Abstracting meaning from complex information (gist reasoning) in adult traumatic brain injury

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Abstracting meaning from complex information (gist reasoning) in adult traumatic brain injury

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Gist reasoning (abstracting meaning from complex information) was compared between adults with moderate-to-severe traumatic brain injury (TBI, n = 30) at least one year post injury and healthy adults (n = 40). The study also examined the contribution of executive functions (working memory, inhibition, and switching) and memory (immediate recall and memory for facts) to gist reasoning. The correspondence between gist reasoning and daily function was also examined in the TBI group. Results indicated that the TBI group performed significantly lower than the control group on gist reasoning, even after adjusting for executive functions and memory. Executive function composite was positively associated with gist reasoning (p < .001). Additionally, performance on gist reasoning significantly predicted daily function in the TBI group beyond the predictive ability of executive function alone (p = .011). Synthesizing and abstracting meaning(s) from information (i.e., gist reasoning) could provide an informative index into higher order cognition and daily functionality.

Keywords: Abstraction; Adults; Cognition; Cognitive processes; Executive function; Functional outcomes; Gist; Healthy; Reasoning; Traumatic brain injury.

One essential skill that allows an individual to effectively understand and absorb complex and lengthy information is the inherent ability to abstract core meaning(s) (Gabrieli, 2004). Abstracting meanings is achieved by ignoring less relevant details, focusing on important information, and drawing upon our experiences and knowledge to construct generalized ideas (Chapman, 1995; Ulatowska & Chapman, 1994). Abstracting meanings represents a complex integrative function that is ubiquitous in everyday life. Healthy adults typically are able to engage in abstracting meaning with relative ease. In contrast, little is known about the degree to which a traumatic brain injury (TBI) in adulthood affects the critical everyday life skill of abstracting meaning(s) from massive information to which one is exposed.

A TBI affects one’s ability to effectively manipulate and organize information. Specifically, moderate-to-severe TBI can affect recall of details from paragraph-level information and/or word-lists, and organization of information (Coelho, Youse, Le, & Feinn, 2003; Ferstl, Walther, Guthke, & von Cramon, 2005; Hartley & Jensen, 1991; Holliday, Hamilton, Luthra, Oddy, & Weekes, 2005; Hough & Barrow, 2003; Nicholas & Brookshire, 1995). Whereas paradigms that examine recall and organization of information are informative, such methodologies fall short in examining the level to which one is able to derive and convey deeper level meanings (e.g., abstracted meanings) from a wide variety of information sources including talks, newspaper articles, works of art, movies, and legal documents, to mention a few (Chapman, 1998). Perhaps abstract thinking impairments, amongst other factors, could explain the dichotomy documented in standard TBI assessments of near normal performance on traditional cognitive testing, yet reporting significant difficulties in complex daily life tasks. Therefore, Chapman and colleagues proposed a cognitive construct that examines how one extracts and conveys meanings from information, an ability referred to as gist reasoning. Gist reasoning is defined as the ability...
to synthesize complex information, whether written, auditorily presented, or visually depicted, into abstracted meanings that are not explicitly stated (Chapman, 1995). The gist reasoning construct has been employed to characterize abstraction abilities in both healthy adults and clinical populations including adults with stroke, right-hemisphere brain damage, and mild cognitive impairment, adolescents with attention deficit hyperactivity disorder, and youth with TBI (Ulatowska, Allard, & Chapman, 1990; Ulatowska, Chapman, Highley, & Prince, 1998; Chapman et al., 2002; Gamino & Chapman, 2009; Gamino, Chapman, & Cook, 2009; Glosser & Deser, 1991). Evidence also suggests that adults with TBI who sustain their injuries in adolescence have gist reasoning deficits that persist years post injury despite recovery to relatively normal levels of performance on daily living activities (Vas & Chapman, 2012).

