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Narrative and Horticultural Imperative: Predicting Discourse Ability in Traumatic Brain Injury from Cognitive and Communicative Factors

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Narrative and Horticultural Imperative:
Predicting Discourse Ability in Traumatic Brain Injury
from Cognitive and Communicative Factors

Karen Lê, Ph.D., CCC-SLP
University of Connecticut, 2015

ABSTRACT

Purpose: The goal of the current research study was to advance our knowledge of cognitive-communicative disorders following traumatic brain injury (TBI) by identifying the cognitive and communicative processes underlying narrative discourse ability. The study 1) examined the role of working memory (WM) and inferencing in narrative discourse, 2) tested key assumptions posited by the Structure Building Framework (SBF; Gernsbacher, 1990), a cognitive model of normative discourse comprehension and 3) attempted to disambiguate the relationship between discourse comprehension and discourse production.

Methods: Forty-four native English speakers participated, comprising 21 individuals with TBI, all with closed-head injuries, and 23 non-brain-injured (NBI) comparison individuals. Participants completed six core study tasks yielding seven measures of interest: verbal and nonverbal working memory updating (WMU-V, WMU-NV), predictive inference, the Discourse Comprehension Test (DCT; Brookshire & Nicholas, 1993), a picture story comprehension task (PSC) and story retelling (story grammar and story completeness). Three regression analyses were performed. In the first and second set of models, WM and

inferencing were predictors for discourse comprehension and production outcomes, respectively. In the third set of models, discourse comprehension measures were predictors production outcomes.

Results: WMU-V and WMU-NV were found to be highly collinear. Thus, only WMU-V was used as the WM measure in the regression models. WM and inferencing accounted for one-third of the variance in DCT but the model for PSC was nonsignificant. WM and inferencing were not significant predictors for either story grammar or story completeness. DCT and PSC did not significantly predict story grammar. However, the discourse comprehension measures accounted for 60% of the variance in story completeness with DCT as the significant predictor.

Discussion: Findings were interpreted as supporting SBF assumptions of domain-generalty of cognitive processes and mechanisms involved in discourse and partially supporting assumptions that the same cognitive substrates are marshalled for comprehension and production processes. WM was more strongly associated with comprehension processes. Yet, comprehensions measures were highly predictive of narrative content, a production measure, suggestive of shared mental representations and share cognitive substrates outside of WM. In recent accounts, declarative memory has been shown to be critical for short-term recall, highlighting its potential for subserving both discourse comprehension and production systems and merits consideration for future investigations of the cognitive-communicative underpinnings of discourse ability.

**Narrative and Horticultural Imperative:
Predicting Discourse Ability in Traumatic Brain Injury
from Cognitive and Communicative Factors**

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A Dissertation

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at the
University of Connecticut

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Karen Lê

2015

APPROVAL PAGE

Doctor of Philosophy Dissertation

Narrative and Horticultural Imperative:
Predicting Discourse Ability in Traumatic Brain Injury
from Cognitive and Communicative Factors

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Table of Contents

Abstract.....	i
Acknowledgments.....	vi
Chapter I.....	1
Introduction.....	1
Fluent Language Disorders and Traumatic Brain Injury.....	1
Clinical Significance of the Study of Discourse in Traumatic Brain Injury.....	4
A Primer on Discourse Genres.....	10
General Methodological Approaches to Discourse Analysis.....	12
Discourse Impairments in Traumatic Brain Injury.....	15
Monologic Discourse Impairments.....	15
Conversational Discourse Impairments.....	25
Cognitive Explanations for Discourse Impairments in Traumatic Brain Injury.....	31
Sequencing and Inferencing.....	32
Working Memory.....	35
Executive Functions.....	38
Cognitive Models of Discourse Comprehension.....	42
Requirements for a Model of Discourse Production.....	45
Chapter II.....	51
Motivation for the Current Study.....	51
Rationale for Use of Narratives and Narrative Discourse Measures.....	52
Chapter III.....	54
Pilot Data.....	54
Purpose of the Study.....	58
Chapter IV.....	63
Methods.....	63
Methodological Overview.....	63
Participants.....	64
Procedure.....	73
Stimuli.....	75
Data Analyses.....	83

Chapter V.....	87
Results.....	87
Descriptive Statistics.....	87
Group Comparisons.....	90
Correlations.....	97
Multiple Regression Analyses.....	101
Chapter VI.....	105
Discussion.....	105
Group Comparisons.....	105
Core Study Questions.....	112
Limitations of the Study.....	125
Conclusions, Clinical Implications and Future Directions.....	126
Appendices.....	129
References.....	132

CHAPTER I

Introduction

Fluent Language Disorders and Traumatic Brain Injury

Fluent language disorders refer to communication disorders in which affected individuals produce language with relative ease but have breakdowns in other communicative aspects. They are diverse both in etiology and clinical presentation (Glosser & Deser, 1991). The emergence of fluent language disorders may follow either focal or diffuse brain damage, as in the case of fluent aphasia caused by a left-hemisphere stroke or the cognitive-communicative impairments precipitated by Alzheimer's disease or traumatic brain injury. The nature of the fluent language disorder varies with the etiology. For example, individuals with fluent aphasia struggle with language more at the level of words and sentences, which are microlinguistic problems. In contrast, those with Alzheimer's disease have been noted to have difficulty with language at a more conceptual and pragmatic level, which are considered macrolinguistic problems (Glosser & Deser, 1991).

Similar to stroke and progressive neurological pathologies which are considered internal forces on the brain, external physical forces on the brain may also cause fluent language disorders. Traumatic brain injury (TBI) is brain damage due to the impact of external physical forces. Typically, TBI results in diffuse damage throughout the brain, leaving a host of catastrophic breakdowns in physical, psycho-social, cognitive and communicative abilities in the aftermath. Mild TBI accounts for the majority of TBIs, approximately 70 to 90 percent of all treated cases (Cassidy et al., 2004). Clinical neuroimaging is frequently negative in mild TBI

because conventional computed tomography (CT) and magnetic resonance imaging (MRI) scans are not sensitive enough to detect the microscopic injuries to axons that are prevalent in mild TBI (Shenton et al., 2012). These microscopic axonal injuries occur throughout the brain and are known as diffuse axonal injury (DAI).

