can have a differential impact on reading comprehension (Lee & Spratley, 2010). To mitigate these potential passage effect factors, we selected passages from the same discipline area and student level: introductory earth science (Lee & Spratley, 2010). Selected texts were modified to ensure that each passage was approximately 500 words in length, divided into four sections, with each section preceded by a topical heading. Text difficulty was analyzed and compared using Flesch-Kincaid Grade Level (Kincaid, Fishburne, Rogers, & Chissom, 1975), the standard used by the Department of Defense to estimate the grade level considered necessary to understand a document: $M = 11.85$, $SD = 0.35$. To further verify the equivalency of passages, we re-analyzed text difficulty using Lexiles (Lennon & Burdick, 2004), an analysis tool used increasingly in education; 1170L to 1410L[1] is within the range of text difficulty for a proficient reader with a 12th-grade level of education. Confidence intervals were calculated at 95% based on an estimated standard error of 32L (Stenner, Burdick, Sanford, & Burdick, 2006): $M = 1183$L, $SD = 58$; Passage 1 (P1) = 1170L, 95% CI [1138, 1202]; P2 = 1200L, 95% CI [1168, 1232]; P3 = 1142L, 95% CI [1078, 1142]; and P4 = 1250L, 95% CI [1218, 1282].

All of the text passages were presented on Hewlett Packard Elitebooks 2740p. These netbooks had 10.5-in. touch screens, with stylus, keyboard, and mouse input capabilities. In the no-strategy condition, passages were presented as straight text using a standard reading interface; in the strategy condition, passages were presented using the STIR condition interface. To control for possible passage effects, we required all participants to read all four passages. Counterbalancing was used to determine which passages would be read in the strategy condition, and which would be read in the no-strategy condition, for each participant. For example, one participant read the ecosystems passage in the strategy condition, and another read that passage in the no-strategy condition. The order of presentation was further counterbalanced; for example, one participant might receive the strategy condition first, and another might receive the no-strategy condition first. Ultimately, six permutations were possible.

Measures

For this study, the measures needed to characterize differences between the TBI and control groups and to

[1]The "L" after the number designates the score as a Lexile score.

ascertain if the strategy prompts had more effect on particular levels of understanding. Ultimately, two comprehension tasks were used for this study: an SVT and a free recall task.

SVT. The SVT is a widely used experimental paradigm in reading research (Carlisle, 1989; Royer, Hastings, & Hook, 1979; Stine-Morrow et al., 2008). In an SVT, a reader is presented with a set of sentences after reading a text. The reader must decide whether each sentence is true or false based on the content of what he or she read. Depending on the research objectives, researchers develop different types of sentences, including verbatim sentences, paraphrase sentences, and inference sentences (Carlisle, 1989; Royer et al., 1979; Stine-Morrow et al., 2008). For this study, established procedures drawn from the experimental literature guided the development of 25 sentences for each passage: five verbatim sentences, copied directly from the passage; five paraphrase sentences, reworded versions of the verbatim sentences; five inference sentences, implicit statements drawn from the passage; and 10 filler sentences (Royer et al., 1979). The sentences were designed to distinguish between three different levels of text comprehension as depicted in the IA model: the surface, or verbatim, level; the propositional, or paraphrase, level; and the situational, or inference, level. In the testing interface, participants were instructed to indicate if each sentence was true or false by tapping on the true (green) or false (red) button on the computer screen. Responses were captured and scores were calculated by the computer.

Internal consistency of items within each sentence type (e.g., verbatim, paraphrase, inference) was evaluated using Cronbach's alpha, with confidence intervals at the 95% level (George & Mallery, 2003). Separate coefficients were calculated for each condition by group and are reported in Table 1. An analysis and implications of the reliability measures are included in the Discussion section.

Table 1. Internal consistency of the sentence verification task (SVT) items for the group with traumatic brain injury (TBI) and the control group.

	TBI (n = 15)		Control (n = 15)	
Measure	**Cronbach's α**	**95% CI**	**Cronbach's α**	**95% CI**
Verbatim				
NS condition	.72	[.45, .89]	.49	[.00, .80]
S condition	.60	[.21, .84]	.64	[.36, .90]
Paraphrase				
NS condition	.71	[.44, .89]	.67	[.38, .92]
S condition	.63	[.23, .85]	.70	[.43, .88]
Inference				
NS condition	.72	[.45, .89]	.21	[.00, .69]
S condition	.81	[.62, .93]	.58	[.17, .84]

Note. NS = no-strategy condition; S = strategy condition; each SVT sentence type had 10 items per condition, for a total of 60 items. Per Nunnally and Bernstein (1994), coefficient values greater than .90 are considered excellent, between .80 and .89 good, between .70 and .79 adequate, between .60 and .69 questionable, and less than .60 poor. A ceiling effect occurred across the items.

Because participants read two passages for each condition, a split-half method was also completed to evaluate the consistency of responses across the two passages used for each group and condition. Spearman-Brown's prophecy formula was applied to correct for reduced sample size in the split samples. Confidence intervals were calculated following steps outlined by Fan and Thompson (2001, p. 525); these confidence intervals are reported at a 95% level of confidence. Split-half reliability results are reported in Table 2.

