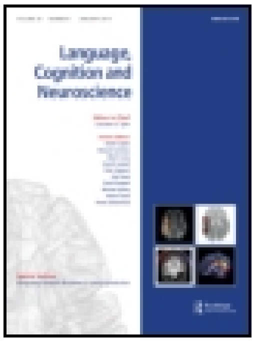

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Sentence-level processing predicts narrative coherence following traumatic brain injury: evidence in support of a resource model of discourse processing

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REGULAR ARTICLE

Sentence-level processing predicts narrative coherence following traumatic brain injury: evidence in support of a resource model of discourse processing

Richard K. Peach and Lindsey E. Hanna

Dept. of Communication Disorders and Sciences, Rush University Medical Center, Chicago, IL, USA

ABSTRACT
Research suggests that coherence processing of narratives produced by speakers with traumatic brain injury is dissociated from processing of inter-sentential cohesion and intra-sentential production. The goal of this study was to investigate the relationships between microlinguistic abilities and macrolinguistic operations in narratives produced by individuals with TBI. Narratives with variable story grammar were analysed for co-occurring instances of correct and erroneous cohesive ties, sentence pausing, and mazing to determine the relationships among global coherence, inter-sentential cohesion, and intra-sentential production. Story grammar was predicted by both increased inter-sentential cohesion and increased pausing within sentences. Logistic regression classified the completeness of the story episodes with 94% accuracy based on inter-sentential cohesion and sentence pausing. The results support a resource model of discourse processing where executive disturbances that impair the way individuals with TBI recruit and control cognitive resources result in deficits in multiple levels of discourse processing during narrative construction.

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KEYWORDS
Traumatic brain injury; cognition; language disorders; discourse; executive function

Introduction

Disturbed discourse is commonly observed in adults with moderate to severe traumatic brain injury (TBI) (Biddle et al., 1996; Coelho, 2002; Galetto et al., 2013; Glosser & Deser, 1991; Hartley & Jensen, 1991; Hough & Barrow, 2003; Marini et al., 2011, 2014, 2017; Peach & Coelho, 2016; Stout et al., 2000). Discourse following TBI has been described as disorganised, off-topic, often tangential and poorly planned (McDonald et al., 1999; Togher, 2012). These patterns are thought to be the result of deficits at both the macrolinguistic and microlinguistic levels of discourse processing (Coelho et al., 2005; Ellis & Peach, 2009; Marini et al., 2014; Peach, 2012, 2013; Peach & Coelho, 2016).

Macrolinguistic processing governs the overall meaning and organisation of language (Kintsch & van Dijk, 1978). Speakers attempt to effect global goals when they speak and use conversational or narrative plans to accomplish them. The plans are built frequently out of smaller, pre-structured plans such as those used in telling a story (Agar & Hobbs, 1982; Hobbs & Agar, 1985). Impairments at the macrolinguistic level following TBI lead to problems in maintaining the overall theme or coherence of narratives produced across a variety of genres (Coelho, 2002; Galetto et al., 2013; Hough & Barrow, 2003; Liles et al., 1989; Marini et al., 2011, 2014, 2017; Mozeiko et al., 2011). Such problems include (a) difficulty with developing or organising the episodes within narratives, (b) inserting tangential or extraneous information into narratives, and (c) problems maintaining the topic of narratives. Table 1 provides a summary of the studies investigating discourse coherence following TBI.

Microlinguistic processes involve the local levels of discourse, i.e. the use of sentential elements (cohesive ties) to signal the meaning relations between propositions (inter-sentential) (Armstrong, 2000; Haravon et al., 1994; Kintsch & van Dijk, 1978) and the planning for and production of the structural and temporal characteristics of the sentences (intra-sentential). Inter-sentential deficits following TBI affect the cohesion of narratives, as evidenced by impaired use of cohesive ties and reduced cohesive adequacy in narratives. A few studies have suggested that inter-sentential cohesion is not impaired following TBI.

Intra-sentential deficits include decreased fluency, use of fewer syllables and words, shorter mean lengths of utterances, increased syntactic errors, diminished content, frequent mazes (filler words, repetitions, and revisions), incomplete sentences and less complex

CONTACT Richard K. Peach richard_k_peach@rush.edu Dept. of Communication Disorders and Sciences, Rush University Medical Center, 1018B Armour Academic Center, 600 South Paulina Street, Chicago, IL 60612, USA
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Table 1. Summary of methods and findings from studies investigating global coherence in the discourse of individuals with traumatic brain injury.

Focus	Genre	Elicitation Procedure(s)	Findings	Studies
Story grammar (episode organisation)	Story retelling Story generation	Filmstrip Picture description	No episodes produced by 3 out of 4 participants with TBI	Liles et al. (1989)
	Story retelling Story generation	Filmstrip Picture description	More extraneous information (i.e. *T*-units [a main clause plus any subordinate clauses that may be attached to it]) per episode than healthy speakers	Coelho (2002)
	Story retelling	Digitized picture book	Significantly fewer episodes and *T*-units per episode than a comparison group	Mozeiko et al. (2011)
Coherence errors	Story generation	Description of picture and cartoon picture sequences	Significantly more errors in global coherence (tangential utterances or extraneous content) than healthy controls	Marini et al. (2011, 2014, 2017)
Topic maintenance	Descriptive discourse	Interview regarding family and past work experience	Significantly lower ratings of TBI participants' discourse coherence for either topic compared to healthy controls	Glosser and Deser (1991); Hough and Barrow (2003)

sentences. They also include more inefficient discourse characterised by a slower rate of speech, more pauses within and/or between utterances and fewer concepts or propositions produced over time. However, a few investigations have found relatively preserved intra-sentential processing in speakers with TBI. Table 2 provides a summary of studies investigating sentence-level processing after TBI.

Theoretical issues

Based on this literature, three models for discourse processing after TBI have been proposed. One model argues for top-down processing in which the global coherence of discourse is constructed independently of inter-sentential cohesion and intra-sentential processing. That is, discourse level processing is dissociated from sentence level processing. Errors of global coherence then, may occur in the absence of errors in sentence processing (Adornetti, 2014; Cosentino et al., 2013; Glosser & Deser, 1991; Hough & Barrow, 2003). A second model posits bottom-up processing of discourse. In this approach, macrolinguistic processes are reliant on microlinguistic processes so that intra-sentential errors and erroneous cohesive ties lead to impaired global coherence (Kintsch & van Dijk, 1978). More recently, a third model based on a resource approach to discourse processing has been proposed. This model suggests that the processes for establishing global coherence are performed in parallel with those required for local processes and that cognitive resources are shared among these levels when constructing discourse. According to this model, breakdowns in discourse are attributed to competition for the same resources needed for multiple levels of processing (Coelho, 2002; Peach, 2013; Peach & Coelho, 2016). In the next sections, we provide detailed descriptions of these models based on the foregoing literature and patterns of performance.

