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Visuospatial, Visuoperceptual and Visuoconstruction Abilities in Traumatic Brain Injury: The Effects of Injury Severity and Effort

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Abstract

The study's objective was to determine the effects of Traumatic Brain Injury (TBI) on visuospatial, visuoperceptual and visuoconstruction skills while controlling for effort. TBI cases were classified by injury severity as mild or moderate-severe, and by effort measured based on performance on four validity-indicators. TBI cases were also compared to demographically-matched healthy control subjects. Visuospatial, visuoperceptual and visuoconstruction abilities scores were obtained from the performance on five common neuropsychological tests: Rey-Osterrieth Complex Figure, Benton Facial Test as well as Matrix Reasoning, Picture Completion and Block Design from the Wechsler Adult Intelligence Test-III. Patients classified as mild TBI good effort demonstrated no meaningful impairments in the visual skills tests. Those classified as moderate-severe TBI and mild TBI poor-effort demonstrated moderate impairments in these same skills. Therefore, effort aside, a dose-response effect was obtained between injury severity and visuospatial, visuoperceptual and visuoconstruction performance. Poor effort was responsible for visual skills impairments in mild TBI. As a result, it is important to extensively test motivational factors in mTBI before attributing impairments in visuospatial, visuoperceptual and visuoconstruction neuropsychological tests to brain damage.

Keywords: Traumatic Brain Injury, Visuospatial, Visuoperceptual and Visuoconstruction, Effort, Neuropsychological Assessment.

Introduction

Visuospatial, visuoperceptual, and visuoconstruction skills underlie some of our non-verbal understanding of the world. The effects of traumatic brain injury (TBI) on measures of visuospatial, visuoperceptual, and visuoconstruction skills, similar to other cognitive functions, should correspond to a dose-response relationship between degree of the injury severity and the intensity and persistence of cognitive impairments. That is, cases with moderate to severe TBI (M-S TBI) have significant impairments that can last for more than a year (Dikmen, Ross, Machamer, & Temkin, 1995), while cases with mild TBI (mTBI) present some deficits that do not usually persist longer than three months (Ponsford, Willmont, Rothwell, Cameron, Kelly, et. al., 2000). However, studies have demonstrated that a group of individuals with mTBI exhibit severe and persisting deficits on a number of visuospatial, visuoperceptua,l and visuoconstruction measures, challenging the assumed dose-response severity-impairment relationship (Vanderploeg, Curtiss, Luis, & Salazar, 2007).

TBIs often occur in the context of legally compensable events such as a work-related injury or incident. In these contexts, poor effort when performing cognitive tasks is a potential problem because some individuals may want to appear disabled to potentially get more monetary compensation. The main goal of this study was to better elucidate the effects of brain injury on visuospatial, visuoperceptual, and visuoconstruction performance when taking in consideration the effect of poor effort, particularly in mild TBI cases. To accomplish this goal, patients with mTBI and M-S TBI were grouped as good and poor effort based on performance validity test scores, and these groups were then compared on five measures of visual abilities.

Method

Archival data were obtained from 163 TBI patients seen from 1998 to 2005 for neuropsychological evaluations at a suburban neuropsychology practice located in southern Louisiana. Data was obtained in compliance with institutional regulations. Inclusion criteria were: 1) age between 18 and 60; 2) at least one year between injury and evaluation; and 3) administration of all the visuospatial, visuoperceptual, and visuoconstruction tests (see below) and at least two of the four performance effort measures discussed below. A total of 121 TBI patients were included in this study. All had incentive to perform poorly, usually in the form of workers compensation (66%) or a personal injury claim (23%). The remaining 11% were involved in disability claims. In addition, 20 subjects demographically-matched to the TBI patients were recruited from the for comparison purposes. These subjects were screened using a self-report questionnaire and excluded if they were ever in an injury related litigation case, reported a previous brain injury, or were ever formally diagnosed with a psychiatric or neurological illness. None were excluded.

TBI cases were classified according to injury severity as mild or moderate-severe. Injuries were considered mild if they claimed they had sustained a blunt trauma to the head or if they met the criteria set by the Mild Traumatic Brain Injury Committee of the Head Injury Interdisciplinary Special Interest Group of the American Congress of Rehabilitative Medicine (1993). These criteria include: 1) an initial Glasgow Coma Scale (GSC) of 13 to 15 after 30 minutes from the time of the injury/accident; or 2) loss of consciousness (LOC) of approximately 30 minutes or less; or 3) posttraumatic amnesia (PTA) not greater than 24 hours. Any injury more severe than indicated by the above criteria, including the presence of intracranial pathology, was classified as moderate-to-severe. Out of the full clinical sample, 88 cases were classified as mTBI and 33 cases were classified as M-S TBI.

