Gist-Reasoning in Adults with Traumatic Brain Injury

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INTRODUCTION

One remarkable capacity of the human brain is its adeptness in extracting ‘gist’ from information that we encounter everyday (Bartlett, 1932, Chapman, Sparks, Levin et al., 2004; Reyna & Brainerd, 1995). Researchers refer to gist as global meanings gleaned from verbal or auditory information (e.g., Kintsch, 1994; vanDijk & Kintsch, 1983). For example, the gist of a movie may include a general sense of the story line or the relation between the key characters and events in the movie. Chapman and colleagues (2004) extend this notion of gist to introduce a construct labeled ‘gist-reasoning’ that denotes the ability to form novel and abstract level meanings than conveyed by the concrete details. That is, gist-reasoning involves combining the explicit input/details of the movie through complex reasoning to construct deeper level interpretations. In essence, gist reasoning is a perfect example of the adage ‘the whole is more than the sum of its parts”.

The metric of gist-reasoning has proven sensitive in characterizing deficiencies in abstracting meanings from complex information in adoloscents with TBI, who had near normal IQ as compared to their non-injured peers (Chapman, Gamino, Cook et al., 2006). Furthermore, improvements in gist-reasoning ability have been associated with increased performance on measures of immediate memory, working memory, inhibition, and switching (Anand, Chapman, Rackley et al., 2010; Vas, Chapman, Cook et al., 2011). However, training of basic cognitive processes such as memory and attention did not improve higher-level gist-reasoning (Gamino, Chapman, Hull et al., 2010). Thus, gist-reasoning could be best understood as a complex task that is positively associated with cognitive control processes (e.g. working memory, inhibition, switching) and immediate memory.

The effects of TBI on gist-reasoning abilities have not been studied in adult TBI populations. The gist-reasoning metric may help elucidate the disparity between regaining near normal general intellectual functioning yet persistent difficulties on functional tasks that necessitate higher-order reasoning skills (e.g., communicating coherent and well-formed messages ideas during a job interview without dwelling on extraneous and irrelevant details) that are widely documented in adults with TBI (Galski, Tompkins, & Johnston, 1998). The current pilot study examined group differences between adults with TBI and healthy adults (control group) on gist-reasoning performance. The study also examined group differences in the memory systems of immediate memory and working memory (WM). Additionally, the contribution of immediate memory and WM to gist-reasoning was examined. We hypothesized that adults with TBI would show significantly reduced ability to abstract gist concepts as compared to the control group. We predicted comparable immediate memory between the groups (based on recent evidence from adolescents with TBI) and lower WM in the TBI group as compared to the controls. It was hypothesized that WM, as compared to immediate memory, would contribute significantly to gist-reasoning in both adults with TBI and the control group. We also explored the relationship between levels of gist-performance, memory functions (i.e. immediate memory and WM), and premorbid estimate of verbal intellectual abilities.

METHODS

Participants

The present study included 35 community dwelling adults, 15 participants (ages 20-55 years) with moderate-severe TBI (at the time of injury) in chronic stages of recovery (at least one year post-TBI) and 20 healthy adults (ages 20-50 years) with no known history of neurological and psychiatric disorders. Adults with TBI were recruited from the local brain injury support groups. The majority (12 out of 15) of the participants with TBI sustained their injuries over 15 years ago, and hence there was limited access to medical records reporting initial severity of the TBI. Therefore, the self-reported period of retrospective post-traumatic amnesia (PTA), a commonly used predictor of functional outcomes following a TBI, was used as an estimate of early injury severity. We acknowledge that estimation of injury severity based on self-reports is not the gold standard in TBI research. Nonetheless, retrospective PTA as a rough index of early injury severity has been used in previous studies and vital information has been gleaned from such studies despite this limitation (Forrester, Encel, & Geffen, 1994; Shores, Marosszekjy, Andanam et al., 1986). The control group was recruited through flyers posted at the research center. Participants (TBI and control group) did not receive any monetary compensation.