Top-down model

The top-down model asserts that global coherence is constructed independently from inter-sentential cohesion and intra-sentential processing. Accordingly, deficits in global coherence do not lead necessarily to impairments in local sentential processes (Adornetti, 2014; Cosentino et al., 2013). This model is based on studies reporting impaired global coherence in TBI speakers in a context of minimal disruption to inter-sentential cohesion or intra-sentential processing (Ehrlich, 1988; Galetto et al., 2013; Glosser & Deser, 1991; Hough & Barrow, 2003; Marini et al., 2011). These findings have been taken as evidence for a dissociation between macrolinguistic and microlinguistic processes during discourse production following TBI.

Cosentino et al. (2013) proposed that global coherence and "the ability to process discourse takes priority over the ability to process sentences" (p. 62). They suggest that executive functions, such as planning and monitoring, are used to manage global coherence for discourse and are, therefore, different from the cognitive resources used to process sentences (Adornetti, 2014; Cosentino et al., 2013). This explanation was offered to account for the struggle TBI speakers experience in relating individual sentences to an overall theme and maintaining that theme throughout a narrative without adding irrelevant information (Cosentino et al., 2013; Mozeiko et al., 2011).

Additionally, it has been suggested that global coherence is the product of higher-level controlled processes under the influence of the central executive while inter-sentential cohesion and intra-sentential planning and production are artifacts of automatic processes (Cosentino et al., 2013). While considering only the studies that reported minimal disruption to the microlinguistic levels of discourse following TBI, these authors argue for greater impairment to controlled processing following TBI and largely preserved automatic processing of

Table 2. Summary of methods and findings from studies investigating sentence-level processing in individuals with traumatic brain injury.

Focus	Genre	Elicitation procedure(s)	Findings	Studies
Inter-Sentential Cohesion				
Cohesive ties/ cohesive adequacy	Story generation	Picture description	TBI participants produced significantly fewer cohesive ties (complete and erroneous) than non-brain-damaged participants	Peach and Coelho (2016)
	Story generation	Description of picture and/or cartoon picture sequences	Impaired inter-sentential cohesion in the narratives of speakers with TBI	Carlomagno et al. (2011); Davis and Coelho (2004); Marini et al. (2011)
	Story retelling Story generation	Filmstrip Picture description	TBI speakers' cohesive adequacy is more impaired for story generation than for story retelling for which it is similar to healthy controls	Coelho (2002); Liles et al. (1989)
	Jointly produced story retelling	Video segment retold with friend	Cohesive adequacy of TBI speakers' narratives is like that of healthy control participants	Jorgensen and Togher (2009)
	Procedural discourse	Explain a novel procedure to a blindfolded listener	Cohesion of TBI productions generally similar to healthy controls	McDonald (1993)
	Story retelling Story generation Procedural discourse	Audio-taped story Description of picture and/or cartoon picture sequences Explain how to buy groceries	TBI speakers used significantly fewer cohesive ties than control participants across all tasks	Hartley and Jensen (1991)
	Descriptive discourse	Interview regarding personal experience	Persons with TBI used more inaccurate cohesive ties than their non-injured peers	Biddle et al. (1996)
	Descriptive discourse	Interview regarding family and past work experience	Minimal disruption to cohesion of TBI participants' narratives	Glosser and Deser (1991); Hough and Barrow (2003)
	Descriptive discourse Procedural discourse Conversation	Narrative of current programme/ work told to familiar partner Narratives about how to play a favourite sport and how to change a tire or bake a cake Unstructured discourse with familiar partner	TBI speakers use fewer cohesive ties than healthy speakers in narratives, use dissimilar proportions of different types of ties than healthy speakers in both narratives and conversation, and, unlike healthy speakers, produce incomplete ties	Mentis and Prutting (1987)
Intra-Sentential Production				
Grammar and lexicon	Standardised testing	Comprehensive batteries of language assessment	Conversational fluency and naming among most impaired abilities	Barwood and Murdoch (2013); Hartley and Jensen (1991); Hough (2008); King et al. (2006)
	Story generation	Picture description	Equivalent, small number of errors in TBI versus healthy speakers, no differences in error type	Peach (2013)
	Story generation	Description of picture and/or cartoon picture sequences	Significantly more semantic and verbal paraphasic and paragrammatic errors	Carlomagno et al. (2011); Marini et al. (2011)
	Story generation Conversation	Picture description Standardised contextual communication tasks	Significantly more types and numbers of syntactic errors than healthy controls	Peach and Schaude (1986)
	Descriptive discourse	Interview regarding family and past work experience	Significant impairment on measures of syntactic errors and significantly more verbal paraphasias compared to healthy controls	Glosser and Deser (1991)
Language productivity	Story retelling Jointly produced story retelling Story generation Procedural discourse	Filmstrip; audio-taped story Video segment retold with friend Description of picture and/or cartoon picture sequences Explain how to buy groceries	Reduced number of syllables and/or words; shorter mean lengths of utterances	Coelho (2002); Hartley and Jensen (1991); Jorgensen and Togher (2009); Marini et al. (2011); Stout et al. (2000)
Sentence processing and monitoring	Story retelling Story generation Procedural discourse Descriptive discourse	Audio-taped story Picture description Explain how to buy groceries Interview regarding personal experience	Significantly more and longer mazes (i.e. word and nonword fillers, repetitions, and revisions) than healthy controls	Biddle et al. (1996); Hartley and Jensen (1991); Peach (2013); Stout et al. (2000)
	Story generation Descriptive discourse	Description of picture and/or cartoon picture sequences Interview regarding family and past work experience	Significantly more incomplete sentences	Glosser and Deser (1991); Marini et al. (2017)
Efficiency of sentence production	Story retelling Story generation Procedural discourse	Audio-taped story Description of picture and/or cartoon picture sequences Explain how to buy groceries	Slower rate of speech	Galetto et al. (2013); Hartley and Jensen (1991); Marini et al. (2011, 2017)
	Story retelling Story generation	Summarize video-taped lectures Picture description	More pauses both within and/or between utterances	Ellis and Peach (2009); Lundine and Barron (2019); Peach (2013)

(*Continued*)

Table 2. Continued.

Focus	Genre	Elicitation procedure(s)	Findings	Studies
	Elicited sentence production	Sentence repetition/oral sentence reading		
	Story retelling	Audio-taped story	Fewer concepts or propositions produced per time period	Biddle et al. (1996); Matsuoka et al. (2012); Stout et al. (2000)
	Story generation	Description of picture and/or cartoon picture sequences		
	Descriptive discourse	Interview regarding personal experience		
Sentence complexity	Story generation	Picture description	Speakers with TBI have difficulty integrating final propositions into complex utterances	Peach et al. (1990)
	Conversation	Standardised contextual communication tasks		
	Elicited sentence production	Sentence repetition/oral sentence reading	Strong, positive relationship between total pauses and sentence complexity	Ellis and Peach (2009)
	Story generation	Picture description	TBI participants produced fewer propositions per *T*-unit than participants without TBI suggesting TBI speakers have difficulty producing complex sentences	Coelho et al. (2005)
	Descriptive discourse	Interview regarding family and past work experience	No difference compared to healthy control speakers on an index of syntactic complexity	Glosser and Deser (1991)

sentential computations. The resulting pattern then is characterised by problems with topic maintenance, organisation, and completion of narratives but little microlinguistic impairment (Adornetti, 2014; Cosentino et al., 2013).