Free recall with discourse analysis. Discourse tasks such as story retell, story generation, and procedure description have been used with the population with brain injuries to evaluate other cognitive–communicative functions, including listening comprehension and discourse production abilities (Coelho et al., 2005). These cognitive–communicative functions have established parallels to reading comprehension (Verhoeven & Perfetti, 2008). For our study, participants were instructed to retell the text passage "as if you were telling someone everything you learned from the passage you just read." Each participant's free recall samples were recorded and later transcribed by a research assistant. Transcriptions were then analyzed to obtain three different measures: (a) number of communication units (C-units; Hughes, McGillivray, & Schmidek, 1997; Loban, 1976), (b) number of words per C-unit (Hughes et al., 1997; Loban, 1976), and (c) number of type–token ratios (TTRs; Caspari & Parkinson, 2000).

Table 2. Consistency of the SVT and free recall measures across two text passages within each condition.

	TBI		Control	
Measure	**Spearman's ρ**	**95% CI**	**Spearman's ρ**	**95% CI**
		SVT		
Verbatim				
NS condition	.84	[.45, .96]	.58	[.00, .89]
S condition	.73	[.19, .93]	.70	[.13, .92]
Paraphrase				
NS condition	.84	[.45, .96]	.62	[.00, .90]
S condition	.72	[.17, .93]	.87	[.53, .97]
Inference				
NS condition	.84	[.45, .96]	.37	[.00, .81]
S condition	.62	[.00, .93]	.39	[.00, .82]
		Free recall measures		
C-units				
NS condition	.93	[.73, .98]	.93	[.73, .98]
S condition	.89	[.59, .97]	.85	[.48, .96]
Words per C-unit				
NS condition	.65	[.04, .91]	.62	[.04, .97]
S condition	.81	[.37, .95]	.89	[.59, .97]
TTR				
NS condition	.65	[.04, .91]	.65	[.04, .91]
S condition	.82	[.39, .96]	.92	[.69, .98]

Note. C-units = communication units (Loban, 1976); TTR = type–token ratio. Split-half reliability was conducted with Spearman Brown's prophecy formula applied to correct for the reduced sample size resulting from the split. For the SVT, five items from the first read passage were compared to five items from the second read passage within each condition. For the free recall measures, two values that resulted for each condition were compared.

Number of C-units and of words per C-unit have been used in discourse evaluation tasks as a measure of verbal production (Hughes et al., 1997; Loban, 1976). A C-unit is an independent clause with its modifiers. A derivative of the T-unit, a C-unit is considered a minimal terminal syntactic unit that can stand on its own to express a complete thought (Loban, 1976; Nippold, 1993). A key difference between C-units and T-units is that a C-unit allows for noun phrase ellipsis, whereas a T-unit does not. For example, the sentence "An ecosystem is a community of living organisms and is found in many areas" would be one T-unit but two C-units: (1) An ecosystem is a community of living organisms, (2) And _ is found in many areas. T-units and C-units originally were used as measures of syntactic complexity (Loban, 1976; Nippold, 1993). Syntax functions to encode semantic relations between ideas and, as such, changes in syntactic complexity are thought to reflect changes in the complexity of semantic relations (Bloom, Lahey, Hood, Lifter, & Fiess, 1980; Nippold, 1993). Syntactic relations serve as cohesive devices that contribute to the logic and coherence of discourse (Bloom et al., 1980; Nippold, 1993). In this study, number of C-units was used to measure the number of complete thoughts, and number of words per C-unit was used to measure the syntactic complexity associated with discourse cohesiveness (Hughes et al., 1997; Nippold, 1993).

TTRs have been used as a measure of lexical and semantic productivity or redundancy (Caspari & Parkinson, 2000; Hess, Ritchie, & Landry, 1984). The TTR is calculated by dividing the number of unique content words produced by the total number of content words produced (e.g., ecosystem said five times, heterotrophy said one time, total words = 6; TTR = 2/6, or .33).

The free recall measures were obtained by a research assistant segmenting the participants' transcripts into C-units that were further coded to identify contributory statements (e.g., "Ecosystems come in different sizes"), meta-cognitive statements (e.g., "So I already said surface mining."), and conversational devices (e.g., "I am going to get some water after this one."). The total number of words within each C-unit was counted to calculate the number of words per C-unit. The total number of contributory C-units and the total number of words per C-unit were used in the analysis. The frequency of each word was counted in order to derive the TTR of unique words to total words.

Reliability of coding was measured by having the second author review 30% of the transcribed discourse samples; interrater reliability was 100% for number of C-units and words per C-unit, 93% for content categorization, and 95% for TTRs. Consistency of measures across the two passages within each condition was evaluated using a split-half method with the Spearman-Brown prophecy formula applied to correct for reduced sample size in the split samples. Confidence intervals were calculated following steps outlined by Fan and Thompson (2001, p. 525). All confidence intervals are reported at a 95% level of confidence.

Participant sessions. Each participant completed two, approximately $2^1/_2$-hr sessions. Both sessions were completed within 1 week of each other, except for those of two control participants who had scheduling constraints. The screening measures were completed in the first session, and participants who met the screening criteria completed the STIR reading tasks during the second session.