No known study to date has examined the impact of moderate-to-severe TBI on gist reasoning in adults who sustained a brain injury in adulthood, one year or longer prior to assessment. The current study examined three questions to advance our empirical knowledge regarding the effects of TBI on gist reasoning. First, the study compared gist reasoning performance between adults with TBI and healthy adults (control group). Second, the study examined the contribution of executive functions and memory to gist reasoning. Third, the relation between gist reasoning and performance on daily-life tasks was examined in the TBI group. We hypothesized lower performance on gist reasoning in the TBI group than in the control group. We predicted significant contribution of executive functions over and above that of memory to gist reasoning. We also hypothesized that gist reasoning would predict daily function in the TBI group.

**METHOD**

**Participants**

Participants included seventy adults: 30 adults (out of 32 recruited) with TBI and 40 healthy adults (control group); all between 25–55 years of age at testing. The TBI group included participants in chronic stages of recovery (at least one year post injury), who sustained a moderate-to-severe TBI (Glasgow Coma Scale, GCS, <12 at the time of injury) at or after the age of 18 (Teasdale, Jennett, Murray, & Murray, 1983). All participants were native English speakers with (a) minimum high school education, at least 8th-grade equivalency on vocabulary and reading comprehension as gist reasoning measure involves reading lengthy information, (b) IQ of 85 or above, as lower intellectual abilities could contribute to variance in processing information in gist reasoning task (Table 1). Exclusion criteria for both groups (TBI and control) included previous history of stroke, learning disability, substance abuse, and major psychiatric disorders as determined by phone screening with the participant. Participants with significant vision and hearing problems were not included in the study as the experimental procedures involved reading and processing auditorily presented

**TABLE 1**

Demographic and clinical characteristics of TBI and control group

<table>
<thead>
<tr>
<th>Variables</th>
<th>TBI (n = 30)</th>
<th>Control (n = 40)</th>
<th>ES</th>
<th>t(68)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at testing (years)</td>
<td>38.53 ± 9.91</td>
<td>37.67 ± 10.58</td>
<td>0.18</td>
<td>0.34 ns</td>
</tr>
<tr>
<td>Premorbid estimate verbal IQ (WTAR)</td>
<td>113.4 ± 8.72</td>
<td>116.2 ± 7.94</td>
<td>0.34</td>
<td>−1.43 ns</td>
</tr>
<tr>
<td>Current IQ (WASI)</td>
<td>109 ± 13.62</td>
<td>112.9 ± 11.39</td>
<td>−0.25</td>
<td>−1.46 ns</td>
</tr>
<tr>
<td>Education</td>
<td>15.43 ± 1.75</td>
<td>15.52 ± 1.79</td>
<td>−0.05</td>
<td>−0.21 ns</td>
</tr>
<tr>
<td>SES (BSMSS)</td>
<td>43.39 ± 5.66</td>
<td>45.4 ± 8.26</td>
<td>−0.28</td>
<td>−0.92 ns</td>
</tr>
<tr>
<td>Reading grade (WRAT)</td>
<td>12.28 ± 1.17</td>
<td>12.51 ± 1.05</td>
<td>−0.2</td>
<td>−0.86 ns</td>
</tr>
<tr>
<td>Processing speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CW-1,2 SS (D-KEFS)</td>
<td>9.61 ± 2.22</td>
<td>10.51 ± 1.82</td>
<td>−0.44</td>
<td>−1.85 ns</td>
</tr>
<tr>
<td>Trails-A</td>
<td>28.83 ± 11.30</td>
<td>25.62 ± 6.5</td>
<td>0.34</td>
<td>1.49 ns</td>
</tr>
<tr>
<td>Hayling-A</td>
<td>5.86 ± .57</td>
<td>6.00 ± .59</td>
<td>−0.24</td>
<td>−0.94 ns</td>
</tr>
<tr>
<td>Additional characteristics of TBI group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCS</td>
<td>5.3 ± 3.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at TBI</td>
<td>28.8 ± 9.43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years since TBI</td>
<td>9.8 ± 8.83</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* TBI = traumatic brain injury; ES = effect size; ns = group differences were not significant; WTAR = Wechsler Test of Adult Reading; WASI = Wechsler Abbreviated Scale of Intelligence; SES = socioeconomic status; BSMSS = Barratt Simplified Measure of Social Status; WRAT = Wide Range Achievement Test; CW-1,2 = Color–Word Interference Test, Tasks 1 and 2; SS = scaled score; D-KEFS = Delis–Kaplan Executive Function System; GCS = Glasgow Coma Scale. The TBI group consisted of 18 males and 12 females. The control group consisted of 20 males and 20 females.
information. Participants with significantly impaired processing speed (two standard deviations below the respective group average) examined on measures of the Delis–Kaplan Executive Function System (D-KEFS) Color–Word Interference Tasks 1 and 2 (Delis, 2001), Trails-A, (Reitan & Wolfson, 1995), and Hayling Sentence Completion Task–1 (Burgess & Shallice, 1997) were not included in the study as processing speed could confound gist reasoning performance (Felmingham, Baguley, & Green, 2004). Information on education and socioeconomic status was also collected as these factors could influence complex cognition including reading skills during gist reasoning (Coelho, 2002). Socioeconomic status was evaluated on the Barratt Simplified Measure of Social Status (Barratt, 2005). Both the TBI and control group were recruited from the Dallas metroplex area. Recruitment of both TBI and the control group were done with flyers posted at the center and by contacting participants who had previously expressed interest in the center’s research studies. Two TBI participants were not included in the study as their reading grade and IQ did not meet the inclusion criteria. Informed consent obtained from all participants was in approval and accordance with the guidelines of the Institutional Review Board of The University of Texas at Dallas and The University of Texas Southwestern Medical Center.