Bottom-up model

A more traditional view holds that discourse is processed in a bottom-up mode so that the global coherence of a narrative is reliant on its inter-sentential cohesion (Bublitz, 2011; Halliday & Hasan, 1976; Kintsch & van Dijk, 1978). The input to the model is the list of propositions that represent the meaning of the text. The number of propositions that are processed at one time depend on the surface characteristics (sentence and phrase boundaries) of the text. To be coherent, the respective sentences and propositions of a discourse must be connected after which they are organised at a global, macrostructure level. Thus, discourse processing in this model proceeds from the microstructure of a narrative to its macrostructure (Kintsch & van Dijk, 1978).

A few studies have found discourse impairments following TBI that might be interpreted as evidence for bottom-up processing. Hartley and Jensen's (1991) TBI participants demonstrated impairments in the productivity, content, and cohesion of their narratives and procedural discourse. Biddle et al. (1996) found significantly greater dysfluency (defined as false starts, internal corrections, and fillers) and poorer cohesion (defined by the number of implicit propositions, i.e. incomplete ties) in the narratives of their TBI speakers. Coelho (2002) found that TBI participants produced shorter sentences than a group of non-brain-damaged speakers, had reduced (but not statistically significant) cohesive adequacy in their narratives, and exhibited poorer story grammar, an indication of organisational difficulty. Similarly, Van Leer's and Turkstra's (1999) findings, in which adolescent TBI speakers produced narratives with similar sentence length (the sole measure of sentence production in this study), cohesion, and coherence to control speakers, might be interpreted as evidence for a bottom-up mode of discourse processing in their sample.

Resource model

Finally, there has been recognition that these processing operations do not necessarily occur sequentially, but rather, that they operate somewhat simultaneously and in parallel and draw upon a limited pool of cognitive resources. Griffin and Crew (2012) and Willems et al. (2020) have described the temporal course of multiple, overlapping processes for sentence and narrative production respectively. For discourse processing, Kintsch and van Dijk (1978) acknowledged similar, intersecting processes:

> Although we have been concerned here only with the organization of the micropropositions, one should not forget that other processes, such as macro-operations, are going on at the same time, and that therefore the buffer must contain the information about macropropositions and presuppositions that is required to establish the global coherence of the discourse. (p. 370)

In this model, coherence is established, especially when the relationships among the propositions in a discourse are not clear, by a "resource-consuming search" of the content active in short-term memory or even in long-term memory (Kintsch & van Dijk, 1978). These multiple processes are supervised by a control system that coordinates these simultaneous tasks, including, but not limited to, decoding inputs, analysing syntax, assigning semantic and pragmatic interpretations, and deriving macrostructural propositions (van Dijk, 1995).

Peach (2013) investigated sentence production in narratives following TBI using both on-line (pause time) and off-line (maze production, grammatical errors, and abandoned utterances) measures. The results indicated that TBI speakers produced significantly more disruptions to their sentences than did a group of non-brain-damaged speakers. Regression analyses revealed that pause behaviour was associated with working memory deficits while maze behaviour was related to executive function. Thus, the findings suggested that the deficits in sentence production following TBI are due to problems in the way that individuals with TBI recruit and control attentional resources for the multiple processes involved in sentence planning and production.

Peach and Coelho (2016) reasoned further that deficits in executive control that impair sentence production following TBI should also influence other microlinguistic processes (i.e. establishing intra-sentential cohesion). To test their hypothesis, they investigated the temporal patterns related to the production of cohesive markers and sentence level impairments during narrative production to determine the influence of each level of sentence processing on the other. Instances of immediate co-occurrence (i.e. no intervening words) of any cohesive tie (complete and erroneous) and instances of any intra-sentential impairment (pauses, mazes, errors, and abandoned utterances) were tallied and analysed with regard to the relative frequency of intra-sentential failures associated with the production of each type of tie. A significant relationship was found between the construction of cohesive ties and intra-sentential deficits. The findings provided evidence to support a resource model of discourse processing after TBI in that a competition for resources to achieve adequate cohesion and well-formed sentences concurrently appears to negatively affect intra-sentential processing in these speakers.

Summary and experimental questions

Variable profiles of narrative production following TBI have been reported in the literature with each being used to support different models of discourse processing. Studies reporting impaired global coherence in these speakers but relatively preserved inter-sentential cohesion and intra-sentential processing have been used to suggest a top-down mode of discourse processing and a dissociation between macrolinguistic and microlinguistic operations. Studies demonstrating impaired sentence processing and/or inter-sentential cohesion in the context of deficient global coherence have provided evidence for a bottom-up model of narrative production.

More recently, a resource model has been invoked to account for the discourse problems observed after TBI. The evidence supporting this model fits the assumptions regarding executive control for simultaneous processing of multiple linguistic operations. However, a major limitation of the evidence to date is that it only considers microlinguistic operations (Peach, 2013; Peach & Coelho, 2016). It can be said that, in order to more fully embrace a resource model for discourse processing after TBI, the evidence must reconcile how the processes responsible for sentence planning and production and inter-sentential cohesion are aligned with those for establishing global coherence (cf. Cosentino et al., 2013 regarding top-down versus bottom-up models of discourse processing). As pointed out by Peach and Coelho (2016), a stronger test of this model then requires an examination of the relationships between macrolinguistic and microlinguistic processing. This study was designed to address this issue.

The goal of this study then is to investigate the influences of microlinguistic operations on macrolinguistic abilities in individuals with TBI. To do this, narratives with varying story grammar, produced by individuals with TBI, were analysed for co-occurring impairments in inter-sentential cohesion and intra-sentential production to determine the relationships among multiple levels of discourse processing.

In this study, as well as in our previous work, we use speech pause time, as well as sentence maze production. Unlike most previous studies that have relied solely on structural analyses of the narratives of TBI speakers (e.g. numbers of syntactic or lexical errors), we examine both the structural (maze production) and temporal (speech pause time) patterns of narrative production at multiple processing levels (coherence, cohesion, and sentence production). Thus, we examine narrative production directly in the moments that the necessary cognitive operations are unfolding, as well as in the resulting sentence outcomes, thereby providing novel insights into discourse processing that heretofore could only be inferred using purely structural approaches. This approach provides greater potential to better understand how different cognitive operations interact during real-world, language processing (Willems et al., 2020). The following research questions were addressed:

1. Does the accuracy of the cohesive ties constructed in the narratives of speakers with TBI (i.e. inter-sentential cohesion) predict the completeness of the story grammar for those narratives?