Native English speakers with minimum high school education, a minimum of 10th grade equivalency on vocabulary and comprehension on the Nelson-Denny reading test (Brown, Fischo, & Hanna, 1993), and a minimum score of 100 on the premorbid estimate of verbal intellectual functioning (measured on North American Adult Reading Test, Spreen & Strauss, 1998) were included in the study. Additionally, TBI participants with moderate functional impairments at the time of testing were included in the study. Functional impairments were examined on the measures of the Glasgow Outcome Scale-Extended (GOS-E; Wilson, Pettigrew, Teasdale, 1998) and the Functional Status Examination (FSE; Dikmen, Machamer, Miller, et al., 2001).

Exclusion criteria for both groups (TBI and control) included previous histories of stroke, learning disability, substance abuse, and major psychiatric disorder. The current study did not include participants with significant depressive symptoms (>13) as reported on the Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996). Participants in the brain injury group who were receiving cognitive treatments at the time of the assessment were not included in the study as cognitive treatments could potentially confound gist-reasoning performance. 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 with the Test of Strategic Learning (TOSL, Chapman, Hart, Levin et al., 2010). The TOSL measure consisted of three texts, designed to examine how one understands and constructs synthesized meanings or gist from connected language. The three texts vary in length (from 291-575 words) and complexity. For each of the texts, the participant is asked to provide a synopsis of the original text that conveys general ideas from the text and does not include all of the details. The TOSL measure has a manualized objective scoring system wherein the abstracted responses (i.e. gist-meanings) receive a higher score than those that focus on the stated details of the text. Each gist meaning conveyed by the individual receives one point. A total score (composite score) of 28 points is possible for the three summaries of the three texts. Two trained examiners, blinded to the participants’ group status independently scored the three summaries for inclusion of gist-based meanings. Interrater reliability of scores assessed on intraclass correlation coefficients in both groups combined for gist-reasoning performance was over 90% (Cronbach’s α range 0.89-0.98, CI 0.76-0.98).

Immediate memory was examined on probes that examined the recall of details of the texts. Each text has four probe questions for a total of 12 probe questions for all three texts. Each probe receives a score of 2, 1, or 0 points depending upon accuracy and completeness of the response. Thus, a cumulative immediate memory of the details from the three texts ranges from 0-24, with 24 being the highest possible score.

Working Memory was examined using the Letter-Number sequencing (LNS) test, a subtest of WAIS-III (Wechsler, 1997a). The LNS task requires the participant to order sequentially a series of numbers and letters orally presented in a specified random order. Participants must simultaneously track letters and numbers while sequencing each of these stimuli without forgetting any part of the series.

Data Analyses

Student t-test analysis compared participant characterization variables of estimated premorbid verbal intellectual ability, age at testing, years of education, reading and vocabulary between the TBI and control group. One-way ANOVA compared group differences between adults with TBI and control group on measures of gist-reasoning, immediate memory, and WM. Regression analysis examined the contribution of immediate memory and WM to gist-reasoning within groups. The relation between of gist-reasoning levels (low and high), memory functions (immediate memory and WM), and premorbid estimate of verbal intellectual functioning was explored using Pearson correlations.

RESULTS

Adults with TBI were comparable to the control group on participant characterization variables including estimated premorbid verbal intellectual ability, age at testing, years of education, reading and vocabulary (Table 1). Hence, no further analyses were conducted on these participant variables. The groups showed significant differences on gist-reasoning performance, immediate memory, and WM. The TBI group performed significantly lower on abstracting gist-concepts when compared to the control group. Similarly, immediate memory for text details and

WM in the TBI group were significantly lower than the control group (Table 2). Regression analysis indicated that immediate memory and WM (combined) accounted for 41% of the total variance in gist-reasoning (R^2 = .41) in the TBI group, which was significant, F (2, 12) = 4.31, p=.03. However, contribution of WM to gist-reasoning was over and above immediate memory (β= .65, p=.01). In the control group, memory functions (immediate memory and WM combined) accounted for 33% of the total variance in gist-reasoning performance (R^2 = .33) which was significant, F (2, 17) = 4.25, p=.03. Similar to the TBI group, WM contribution to gist-reasoning was over and above that of immediate memory (β = .45, p=.03).