Measures

Gist reasoning was examined using the Test of Strategic Learning (TOSL; Chapman, Gamino, & Cook, under review). The TOSL measure consists of three texts designed to examine two components: (a) how one constructs generalized/gist meanings from lengthy information (i.e., gist reasoning) and (b) number of details recalled (i.e., memory for details). The three texts vary in length (from 291–575 words) and complexity. For the gist reasoning component of each text, the participant is asked to construct a gist-based overview/synopsis of ideas that are not explicitly stated in the text. An example of a gist-based overview/synopsis is first illustrated to clarify that the task entails combining and synthesizing the explicit details in the text to construct generalized ideas. The participant is provided with a copy of the text to follow along as the examiner reads each text aloud. After the examiner finishes reading the text, the participant’s copy is taken away so that the participant does not have the option to refer to the original text

providing his or her abstracted ideas in the form of a written overview/synopsis. Prior work has demonstrated that individuals are less likely to abstract meaning when the literal information remains in front of them (Chapman, Ulatowska, King, Johnson, & McIntire, 1995). The TOSL has demonstrated test–retest reliability and is validated as a measure of ability to abstract meaning from complex information in typically developing youth (Gamino et al., 2009), in healthy adults (Anand et al., 2010), in children with TBI (Cook, Chapman, & Gamino, 2007), and in adults with TBI (Vas, Chapman, Cook, Elliott, & Keebler, 2011). The TOSL measure has a manualized objective scoring system wherein each abstracted gist-idea receives one point. A total composite of 38 points is possible for the three overviews/synopses of the three texts. Two trained examiners blinded to the participants’ group status scored the overviews/synopses for gist-based meanings. Interrater reliability of scores assessed on intraclass correlation coefficients in both groups for gist reasoning performance was over 90% (Cronbach’s α range .86–.99; confidence interval, CI .76–.98). For the memory for details component, each participant is asked a set of questions that elicit memory for factual details of the texts.