2. Does the frequency of sentence pausing and maze production in the narratives of speakers with TBI (i.e. intra-sentential production) predict the completeness of the story grammar for those narratives?

Because this study is designed to test a resource model as it applies to speakers with TBI, and that establishing the overall coherence of a discourse would appear to be the primary goal of a speaker (Agar & Hobbs, 1982; Hobbs & Agar, 1985), we hypothesise that these TBI participants will allocate resources primarily to producing complete narratives and that, as a result, fewer resources will be available for constructing inter-sentential cohesion and/or for formulating sentences in narratives. The resulting pattern, therefore, will be one of more complete narratives characterised by (a) mostly accurate cohesive ties but frequent intra-sentential deficits, (b) mostly inaccurate cohesive ties with few intra-sentential deficits, or (c) mostly inaccurate cohesive ties accompanied by frequent intra-sentential deficits.

Alternatively, but also in accord with a resource model, more erroneous cohesive ties and greater micro-linguistic problems might be found in incomplete rather than complete narratives because of the competition created by allocating attentional resources to multiple levels of discourse processing. In either scenario, the completeness of the story grammars should be predicted by the accuracy of the cohesive ties and the frequency of sentence pausing and maze production.

Finally, from the perspective of a resource model, we do not expect to find well-preserved sentences with adequate inter-sentential cohesion in any narratives with incomplete story grammar, as might be assumed from a top-down view. As well, we do not expect to find impaired inter-sentential cohesion and intra-sentential problems in any narratives with complete narratives, as might be predicted by a bottom-up approach.

Methods

Data source

The language samples for this study were obtained from the Coelho (2002) corpus in TBIBank (MacWhinney, 2007). TBIBank is a public, shared database of multimedia interactions for the study of communication in people with TBI. The data are not individually identifiable so that studies using these data do not require IRB review. The database for this study included 55 native speakers of English with closed-head TBI who had recovered a high level of functional language. According to the project description, all of the participants in the database had fluent conversation. Inclusion criteria were (a) no history of substance abuse, (b) no history of mental illness, (c) visual acuity and adequate perceptual abilities for stimuli, (d) adequate hearing ability to follow task directions, (e) an Aphasia Quotient above 93 on the Western Aphasia Battery (WAB) suggesting an absence of frank aphasia (Kertesz, 1982, 2007), (f) absence of significant motor speech disorder as determined by a certified speech-language pathologist, (g) a Rancho Los Amigos Level of Cognitive Functioning (Hagen et al., 1972) of VII or higher, (h) a Galveston Orientation and Amnesia Test (Levin et al., 1979) score of 75 or greater, and (i) a Dementia Rating Scale (Mattis, 1988) score of 120 or greater. Participants in this study were identified as having a moderate (less than 6 hours) to severe (more than 6 hours) injury based upon their lengths of coma (Lezak, 1995).

From this larger, matched database, additional selection criteria were applied to further match the participants in this study. Participants were aged 16 years or more, were greater than 2 months post onset of their brain injuries (suggesting they were no longer in the acute recovery period [Stuss et al., 1999]) and had 10 or more years of education. Twenty-four participants who met these criteria were selected from the larger database and their language samples analysed. The participants had a mean age of 28.8 years (median = 23 years) and a mean education of 13.8 years (median = 13 years). The mean time post injury was 7 months (median = 3 months). The socioeconomic class of each participant also is provided in the database and is included here. The demographic information for the 24 participants is provided in Table 3.

Materials and procedures

The audio recordings of narratives produced by the participants retelling the picture story *The Bear and the Fly* (Winter, 1976) were transcribed and analysed. To elicit the narratives, participants were shown a 19-picture film strip with no audio. Participants were instructed to tell the story in the film strip. The task was ended when the participant stopped telling the story and added no additional information after 10 seconds. All transcripts had a minimum of five sentences and met the criterion for a narrative sample established by Coelho (2007).

The narratives were segmented into *T*-units (a main clause plus any subordinate clauses that may be attached to it) following recommended procedures (SALT Guide version 9, 2008). Incomplete and/or abandoned utterances, as well as metalinguistic comments were removed, also as per the SALT Guide, and not included within the story structure. The resulting

Table 3. Demographic and clinical characteristics of TBI participants.

P	TB#[a]	Age	Sex	Education	Class[b]	MPO[c]	LOC[d]
1	13	20	M	13	S	21	6
2	36	54	M	16	P	8	0
3	39	42	M	16	P	7	NA
4	44	31	M	12	U	29	30
5	49	40	F	16	P	26	0
6	01	21	M	10	U	8	4
7	08	21	M	14	P	4	19
8	40	17	M	11	S	4	NA
9	19	17	M	11	P	3	NA
10	22	16	M	12	P	3	14
11	02	39	M	10	U	2	13
12	09	17	M	13	S	2	3
13	17	30	M	12	S	2	7
14	21	22	F	16	P	2	21
15	24	19	F	12	S	2	3
16	25	49	M	21	P	2	<1
17	26	47	M	18	P	2	10
18	29	27	M	12	S	2	14
19	33	24	F	13	S	9	24
20	34	22	M	16	P	2	4
21	38	19	M	12	S	2	NA
22	41	33	F	15	P	12	NA
23	45	47	M	18	P	14	<1
24	50	18	M	12	P	2	2

[a]TB# = Coelho database participant ID number; [b]Socioeconomic class according to Hollingshead (1972) ratings, S = Skilled, U = Unskilled, P = Professional; [c]MPO = months post onset; [d]LOC = length of coma in days; NA = not available.

transcripts were then entered into Systematic Analysis of Language Transcripts (SALT, v. 9.0) (Miller & Iglesias, 2008) for further analysis.

The following measures were completed to address the study questions.

Story grammar. The measure for global coherence in this study was story grammar. The story grammar of each narrative was analysed for complete and incomplete episodes (Cannizzaro & Coelho, 2012; Coelho, 1998). A complete story episode included an initiating event, an action related to the initiating event, and a direct consequence of the action. Absence of any of these episodic components resulted in an incomplete episode (Lê et al., 2011; Mozeiko et al., 2011). Complete and incomplete episodes were marked and summed for each of the transcripts.

Inter-sentential cohesion. Inter-sentential cohesion was analysed by identifying the number of correct and erroneous cohesive ties in each narrative (Coelho, 2002; Peach & Coelho, 2016). Liles and Coelho (1998) define cohesive ties as words that require the listener to search for information outside the sentence (e.g. using a pronoun following a more specific identity). Ties are classified as denoting reference, substitution, ellipsis, conjunction, and lexical relations (Halliday & Hasan, 1976). A cohesive tie is correct when the information referred to by the tie is easily found. An erroneous tie guides the listener to ambiguous information (Liles & Coelho, 1998). The cohesive ties were identified and judged for their accuracy (see Appendix). The numbers of correct and erroneous cohesive ties produced by each participant were then calculated for complete versus incomplete stories.