Although diffuse damage is often associated with mild TBI, focal and diffuse pathologies can occur together, particularly in more severe cases (Povlishock & Katz, 2005). In a review of the neurological changes and recovery in TBI, Povlishock and Katz (2005) provided a delineation of the neuropathology of TBI that is summarized here. Primary brain injuries are due directly to the mechanical impact of the external physical forces on the brain. Primary focal brain injuries include cortical contusions, deep cerebral hemorrhages and extracerebral hemorrhages whereas primary diffuse brain injuries include DAI and petechial white matter hemorrhage (i.e., bleeding secondary to broken capillary vessels). Secondary brain injuries, unlike primary injuries, occur over time and may include delayed neuronal injury, microvascular injury, hypoxic-ischemic injury and hypometabolism. The secondary injuries listed above can occur as either focal or diffuse lesions. Additionally, TBI sets into a motion a cascade of changes in neurotransmitters that disrupts cognitive and behavioral homeostasis (McAllister, 2008).

Certain areas of the brain are more involved in and, consequently, are more vulnerable to TBI. These areas of increased vulnerability to TBI comprise the frontal lobes, sub-frontal white matter tracts and temporal lobes, including the hippocampi (McAllister, 2008). The involvement of the frontal and temporal cortices in addition to DAI underlies many of the cognitive and behavioral consequences of TBI. Chronic cognitive deficits are hallmarks of TBI. Cognitive impairments following TBI affect several domains, including attention, information processing,

short-term memory and learning and executive functions (McAllister, 2008; Sohlberg & Mateer, 2001). Executive functions refer to higher level control or self-regulatory processes.

Impairments of executive functions include difficulty with planning, self-awareness and goal-setting, initiation, behavioral inhibition, self-monitoring, organization of learning, memory and learning, self-evaluation and flexible problem solving (Gioia & Isquith, 2004; Ylvisaker & Szekeres, 1998). Lesions in the limbic and association areas of the anterior frontal and temporal cortices are strongly associated with impairments in executive functions, working memory, memory encoding and retrieval, higher-level attention processes and behavioral modulation (Povlishock & Katz, 2005). Diffuse brain damage, such as DAI, is often associated with deficits in information processing and attention (Felmingham, Baguley & Green, 2004; Mathias, Beall & Bigler, 2004).

Cognitive impairments can and indeed often affect the ability to communicate following TBI. The American Speech-Language-Hearing Association (ASHA; 2005) defines cognitive-communicative disorders as “difficulty with any aspect of communication that is affected by disruption of cognition.” ASHA (2005) specifies that communication may be verbal or nonverbal and comprises all language modalities (i.e., listening, speaking, reading, writing and gesturing) and language domains (i.e., phonology, morphology, syntax, semantics and pragmatics). Cognitive-communicative impairments are common and defining sequelae of TBI (Coelho, DeRuyter & Stein, 1996; Coelho, Ylvisaker & Turkstra, 2005; Douglas, 2010; Togher et al., 2014).

Clinical Significance of the Study of Discourse in Traumatic Brain Injury

Situated at the nexus of cognition and communication, discourse abilities are an important aspect of cognitive-communicative functioning and are frequently disrupted following TBI. Although definitions of discourse vary widely across different fields of study, they share similarities in their reference to connected language beyond the level of words and sentences and in the holistic derivation of meaning from the body of the text as a semantic unit. Discourse is “a series of connected sentences or related linguistic units that convey a message” (Cherney, Coelho, & Shadden, 1998, p. 2). It is the purposeful operation of complex and contextualized language. Discourse analysis accords much utility as an avenue to study fluent language disorders in TBI. The possibilities of multi-level examinations are well-suited and, arguably, necessary to capture the diversity and array of language abilities and impairments following TBI.

Examination of discourse in TBI can reveal subtle communicative impairments that frequently are undetected on traditional standardized language tests. Standardized language batteries typically tap lexical-semantic and syntactic abilities that are useful for the diagnosis of aphasia. However, frank aphasias are not a common occurrence following TBI. In a study of 750 patients with closed head injury, only 13 individuals met the criteria for aphasia (Heilman, Safran, & Geschwind, 1971). Consonantly, another study diagnosed only 34 cases of aphasia out of 1,544 individuals with TBI (Arseni, Constantinovici, Iliescu, Dobrota, & Gagea, 1970). These larger studies identified aphasia in approximately 2% of cases. The occurrence of aphasia was greater in some reports, accounting for roughly one-third of 56 to 69 individuals with TBI (Sarno, 1980; Sarno, 1984). Incidences as high as 46% have been reported (Levin, Grossman, & Kelly, 1976; Thomsen, 1975), but studies demonstrating higher incidences have examined

smaller samples sizes (≤ 50) with higher proportions of severe TBI than epidemiological reports of the TBI population. Moderate to severe injuries constitute 20% of the population while diagnoses of mild TBI occur much more frequently (Sohlberg & Mateer, 2001). Additionally, presence of aphasia has been correlated with severity of injury. Given that most cases of TBI are not severe, aphasia is considered an infrequent sequela of TBI. As such, traditional language batteries that probe for symptoms of aphasia are likely to be insufficient assessments of communicative performance following TBI.