Exploratory analyses

The current study explored the relation between degrees of gist-reasoning (i.e. low and high gist-performers) to the memory systems (i.e., immediate memory and WM) and premorbid estimate of verbal intellectual functioning in each group separately. Given the small sample size in each group, median split analyses was considered informative to provide pilot evidence of the relation. Median-split of the gist-reasoning scores in both the TBI and the control group divided each group into low- and high-gist performers. Correlation analysis indicated significant positive relationship between gist-reasoning and WM in high-gist performers in the TBI group (M = 12.57, SD = 2.07, N = 8) and low-gist performers in the control group (M = 14.77, SD = 2.48, N=9). Immediate memory did not significantly correlate with gist-reasoning in either group. Significant positive relation was found between gist-reasoning performance and premorbid estimate of verbal intellectual functioning in the TBI group (r^2=0.59, $p=0.02$). However, no significant relation between gist-reasoning and intellectual functioning was evident when the group was split into low and high gist performers. No significant relation between gist-reasoning performance and intellectual functioning was found in the control group.

DISCUSSION

The current study provides new evidence of the lasting impact of TBI on ability to synthesize meanings from lengthy information. Gist-reasoning performance (examined in the form of synopses) varied significantly between the TBI and control group. Specifically, the condensed versions of the texts produced by adults with TBI were more typically direct retell and/or only minimal use of generalized meanings as compared to the control group that adopted strategic binding of details to convey gist-concepts. Researchers reported a similar pattern of predominantly retelling explicit details in condensed texts in adolescents with TBI as compared to typically developing youth (Chapman et al., 2004, 2006).

In addition to the gist-reasoning deficits found in the current study, adults with TBI demonstrated lower immediate memory for text details when compared to the control group. Although comparable memory for text details between adults with TBI and the control group was predicted (based on evidence from adolescent TBI), lower performance on immediate recall of details is not surprising given extensive evidence of memory impairments in adults with TBI (McDonald, Flashman, & Saykin, 2000). Similarly, lower WM in the adult TBI group concurs with extensive evidence of such impairments on WM measures including LNS, listening span, digit- backward measures, and n-back tasks (McAllister, Sparling, Flashman et al., 2001).

Relationship between gist-reasoning and memory systems

Significant contribution of WM above and beyond what is explained by immediate memory to gist-reasoning could be indicative of a supportive dynamic relation between working memory and gist-reasoning. A similar finding of a positive relation between WM (examined on an n-back measure) and the ability to produce a cohesive and coherent gist-based summary was reported in adolescents with TBI (Chapman et al., 2006). In fact, Chapman and colleagues found that adolescents with TBI had impaired gist-reasoning performance despite recall of text details at a level comparable to typically developing children.

Theoretical postulations could further elucidate the potential role of WM in gist- reasoning. For example, Baddeley's WM model (1992) proposes that while the subsidiary components of the WM system (i.e. the articulatory loop and the visuospatial sketchpad) assist in storage of verbatim information, the central executive component oversees processing and allocating attentional resources to successfully manipulate information online. In the current study, one explanation we offer is that the central executive component of the WM system may adopt higher-level cognitive strategies (such as chunking) to effectively reorganize and recall the important details to assist in abstracting meanings. Theorists have also demonstrated a significant role of cognitive control factors of inhibition and flexibility in the performance of complex tasks. We speculate the inhibition (inhibiting less relevant details of the texts) and cognitive flexibility (to generate multiple interpretations by examining the information from different perspectives) may contribute significantly to gist-reasoning. Future studies could examine this speculation. Additionally, the role of IQ in gist-reasoning need further investigation. The role of IQ in gist-reasoning remains equivocal. Previous studies found that the traditional IQ measures do not predict gist-reasoning capacity. For instance, Chapman and colleagues (2004, 2006) demonstrated that gist-reasoning in adolescents with TBI is impaired despite near normal intelligence. Future studies should investigate the relation between gist-reasoning and performance on traditional IQ measures in adults TBI population.

In addition to examining the role of cognitive control functions (e.g. inhibition, flexibility) and IQ that may contribute to gist-reasoning, future research should take into account three significant factors, that may improve our understanding of the impact of TBI on gist-reasoning, that of (a) initial injury severity, (b) evidence of significant MRI findings, and (c) age at injury. Documenting initial injury severity is critical to accurately establish the relation between injury severity, later recovery level, and performance on higher-level critical thinking tasks. Participants in the present study were recruited primarily from the community at periods years and decades after brain injury and hence had limited access to documentation of acute severity of TBI. Radiological findings including MRI reports would be informative to correlate the region of injury to gist-reasoning.