Intra-sentential production. Two procedures were used to analyze intra-sentential performance: (a) sentence pause time and (b) maze production (see Appendix). The counting rules for determining pauses and mazes have been published previously (Peach, 2013; Peach & Coelho, 2016). To measure pause time, the audio recordings of the narratives elicited by the story retell task were entered into Praat (v.5.3.56) (Boersma & Weenink, 2012), and displayed visually on a computer monitor. Pauses were defined as any silent interval within a sentence of a minimum of 200 ms between voice offset of one word and voice onset of the next uttered word (Goldman-Eisler, 1968; Kirsner et al., 2002) and were identified using the programme cursors. Pauses of this scale have been associated with semantic and syntactic planning and the difficulty of the speaking task (Goldman-Eisler, 1968; Grosjean & Collins, 1979; Harley, 2014).

Mazes consist of false starts, repetitions, revisions, reformulations, or word/nonword fillers. Mazes are thought to be related to continuous monitoring of language output (Levelt, 1989; Navarro-Ruiz & Rallo-Fabra, 2001) and are typically used to draw inferences about difficulties with language production (Rispoli, Hadley & Holt, 2008; Thordardottir & Ellis Weismer, 2002). The total number of pauses and mazes produced in complete versus incomplete stories were calculated for each TBI participant.

Analyses

Descriptive statistics were calculated for the group trends on each study measure. One-way analysis of variance was performed to determine whether there were any statistically significant differences in the frequency of correct and erroneous ties and pauses and mazes in complete and incomplete stories. The effect of these behaviours on the production of complete versus incomplete narratives was analysed using binomial logistic regression.

Reliability

Inter-rater reliability was established using narratives produced by the first 3 participants (12.5%) entered into the study. A primary rater and a second rater first reviewed and discussed the written guidelines for conducting each of the analyses used in this study. The number of *T*-units, the episode structure (story grammar), the number of correct and erroneous cohesive ties, and the number of intra-sentential pauses and mazes in these narratives were coded independently by each rater. Point-to-point reliability was calculated for both sets of measurements. Inter-rater reliability was 100% for counting *T*-units, incomplete utterances, complete and incomplete story episodes, and erroneous cohesive ties; 98% for counting pauses; 94% for counting correct cohesive ties and 89% for counting mazes. These results indicate excellent inter-rater reliability.

To establish intra-rater reliability, the primary rater re-analysed the 3 transcripts after an interim period of at least 2 weeks. Point-to-point reliability was then calculated for the initial and second sets of measurements. Intra-rater reliability was 100% for counting complete and incomplete story episodes and erroneous cohesive ties; 98% for counting *T*-units; 97% for counting correct cohesive ties and incomplete utterances; and 96% for counting pauses and mazes. These results indicate excellent intra-rater reliability.

Results

Patterns of performance

Twenty-two of the 24 participants had at least some evidence of story grammar impairment. The participants' mean story grammar score was 54% (S.D. = 28%, range = 0–100%) suggesting that, as a group, they have substantial deficits in the global coherence of their narratives. Not surprisingly, the participants produced twice as many *T*-units in complete (mean = 10.4) versus incomplete (mean = 5.23) episodes as well as, on average, almost twice as many correct ties in complete episodes (mean = 22.9) than in incomplete episodes (mean = 10.3) (Table 4). A small, but marginally greater number of erroneous ties was produced in incomplete episodes than in complete episodes. Participants produced 38% more pauses and almost twice as many mazes in complete than incomplete episodes.

As can be seen from the ranges reported in Table 4, there was high variability in each of the measures across participants. To standardise the scores, the total numbers of cohesive ties (correct, erroneous), pauses, and mazes in complete and incomplete episodes were divided by the total number of *T*-units produced for episodes by each participant. This yielded 8 ratios for each measure: (a) correct ties in complete (CompCT) and incomplete (IncCT) episodes; (b) erroneous ties in complete (CompET) and incomplete (IncET) stories; (c) pauses in complete (CompPaus) and incomplete stories (IncPaus); and (d) mazes in complete (CompMaze) and incomplete (IncMaze) stories. The ratios for each participant on these measures are presented in Table 5.

The ratios were examined to identify individual patterns within the larger group (see Table 6). In the largest subgroup, 10 participants had equal numbers of complete and incomplete episodes. Of these, 9 produced a greater number of pauses than mazes per *T*-unit and 8 produced more erroneous cohesive ties than correct ties per *T*-unit. The second largest subgroup consisted of 9 participants who produced more complete episodes than incomplete episodes. Like the first subgroup, 7 of these participants produced more pauses than mazes per *T*-unit and all 9 exhibited more erroneous cohesive ties than correct ties per *T*-unit. The last group consisted of 5 participants who produced more incomplete episodes than complete episodes. All of these participants produced a greater number of pauses than mazes per *T*-unit but, unlike the previous two groups, they were nearly split (3 vs. 2) in whether they exhibited more erroneous cohesive ties than correct ties per *T*-unit. Based on these individual profiles, participants who produced narratives with preserved global coherence, or in similar numbers with preserved or impaired coherence, produced large numbers of pauses in their sentences and displayed impaired inter-sentential cohesion. On the other hand, participants who produced narratives with impaired global coherence also produced greater numbers of pauses in their sentences but showed variable inter-sentential cohesion.

Table 4. Descriptive statistics for group results on each study measure.

Measures	Complete episodes			Incomplete episodes		
	Mean	SD	Range	Mean	SD	Range
T-Units	10.4	7.00	3–28	5.23	3.09	2–12
Correct Ties	22.9	14.6	3–48	10.3	7.81	0–30
Erroneous Ties	0.24	0.44	0–1	0.36	0.58	0–2
Pauses	4.38	4.78	0–16	2.36	2.82	0–9
Mazes	4.76	4.02	0–13	2.36	3.86	0–16

Relationships among global coherence, inter-sentential cohesion and intra-sentential production

To address whether the accuracy of the cohesive ties and/or the frequency of sentence pausing and maze production predict the completeness of the story grammar of the narratives, a one-way analysis of variance was performed to determine if there were differences among the measures relating to numbers of cohesive ties (correct, erroneous) and/or pauses and mazes in complete versus incomplete episodes.

Table 5. Individual participant ratios per *T*-unit across measures.