Standardized aphasia batteries overestimate communicative abilities because they assess language at word and sentence levels and focus on linguistic form and content, both of which are relatively preserved in TBI or generally recovered within a year post-injury (Groher, 1990; Sohlberg & Mateer, 2001). Yet, despite facility in speaking, observations of individuals with TBI in conversation often mention tangentiality of topic, disorganization, and poor turn-taking (Coelho, Liles, & Duffy, 1991c; McDonald, 1993). They convey words with ease but do not transfer the message. While there is often preservation of basic and fundamental language skills, these individuals struggle with the *use* of language, alternatively referred to as *pragmatics*. In broad terms, pragmatics is defined as a “comprehensive set of skills required for competence in natural and functional language” (Sohlberg & Mateer, 2001, p. 308). Pragmatics is concerned with the “linguistic choices” a language user makes and the social context in which communication takes place (Body, Perkins, & McDonald, 1999). Psychometric approaches often do not take into account the context of communication and, thus, provide an inaccurate gauge of functional abilities.

The language disorder that results from traumatic insult cannot be isolated from underlying cognitive deficits (Hagen, 1981; Thomsen, 1975). In keeping with this notion,

pragmatics is closely associated with cognitive processes, including memory and executive functions. The communication impairments of TBI reflect the interplay of multiple processes. Discourse skills, such as storytelling, are a culmination of the interaction between linguistic, cognitive, and social domains (Coelho, Liles, & Duffy, 1991c). Therefore, the examination of discourse ability is critical in the evaluation of cognitive-communicative ability in the TBI population. The analysis of discourse production allows for examination of these different domains and takes into account the situational or social context of the language user, offering insights into the communicative ability of individuals with TBI above and beyond information gleaned from traditional language testing.

Because of its focus on naturalistic language use, discourse analysis is an ecologically valid approach to assessment of communication. Discourse is the level at which much of everyday communication occurs in natural settings, such as the home, school, and workplace. Effective discourse skills are integral to successful communication and overall success. Because discourse skills require a combination of linguistic, cognitive, and social abilities, it is a logical choice for studying communicative deficits as they relate to community reintegration of individuals with TBI. One study investigated the relationship between 1) 23 discourse variables that tapped efficiency, complexity, topic management, information, and pragmatic behaviors across three discourse genres (i.e., narrative, procedural, and conversational) and 2) patient-reported outcomes (i.e., social integration, quality of life, depression, and personality) (Galski, Tompkins, & Johnston, 1998). All discourse genres were significantly correlated with the index of social integration. Multiple regression analyses also indicated that *only* discourse variables, *rather than* psychosocial variables, were predictive of social integration. Quality of life was significantly correlated with performance on procedural and narrative discourse tasks.

In a similar study of the relationship between discourse skills and community reintegration as well as life satisfaction, questionnaires tapping the three areas were completed by individuals with TBI, significant others, and clinicians (Dahlberg et al., 2006). Pronounced areas of difficulty in social communication were related to ratings of conversational competence and communicative skills involving executive functions (e.g., planning and initiation). The results indicated significant moderate correlations between the perception of social communication skills and each of the following: life satisfaction, social integration, social productivity, and occupational participation. Both studies arrived at similar conclusions—that effective discourse ability figures importantly in the ability of the individual with TBI to re-enter his/her community, to be a contributing, working member of that community, and to achieve a sense of well-being.

There is some evidence to suggest that discourse is not only important for social communication but also *necessary* for one's health (Mar, 2004). Studies focusing on individuals who have endured traumatic events found that those who were able to form coherent narrative accounts of their hardship experienced gains in mental and physical health associated with the narration (Pennebaker & Seagal, 1999; Ramírez-Esparza & Pennebaker, 2006). The therapeutic nature of the narratives seems to arise from the process of forming the story more so than the end product of a well-formed story (Pennebaker, 1993). Aspects of narrative discourse associated with salutary benefits include greater use of positive-emotion words and greater awareness of others' perspectives observed through pronoun usage. Increases in the incorporation of cognitive words related to cause-effect (e.g., because) and insight (e.g., understand), reflecting the construction of the story, have also been noted to predict improved health (Ramírez-Esparza &

Pennebaker, 2006). Therapeutic narratives offer possible avenues for learning about and treating the psychological devastation and cognitive-communicative impairments of TBI.

Although some linguistic elements of communication abate within the first year, discourse impairments are persistent and do not often resolve over time. In a longitudinal study, 26 adults with severe TBI were followed from the time of initial assessment (3-6 months post-onset). Approximately 70% of individuals with TBI demonstrated deficits in conversational discourse two years after the injury and beyond (Snow, Douglas, & Ponsford, 1998). In particular, the TBI group experienced difficulty with transferring information during conversation when initially evaluated and upon follow-up. A similar longitudinal study on changes in narrative discourse found that TBI and orthopedic comparison groups were not significantly different on a pragmatic rating scale (Snow, Douglas, & Ponsford, 1999). The TBI group, however, demonstrate greater variability, suggesting that there may be subgroups of recovery. Another longitudinal case study of two adults with TBI provided evidence of differing discourse profiles (Coelho, Liles, & Duffy, 1991b). One participant struggled with narrative organization but had appropriate content. Conversely, the second participant produced organized stories that were deficient in relevant information. Although both had discourse impairments, the first participant eventually returned to work full-time whereas the second participant withdrew from school and had difficulty maintaining social relationships. The disparate discourse patterns suggested that content measures appear to be of prognostic value in determining functional recovery.

As with adults, the effects of TBI on communicative ability in children are long-lasting. Children who sustained severe TBI as infants and preschoolers demonstrate sub-par communicative skills several years after the injury (Ewing-Cobbs & Barnes, 2002). In another

follow-up study performed over three years in multiple intervals, children who had sustained severe TBI performed worse on measures of productivity, propositions, organization, and extrapolation of global content than children with mild-to-moderate TBIs (Chapman et al., 2001). Although both groups improved over time, the severe TBI group had the same discourse deficits at 12 months post-injury as they did at three months. When assessed at three years post-injury, two-thirds of the severe TBI group continued to demonstrate discourse deficits.