Executive functions were measured using tests of working memory, inhibition, and switching. Memory function was examined on measures of immediate recall and memory for facts. Two reliable and valid measures were chosen to examine performance for each of the functions of working memory, inhibition, switching, immediate recall, and memory for facts (see Table 2 for description of measures). Daily-life function in the TBI group was examined on three self-reported functional measures, including Glasgow Outcome Scale–Extended (GOS–E, Wilson, Pettigrew, & Teasdale, 1998), Functional Status Examination (FSE, Dikmen, Machamer, Miller, Doctor, & Temkin, 2001), and Community Integration Questionnaire (CIQ, Willer, Ottenbacher, & Coad, 1994; see Table 2 for description of measures, and Table 3 for daily function status). Each of these functional measures has been validated and used extensively in characterizing daily-life functioning in adults with TBI (Hudak et al., 2005; Shukla, Devi, & Agrawal, 2011).

Overview of statistical analyses

Descriptive analyses examined distribution patterns of participant characterization variables of age at testing, IQ, education, socioeconomic status,
reading proficiency, and speed of processing as these variables could influence gist reasoning performance. A standardized z score was derived for all the individual measures including gist reasoning, working memory, inhibition, switching, immediate recall, memory for facts, and daily function (TBI group) as the current measures involved a combination of standardized and experimental measures with varied scales of performance. An executive function composite score was derived by averaging the z scores of each of the individual measures of working memory, inhibition, and switching. Similarly, memory composite score was the z score average of immediate recall and

<table>
<thead>
<tr>
<th>Variable</th>
<th>Measure</th>
<th>Description</th>
<th>Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working memory</td>
<td>WAIS–III Digit Backward</td>
<td>Orally recall number strings read aloud in backward order</td>
<td>14 total points possible</td>
</tr>
<tr>
<td></td>
<td>Listening Span (Daneman &amp; Carpenter, 1980)</td>
<td>Participant recalls the last word of sentences followed by answering questions related to the sentence.</td>
<td></td>
</tr>
<tr>
<td>Inhibition</td>
<td>D-KEFS, CW inhibition task–3</td>
<td>Name the color of ink a word is printed in versus reading the word (word color spellings are always incongruent with color of ink)</td>
<td>Total time to complete the task + the number of errors.</td>
</tr>
<tr>
<td></td>
<td>Hayling sentence completion test</td>
<td>Orally complete a set of sentences in which the last word is missing. Specifically, complete the sentences with an unrelated word that does not fit within the context of the sentence.</td>
<td>Total time to complete the sentences + number of errors (completing the sentence with a word that fits within the context of the sentence).</td>
</tr>
<tr>
<td>Switching</td>
<td>Trails B</td>
<td>Alternately connect a set of numbers and alphabets in a certain sequence.</td>
<td>Total time to successfully complete the task.</td>
</tr>
<tr>
<td></td>
<td>D-KEFS Category Switching</td>
<td>Verbally produce as many names of fruits and furniture by alternating between the categories.</td>
<td>Number of successful switches between the categories in 60 seconds.</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>WAIS–III Digit Forward</td>
<td>Oral recall of number strings</td>
<td>0–16</td>
</tr>
<tr>
<td></td>
<td>WMS–IV Logical Memory</td>
<td>Oral recall of two short stories read aloud one at a time.</td>
<td>0–50</td>
</tr>
<tr>
<td>Memory for details (2 subtests)</td>
<td>TOSL</td>
<td>Question probes of specific details and explanations of key information in the texts.</td>
<td>0–48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Probe example (specific detail): What happened to John’s career as a teacher?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Probe example (explanation): Why did John feel like a failure?</td>
<td></td>
</tr>
<tr>
<td>Daily function</td>
<td>GOS–E</td>
<td>Gross outcome measure that tracks degree of functional recovery with broad functional categories</td>
<td>2–8</td>
</tr>
<tr>
<td></td>
<td>FSE</td>
<td>Tests 10 functional categories including personal care, mobility/ambulation, travel, work and/or school, leisure and recreation, home management, social integration, cognitive and behavioral competency, standard of living, and financial independence.</td>
<td>10–40</td>
</tr>
<tr>
<td></td>
<td>CIQ</td>
<td>Provides a general overview of an individual’s functioning based on responses to 15 questions related to participation in activities at home, social, and education or vocation settings.</td>
<td>0–29</td>
</tr>
</tbody>
</table>