TBI cases were also classified according to the validity of patient performance based on four commonly used indicators of validity: Test of Memory Malingering (Tombaugh, 1996), Portland Digit Recognition Test (Binder, 1993), Word Memory Test (Green, Allen, & Astner, 1996), and Reliable Digit Span (Greiffenstein, Baker, & Gola, 1994). Poor effort cut-offs were based on published validity indicator cutoffs for each test (see Appendix A for details). A failure on one or more of these measures was considered an indication of poor effort during testing. Patients were included in the good effort group only if they scored above cutoffs on each performance validity measure. Based on the participant's type and severity of injury, and performance on measures of effort, the total sample was categorized in the following six groups: 1) mTBI good effort (n= 46); 2) mTBI poor effort (n= 42); 3), M-S TBI good effort (n = 27); 4) M-S TBI poor effort (n = 6); 5); and controls (n= 20). Note that there were an insufficient number of M-S TBI patients who gave poor effort for appropriate group comparison so this group was excluded from the analyses.

As part of a neuropsychological evaluation, all participants completed the following measures of visuospatial, visuoperceptual, and visuoconstruction abilities: Rey-Osterrieth Complex Figure (ROCF; Osterrieth, 1944), Benton Facial Recognition Test (BFRT; Levin, Hamsher, & Benton, 1975), Block Design, Matrix Reasoning, and Picture Completion from the Wechsler Adult Intelligence Scale - 3rd Edition (WAIS-III; Wechsler, 1997). Raw scores were evaluated for all tests.

Results

First, demographic and injury-related variables were evaluated to determine differences among the control group and the TBI groups. The groups did not differ on sex, age, education level, time since injury, or ethnic background. Note that the control group was not included in the month since injury comparison.

Table 1

Means and standard deviations related to the Demographic Characteristics of the Current Sample by Group.

Group		Controls	mTBI good effort	mTBI poor effort	M-S TBI	*F*	*p*=
	n	*20*	*46*	*42*	*27*		
Age (years)	*M*	32.8	40.2	40.8	35.4	2.80	.064
	(SD)	(13.5)	(12.7)	(9.1)	(16.2)		
Education (years)	*M*	12.8	12.3	11.9	11.9	1.41	.175
	(SD)	(2.1)	(3.3)	(3.4)	(4.2)		
Months Since	*M*	--	34.0	36.2	46.8	1.82	.120
Injury (months)	*(SD)*	--	(14.7)	(26.4)	(43.4)		
						X^2	*p*=
Gender (males)	*%*	80.0	63.0	73.8	85.2	4.89	.180
Race							
Caucasian	*%*	71.4	73.9	67.1	65.6	10.8	.287
African Am.	*%*	23.8	10.9	10.0	11.1		
Hispanic	*%*	4.8	0.0	5.7	7.4		
N/I	*%*	0.0	15.2	17.1	15.9		

Note. R-H = Right Hemisphere; M-S TBI = Moderate-to-severe Traumatic brain Injury; mTBI = mild Traumatic Brain Injury; Am. = American; N/I = Not Indicated.

Second, a multivariate analysis of variance (MANOVA) and a series of ANOVAs were conducted to examine visuospatial, visuoperceptual, and visuoconstruction score differences on the four groups. Table 2 shows between group analyses and effect sizes (Cohen's *d*) related to the performance of the control group for each visuospatial, visuoperceptual, and visuoconstruction tests.

Table 2

Group Mean, SD, statistical differences and Effect Sizes (Cohen's d) of brain injury/damage severity and effort on visual perceptual measures.

Group		Controls	mTBI good effort	mTBI poor effort	M-S TBI	*F*	*p*≤	Cohen's D compared to controls: mTBI good effort	mTBI poor effort	M-S TBI
	n	*20*	*47*	*41*	*27*					
ROCF	*M*	31.0 [a]	30.9 [ab]	26.6 [b]	27.8 [ab]	3.2	.016	-0.09	-0.22	-0.24
	(SD)	(3.80)	(6.10)	(6.20)	(7.50)					
BFRT	*M*	47.3 [a]	44.8 [a]	40.5 [b]	42.3 [b]	10.7	.001	-0.04	-0.43	-0.29
	(SD)	(2.70)	(2.60)	(5.30)	(6.20)					
Block Design	*M*	9.1 [a]	9.0 [a]	7.5 [b]	7.9 [ab]	3.7	.007	-0.09	-0.35	-0.26
	(SD)	(2.8)	(2.5)	(2.3)	(2.8)					
Matrix reasoning	*M*	11.4 [a]	10.8 [ab]	7.8 [c]	8.6 [bc]	6.9	.001	-0.08	-0.65	-0.49
	(SD)	(2.60)	(2.80)	(2.80)	(2.50)					
Picture Completion	*M*	10.6 [a]	9.6 [ab]	7.2 [bc]	6.8 [c]	7.5	.001	-0.20	-0.73	-0.74
	(SD)	(3.10)	(3.70)	(3.30)	(2.50)					

Note. R-H = Right Hemisphere; M-S= Moderate-to-severe Traumatic brain injury; mTBI = mild Traumatic Brain Injury; ROCF = Rey Osterrieth Complex Figure; BFRT = Benton Facial Recognition Test; POI = Perceptual Organization Index.