The second session began with a brief orientation. Participants were told that they would be reading four different 500-word introductory science college text passages on a netbook and would be tested on what they learned after each passage. They were then shown the user interfaces for each condition using the same sample passage and were advised that sometimes they would be presented with written instructions on the netbook to do certain tasks while they were reading. They were also shown the testing interfaces and were instructed how to respond to the SVTs and how to initiate recording for the free recall task. Standard navigation features such as forward and back arrows and scroll bars were demonstrated, and the participants were given the opportunity to use these features. All of the participants were able to use each of the features following demonstration, with additional practice needed for using the stylus to select and relocate text.

Each participant was left alone in order to minimize distraction but was advised that researchers would be observing from the closed-circuit camera and could intervene if needed. When the participant finished the first passage, he or she was offered a 5-min break before being presented with the next passage. Written scripts were followed to ensure administration fidelity, and all sessions were monitored by one of the researchers, a licensed speech-language pathologist, via the closed-circuit cameras.

Results

Analyses of Conceptual Assumptions

We conducted analyses of the underlying conceptual assumptions first. The first assumption was that the cognitive skills were significantly different between the two participant groups. To verify this assumption, we compared scores from the cognitive screening tests using a multivariate analysis of variance (MANOVA). Distribution of scores on the cognitive test was roughly normal, with equivalent patterns of variance and covariance. Pillai's trace confirmed that the two groups were significantly different on the multivariate composite, $V = 0.55$, $F(5, 24) = 5.86$, $p = .001$, $\eta^2 = .55$. Inspection of individual analyses of variance (ANOVAs) with Bonferroni correction of alpha ($\alpha = .05/5 = .01$) indicated significant differences between the two groups for CPT II commission, $F(1, 28) = 6.41$, $p = .01$, $\eta^2 = .19$, and CVLT–2 trials 1–5, $F(1, 28) = 15.06$, $p = .001$, $\eta^2 = .35$. Significant differences were not found between the groups for CPT II omission, $F(1, 28) = 4.01$, $p = .05$, $\eta^2 = .13$; the PASAT, $F(1, 28) = 3.85$, $p = .06$, $\eta^2 = .12$; or the CVLT–2 trial B, $F(1, 28) = 4.67$, $p = .04$, $\eta^2 = .14$.

The second assumption was that the prerequisite reading skills of the two participant groups were equivalent. To verify this assumption, we compared scores from the reading comprehension measures using a MANOVA. Distribution of scores on both measures was roughly normal, with equivalent patterns of variance and covariance. Pillai's trace revealed that the groups were significantly different on the multivariate composite, $V = 0.53$, $F(2, 27) = 14.94$, $p = .001$, $\eta^2 = .53$. Inspection of individual ANOVAs with Bonferroni correction of alpha ($\alpha = .05/2 = .025$) revealed significant differences for both ORF, $F(1, 28) = 11.67$, $p = .002$, $\eta^2 = .29$, and the PPVT–4, $F(1, 28) = 28.98$, $p = .001$, $\eta^2 = .51$. A summary of the groups' cognitive and reading measures is provided in Table 3.

A third assumption was that reading comprehension performance and cognitive skills were systematically related. To verify that significant linear relationships existed between reading comprehension and cognitive measures, we calculated a Pearson product–moment correlation (see Table 4).

Analyses of Reading Comprehension Measures

To evaluate the reading comprehension measures, we conducted a mixed-design MANOVA using averaged scores of measures from the two passages for each condition, with group as a between-subjects variable. A summary of the descriptive scores is provided in Table 5. Examination of histograms and box plots revealed severe left skew and uneven between-group variances for the verbatim and paraphrase items. Distribution of the inference items, C-units, words per C-unit, and TTRs was grossly normal. Within- and between-group variances were roughly even for these remaining dependent variables. Data from the verbatim and paraphrase items were transformed to improve normality and homogeneity of variances. Specifically, verbatim items were cubed, and paraphrase items were squared; transformations were effective, and parametric assumptions were met (Chambers, Cleveland, Kleiner, & Tukey, 1983). Distribution of difference scores was also roughly normal, with equivalent patterns of variance and covariance across all dependent variables.

To account for a possible passage effect or order-of-condition effect, we included a fixed variable called *permutation* that indicated one of six different combinations possible for each participant. Given that the focus of the study was on reading comprehension, ORF and PPVT–4 were also initially included as covariates in order to account for possible variance related to the prerequisite reading measures. However, the covariates were not significant for any of the comparisons, so they were removed and the analyses were rerun.

The between-subjects MANOVA for group using Pillai's trace revealed significant differences between the two groups, $V = 0.68$, $F(6, 13) = 4.5$, $p = .01$, $\eta^2 = .68$. Further examination of the individual ANOVAs with Bonferroni correction of alpha ($\alpha = .05/6 = .008$) indicated significant differences between the TBI and control groups for paraphrase items, $F(1, 18) = 11.43$, $p = .003$, $\eta^2 = .37$, but not for verbatim items, $F(1, 18) = 1.96$, $p = .18$, $\eta^2 = .10$, or inference items, $F(1, 18) = 0.78$, $p = .39$, $\eta^2 = .04$. Significant differences between the two groups were also noted for C-units, $F(1, 18) = 10.62$, $p = .004$, $\eta^2 = .37$, but not for words per C-unit, $F(1, 18) = 2.13$, $p = .16$, $\eta^2 = .11$, or TTRs, $F(1, 18) = 0.15$, $p = .71$, $\eta^2 = .01$. The between-subjects MANOVA for permutation was not significant, $V = 1.23$, $F(30, 85) = 0.92$, $p = .59$, $\eta^2 = .25$; neither was the interaction multivariate for Group × Permutation, $V = 1.24$, $F(30, 85) = 0.94$, $p = .56$, $\eta^2 = .25$.