Note. WAIS = Wechsler Adult Intelligence Scale (Wechsler, 1981); D-KEFS = Delis–Kaplan Executive Function System; CW = Color–Word Interference Test; WMS = Wechsler Memory Scale (Wechsler, 2002); TOSL = Test of Strategic Learning; GOS–E = Glasgow Outcome Scale–Extended; FSE = Functional Status Examination; CIQ = Community Integration Questionnaire.
memory for facts. The daily function composite (TBI group) was the average $z$ score of the three functional measures. A $z$ score composite allows scores across individual measures that have different scales to be combined for analyses and to improve statistical power for analyses that have small sample size (Curtiss, Vanderploeg, Spencer, & Salazar, 2001; Hart, Whyte, Kim, & Vaccaro, 2005; Kim et al., 2005).

Gist reasoning performance was assessed by a standard general linear model (GLM) in SPSS (Stern, 2009). The GLM included group indicators (TBI and the control group), the executive function composite, the memory function composite, and the interaction between each of the executive and memory function composites with group. Additionally, a reduced GLM assessed the relative contribution of each of the executive and memory function composites (including their respective interactions) on gist reasoning and difference in gist reasoning between the TBI and control groups. Full and reduced GLMs were hierarchical so that each covariate in the model could be tested by the principle of conditional sums of squares.

A separate GLM assessed the relative importance of gist reasoning, executive function, and memory on predicting daily function scores in the TBI group. As above, these GLMs were hierarchical to test each separately and to test each in the presence of the others. Thus, the best predictor (gist reasoning, executive function, or memory) of daily function was derived.

RESULTS

Independent-sample $t$ tests demonstrated no significant differences between the TBI group and control group on participant characterization variables of age, education, socioeconomic status, IQ, and reading comprehension (Table 1). Performance on gist reasoning, executive functions, memory, and daily function (TBI group) was normally distributed in both TBI and control groups.

Gist reasoning: Group differences and contributive factors

The TBI group had significantly lower gist reasoning performance than the control group (Table 4) despite comparable education, IQ, reading comprehension, and speed of processing (Table 1). With regard to the contributive factors to gist reasoning, executive function explained a significant proportion (36%) of the variance in gist reasoning $z$ scores, $F(2, 64) = 10.03, p < .001$ (see Table 5). In contrast, the memory composite did not significantly contribute to any of the variance in the gist reasoning $z$ scores, $F(2, 64) = 0.853, p = .431$. Therefore, group differences in gist reasoning was assessed using the reduced GLM that contained only the executive function composite and its interaction with group.