Discourse is an important area of communicative functioning, especially when evaluating individuals with TBI. The relative infrequency of aphasia but prevalence of pragmatic deficits calls for assessments with greater sensitivity to the cognitive-communicative impairments of the TBI population. The success of re-entering community life and overall quality of life are linked to discourse competence. Improvements in mental and physical well-being also correlate with the actual process of constructing a narrative of a traumatic experience. Furthermore, discourse deficits do not demonstrate spontaneous resolution over time, and discourse tasks pose challenges to those with brain injuries even several years post-injury. The relationship between discourse impairments and functional recovery and the protraction of these deficits prevails upon the need for intervention. Yet, guidelines regarding treatment of discourse impairments have not been fully developed due to the paucity of empirical studies (Coelho, 2007b) and the lack of a theoretically-based model that explains the discourse deficits in the TBI population. Together, these reasons warrant the continued study of discourse impairments in TBI.

A Primer on Discourse Genres

A discussion of the discourse impairments in TBI necessitates an explanation of the discourse genres. The multiple forms in which individuals craft utterances and convey messages give rise to different genres of discourse. Six discourse genres have been identified that have utility in clinical domains: descriptive, narrative, procedural, persuasive, expository, and conversational (Müller, Guendouzi, & Wilson, 2008). What distinguishes clinical approaches to discourse analysis from other approaches is the focus on functional communication (Müller et al., 2008). In other words, clinical application of discourse analysis is concerned with the individual's ability to use language in the various communicative contexts of daily life and with the disruptions in functional language use. While all the discourse genres listed can be used in an interactive context, not all *require* a communicative partner. The necessity of interaction groups discourse genres into one of two categories: monologues or conversation.

Discourse genres that are not interactive by definition are considered monologic and include all genres except for conversational discourse, which must take place in a communicative dyad. Descriptive discourse is a type of monologic discourse that involves the enumeration of features and concepts for the purpose of rendering a non-linguistic form into a linguistic representation. The focus of the description may be an item presented to the participant, such as a picture or object, or an experience of personal salience, such as a favorite hobby or work-related task (Cherney, 1998; Coelho, Liles, & Duffy, 1991c). There is no compulsory ordering of the content in descriptive discourse as there are in other discourse genres.

In contrast to the relative unstructured sequencing of utterances in descriptive discourse, narratives are characterized by rule-based organization. Narrative discourse involves the telling

of a story in which the presentation of characters and actions follows a logical sequence established through temporal and causal links (DiSegna Merritt & Liles, 1989; Stein & Glenn, 1979). The narrative genre achieves the purpose of recounting a real or fictional event often to entertain an audience. There are four identified types of narrative discourse: *recounts*, *eventcasts*, *accounts*, and *stories* (Heath, 1986). Recounts detail a past event whereas eventcasts explain the scenes of an ongoing or future event. Personal narratives spontaneously shared are referred to as accounts. Stories involve a character or cast of characters set into a sequence of events to accomplish a goal and are frequently used in the examination of discourse in individuals with TBI. Elicitation of narrative discourse is achieved through story retelling, in which the individual relates a story previously presented, or story generation, in which the speaker creates an original story. The stimuli may be auditory or visual. The presentation of visual stimuli may also be a single picture or a sequence of pictures.

Procedural discourse entails explanations of a series of actions to perform a task and functions to instruct the listener regarding how to carry out an activity. Like narrative discourse, the organization of procedural discourse is paramount. The ordering of the steps is critical for successful execution of the procedure (Hinchliffe, Murdoch, & Theodoros, 2001). Participants are often asked to describe a familiar task or activity (e.g., baking a cake) although novel or newly-learned tasks have also been used (McDonald, 1993).

Drawing upon more complex reasoning ability, persuasive and expository discourse place greater cognitive demands on the speaker in contrast to procedural discourse (Cherney, 1998). Persuasive discourse calls for the assertion of an opinion and the grounds on which the opinion is based, serving to influence the listener toward the speaker's viewpoint. Asking participants to take a stand on a political issue and provide justification for their view is an example of an

elicitation method for persuasive discourse. Expository discourse is meant to inform the listener about a topic through facts or interpretation and encompasses comparison and contrast, cause and effect, and generalization (Cherney, 1998). Expository discourse may subsume procedural discourse, particularly in situations where the task is unfamiliar, placing greater demands on the participant. Expository discourse skills are critical for academic success (Moran & Gillon, 2010).

Conversational discourse is interactive, drawing upon the collaborative effort between, at least, two communicative partners in exchanging ideas, thoughts, and feelings. Turn-taking is central to the process in which the participants alternate roles as speaker and listener. Pairing the participant with a familiar individual (e.g., family member or friend) produces a naturalistic communicative dyad. However, the use of an unfamiliar individual (e.g., examiner) can reveal how the participant responds in novel communicative situations. The interview format is frequently used to elicit conversation but the tenor of conversational discourse in that format may influence outcome variables (Coelho, Youse, & Lê, 2002). Tenor refers to the communicative context that includes who the participants are, their relationship to one another, and roles (Halliday, 1985).

General Methodological Approaches to Discourse Analysis

General methodological approaches to discourse analysis are briefly discussed here to provide a general understanding of the assessment of discourse deficits and definitions of key terms used in discourse analysis prior to delineating the specific discourse deficits associated with TBI.

The spoken discourse sample is typically collected during the elicitation process by audio- or video-recording and should be at least five sentences in length (Coelho, Liles, & Duffy, 1991c). Although a few discourse analyses can be performed concurrently with elicitation, many first require transcription. The recording is transcribed verbatim and then broken down into smaller utterance segments in preparation for further analysis. Spoken language lacks punctuation to mark the end of utterances, confounding identification of the conventional sentence. Particularly in the case of monologic discourse, speakers frequently produce continuous strings of utterances, using conjunctions (e.g., and) to repeatedly append clauses.