P	Complete episodes				Incomplete episodes			
	CT[a]	ET[b]	Pauses	Mazes	CT	ET	Pauses	Mazes
1	2.33	0.06	2.00	0.00	0.89	0.72	0.00	0.00
2	2.86	0.00	1.43	0.00	1.29	0.86	0.86	1.29
3	2.50	0.00	1.75	0.00	0.88	0.13	0.25	0.00
4	2.75	0.13	1.75	0.25	0.63	0.50	0.63	0.13
5	2.25	0.00	2.00	0.00	0.25	0.25	0.20	0.60
6	3.07	0.00	2.60	0.00	0.13	0.53	0.20	0.20
7	2.23	0.00	2.00	0.00	0.38	0.62	0.33	0.50
8	3.60	0.00	1.80	0.20	0.00	0.40	0.00	0.20
9	2.33	0.00	1.50	0.00	0.33	0.67	0.00	0.50
10	0.00	0.00	2.00	0.25	0.00	0.00	0.00	0.50
11	2.00	0.00	2.00	0.00	0.83	0.33	0.00	0.00
12	2.15	0.08	1.33	0.00	0.69	0.69	0.00	0.00
13	2.00	0.20	2.50	0.00	0.00	0.00	1.00	0.50
14	2.00	0.00	2.00	0.00	0.00	0.31	0.00	0.00
15	0.00	0.00	2.18	0.09	0.00	0.00	0.64	0.09
16	2.50	0.00	2.50	0.00	0.25	1.25	0.75	1.33
17	1.83	0.00	0.00	0.00	0.61	0.17	0.00	0.00
18	1.90	0.00	0.00	0.00	0.05	0.52	0.00	0.00
19	2.00	0.00	2.00	0.25	0.00	0.00	0.75	0.25
20	0.00	0.00	2.67	0.00	0.00	0.00	1.33	0.33
21	1.50	0.00	0.00	0.50	0.25	0.25	0.50	0.50
22	1.00	0.00	1.00	0.00	1.33	0.00	0.75	0.00
23	1.71	0.00	1.00	0.00	0.14	0.36	0.33	0.33
24	2.64	0.09	2.17	0.08	0.27	0.82	0.17	0.67
Mean	1.97	0.02	1.67	0.07	0.38	0.39	0.36	0.33

[a]CT = Correct cohesive ties; [b]ET = erroneous cohesive ties.

Inspection of the Q-Q plots for each of these measures revealed that the data were normally distributed.

A significant effect was found for measure type [F (7, 194) = 51.02, p = .000]. Post-hoc comparisons using the Tukey HSD test indicated that two mean scores, one for correct ties in complete episodes and the other for pauses in complete episodes, were significantly greater than the scores for all other measures. No statistically significant differences were found among the remaining measures. The mean scores for each measure are shown in Figure 1.

Binomial logistic regression was performed to determine the effects of these two measures on the participants' production of complete episodes. Pearson bivariate correlation indicated that the scores for cohesive ties in complete episodes and pauses in complete episodes, were independent of one another (r = .028, p = .896). These measures were entered into logistic regression as predictor variables. The regression model was statistically significant [$\chi^2(2) = 52.58$, $p = .000$] and found to fit the data well (Hosmer- Lemeshow test, $\chi^2(8) = p = .965$). The model explained 89% (Nagelkerke R^2) of the variance and correctly classified 94% of the participants' episodes (see Table 7). These results demonstrate that complete episodes are associated with increasingly correct inter-sentential cohesive ties and increased pausing during sentence production.

Table 6. Story grammar patterns for narratives produced by study participants.

Pattern	# of Participants
Majority complete episodes	9
Greater number of pauses than mazes	*7*
Greater number of mazes than pauses	*0*
With cohesive deficits	*9*
Without cohesive deficits	*0*
Majority incomplete episodes	5
Greater number of pauses than mazes	*5*
Greater number of mazes than pauses	*0*
With cohesive deficits	*2*
Without cohesive deficits	*3*
Equal complete and incomplete episodes	10
Greater number of pauses than mazes	*9*
Greater number of mazes than pauses	*1*
With cohesive deficits	*8*
Without cohesive deficits	*2*

Discussion

In the current study, we examined narratives with varying story grammar produced by individuals with

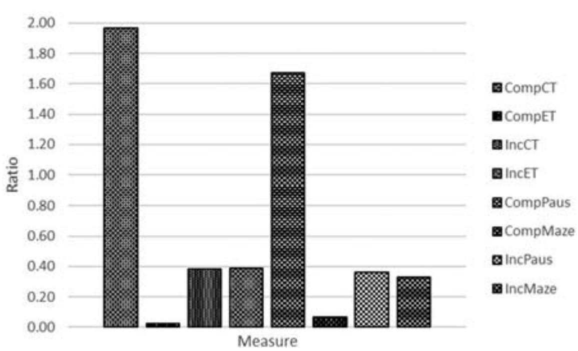

Figure 1. Mean ratios per *T*-unit for each measure.

Table 7. Classification table for logistic regression predicting complete and incomplete episodes from correct cohesive ties and intra-sentential pauses.

		Predicted		
		Episode		
Observed		Incomplete	Complete	Percentage Correct
Episode	Incomplete	22	2	91.7
	Complete	1	23	95.8
Overall Percentage				93.8

TBI for impairments to inter-sentential cohesion and intra-sentential production to determine the relationships among these multiple layers of discourse processing. Based on previous work (Peach, 2013; Peach & Coelho, 2016), we hypothesised that, if the goal of these speakers was to produce globally coherent narratives, TBI participants would (a) allocate attentional resources primarily to the story grammar of their narratives and (b) have fewer resources for constructing inter-sentential cohesion and/or for sentence formulation in the narratives. The resulting pattern, therefore, would be more complete story grammar in their narratives but increased erroneous cohesive ties and/or intra-sentential deficits. Alternatively, we hypothesised that the competition for resources to accommodate multiple layers of discourse processing would result in narratives with varying combinations of incomplete story grammar, erroneous cohesive ties and/or intra-sentential problems.

Patterns of discourse

As expected, almost all participants (22/24) had at least some reduction in story grammar with the majority demonstrating moderate to severe impairments. Greater numbers of *T*-units were produced in complete stories than in incomplete stories. The participants constructed a larger number of correct cohesive ties in complete stories and a small but relatively higher number of erroneous ties in incomplete stories. The numbers of pauses and mazes were noticeably higher in complete versus incomplete stories although only the first measure was significantly higher.

Based on group performance, participants could be divided into three subgroups. One subgroup produced more complete stories than incomplete stories, another subgroup produced more incomplete stories than complete stories, and the third subgroup produced an equal number of complete and incomplete stories. The results showed that all subgroups displayed microlinguistic deficits in their narratives regardless of story completeness. Participants who produced mostly complete stories or an equal number of complete and incomplete stories also had deficits in inter-sentential cohesion and relatively increased intra-sentential pausing. On the other hand, participants who produced mostly incomplete stories were mixed in terms of inter-sentential cohesion but also had relatively increased intra-sentential pausing. These findings are generally consistent with our initial expectations that speakers with TBI may focus more on the overall coherence of their narratives (i.e. producing complete stories) and, as a result, are unable to devote sufficient attention to inter-sentential cohesion and sentence production. Despite this, the competition among resources may result in problems with global coherence accompanied by inadequate cohesion and microlinguistic deficits.

