Title: The Cognitive Basis for Sentence Planning Deficits in Discourse Following Traumatic Brain Injury

Abstract

Recent analyses of the language produced by individuals with traumatic brain injury place increasing emphasis on within-sentence patterns as well as those between sentences. Discussions of production deficits within sentences following TBI have questioned whether these problems involve the implementation of well-formed sentence frames or whether they represent a more fundamental linguistic disturbance in computing sentence structure. This study used online methods to investigate whether problems with sentence planning for discourse after TBI are associated with impaired language functioning or other cognitive processes. The results demonstrated that sentence planning deficits were associated with short-term memory span and attentional processing.

Introduction

Recent analyses of the language produced by individuals with traumatic brain injury (TBI) have placed increasing emphasis on describing patterns observed within sentences as well as between sentences. For example, TBI speakers produce more syntactic errors (i.e., omissions of subject, main verb, and required grammatical morphemes, word transpositions, verb tense and agreement errors, and incomplete verbalizations) (Peach & Schaude, 1986; Glosser & Deser, 1990) and are less efficient in producing sentences (Ehrlich, 1988; Stout, Yorkston, & Pimental, 2000, Marini, Galetto, Zampieri, Vorano, Zettin, & Carlomagno, 2011) than normal speakers. TBI speakers also produce less complex sentences than do normals and show difficulty embedding final propositions into their utterances (Coelho, 2005; Peach, Shapiro, Rubin, & Schaude, 1990). They also appear to have substantial difficulty planning for the production of sentences varying in syntactic complexity (Ellis & Peach, 2009) that may result in frequent interruptions of ongoing utterances (Marini et al., 2011).

In discussing sentence planning deficits following TBI, Ellis and Peach (2009) questioned whether these problems involve only the implementation of well-formed sentence frames or whether they represent a more fundamental linguistic disturbance in computing sentence structure. Using online analyses of sentence production (pause time and verbal initiation time), these authors found evidence for difficulty with grammatical encoding and lexical retrieval that was sufficient to suspect that a linguistic deficit accounted for the observed patterns. More recently, Marini et al. (2011) examined sentence production following TBI and concluded, based on an absence of overt grammatical and lexical errors and normal content, more global coherence errors, and specific neuropsychological deficits, are not due to specific linguistic deficits. Despite finding no correlation among any of their neuropsychological and language measures, they suggested that such problems "reflect a deficit in the interface between cognitive and linguistic processing."

To date, there have been no studies reported that have investigated patterns of sentence production in discourse following TBI that have used online analyses (i.e., pause time) while attempting to identify the cognitive bases for these patterns. Further research is needed to characterize a) the presence and type of deficits within sentences produced by TBI speakers and b) the cognitive underpinnings for these deficits. This study investigated whether problems with sentence planning for discourse after TBI are associated with impaired language functioning, disturbances to attention, memory, executive functioning, concept formation and/or reasoning, or some combination of these processes. The experimental questions were as follows:

1. Do TBI and normal speakers show different patterns of sentence planning for simple discourse as evidenced by an online index of sentence planning, i.e., pause time.
2. Do TBI and normal speakers show different patterns of sentence planning for discourse as evidenced by an offline index of sentence planning, i.e., maze production.
3. What cognitive skills predict patterns of pausing during sentence planning following TBI?
4. What cognitive skills predict patterns of maze production following TBI?

Methods

Fifteen nonaphasic individuals six months post severe traumatic brain injury (TBI) and six normal adults matched for age and education participated in this study (Table 1). Monologic discourse samples consisting of WAB *Picnic Scene* descriptions were obtained and audio recorded. The language samples were transcribed orthographically and uploaded into *Praat* (Boersma & Weenink, 2010). Within each utterance, pauses of greater than 200 ms were identified as occurring between or within clauses. The data were entered into *Systematic Analysis of Language Transcripts* (SALT, v. 9.0). Three types of events (pauses, mazes [fillers, repetitions, revisions], and errors [subject-verb agreement, omissions, abandoned]) were recorded for each utterance. Mean length of utterance (MLU) (morphemes) and mean pauses per utterance, pauses between clauses, pauses within clauses, and mazes per utterance were calculated for each group of participants (Table 2).

Measures of language and other cognitive abilities were drawn from comprehensive neuropsychological and speech-language evaluations that were completed at the time of each recording (Table 3). The measures included: Trail Finding B (complex attention and planning), Digit Span Forward and Sentence Repetition (simple recall), Digit Span Backwards (working memory), WAB AQ and Boston Naming Test (language functioning), and Controlled Oral Word Association (cognitive flexibility), DTLA Likenesses and Differences (concept formation), and Ravens Coloured Progressive Matrices (RCPM) (nonverbal reasoning).