Table 3. The participants' scores on the cognitive screening measures and the reading comprehension measures.

	TBI			Control					
Measure	***M***	***SD***	***SE***	***M***	***SD***	***SE***	***F***	***p***	η^2
Cognitive							5.86	.001[a]	.55
CPT II:C	46.4	10.4	2.69	54.4	6.5	1.67	6.41	.01*	.19
CPT II:O	51.1	8.1	2.08	55.8	4.1	1.05	4.01	.05	.13
PASAT	50.6	14.2	3.67	59.4	10.0	2.59	3.85	.06	.12
CVLT–2 1–5	45.2	9.3	2.41	57.1	7.4	1.90	15.10	.001*	.35
CVLT–2 B	40.4	12.1	3.13	47.8	5.4	1.40	4.67	.04	.14
Prerequisite reading							14.94	.001[b]	.53[b]
PPVT–4_SS	49.9	6.9	1.78	62.9	6.36	1.64	28.98	.001**	.51
PPVT–4_Raw	203.9	10.0	2.58	216.9	5.48	1.42			
ORF	144.7	9.5	2.44	164.2	19.96	5.16	11.67	.002**	.29

Note. CPT II = Conners' Continuous Performance Test II; C = commission score; O = omission score; PASAT = Paced Auditory Serial Addition Test; CVLT–2 = California Verbal Learning Test—Second Edition; 1–5 = *T*-score for trials 1–5; B = *T*-score for trial B; PPVT–4 = Peabody Picture Vocabulary Test—Fourth Edition; ORF = oral reading fluency. CPT II *T*-scores program typically reports *T*-scores so that a high score means greater deficits. In this table, the CPT II scores are reversed from the scores provided in order to be consistent with other measures so that a lower score is equal to lower performance; standardized scores used in multivariate analysis of variance (MANOVA); raw PPVT–4 used as criterion measure (≥198 = 12th grade); standardized scores for CPT II, PASAT, CVLT–2, and PPVT–4 are reported as *T*-scores with a range of 20 to 80; ORF criterion (>135 wpm).

[a]Cognitive measures Pillai's trace $V = 0.55$, $p < .001$. [b]Prerequisite reading Pillai's trace $V = 0.53$, $p < .001$.

*$\alpha = .05/5 = .01$ for cognitive analyses of variance (ANOVAs); Prerequisite reading measures Pillai's trace $V = 0.53$, $p < .001$. **$\alpha = .05/2 = .025$ for reading ANOVAs.

Table 4. Correlations between the cognitive screening measures and the reading comprehension measures from both groups of participants (n = 30).

Measure	CPT II–C	CPT II–O	PASAT	CVLT–2 1–5	CVLT–2 B
			SVT		
Verbatim	.062	.095	.057	.363*	–.097
Paraphrase	.342	.514**	.471**	.456*	.575**
Inference	.659**	.446*	.431*	.236	.270
			Free recall measures		
C-units	.204	.264	.115	.317	.202
Words per C-unit	.054	–.191	.117	–.249	.031
TTR	.428*	.160	.249	.175	.206

Note. Average scores per participant from two passages read in the no-strategy condition were used.
*p < .05. **p < .001.

The within-subjects MANOVA for condition revealed significant differences between the conditions, Pillai's trace $V = 0.66$, $F(6, 13) = 3.32$, $p = .01$, $\eta^2 = .66$. Further examination of the individual ANOVAs with Bonferroni correction of alpha ($\alpha = .05/6 = .008$) indicated significant differences between conditions for words per C-unit, $F(1, 18) = 8.80$, $p = .008$, $\eta^2 = .33$, and for TTRs, $F(1, 18) = 13.1$, $p = .002$, $\eta^2 = .42$. No significant differences were found for C-units, $F(1, 18) = 7.3$, $p = .015$, $\eta^2 = .02$, or for any of the SVT items: verbatim, $F(1, 18) = 0.21$, $p = .65$, $\eta^2 = .01$; paraphrase, $F(1, 18) = 0.53$, $p = .48$, $\eta^2 = .03$; or inference, $F(1, 18) = 1.09$, $p = .31$, $\eta^2 = .06$. None of the within-subject interaction multivariates were significant: Group × Condition, $V = 0.24$, $F(6, 13) = 0.70$, $p = .65$, $\eta^2 = .24$; Condition × Permutation, $V = 1.47$, $F(30, 85) = 1.18$, $p = .27$, $\eta^2 = .30$; or Condition × Group × Permutation, $V = 1.56$, $F(30, 85) = 1.29$, $p = .19$, $\eta^2 = .31$. See Figure 1 for box plots of scores for each group by condition.