Implications for discourse models

How do these findings bear on the models that have been proposed previously for discourse processing following TBI? The top-down model purports that global coherence is constructed by executive functions that are independent of the cognitive operations involved in establishing inter-sentential cohesion and the automatic linguistic processes that underlie intra-sentential planning and production. The approach is based on studies that have suggested that inter-sentential cohesion is largely preserved in TBI speakers but global coherence is not (Glosser & Deser, 1991; Hough & Barrow, 2003; Marini et al., 2011; McDonald, 1993). It also assumes that sentence construction is preserved following TBI. Supporters of this model, therefore, argue that there is a dissociation between macrolinguistic (global coherence) and microlinguistic (inter- and intra-sentential processing) (Adornetti, 2014; Cosentino et al., 2013).

The current results argue against the top-down model of discourse processing. As a group, the participants displayed impaired global coherence in their narratives, as would be expected. But they also exhibited cohesive deficits, increased sentence pausing, and maze production that would not be predicted by the top-down model. Of course, one might claim that a concurrent impairment to both executive and automatic processes could account for these findings. But such a position would still be inconsistent with that of the top-down model (i.e. preserved automatic linguistic processes). Binomial logistic regression also demonstrated that story coherence is strongly related to inter-sentential cohesion and sentence planning (as indicated by extended pausing) and that the completeness of the stories produced by these TBI speakers can be predicted on the basis of the accuracy of their cohesive ties and the frequency of intra-sentential pausing. These results provide strong evidence that global coherence is not achieved independently of the processes underlying construction of narrative cohesion or sentence formulation.

A second model suggests bottom-up processing of discourse. In this model, macrolinguistic processes are dependent upon microlinguistic processes. In other words, discourse processing begins with sentence-level operations that are necessary for establishing the structural and temporal form of sentences and the semantic relationships between them. Thematic processing then proceeds hierarchically to organise these meaning relations into a unified whole (Bublitz, 2011; Halliday & Hasan, 1976; Kintsch & van Dijk, 1978). Accordingly, this model would predict that complete episodes produced by TBI speakers would be characterised by an absence of intra- and/or inter-sentential deficits and that incomplete stories would have obligatory deficits in both sentence production and inter-sentential cohesion. Our findings do not support a bottom-up processing model after TBI either. All of the participants who produced mostly complete episodes showed cohesive impairment and frequent intra-sentential deficits. Of those who produced a majority of incomplete episodes, several showed no impairment of inter-sentential cohesion. Participants who produced an equal number of complete and incomplete episodes either demonstrated microlinguistic deficits in complete stories or an absence of microlinguistic deficits in incomplete stories. Many of these participants also produced erroneous ties in complete stories or complete ties only in incomplete stories. Thus, the performance patterns that would be expected under this model were not found.

Finally, a resource model of discourse processing following TBI has been proposed. This approach holds that the operations for establishing global coherence, inter-sentential cohesion, and well-formed sentences overlap temporally and compete for limited cognitive resources (Peach, 2012). It also holds that on-line aspects of discourse processing vary in terms of their resource demands (Granier et al., 2000). Executive disturbances that negatively influence the way that individuals with TBI recruit and control these resources result in impairments to multiple levels of discourse processing during narrative construction. Peach and Coelho (2016) found that a relatively large number of the cohesive errors and intra-sentential deficits produced by TBI speakers were temporally linked. Significantly more TBI speakers demonstrated intra-sentential deficits associated with the production of cohesive ties than not. The results of this study extend these findings and provide additional support for a resource perspective. In this study, the expected pattern of impaired global coherence in the narratives of these speakers was confirmed and accompanied by variable inter-sentential and intra-sentential deficits. However, when these speakers were able to achieve globally cohesive story episodes, there appeared to be a cost to inter-sentential cohesion and/or sentence production suggesting problems in the graded allocation of processing resources simultaneously. That is, to achieve more complete story episodes, more resources were assigned to story grammar, leaving potentially fewer resources available for processing cohesion and sentence production. The result was co-occurring errors in cohesive ties and a higher frequency of pauses. Or, when participants attempted to allocate resources to all levels of discourse processing simultaneously (much as healthy speakers do), inefficiencies in executive control associated with their brain injuries produced incomplete story episodes with frequent and variable cohesive deficits.

Congruence with cognitive impairments following TBI

Although executive control was not assessed directly in this study, the resource approach aligns well with the literature concerning the cognitive bases for the discourse impairments that are observed following TBI in that it emphasises executive control (Peach & Shapiro, 2012). For example, in a factor analysis of the standardised neuropsychological testing scores of 48 participants with severe TBI, Peach (1992) found a general language factor that included not only the language scores from the Western Aphasia Battery, but a split loading of two Wechsler Adult Intelligence Scale-Revised (WAIS-R) (Wechsler, 1981) subtests, Digit Span and Vocabulary. These two subtests are thought to index mental efficiency, which is heavily influenced by attention and concentration (Lezak, 1983, 1995). Peach suggested that the loading of WAB and WAIS-R verbal subtests together on the language factor may reflect an impairment in these individuals' executive control of cognitive resources for linguistic processing, a conclusion that is supported by the current study.

Coelho (2002) and Mozeiko et al. (2011) found that the story grammar performances of their participants with TBI were significantly correlated with scores from the Wisconsin Cart Sorting Test (Grant & Berg, 1948) and the Sorting Test from the Delis-Kaplan Executive Function System (Delis et al., 2001), two measures of mental shifting (i.e. attention shifting) or cognitive flexibility. These authors proposed that the generation of episodes exploits these abilities to identify goals and plans as well as to evaluate the success or failure of the plan. Marini et al. (2014) also found that coherence errors in the narratives of TBI speakers were correlated with the WCST. Together, these results have been used as evidence that the coherence errors in these speakers are associated with executive dysfunction. The results of the current study expand these results and indicate that the discourse deficits in these speakersare due to competition among both macrolinguistic and microlinguistic processes during discourse formulation.

Marini et al. (2017) also analysed the relationships among the micro- and macrolinguistic skills of TBI speakers with differing severities of brain injury (mild-moderate and severe) and their cognitive abilities. Participants with severe TBI performed significantly worse than those with moderate TBI on tasks assessing speed of shifting (Trail Making Test, Part B; Reitan & Wolfson, 1985) and immediate and delayed word list (Rey's Auditory Verbal Learning Test; Rey, 1958) while both groups performed significantly worse than healthy controls on a task assessing shifting and inhibition (WCST). The findings were used to suggest that violations of cohesion and coherence in the narratives of these individuals is due to difficulties in monitoring their ongoing performance and inhibiting irrelevant responses that are likely the result of these attentive and executive impairments.