T-unit segmentation is a widely used parsing method that resolves the quandary of spoken discourse. A *T-unit*, or *minimal terminable unit*, is an independent clause and any attached dependent clauses and is more reliably identified than a sentence (Hughes, McGillivray, & Schmidek, 1997; Hunt, 1970). Referred to as the *C-unit*, the *communication unit* is defined as an independent clause and its modifiers and is equivalent to a T-unit (Loban, 1976). Several monologic and conversational discourse indices utilize T-units in their metrics. The operationalized definitions of the T-unit and C-unit facilitate comparison across different research studies.

Alternatively, conversational discourse is often divided by *turns*. A turn begins when an individual produces an utterance, thereby becoming the Speaker, and ends when the turn is relinquished to the conversational partner, who then becomes the Speaker. Many discourse indices, such as those examining grammatical complexity, story grammar, and response appropriateness, necessitate transcript segmentation of some sort prior to initiation of the analysis procedure.

There is some evidence to suggest that the elicitation task has an effect on discourse outcome variables. For example, story generation proved to be more challenging than story retelling in one investigation (Coelho, 2002). In another study, participants demonstrated greater word and utterance productivity and syntactic complexity during production of the narrative than during the expository discourse task (Hay & Moran, 2005). Studies such as these advocate for careful selection of elicitation tasks in answering research questions and caution against sweeping generalizations based on one discourse procedure.

Since conversation is the prevalent mode of human communication, some may argue that it has greater ecological validity than monologic discourse and, therefore, that examinations of discourse should focus solely on conversational discourse. However, monologic discourse offers a number of advantages over conversational discourse that are perhaps not obviously discernible. While daily communication is interactive, it simultaneously encompasses a preponderance of narratives nested within social exchanges (Mar, 2004). Everyday conversation incorporates narrative architecture to guide communication.

In a study that examined the relationship of discourse to functional outcomes after TBI, narrative and procedural discourse measures were correlated with social integration and quality of life comparably to conversational discourse measures (Galski et al., 1998). Regression analysis identified five significant predictors of social integration, four of which were monologic discourse measures related to efficiency, organization, and productivity. Additionally, quality of life was correlated with content and error measures in monologic discourse only. The findings suggest that conversational tasks may not be sufficiently difficult or cognitively demanding to ascertain the aspects of communication that 1) differentiate individuals with TBI from those who are not brain-injured and 2) underlie community reintegration and quality of life.

Methodologically, monologic discourse presents the possibility of systematic and quantitative examinations not granted by conversational discourse. Furthermore, elicitation of discourse through the use of stories or procedures identifies a target outcome which serves as the standard for comparison. For example, a story retelling task requires all participants to provide an account of the same stimulus story. By contrast, conversational tasks do not provide an equivalent conversational archetype against which to set elicited interactions. While interactive and monologic discourse each reveal features of communication following TBI that the other does not, monologic discourse appears better-suited to address inquiries related to ecological validity and identification of cognitive substrates.

Discourse Impairments in Traumatic Brain Injury

Examination of the literature on discourse production deficits following TBI reveals difficulty across a variety of discourse genres. Analyses of discourse vary depending on the discourse genre of interest and the goal of assessment. Monologic and conversational discourse offer different avenues for analysis and are discussed separately in the following section.

Monologic Discourse Impairments

There is a hierarchical organization of monologic discourse measures determined by the level at which the analysis occurs: the *microlinguistic*, *microstructural*, *macrostructural*, or *superstructural* level. *Microlinguistic* measures are within-sentence analyses focused on lexical, semantic, and grammatical processes whereas *microstructural* analyses examine discourse across

sentences. *Macrostructural* analyses are global discourse assessments considering the entire text, such as the overall theme. *Superstructural* analyses evaluate the over-arching structure that organizes discourse content.

Microlinguistic discourse impairments. Findings from microlinguistic examinations of monologic discourse are conflicting. Microlinguistic measures typically target lexical productivity, grammatical complexity and accuracy, or counts of propositional information and content units. *Propositions* refer to the set of semantic relations specified by an utterance's predicate and associated arguments. Inconsistent results have been found in investigations of syntactic processing. Evaluations of syntactic ability frequently address sentential complexity and include measures such as proportion of dependent clauses to total clauses, number of subordinate clauses per T-unit, embeddedness of dependent clauses, and words per T-unit (Coelho, 2007a). In one study of narrative discourse performance, no significant differences were found on sentential complexity in 23 children with severe TBI and those in the non-brain-injured (NBI) comparison group, paralleling findings from an earlier study led by the same investigator (Chapman et al., 1992; Chapman, Levin, Wanek, Weyrauch, & Kufera, 1998). Similarly, an examination of 4 adults with TBI found that grammatical complexity was within normal limits on both story retelling and generation tasks (Liles, Coelho, Duffy, & Zalagens, 1989). In an investigation using descriptive discourse, individuals with TBI embedded subordinate clauses comparably to NBI participants (Glosser & Deser, 1991).

Several studies have challenged the idea of relatively preserved syntactic processes following TBI. Children with TBI had poorer scores on sentential complexity in an investigation of narrative and expository discourse abilities (Hay & Moran, 2005). Likewise, another study found that 6 of 9 children with TBI performed poorly on the production of

utterances with at least one verb more than one year post-injury (Campbell & Dollaghan, 1990). Participants with TBI have also been noted to make more syntactic errors (e.g., lower proportion of syntactically complete utterances and omissions of subject and verb) although these findings should be interpreted cautiously as some participants were also aphasic (Glosser & Deser, 1991). Grammatical errors (e.g., incorrect word order, verb tense and agreement errors) have been shown to occur in the presence of preserved syntactic complexity (Peach & Schaude, 1986). A recent study examined pause time during sentence production in TBI and found that syntactic complexity affected intrasentential pausing, suggesting that sentence production deficits may be characteristic of early stages of TBI recovery (Ellis & Peach, 2009).