The reduced GLM determined that only the linear term, rather than the interaction coefficient, of the executive function composite significantly predicted gist reasoning. That is, there was a significant positive association between executive function and gist reasoning, $t(66) = 4.73, p < .001$, and this association did not differ between the TBI and control groups, $t(66) = 0.04, p = .963$. However, even after accounting for the positive association between executive function and gist reasoning, the TBI group maintained a significantly lower gist reasoning score than the control group, $t(66) = –2.40, p = .019$.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Measures</th>
<th>TBI ($n = 30$)</th>
<th>Control ($n = 40$)</th>
<th>ES</th>
<th>$F(1, 68)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gist reasoning</td>
<td>TOSL</td>
<td>11.43 ± 7.65</td>
<td>21.10 ± 7.04</td>
<td>–1.3</td>
<td>30.00***</td>
</tr>
<tr>
<td>Working memory</td>
<td>Digit Backward</td>
<td>6.26 ± 2.13</td>
<td>7.47 ± 2.48</td>
<td>–0.52</td>
<td>4.57*</td>
</tr>
<tr>
<td></td>
<td>Listening Span</td>
<td>2.8 ± 1.22</td>
<td>4.08 ± 1.14</td>
<td>–1.08</td>
<td>20.50***</td>
</tr>
<tr>
<td>Inhibition</td>
<td>Color–Word–3</td>
<td>8.03 ± 3.46</td>
<td>10.78 ± 1.87</td>
<td>–0.98</td>
<td>18.14***</td>
</tr>
<tr>
<td></td>
<td>Hayling</td>
<td>4.81 ± 1.73</td>
<td>6.1 ± 0.89</td>
<td>–0.93</td>
<td>16.15***</td>
</tr>
<tr>
<td>Switching</td>
<td>Trails-B</td>
<td>86.1 ± 49.16</td>
<td>55.57 ± 23.42</td>
<td>0.79</td>
<td>11.87**</td>
</tr>
<tr>
<td></td>
<td>Category Switching</td>
<td>10.93 ± 2.83</td>
<td>13.95 ± 3.37</td>
<td>–0.97</td>
<td>15.62***</td>
</tr>
<tr>
<td>Immediate recall</td>
<td>Digit Forward</td>
<td>10.13 ± 1.99</td>
<td>11.3 ± 2.37</td>
<td>–0.54</td>
<td>4.74*</td>
</tr>
<tr>
<td></td>
<td>Logical Memory</td>
<td>9.16 ± 3.83</td>
<td>11.82 ± 3.6</td>
<td>–0.71</td>
<td>8.83**</td>
</tr>
<tr>
<td>Memory for facts</td>
<td>TOSL</td>
<td>36.33 ± 7.34</td>
<td>41.65 ± 3.69</td>
<td>–0.91</td>
<td>15.73***</td>
</tr>
</tbody>
</table>

Note. TBI = traumatic brain injury; TOSL = Test of Strategic Learning; ES = Cohen’s $d$ effect size; ns = group differences were not significant.

*p < .05. **p < .01. ***p < .001.

*Sum of two subtests.
Association of gist reasoning, executive function, and memory with daily function in the TBI group

Significant positive relations were found between gist reasoning and each of the self-reported functional measures of CIQ ($r = .54$, $p < .01$), FSE ($r = .66$, $p < .001$), and GOS–E ($r = .48$, $p < .01$) in the TBI group. As hypothesized, positive relation was found between gist reasoning and composite of the three functional measures($r = .67$, $p < .01$). Stepwise variable selection, through hierarchical GLM, revealed that the memory composite did not significantly predict daily function in the presence of the executive function composite and gist reasoning scores, $t(26) = 1.70$, $p = .101$. However, both executive function and gist reasoning were important predictors of daily function in the TBI group. Alone, the executive function composite was significantly positively associated with daily function, $F(1, 28) = 22.671$, $p < .001$, and explained 34% of the variance in daily function. Gist reasoning contributed an additional 16% of the predictive value of daily function beyond that explained by executive function, $F(1, 27) = 7.45$, $p = .011$. In fact, the predictive value of gist reasoning was even higher ($p < .001$) when an outlier participant was excluded from the analyses. The outlier participant had experienced a significant life event a few weeks prior to the assessment that temporarily affected his ability to participate in significant number of daily life functions. The outlier participant’s performance on other measures, including gist reasoning, executive function, and memory, was within range of the TBI group performance.

DISCUSSION

The discussion focuses on three significant findings in the study. First, the study provided new evidence that gist reasoning was lower in adults with moderate to severe TBI than in healthy controls, even after accounting for the influence of executive function on gist reasoning. Second, the study extended prior evidence of a significant positive relation between gist reasoning and executive function as compared to memory for both healthy controls and TBI. Third, the study demonstrated a significant contribution of gist reasoning, beyond that of executive function, to the prediction of scores obtained from widely used self-reported measures of daily function.