Marini et al. (2017) attributed sentence level impairments involving speech rate and lexical selection to differing mechanisms in the two groups. For moderately-impaired speakers, these problems were attributed to difficulties in keeping the information active in declarative memory while establishing the ongoing narrative. For severely impaired speakers, these impairments were thought to arise from interruptions in the flow of speech, thus reducing the ability to generate grammatically well-formed sentences and/or difficulties in the ability to adequately connect the ideas across contiguous utterances. Furthermore, Peach (2013) found that scores from the Raven Coloured Progressive Matrices (Raven, 1965) and the Likenesses and Differences subtest of the Detroit Test of Learning Aptitude (Baker & Leland, 1967) strongly predicted the occurrence of pauses and mazes in the sentence production of speakers with TBI. The results were used to suggest that the microlinguistic impairments of individuals with TBI are related to problems organising and monitoring language representations in working memory and that these deficits are due to the way individuals with TBI recruit and control attention.

Together, these studies have identified cognitive impairments associated with multiple levels of narrative production and provide support for the resource approach to the impairments in discourse processing observed in TBI speakers. As highlighted previously, it is reasonable to conclude that these processes unfold temporally during the production of narratives and therefore place a premium on executive control for the successful completion of these operations. Recent work has emphasised how these many layers can be structured into a cortical processing hierarchy of temporal windows (Willems et al., 2020). These findings, then, provide further support for the current results as well as those of Peach (2013) and Peach and Coelho (2016) in that the temporal architecture for narrative production in TBI speakers appears to be tightly coupled to impairments across multiple, parallel cognitive maneuvers during discourse processing.

Limitations of the current study

The participants in this study were selected using similar demographic and clinical variables to those used frequently in previous studies. These included age, education, speech, hearing and vision, type of injury (closed versus open head), severity of injury (i.e. length of coma, orientation, and post-traumatic amnesia), time after injury, and cognitive abilities (language level, mental status). Yet despite this level of matching and evidence that the discourse scores in this group were normally distributed, other variables that were not controlled and relate to the cognitive reserves of these participants may have contributed to the wide range of scores that was observed. This may be potentially problematic for the representativeness of these scores even though the group size met standard rules of thumb (i.e. 10 participants per predictor) to obtain reliable estimates for the regression coefficients that were found (van Belle, 2008),

Cognitive reserve "refers to how flexibly and efficiently the individual makes use of available brain resources" (Bigler & Stern, 2015). The cognitive reserve theory postulates that individual differences in pre-existing processing approaches and/or compensatory strategies might allow some people to cope better with brain damage than others. Higher educational and occupational attainment are thought to enhance cognitive reserve but so too do engagement in physical and social and leisure activities. Cognitive reserve, then, might explain the individual differences observed in these participants despite their similar degrees of brain damage (Stern, 2013).

The current participant group was controlled for level of education, a standard proxy for cognitive reserve (Barulli & Stern, 2013). The occupational levels of the participants were reported (see class ratings in Table 3) but not used to provide further control within the group. Inspection of these ratings shows that the group was approximately split between those with professional occupations versus those with skilled or unskilled jobs. Controlling the groups for both education and occupation (among other variables) might have provided more homogeneity regarding the participants' cognitive reserve, resulting in less variability among the discourse scores across participants.

We have also observed similar variability previously when analysing the microlinguistic performance of participants with TBI not included in the current group (Peach & Coelho, 2016). Besides cognitive reserve, some authors have suggested that participants for discourse studies might better be selected by their executive profiles rather than their demographic and clinical profiles (Zimmermann et al., 2015). To this we would add that, given sufficient numbers, it might be fruitful to use cluster analysis to create more homogenous subgroups and then analyze the relationships among these discourse variables in each group. However, while this approach most likely will reduce the range of scores within these groups, it might also have the unintended effect of obscuring the influences of impaired executive control on discourse processing in the larger population with TBI.

The participant group also was limited to five women. This may raise questions regarding the representativeness of these findings for the larger population of people with TBI. On further inspection, these females produced fewer cohesive ties in both complete and incomplete stories, and fewer pauses in complete stories than the male participants. Alternatively, they paused more often in incomplete stories and produced more mazes overall. While interesting, these quantitative patterns say little about the relationships among these measures at multiple levels of discourse processing.

Studies of sex differences for language processing, and more specifically, for discourse processing following TBI, are scarce. In one study, no significant differences were found between females and males, matched for severity of injury and time since injury, on a composite measure of language performance (Liossi & Wood, 2009). In another study, females and males with TBI of mixed severity, as well as close others of these participants, rated their discourse impairments similarly (Despins et al., 2016). Also, inconsistent results have been reported regarding any differences for females with moderate to severe TBI on tests of executive function when compared to males with similar injuries (Moore et al., 2010; Niemeier et al., 2007). This is important with regard to accounting for any sex differences in resource allocation, and therefore, discourse processing, following TBI. Based on these findings, perhaps sex differences for discourse processing shouldn't be expected. Nonetheless, the pattern observed here for the female participants certainly seems to raise the question.

Finally, it should be recognised that the data for this study were drawn from a single discourse sample in a single genre. This might raise concerns regarding the reliability of the findings as well as the generalizability of the results to other forms of discourse. The database from which these samples were chosen contains 2 discourse samples for each participant collected in different genres (story retelling, story generation). The current findings could be strengthened by comparing the participants' performance in both of these genres. Previous studies that have done this have found that coherence, cohesion, and sentence production are influenced after TBI by the genre of the discourse elicitation task (Coelho, 2002; Liles et al., 1989). Differences in global coherence and lexical diversity have also been found in the discourse of healthy speakers when elicited under varying circumstances (Fergadiotis & Wright, 2011; Fergadiotis et al., 2011; Wright et al., 2014). Future tests of the resource model for discourse processing therefore should include different types of discourse.

Conclusions

By examining the time course and structural characteristics of narratives produced by speakers with TBI, our data suggest that these speakers may pay a cost during sentence processing for creating coherent discourse. The results extend the findings of Peach and Coelho (2016), who found a temporal relationship between the construction of cohesive ties by TBI speakers and the time required for sentence planning. Thus, it appears that, after TBI, speakers have a fundamental problem in allocating resources among multiple levels of discourse. These are likely associated with the impairments to executive control in individuals with TBI that have been reported previously.

These results are also important regarding cognitive rehabilitation following TBI. If the goal of the treatment is to improve executive control for discourse, the training needs to be specific to the production of discourse (e.g. narratives) (cf. Peach, 1993). Extensive executive training with a complex task involving multiple control components has been shown to produce effects that are highly specific to the trained tasks (Simonet et al., 2019; Spierer et al., 2013; see also Peach et al., 2017, 2019; Simons et al., 2016). Discourse training using narratives offers an opportunity to analyze a speaker's executive attention under conditions that capture the everyday potential for distraction and the demands for coordination of multiple resources. To the extent automatic processes and skills for discourse are impaired, the goal of treatment should be to re-establish the automaticity of those processes (Fischler, 2000). Thus, based on the resource model proposed here, executive control training for discourse would be expected to yield the greatest improvements when training involves narrative production.

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