[abc]Row Means with same letter represent homologous subgroups using Tukey's corrections at p = .05

In all examined tests, mTBI good effort group did not differ from controls while the mTBI poor effort and M-S TBI groups performed worse than the mTBI good effort and control groups; although, this difference was not always significant. Lastly, after standardizing each test score using sample and test specific means and standard deviations, a mean effect size for all visuospatial, visuoperceptual, and visuoconstruction tests was calculated by group. For mTBI good effort, the mean Cohen's *d* was -.10 indicating no meaningful overall effect. For mTBI poor effort the mean Cohen's *d* was -.48, and for M-S TBI the mean Cohen's *d* was -.40, indicating moderate detrimental effects for both groups.

Discussion

The present study examined the visuospatial, visuoperceptual, and visuoconstruction performance of traumatic brain injury (TBI) patients classified by their injury severity and their effort during the examination. Results demonstrated a dose-response relationship between visuospatial, visuoperceptual, and visuoconstruction performance and TBI severity when effort was controlled. Poor effort aside, there were no observable overall differences between the mTBI group and a demographically-matched healthy control group, demonstrating that those with mTBI injuries do not exhibit persisting visual skills impairments beyond the expected period of recovery of three months to one year. The M-S TBI group presented moderate visual skills impairments, further confirming the significant detrimental effects of M-S TBIs on cognitive abilities (McKenna, Cooke, Fleming, Jefferson, & Ogden, 2006). This study also found that poor effort during testing was responsible for noticeably low visuospatial, visuoperceptual, and visuoconstruction scores on neuropsychological tests. In fact, the detrimental effect of poor effort on visuospatial, visuoperceptual, and visuoconstruction scores was comparable, and at times greater than, the effects of M-S TBI. These results are consistent with data related to other cognitive abilities, including memory (West, Curtis, Greve & Bianchini, 2011) and executive functions (Ord, Greve, Bianchini & Aguerrevere, 2010) in that those who fail one symptom validity test (SVT) demonstrate significant detriments in test scores. Moreover, our results were similar to the findings by Green and colleagues (Green & Iverson 2001; Green, Rohling, Iverson, & Grevais, 2003; Green, Rohling, Lees-Haley, & Allen, 2001), who demonstrated that effort as measured by one symptom validity test (i.e., Word Memory Test, WMT) was greater than the effects of M-S TBI (Green, Allen, & Astner, 1996). Similar to our results, Green and colleagues (2001) also found that the dose-response relationship between injury severity and test performance was only observed in patients who passed the WMT. Thus, in mTBI patients, one should exercise caution when attributing impairments in neuropsychological test performance to brain damage without comprehensively assessing effort. Data from this study should further alert clinicians about the effects of poor effort during neuropsychological testing, and its possible implications on planning effective treatments and interventions for traumatic brain injuries.

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Appendix A

Effort Measures and cutoffs

Portland Digit Recognition Test (PDRT; Binder, 1993). The PDRT is a commonly used cognitive performance validity measure employing a forced-choice digit-recognition format. All patients in the TBI and control groups were administered this measure. Any score below 22 for the easy portion, 20 for the hard portion, or 44 total was considered an indication of poor effort. These scores are based on recommendations from the manual (Binder, 1993). A number of studies also confirm accurate classification of performance validity in patients with TBI at these cutoffs (Bianchini, Mathias, & Greve, 2001; Binder & Kelly, 1996; Greve & Bianchini, 2006).

Test of Memory Malingering (TOMM; Tombaugh, 1996). The TOMM is a commonly used cognitive performance validity measure employing a forced-choice recognition visual memory format. The TOMM was used to identify invalid cognitive performance in patients with TBI. Any score below 45 on Trial 2 or Retention was considered an indication of poor effort based on recommendations from the manual (Tombaugh, 1996) and classification accuracy from Greve, Bianchini, and Doane (2006).

Word Memory Test (WMT; Green, Allen, & Astner, 1996). The WMT was also used to identify invalid cognitive performance in patients with TBI. Methodological concerns regarding the development of cutoffs recommended in the WMT manual by Green et al. suggest that these cutoffs may produce an unacceptably high level of false positives. Thus, a cutoff of less than 72.5 on either Immediate or Delayed Recall was chosen to identify poor effort based on the review of the data from Bianchini, Mathias, & Greve, (2001) .

Reliable Digit Span (RDS; Greiffenstein, Baker, & Gola, 1994). RDS is an internal validity indicator derived from the Digit Span subtest of the Wechsler Adult Intelligence Scale (Revised or 3rd Edition; Wechsler, 1981; Wechsler, 1997) by summing the longest forward and backward digit spans on which both trials were repeated correctly. RDS was available for all examined TBI. RDS has been validated as an accurate measure of performance validity in a number of studies (Mathias, Greve, Bianchini, Houston, & Crouch, 2002; Meyers & Volbrecht, 1998) .