Gist reasoning: Complex cognitive function

In the current study, the majority of the TBI group had considerable difficulty in transforming the details into abstracted meanings. For example, one of the three texts explains the journey of a noble man who valued societal welfare over his own, which led to several job losses and limited monetary gains. One of the ideas commonly expressed by a majority of the TBI group participants was that the character “held various jobs as he was not satisfied with any job.” This type of response conveys important details (i.e., moving from one job to another), but fails to integrate explicit ideas to form abstracted/generalized meanings. In contrast, a majority of the control group conveyed abstracted themes of compassion and service dedicated to a higher cause of equality and justice (see Appendix).

The finding of lower gist reasoning extends prior evidence in adolescents with moderate-to-severe TBI and adults with TBI injured in adolescence who nonetheless showed return of normal to near-normal cognition on standardized IQ measures, vocabulary, and reading levels (Gamino et al., 2009; Vas & Chapman, 2012). Gist reasoning impairments in individuals who sustained a TBI during adolescence is postulated to correlate with the disruption of the frontal myelination that could affect development of higher order cognitive skills including gist reasoning (Chapman et al., 2006; Chapman & Mckinnon, 2000). All the TBI participants in the current study sustained their injuries at or later than the age of 18, yet a majority of them had significant gist reasoning difficulties as compared to the control group.

The combined evidence of gist reasoning impairments in (a) adolescents with TBI, (b) adults who sustained a TBI in preteen and teenage years, and (c) adulthood TBI (current study) suggests that a TBI can have a lasting detrimental impact on the ability to abstract meanings (as compared to the control group), despite no measureable difficulty in comprehending the literal content at word and sentence levels. In the current study, the TBI participants’ word and sentence comprehension was comparable to that of the control group as measured on the Wide Range Achievement Test.
Gist reasoning and executive functions

The second major finding was a significant relation between performance on gist reasoning and executive function. The positive relation between gist reasoning and executive function supports prior imaging evidence implicating the supportive role of frontal lobe mediated executive functions in complex cognitive task performance in healthy and TBI populations (Chambers et al., 2006; Elliott, 2003; Smith & Jonides, 1999; Stuss & Levine, 2002). In healthy adults, researchers found significant contributions of working memory, inhibition, and switching in performing complex tasks such as the Random Number Generation and Tower of Hanoi (Miyake et al., 2000). In adults with TBI, researchers reported correspondence between executive functions (e.g., working memory and inhibition) and organization of details and recognition of implied meanings from segments of paragraphs (Coelho, 2002; Ferstl et al., 2005; Hough & Barrow, 2003). That is, executive functions assist in regulating and coordinating goal-directed behavior by enabling appropriate selection and updating to complex task performance. Therefore, it is vital to characterize higher order cognition that draws upon integrative abilities versus specific cognitive processes in comprehensive TBI assessment. Chapman and colleagues propose gist reasoning as a top-down functionally relevant cognitive construct that entails strategically inhibiting less relevant information, integrating relevant information with past knowledge and experience to form generalized ideas, and flexibly examining the information and/or problem from different perspectives (Anand et al., 2010; Gamino et al., 2009; Vas et al., 2011).

Gist reasoning and daily function

Perhaps one of the most important findings of the study is the positive relationship between gist reasoning and a wide range of self-reported functional measures. The predictive value of gist reasoning highlights the ecological relevance of characterizing the ability to abstract meanings from complex information. That is, the gist reasoning (amongst other metrics) could serve as a performance index to predict and capture a broad range of daily life skills following a TBI. Gist reasoning impairments could reflect impairments in flexible and innovative thinking and may hinder optimal daily life functioning, including job performance and social functioning.