Reliability

Language samples from four (27%) participants with TBI were selected randomly to calculate interjudge reliability. Correlations for measurements obtained from two independent examiners ranged from .84 to 1.0 for calculation of MLU (morphemes), total number of pauses, pauses between clauses, and pauses within clauses.

Results

Planned comparisons of the group means for mean length of utterance, pauses, mazes, and errors were conducted. No differences were observed between the two groups for the number of morphemes produced per utterance (Table 3). Both groups produced an equivalent small number of errors that were distributed similarly across error types. The total number of pauses produced by TBI participants was significantly greater than that observed in normal speakers ($t=-2.14$, $p=.047$). While both groups produced substantially more pauses within than between clauses, the mean number of pauses between clauses produced by the TBI speakers was significantly greater than that produced by the normal speakers ($t = -2.16$, $p=.044$). TBI participants also produced a significantly larger number of mazes than did the normal speakers ($t=-2.80$, $p=.011$).

Stepwise linear regression analyses were performed to determine the way that TBI participants' cognitive deficits contributed to their increased pausing between clauses and the relationship between cognitive deficits and maze production. Using the cognitive measures identified above as predictor variables, significant models were built for both analyses. Digit Span Forward was chosen as the only significant predictor for pause behavior while Sentence Repetition and RCPM were chosen as significant predictors of maze behavior. RPCM was found to have a strong correlation ($r=-.75$) with one other cognitive measure, Trail Finding B.

Discussion

Online analyses of the language production of TBI speakers provide substantial evidence for sentence planning difficulties consisting of increased pausing between clauses and utterance reformulation. These problems were found to be associated with measures of short-term memory span and attentional processing. The results appear to bear strongly on recent models of sentence processing that emphasize short-term activation and maintenance of language representations (Martin, Miller, & Vu, 2004; Martin for accurate sentence production. The findings suggest that the sentence production impairment of these individuals is not one of “interface” between independent language and cognitive abilities but rather, one of a fundamental deficit in the way attention and memorial processes are recruited for sentence planning.

References

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Table 1
Central tendencies of demographic and clinical characteristics of a group with traumatic brain injury (TBI) and a healthy control group

	TBI			Control		
	Mean	(SD)	(Range)	Mean	(SD)	(Range)
Age	26.1	(6.0)	(19-36)	22.7	(2.2)	(20-26)
Education (years)	13.5	(2.0)	(11-18)	13.8	(1.8)	(12-16)
Time post injury (months)	6.3	(0.5)	(6-7)			
Coma duration (days)	4.2	(3.4)	(1-11)			
Length of Hospitalization (days)	42.6	(19.1)	(16-79)			

Table 2
Sentence production characteristics for group with traumatic brain injury (TBI) and a healthy control group

	TBI			Control		
	Mean	(SD)	(Range)	Mean	(SD)	(Range)
MLU morphemes	11.7	(2.6)	(.8-16.3)	10.4	(1.3)	(8.5-12.43)
Pauses per utterance	.75	(.52)	(.13-1.64)	.39	(.25)	(.00-.75)
Between Clauses	.11	(.13)	(.00-.36)	.02	(.06)	(.00-.14)
Within Clauses	.62	(.48)	(.08-1.57)	.37	(.25)	(.00-.75)
Mazes per utterance	.40	(.36)	(00.-1.00)	.10	(.13)	(.00-.27)
Errors						
Subject-Verb Agreement	.04	(.06)	(.00-.17)	.02	(.05)	(.00-.12)
Omissions	.12	(.17)	(.00-.57)	.06	(.07)	(.00-.17)
Abandoned	.03	(.06)	(.00-.15)	.05	(.05)	(.00-.12)

Table 3
Neuropsychological test scores for traumatic brain injury group

Test	Mean (SD)
Boston Naming Test	48.9 (7.1)
DTLA Likenesses and Differences	48.9 (9.9)
NCCEA	
Sentence Repetition	15.3 (2.5)
Word Fluency	28.9 (2.5)
Ravens Coloured Progressive Matrices	32 (4.3)
Trail Making Part B (seconds)	160.7 (152.3)
WAB-AQ	96.0 (1.9)
Wechsler Memory Scale	
Digits Forward	6.6 (1.1)
Digits Backward	4.9 (1.2)