As with measures of syntax, propositional analyses have yielded equivocal results. Some investigations of children with TBI have revealed fewer propositions in story retellings and expository passages (Chapman et al., 1992; Hay & Moran, 2005). Similar findings have emerged from the adult TBI literature. In a study of 53 adults with TBI, the production of propositions per sentence was significantly below that for the comparison group (Coelho, Grela, Corso, Gamble, & Feinn, 2005). Case studies of two individuals with TBI on an interactive procedural discourse task suggest that results may fall into either extreme—the production of too few propositions or too many (McDonald, 1993). However, these results are tempered by a study of 10 children and 10 adults with TBI, in which both TBI and NBI comparison groups produced comparable numbers of explicit propositions (Biddle, McCabe, & Bliss, 1996).

Measures of productivity, efficiency, and production of content units have produced somewhat more congruous findings. A recent review of discourse production in TBI identified consistent reductions in verbal output and decreased communicative efficiency in monologic discourse (Coelho, Ylvisaker, & Turkstra, 2005). A variety of productivity, including tallies of

total words and T-unit or C-unit counts, have distinguished discourse functioning between individuals with TBI and NBI individuals (Body & Perkins, 2004; Chapman et al., 1992; Hinchliffe et al., 2001; Liles, Coelho, Duffy & Zalagens, 1989). Increased injury severity appears to correlate with decreased amounts of language (Chapman et al., 2001). Additionally, elicitation task was shown to influence productivity scores in one study, in which participants produced significantly more utterances and fewer words per utterance than the NBI group on monologic discourse tasks although no productivity differences were found on cooperative narratives (Jorgensen & Togher, 2009).

Communicative efficiency at the microlinguistic level pertains to errors in verbal output in addition to how well discourse content is conveyed. A study examining “flow of information,” as measured by the number of mazes and words per propositions, found no differences between children with TBI and NBI participants on narrative discourse tasks (Chapman et al., 1998). Similarly, individuals with TBI have performed within average range with respect to lexical errors and extraneous utterances (Body & Perkins, 2004; Hough & Barrow, 2003). Other studies contradict these findings, providing evidence that TBI disrupts communicative efficiency (Biddle et al., 1996; S. McDonald & Pearce, 1995). Verbal paraphasias were significantly greater in discourse production of the TBI group in one investigation, but the study did not exclude individuals with aphasia (Glosser & Deser, 1991). Likewise, in a study of narrative and procedural discourse, adults with TBI demonstrated decreased discourse productivity on measures that included discourse production speed during both elicitation tasks, however, the presence of dysarthria in a majority of participants precluded attributing the results strictly to TBI (Wyckoff, 1984).

When communicative efficiency is examined in terms of essential content, there is relative consensus in the research literature that individuals with TBI struggle on informational measures. At the microlinguistic level, essential content is often measured by essential propositions or content information units (CIUs). Several studies have demonstrated that individuals with TBI consistently omit critical microlinguistic elements of information across a variety of discourse genres (Chapman et al., 1992; Jorgensen & Togher, 2009; McDonald & Pearce, 1995; Stout, Yorkston, & Pimentel, 2000; Tucker & Hanlon, 1998). For example, in one study, participants with TBI were asked to arrange picture sequences and narrate the story that emerged (Tucker & Hanlon, 1998). Participants continued to leave out essential story elements even when presented with corrected sequence arrangements.

The literature on microlinguistic discourse impairments in TBI is mixed, attesting to the vast heterogeneity so often mentioned when attempting to characterize this population. However, individual analyses may offer some guidance. The overall findings suggest that disruptions of lexical productivity, communicative efficiency, and identification of relevant story information occur with some consistency in TBI and may have more sensitivity to microlinguistic breakdowns than other measures.

Microstructural discourse impairments. The microstructure of discourse relates to its *cohesion*, defined as inter-sentential organization established by meaning relations that connect one utterance to the next (Halliday, 1985). Cohesive markers or ties serve to bridge meaning locally between utterances and are identified as elements whose meaning can only be understood by searching another utterance. Halliday and Hasan's (1976) taxonomy of cohesive ties has five categories: 1) references (e.g., her, this), 2) substitutions (e.g., The *enchiladas* are too spicy. She should make *them* milder.), 3) ellipsis (e.g., Which tastes better, wild salmon or farmed salmon?

Wild is more flavorful.), 4) conjunctions (e.g., and, as a result), and lexical markers (e.g., “Joan Miró” in reference to “the artist”). Analyses of cohesion typically entail frequency counts of cohesive devices used, tallies of errors in their usage, and adequacy ratings. Judgments of cohesive adequacy identify cohesive markers as complete, incomplete, or erroneous, although some studies implement only binary scales (i.e., complete or incomplete) (Jorgensen & Togher, 2009; Liles, 1985).

As the case with microlinguistic analyses, microstructural analyses have rendered an inconclusive view of monologic discourse. Intact cohesion in children and adults has been reported in the literature. In a study of narrative discourse, children with severe TBI committed equivalent numbers of referential errors as NBI participants and demonstrated similar usage patterns for temporal and causal conjunctions (Chapman et al., 1998). Another investigation of children with TBI separated participants into two groups—one with language impairments and those without acute language deficits (Ewing-Cobbs, Brookshire, Scott, & Fletcher, 1998). Both TBI groups performed on par with a NBI sibling comparison group on cohesive adequacy and usage patterns (i.e., number and type) on per-sentence scores. However, distinctions emerged when cohesion was examined at the level of the entire text with the language-impaired TBI group producing fewer complete cohesive ties than the sibling group. The authors suggested that the disparate results may be more a reflection of macrolinguistic rather than microstructural impairments. Adolescents with TBI have demonstrated preserved cohesion of narrative discourse regardless of elicitation task (Van Leer & Turkstra, 1999). These findings are consistent with several reports of relatively preserved microstructural discourse ability in adults with TBI. In a study with 55 participants with TBI, cohesive adequacy was within normal limits in both story generation and story retelling tasks (Coelho, 2002). Furthermore, examination of

descriptive discourse after TBI discerned minimal differences on cohesive adequacy or usage patterns between TBI and NBI groups (Hough & Barrow, 2003).