Discussion

Profiles of Readers With TBI Compared to Uninjured Controls

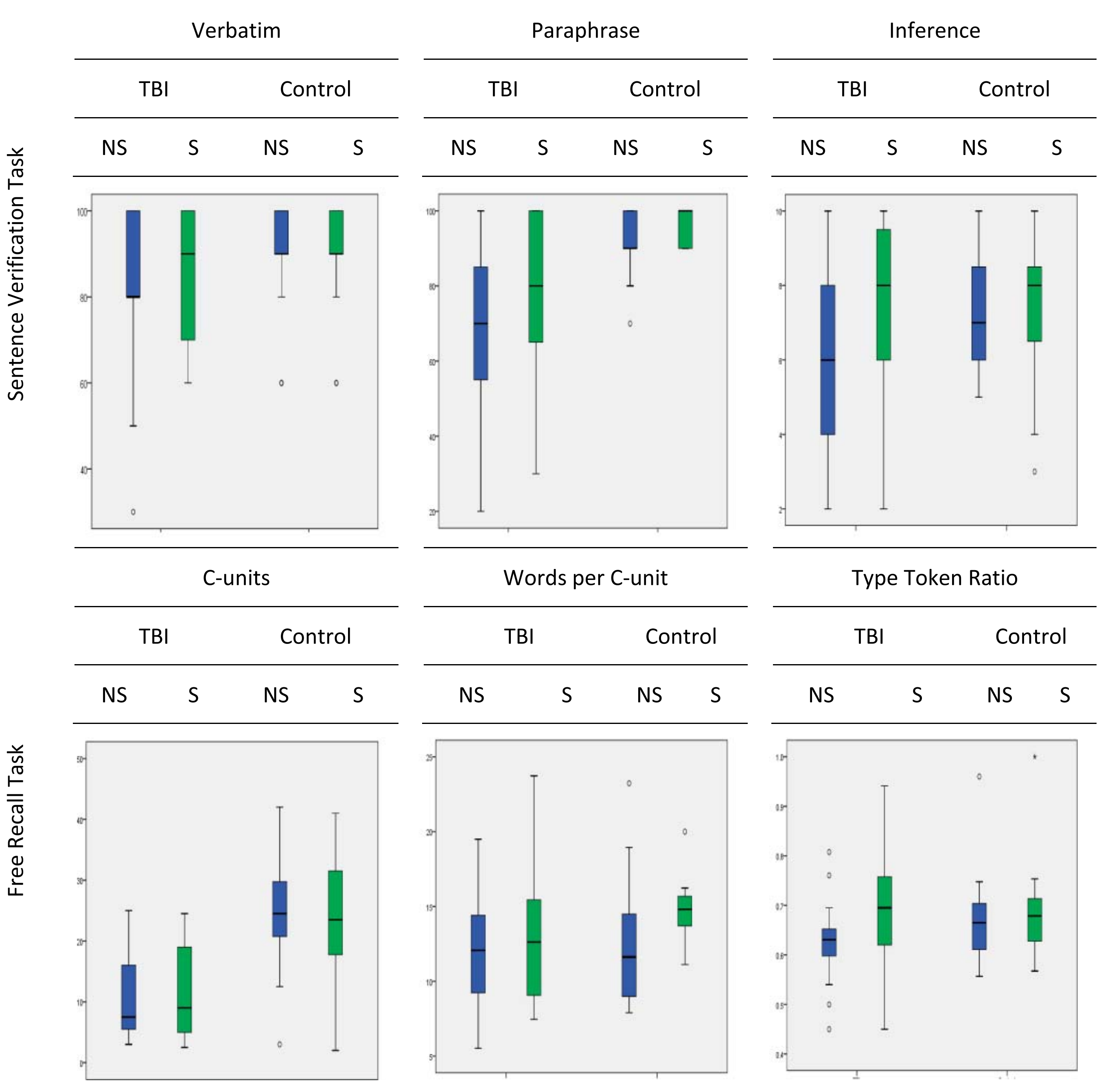
Group differences on vocabulary and ORF. The first purpose of this study was to obtain information about the nature of reading comprehension impairments in the population with TBI by comparing their performance

Table 5. Reading comprehension measures.

	TBI				Control			
Measure	*M*	*X*	*SD*	*SE*	*M*	*X*	*SD*	*SE*
				SVT				
Verbatim								
NS condition	81.3	80	20.7	5.33	89.3	90	13.4	3.45
S condition	82.7	90	16.2	4.19	89.3	90	13.3	3.44
Paraphrase[a]								
NS condition	71.3	70	22.0	6.24	91.3	90	8.3	1.31
S condition	74.7	80	21.5	4.56	96.0	90	5.1	3.98
Inference								
NS condition	58.0	60	23.0	6.34	71.3	70	16.0	6.34
S condition	71.3	80	27.0	6.89	72.7	80	20.5	5.30
				Free recall measures				
C-units[a]								
NS condition	10.9	8	7.4	1.92	24.7	25	9.8	2.52
S condition	11.7	9	8.1	2.09	24.3	24	10.5	2.72
Words per C-unit[b]								
NS condition	12.0	12	4.0	1.03	12.5	12	4.3	1.11
S condition	13.4	13	5.2	1.35	14.8	15	2.0	.51
TTR[b]								
NS condition	.64	.63	.08	.02	.66	.67	.07	.03
S condition	.70	.82	.11	.03	.68	.68	.09	.03

[a]Significant main effect for between-group ($\alpha = .05/6 = .008$) for paraphrase items, $F(1, 18) = 11.43$, $p = .003$, $\eta^2 = .37$, and for C-units, $F(1, 18) = 10.62$, $p = .004$, $\eta^2 = .37$. [b]Signficant main effect for within-group ($\alpha = .05/6 = .008$) for words per C-unit, $F(1, 18) = 8.80$, $p = .008$, $\eta^2 = .33$, and for TTRs, $F(1, 18) = 13.1$, $p = .002$, $\eta^2 = .42$. No interaction effects.