Limitations and future directions

The current findings, while promising, require further validation to address at least five limitations. First, although initial severity of the injury per GCS records was obtained in the current TBI sample, history of radiological findings to establish degree and location of neural damage was not collected due to limited access to medical records. Secondly, the contribution of participants’ current medication (if any) to cognitive performance was not examined. Information on radiological history and current medication use could improve participation characterization and inform the relation between degree of neural damage and cognitive performance. Third, participants had no access to texts while writing the gist-based summaries. It is plausible that individuals with TBI may have difficulty in abstracting meanings from texts with limited memory of details. Therefore, future studies should consider providing the texts while writing gist-based summaries. The fourth limitation is the use of self-rated questionnaires to examine functional status. Information from family, caregivers, and employers (if possible) would corroborate the accuracy of the responses on the functional questionnaires. Comparing gist reasoning performance with naturalistic or real-world tasks (tasks done in real time versus self-reports) could help strengthen the ecological validity of gist reasoning. Imaging methodologies could also improve our understanding of neural processes, which may guide...
development of brain biomarkers of frontal lobe integrity. Fifth, we realize that the sample size is relatively small to confirm relation between gist and executive functions. Future studies with large sample size could further our understanding of the mechanism of gist reasoning. Additionally, investigating the relation between gist reasoning and commonly used abstraction measures could inform us of the unique and common abstraction skills that may underlie gist reasoning.

**Clinical implications and conclusions**

Clinicians are increasingly cognizant of the limitations of traditional cognitive testing to predict long-term functional outcomes, especially in complex daily responsibilities. There is a growing demand to identify and/or develop functionally relevant measures that (a) are sensitive to higher order cognitive performance, (b) have the attributes of being reliably measured, (c) are time efficient in characterizing performance patterns, and (d) are predictive of daily-life functionality (Burgess et al., 2006; Chen & D’Esposito, 2010). With further validation, gist reasoning may fulfill the requirements as an ecologically salient task that reflects the complexities and unstructured nature of everyday life.

The findings from the study propose gist reasoning as a promising and sensitive way to characterize functionally relevant complex integrative function in adults with TBI. Specifically, gist reasoning performance could inform of cognitive impairments that stymie learning and adaptation during rehabilitation and long-term recovery in adults with TBI. In closing, translating the breakthrough of characterizing higher order cognition into clinical practice has never been more vital, particularly considering the increasing number of individuals who suffer “invisible” but life-altering injuries. A paradigmatic shift away from focusing predominately on specific cognitive processes in TBI towards adopting complex integrated cognitive abilities is critical. Therefore, efforts to improve awareness and access to functionally relevant cognitive constructs, including gist reasoning, to practicing neurologists, physiatrists, neuropsychologists, and rehabilitation professionals is critical to guide accurate assessment and subsequent training of higher order cognitive abilities.

**REFERENCES**


**APPENDIX**

**GIST REASONING PERFORMANCE**

**TBI participant**

John started his career as a schoolteacher and went on to becoming a professor. He was considered a failure at these professions, as he was too easy on his students. He then decided to focus his attention on the legal world. He failed as a lawyer as he did not take on big cases that brought in more money. He then became a storeowner, but failed at it as he gave too much credit to his customers and did not make a profit. He also worked as a file clerk in his seventies, but did not enjoy his job. Many years after his death, it was realized that he helped the society.

**Control participant**

One may think of John as a failure. He was a kind and generous man who thought of others’ welfare rather than bringing in more money at all his careers such as teaching, practicing law and so on. He wanted to improve the system at every job. But, those ideas did not go well with the bosses and John could not keep any job for long. Therefore, he was thought of as a failure both by himself and by the society. However, when we look back, John is considered very successful as his ideas that are used even today helped the society over the years.

The TBI and control group participant are comparable on age, IQ, and education. The two overviews of a 575-word text share commonalities and yet reveal stark contrasts as to how meaning is extracted from complex information. On the one hand, both show comparable levels of syntax and similar levels of information reduction. The TBI participant’s overview illustrates a capacity to recall some key information, but fails to convey meaning beyond the literal/concrete facts in the original text. The overview has one abstracted idea (in italics). On the other hand, the control group participant’s overview reflects abstracted gist-based ideas (in italics) of values, kindness, and societal contributions that were not explicitly stated in the original text.