Challenges to the notion of preserved microlinguistic discourse ability have been posed by a number of studies. Usage frequency of cohesive markers was within normal limits for adults with TBI on narrative discourse tasks for both story generation and story retelling (Liles et al., 1989). However, cohesive patterns differed between TBI and NBI groups on the story generation task with the TBI group using a greater proportion of lexical ties and lower proportion of referential markers. Another investigation demonstrated that usage frequencies deviated from typical performance and varied between tasks, evidenced by decreased use of references during narration and lexical markers during explanation of a procedure (Hartley & Jensen, 1991). Decreased use of lexical ties and increased use of elliptical ties in narrative discourse have also been reported (Mentis & Prutting, 1987). In addition to differences in cohesive patterns, individuals with TBI have been noted to use fewer total cohesive ties and fewer cohesive ties per utterance in narrative and procedural discourse tasks (Hartley & Jensen, 1991; Jorgensen & Togher, 2009; Mentis & Prutting, 1987; Wyckoff, 1984). An investigation specifically of referential cohesion in narrative discourse found decreased use of references stories elicited with pictures present and with auditory-oral retelling, but storytelling from memory was unremarkable (Davis & Coelho, 2004). The study further showed impaired cohesiveness when narrative discourse was prompted solely from pictures or memory but not on retelling, suggesting possible effects of elicitation task.

Macrolinguistic discourse impairments. A macrolinguistic view of discourse calls upon a global envisioning of the text. Some macrolinguistic approaches to discourse analysis involve transformative processes that distill and refine the text's essence, such as *gist*

summarization (Chapman et al., 2004). Others consider the thematic unity or logical connections of a text, referred to as *coherence*. Measures of local coherence identify meaningful relationships between utterances while global coherence measures identify those between an utterance and the body of text. Evaluations of discourse coherence frequently implement rating scales (Glosser & Deser, 1991; Van Leer & Turkstra, 1999). Gist summarizations are judged on how well the information has been reduced and transformed from the original text. Coherence ratings are made on the basis of how thematically related each utterance is to the next (local) or the extent to which each utterance reflects the overall theme of the discourse sample (global). The inherent subjectivity of rating scales may attribute to a lower reliability of coherence indices as opposed to other discourse analyses (Coelho, 1995). More quantitative approaches to evaluating discourse coherence analyses involve, for example, determining the proportion of causal connections per proposition or the proportion of essential propositions or gist produced (Chapman et al., 1998; Davis & Coelho, 2004).

The research literature substantiates the presence of disruptions in macrolinguistic discourse abilities after TBI in children and adults (Coelho et al., 2005; Cook, Chapman, & Gamino, 2007; Moran & Gillon, 2010). Children with TBI related fewer global story components and had more difficulty formulating the central idea in a study of narrative and procedural discourse (Hay & Moran, 2005). Similar results came from an investigation of 55 children and adolescents with severe TBI, in which participants were asked to summarize a lengthy narrative previously presented (Chapman et al., 2004). Only 40% of the TBI group told summaries with at least 20% transformed utterances compared to 70% of the NBI group. Macrolinguistic discourse impairments appear to be particularly persistent in severe cases,

evidenced by reductions in essential information in longitudinal comparison studies of severe and mild TBI (Brookshire, Chapman, Song, & Levin, 2000; Chapman et al., 2001).

Investigations into adult macrolinguistic discourse skills further reinforce findings from the pediatric literature. An examination of narrative discourse revealed that impaired generation of implied meanings was a consequence of both mild and moderate TBI (Tucker & Hanlon, 1998). In one study, adults with TBI produced less coherent narratives on local and global levels (Glosser & Deser, 1991). The participants also demonstrated greater impairment on global coherence than local coherence. A subsequent investigation on descriptive discourse replicated these findings, suggesting a pattern of greater deficit at global levels of text (Hough & Barrow, 2003). Disruptions in logical coherence have been noted when discourse production was elicited with an orally presented story although not observed in other elicited conditions (Davis & Coelho, 2004). Such a disassociation among elicitation tasks implicates the effect of presentation modality on discourse ability and highlights the importance of eliciting discourse in different ways.

A few studies have produced results at variance with the notion of breakdowns in macrolinguistic discourse functioning following TBI. An adolescent study using descriptive and narrative discourse found no difference between TBI and NBI groups on local or global coherence (Van Leer & Turkstra, 1999). Injury severity may play a role in discordant findings. In one investigation, participants with severe TBI had deficient global story content compared to NBI participants, but individuals in the mild/moderate TBI group performed no differently from the NBI cohort (Chapman et al., 2001).

Superstructural discourse impairments. The superstructure of a text, alternatively referred to as the story *schema*, provides the broad framework that organizes discourse content.

Stories have a logical ordering that aids comprehension and production. Causal and temporal rules, referred to as *story grammar rules*, specify and guide the connections between characters and events (Stein & Glenn, 1979). Although there are a number of story grammar measures, the episode unit is fundamental to many analyses of monologic discourse superstructure. A complete episode encompasses three core components: 1) an *initiating event* that provides the impetus for a character's action, 2) an *attempt* by the character to achieve the goal, and 3) a *direct consequence* of the character's attempt (Merritt & Liles, 1987). An incomplete episode contains two of the three story components.