Figure 1. Box plots showing scores for each measure by condition and group: the group with traumatic brain injury (TBI; *n* = 15) and the control group (*n* = 15). NS = no strategy; S = strategy; C-units = communication units (Loban, 1976). Possible range for sentence verification tasks is 0 to 100. C-units range from 3 to 40; words per C-unit range from 4 to 21. Type–token ratios range from .0 to 1.0.



on reading comprehension measures to that of uninjured controls matched for age, gender, and education level. Given that the focus was reading comprehension, all of the participants were required to meet screening criteria to verify sufficiency of prerequisite reading skills—specifically, word recognition skills and vocabulary level equivalent to 12th grade. Although all of the participants met the criteria, evaluation of the screening measures conducted to verify the underlying assumptions showed significant group differences on the prerequisite reading skills. Given the unexpected finding, scores from the PPVT–4 and the ORF were included as covariates in order to control for potential effects on the reading comprehension measures, which were the focus of the study. The covariates were not significant for either the between- or within-group comparisons.

Nonetheless, the finding of group differences on vocabulary and ORF raises questions about the participants' underlying reading skills. The assumption was that there would be no group differences on these skills; this assumption was based in part on evidence showing that most TBI survivors do not present with acquired linguistic deficits (Heilman, Safran, & Geschwind, 1971). Word recognition, an automatic skill, and vocabulary, considered part of crystallized knowledge, are typically understood to be spared after TBI (Lezak et al., 2012).

Although prior knowledge may indeed be spared, vocabulary continues to grow into adulthood (RAND Reading Study Group, 2002). One possibility for group differences on vocabulary was that the participants' vocabulary did not grow commensurate with that of peers of the same age and education level. The introduction of new vocabulary is an emphasis in expository text that distinguishes it from narrative texts and is particularly important when reading to learn (Lee & Spratley, 2010). Even though word recognition skills as measured by the ORF may be grossly intact, subtle differences in fluency rate could contribute to overall reading competency. Multiple factors could contribute to slower rates of oral fluency in the TBI sample, including general slowed cognitive processing or a more specific word activation deficit. Subtle changes in visual tracking skills after TBI have also been reported (Neera, 2002; Suh, Kolster, Sarkar, McCandliss, & Ghajar, 2006). More research is needed, but at this point, evaluating vocabulary by comparing expectations at age of onset of TBI to expectations for current age, and ORF tasks, may have potential for detecting subtle reading deficits in the population with TBI.

Group differences on reading comprehension measures. On the SVT, significant differences were established between the two participant groups on paraphrase items but not on verbatim and inference items. To interpret these findings, a closer inspection of the reliability of measures used in this study is necessary. As shown in Tables 1 and 2, within the TBI group, internal consistency and split-half reliability of measures for the SVT were between questionable and adequate, and in general, were higher than the values in the control group, which varied between poor and questionable (Nunnally & Bernstein, 1994). When reliability of the SVT measures in this study's sample are examined along with scores, the total score variability seems to be constrained by ceiling effects, particularly for the control group. That is, a full range of performance could not be demonstrated because the SVT items were too easy. As such, actual between-group differences may be underestimated by the SVT in this study.

Nonetheless, the two groups did perform significantly different on the paraphrase items. In addition, the paraphrase items correlated with four of the five cognitive screening measures. Moderate-to-high correlations were observed with the CPT II omission score, which is a measure of sustained attention; the PASAT, a measure of working memory; and the CVLT–2 trials 1–5 and trial B scores, measures of verbal learning. The results are consistent with Stine-Morrow et al. (2008), who demonstrated that differences in working memory when comparing young and older adult readers were associated with differences in reading comprehension at the paraphrase level. Paraphrase items were not significantly correlated with the CPT II commission scores. Although both CPT II measures required sustained attention, omission errors are more associated with difficulty detecting salient features of stimuli, whereas commission errors are more associated with difficulty suppressing irrelevant features of stimuli (Conners & MHS Staff, 2000b).

The lack of difference between the two groups on the verbatim items is consistent with prior research. Verbatim scores were not correlated with attention or working memory screening measures and were only moderately correlated with the CVLT–2 trials 1–5 measure. Schmitter-Edgecomb and Bales (2005) demonstrated that readers with CHI were more likely to repeat information that was just read during think-aloud comments rather than to elaborate or comment on information from across the chapter. Stine-Morrow et al. (2008) suggested a possible trade-off between verbatim and inference accuracy on the SVT when comparing young and older readers. In that study, younger readers who did particularly well recognizing verbatim items did not do as well recognizing inference items; older readers with higher scores on inference items had relatively lower scores on verbatim items. Similar to Schmitter-Edgecomb and Bales's interpretation, Stine-Morrow et al. suggested that readers who struggle with inference-level processing tend to be particularly focused on verbatim levels of comprehension.