With regard to ‘age at injury’ factor, most of the participants (12 out of 15) sustained a TBI in their pre-teenage and teenage years. Research has demonstrated that frontal network myelination continues into the early third decade of life (i.e. into early twenties) and a TBI disrupts the maturation of frontal functions (Sowell, Thompson, Holmes, et al., 1999; Taylor, Yeates, & Wade, 2002). Researchers have documented a neurocognitive stall, which is a failure to develop higher-order cognitive skills at the appropriate developmental stage, including gist-reasoning in adoloscents with TBI (Chapman et al., 2004, 2006). It is not known if a TBI sustained in adulthood (post-frontal network maturation) affects gist-reasoning to the similar degree as identified in the current pilot study where the majority of the adults with TBI sustained the injury in their teenage or preteen years.

IMPLICATIONS

In sum, we suggest that the construct of gist-reasoning, i.e., the ability to synthesize abstract meaning from a variety of contexts, provides a sensitive measure of the persistent and consequential deficits at chronic stages of TBI in adults. Further, the greater contribution of working memory, over immediate memory, to gist-reasoning capacity supports our view that gist-reasoning is related to top-down, cognitive control processes. The present results also add to recent findings of gains after gist-reasoning training in adult TBI (Vas et al., 2011). In Vas and colleagues' randomized training trial, we found gains not only in ability to synthesize meaning but also in both untrained executive control processes and real life ratings in the adult TBI group. Therefore, we believe that gist-reasoning may provide a promising platform to detect as well as mitigate some of the lasting cognitive sequelae in TBI. We hope this study encourages future research to further elucidate this potential in light of the dramatic recent increases in war-related and athletic related brain injuries. The need to find more sensitive assessment protocols to functionally relevant domains has never been greater.

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Table 1

Demographic and clinical features of TBI and control group

Variables		Mean	SD	Range	95% CI	ES Cohen's *d*	*t(33)*
Estimated premorbid verbal intellectual ability	TBI Control	119.7 121.9	4.69 3.38	109-126.2 114.5-126.2	119.7-122.29 121.9-123.47	0.53	.115 ns
Current Age	TBI Control	39.6 34.8	10.95 8.96	22-55 23-48	39.6-45.65 34.8-38.98	0.47	-1.4 ns
Education	TBI Control	15.66 16.52	1.98 1.31	12-19 14-20	15.66-16.75 16.06-17.03	0.51	1.53 ns
Grade Equivalency	TBI Control	15.28 17.02	2.65 1.47	10.6-18.5 15-19	16.06-17.03 17.02-17.7	0.81	1.96 ns
Age at TBI	TBI	23.12	8.74	11-45	__	__	__
PTA (weeks)	TBI	4.57	1.45	0.2-7	__	__	__
GOS-E	TBI	5.6	0.79	5-7	__	__	__
FSE	TBI	26.87	2.9	23-29	__	__	__

Note. TBI- Traumatic brain injury. The TBI group consisted of twelve males and three females. The control group consisted of thirteen males and seven females. SD- standard deviation, ES-Effect Size, CI-Confidence Interval, PTA- Post Traumatic Amnesia, GOS-E-Glasgow Outcome Scale-Extended, FSE-Functional Status Examination. Grade equivalency was examined on the Nelson-Denny reading test. ns-Group differences were not significant.

Table 2

Group differences on gist-processing and memory measures

Variables		Mean	SD	Range	95% CI	Effect size Cohen's *d*	*F* (1,33)
	TBI	9.86	3.22	5-17	8.23-11.49		
Gist	Control	17.95	3.8	12--27	16.28-19.62	2.29	47.63***
	TBI	19	2.61	14-24	17.68-20.32		
Details	Control	22.2	1.5	20-24	21.54-22.86	1.5	20.81***
	TBI	9.66	1.79	7-14	8.67-10.66		
WM	Control	12.95	1.90	10-18	12.05-13.84	1.78	26.68***

*** $p<.001$

Note. The TBI n=15, Control n=20. WM- Working memory.

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