Despite the possibility that differences were masked by ceiling effects, the lack of findings between the two groups on the inference items was still surprising. We hypothesized that the participants in the group with TBI would struggle the most with inference items. The descriptive data in Table 5 show that within the TBI group, participants performed worse on inference items relative to their performance on verbatim and paraphrase items in the no-strategy condition. Inference scores were also highly correlated with the CPT II commission score, the sustained attention measure associated with suppression, and were moderately to highly correlated with the CPT II omission score, the sustained attention measure associated with detection. Results were also moderately to highly correlated with the PASAT scores for working memory.

An examination of the groups' inference scores showed that the lack of expected difference between groups may also be related to the control group's performance: Compared to its performance on the verbatim and paraphrase items, the control group performed worse on inference items. Poor performance of control participants on inferencing skills when reading expository text parallels trends seen in the general population. Although 75.0% of 12th graders in 2009 could identify elements of meaning and form in expository text—considered basic reading skills—only 37.5% could adequately identify textual support for inferences and generate interpretations (National Center for Education Statistics, 2011). These data underscore that for many adult readers, high-level reading skills may not develop to proficiency until after the 12th grade, if at all. Whether adult readers who struggle with these skills after TBI are having problems because of skill loss or premorbid insufficiency cannot be discerned from the data in this study.

On the free recall tasks, significant differences between the two participant groups were found for the number of C-units. Given what is known about verbal productivity performance of the TBI population from other discourse retell tasks (e.g., Coelho et al., 2005), this finding was expected. Prior studies have primarily examined verbal productivity in narrative retell tasks that were elicited after either auditory or pictorial presentation of a story. This study demonstrated that in a free recall task elicited after reading expository text, verbal productivity was likewise reduced for participants with TBI. Reliability of C-units was good to excellent for both groups across both conditions.

Words per C-unit and TTR were not significantly different between the two groups. Split-half reliability was questionable for both measures for both groups in the no-strategy condition. Some intra-individual variability between passages would be expected because of intra-individual differences in background knowledge on different topics: Participants are more likely to use specific terminology on topics they already know. Counterbalancing of passages was intended as one means of mitigating background knowledge effects, and selection of topics within a generally similar domain was another; all four passages were read in both conditions and all positions (e.g., first, second, third, or fourth). In addition, permutation was included as another fixed variable to further control for possible passage and order effects but was not significant as a fixed variable, and an interaction effect between group and permutation was not seen. The observation that the split-half reliability was much better for both groups for both words per C-unit and TTR in the strategy condition raises the possibility that differences in conditions somehow contributed to how consistent free recalls were in terms of words per C-unit and TTR across the two passages within each condition.

Unlike the SVT variables, only one free recall variable was significantly correlated with any of the cognitive variables. The CPT II commission and TTR scores were low to moderately correlated. Sustained attention, particularly the ability to suppress irrelevant stimuli, was associated with the measure of lexical and semantic productivity. Although number of C-units and words per C-unit were not significantly correlated with the cognitive screening measures, an important point to note is that the screening battery did not include a specific measure for executive function, a key cognitive function implicated in studies of other discourse skills with the TBI population (Coelho, 2002).

Strategy Use by Adult Readers With and Without TBI

The second purpose of this study was to evaluate whether reading strategy prompts improved reading comprehension performance in adult readers, particularly individuals with a history of TBI. A main effect was found between the strategy and no-strategy condition for words per C-unit and for TTRs across both groups. The lack of significant interaction effect indicates that whether or not participants benefited from the strategy prompts was not related to group status: Participants with and without TBI showed improvements in their reading comprehension.

Strategy prompts accounted for 33% of the variance in words per C-unit between conditions and 42% of the variance in TTRs. As discussed in the prior section, split-half reliability for both words per C-unit and TTR was questionable for both groups in the no-strategy condition (Nunnally & Bernstein, 1994). The reliability coefficients were actually better for both groups in the strategy condition, raising the possibility that the strategy condition facilitated increased consistency in performance on these two variables. Nonetheless, given the questionable reliability, these results have to be interpreted cautiously.

Additional caution is necessary when interpreting the difference in TTR values. TTRs were intended as a means for capturing lexical and semantic productivity or redundancy; as participant use of specific vocabulary increased, so should the TTR. However, a greater difference from no strategy to strategy may not necessarily reflect a greater response to strategies. A participant who produced 17 C-units in the strategy condition compared to 11 C-units in the no-strategy condition had a TTR change from .60 to .69 (.09 difference); another participant who produced 3 C-units in the strategy condition compared to 2 C-units in the no-strategy condition had a TTR change from .81 to .94 (.13 difference). In another example, a participant repeated a word in a manner that seemed to contribute to cohesion (e.g., <u>Minerals</u> can be found everywhere, but getting to the <u>minerals</u> is not always possible. Some <u>minerals</u> are found…), but the redundancy lowered the TTR.

No significant differences were found for the number of C-units that were produced in each condition. Split-half reliability coefficients were excellent for number of C-units in both conditions. Significant differences were also not detected between conditions for verbatim, paraphrase, or inference sentences in the SVT, although an increase in both mean and median scores was noted when comparing both conditions. For the SVT, ceiling effects may be one reason that a significant difference in scores was not demonstrated. Split-half reliability coefficients were variable across SVT sentence types and were particularly low for the control group; a difference may have been detected given better reliability.

Another possible explanation that may account for the lack of effect on the number of C-units and the SVT results is that adult readers bring a heterogeneous set of skills to the reading process, particularly readers with TBI (Griffiths & Sohlberg, 2012). In this sample of individuals with TBI, the profiles of cognitive abilities and prerequisite reading skills varied. The differences in ORF and vocabulary detected in this study may be too subtle to impact performance in daily functional reading activities. However, variability may create different reading conditions that ultimately influence the impact of reading strategies. These differences may have a more significant impact on higher level reading comprehension activities, such as reading-to-learn.

An additional possible factor that may have influenced whether strategy prompts were beneficial is how readers responded to the strategy prompts. For example, in this study, some readers highlighted a great deal of information, whereas others were more selective. Some readers created thorough study notes, and others did not write any. How readers approach strategies is likely a function of other underlying skills, including cognition, but is also influenced by educational experiences (Biancarosa & Snow, 2004). Although further analysis is needed to identify potential patterns and the impact of them, these differences in how readers approach strategies likely influenced their performance. Again, the results underscore the importance of recognizing the heterogeneity of readers with TBI and learning about the influence of individual performance patterns.

Ultimately, a benefit was demonstrated for the strategy condition across both groups for TTR and number of words per C-unit. As described in the Method section, TTR was used as a measure of lexical and semantic productivity, and words per C-unit was used as a measure of syntactic complexity associated with cohesiveness. When provided with strategy prompts, participants from both groups produced free recalls that had higher lexical density and greater syntactic complexity. Taken together, these findings support the hypothesis that strategy prompts facilitated a more coherent understanding of content in the strategy condition compared to the no-strategy condition.

Study Limitations

This study provides preliminary information exploring the differences between readers with and without TBI and the impact of strategy use on adult readers. Although the findings support ongoing inquiry in this area, the preliminary nature of the study revealed a number of important limitations that can be used to guide future work.

In terms of methodological limitations, three issues are noted that would strengthen the quality of future studies. First, the selection criteria for participants should be refined to better control for unexplained variability. For the between-group comparison, participants were matched by age, gender, and education, but there are likely other demographic factors that could influence reading comprehension abilities such as income, employment, or race and ethnic variables. Additionally, the language process was not formally screened, which may have affected the sample. For the within-group comparison, the inclusion criteria for participation in the TBI group was liberal, and some of the variability observed could be related to neurological factors such as time post injury, recovery factors, and subtle linguistic differences. In addition, the *N* for this study was small, which may have limited the ability to detect differences.

Second, further developing and refining the measures will improve the study's reliability, validity, and sensitivity. The lack of validated methods for assessing higher level reading comprehension skills is a critical barrier to advancing the understanding of these skills in both the general and struggling populations of readers (RRSG, 2002). For example, inferencing is a very broad construct and is a term that is used loosely across different research disciplines (RRSG, 2002). In this study, inference statements were intended to represent the situational level of understanding; however, the inference statements in the SVT did not discern between the inferencing of global concepts based on the overall structure of the text versus local concepts arising from nearby sentences. As another example, analysis of discourse samples could better exploit other options for evaluating verbal productivity and should include additional measures of cohesions that are appropriate for expository text.

Third, participants were not taught to use strategies using systematic instruction. Strategies were merely embedded into the interface, and participants were prompted with written instructions within the interface. The absent or inefficient utilization of the strategies for some readers was likely due in part to a lack of systematic training.

Besides methodological concerns, the theoretical framework selected to guide this study may be limited. Ideally, a theoretical framework will help identify sources of breakdown as a step toward identifying therapeutic targets. Differentiating between different levels of comprehension can provide interesting information but focuses on the outcome of comprehension rather than on underlying processes. A model that characterizes reading comprehension processes may be more fruitful. The structure-building framework seems to be an alternative model with promise (see Gernsbacher, 1997; Lê et al., 2012).

Implications and Next Steps

This study advances the investigation of reading comprehension in people with TBI in several important ways. The results provide evidence that adult readers with TBI perform worse on certain measures of reading comprehension when compared to matched controls. In particular, participants with TBI were less accurate recognizing paraphrase items on the SVT and produced fewer C-units on free recall tasks in the no-strategy condition. These findings extend evidence from other research on reading comprehension and related cognitive–communicative functions.

Results also provide evidence to suggest that adults may benefit from being prompted to use reading comprehension strategies. In particular, reading strategy prompts facilitated greater lexical and semantic productivity and syntactic complexity in free recall tasks given immediately after reading. These differences may reflect greater depth and coherence of understanding.

Finally, the study also raises important questions about whether underlying skills important for reading comprehension may be subtly impacted after TBI; about how individual differences in the skills and knowledge may impact the reading comprehension process; and about how to improve methods for measuring reading comprehension abilities, impairments, and progress. Despite these questions, this study provides preliminary evidence regarding reading comprehension abilities after TBI and response to reading comprehension strategy prompts. Results warrant further evaluation of reading comprehension strategy use in the TBI population.

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