Converging evidence in the research literature supports the existence of discourse deficits at the superstructural level (Coelho, 2007a; Hinchliffe et al., 2001; Moran & Gillon, 2010). Some evidence from pediatric and adult investigations has shown that individuals with TBI frequently produce fewer story grammar components (Hay & Moran, 2005; Jorgensen & Togher, 2009). In one study, no difference in number of episodes was noted for a story retelling task while 3 of 4 participants with TBI produced no complete episodes on story generation, again suggesting an effect of elicitation task on the outcome variable (Liles et al., 1989). In another investigation, while TBI and NBI participants produced comparable numbers of total episodes, the TBI group had a lower proportion of T-units in episode structure (Coelho, 2002). The proportion of T-units in episode structures appears to be one of the more sensitive narrative discourse indices in discriminating discourse performance between TBI and NBI groups (Coelho, Youse, Le, & Feinn, 2003). Differences in superstructural discourse performance based on injury severity have also been observed. An examination of childhood and adolescent TBI found that the severe TBI group consistently omitted setting information and essential actions while children in the mild/moderate TBI group performed comparably to the NBI group

(Chapman et al., 1992). Overall, the evidence from superstructural examinations of discourse point consistently to breakdowns in organization of semantic content.

Conversational Discourse Impairments

Conversational discourse analyses offer a variety of approaches that differ from those for monologic discourse, thereby allowing detection of discourse impairments in an interactive context. Measures of conversational discourse include pragmatic rating scales, checklists, and highly structured types of analyses. A wide range of communicative skills are evaluated by conversational analyses, the more common ones being response appropriateness, topic management, turn-taking, and appropriateness of verbal and non-verbal behaviors during interaction.

Response appropriateness. One approach to evaluating response appropriateness in conversations is based on Blank and Franklin's protocol (Blank & Franklin, 1980). As conversational partners interact, they take turns as initiators and responders. In Blank and Franklin's procedure, each turn is assigned to a speaker and designated as either an initiation or response. Speaker initiations may take the form of *obliges* (i.e., utterances that require a response from the conversational partner, such as a question) or *comments* (i.e., utterances that do not require a response). Adequacy of speaker responses are judged according to the following rubric: 1) *Adequate* responses appropriately address the initiator's statement, 2) *Adequate Plus* responses subsume criteria for Adequate responses and elaborate the response, extending beyond the requested information, 3) *Inadequate* responses do not meet the initiator's requests either

because they have no relevance or do not completely address the initiator's utterance, and 4) *Ambiguous* responses are those that were unclear so that adequacy could not be determined.

Individuals with TBI have manifested different patterns on turn-taking and response appropriateness compared to NBI participants. In one study, participants with TBI took a greater number of turns with shorter utterances and decreased response adequacy (Coelho, Liles, & Duffy, 1991a). Their conversations were also characterized by a higher proportion of obliques on the part of the conversational partner, suggesting difficulty with initiating and sustaining the communicative interaction. A follow-up study replicated these findings (Coelho, Liles, Duffy, & Clarkson, 1993). A second follow-up study of 32 participants with TBI was generally in agreement with previous findings with a few differences (Coelho et al., 2002). TBI and NBI groups took comparable numbers of turns during conversation, but the TBI group acted more as the responder than the initiator. This suggests that the conversational partner shouldered more of the communicative burden during interactions with the TBI group. Although the TBI group produced a higher number of adequate plus responses than the NBI group, the elaborated responses were not found to facilitate social interaction even though the responses were not irrelevant or inappropriate. The results suggest that more information is not necessarily better if it does not achieve the goal of meeting the needs of the listener.

Further support for response appropriateness approach comes from evaluating the sensitivity of discourse variables and from qualitative ratings. Measures of conversational response adequacy have distinguished discourse performance following TBI from typical performance. A discriminant function analysis of selected narrative and conversational measures revealed that comments and adequate plus responses, along with a story grammar measure, reliably differentiated TBI and NBI groups better than other variables (Coelho et al., 2003). As

external validation of the response appropriateness approach, perceptions of conversational quality have been tied to measures of response adequacy. In one study, individuals with TBI sustained longer turn durations and initiated conversation less than NBI participants (Bond & Godfrey, 1997). Both variables correlated with rater judgments. Additionally, conversations with individuals with TBI were given low marks for interest, appropriateness, and enjoyment and were judged to be more effortful.

Topic management. Topic management relates to how conversational topics are initiated, maintained, and changed during a communicative exchange. Researchers have assessed topic management ability using different structured approaches. In Mentis and Prutting's protocol (Mentis & Prutting, 1991), the *ideational intonation unit* is a sequence of words that conveys conceptual and propositional information. Classification of the ideational intonation unit depends on its relationship to the conversational topic. The metric differentiates among four categories: 1) new information, 2) no new information, 3) side sequence units, and 4) problematic. Results of ideational unit analyses are divergent. In a study of a single individual with TBI and a NBI participant, there was evidence of poor topic management skills following TBI, as characterized by irrelevant changes of topic and reduced contribution of novel information. A larger study of 10 individuals with TBI employing similar analysis procedures revealed no significant difference between TBI and NBI participants (Wozniak, Coelho, Duffy, & Liles, 1999). However, the authors acknowledged that elicitation methods may have prevented the emergence of topic management impairments.

Brinton and Fujiki's procedure (Brinton & Fujiki, 1989) offers another avenue to structured analysis of topic management and centers on the manner in which topics are introduced and changed during conversation. The taxonomy has three classifications of topic. A

Novel Introduction occurs upon initiation of a new topic. A *Smooth Shift* arises with subtle topic transitions. An abrupt switch in topic is a *Disruptive Shift*. A study of 5 participants with TBI found that conversations with the TBI group resulted in fewer total topic introductions and fewer novel introductions than the NBI group (Coelho et al., 1993). In dyads with the examiner, the NBI group introduced 59% of topics in conversation whereas the TBI group introduced only 28% of total topics. A follow-up study of 32 participants with TBI exhibited no differences in topic initiation compared with NBI participants. Both groups produced similar amounts of novel introductions and smooth shifts with very few disruptive shifts (Coelho et al., 2002). However, the dynamics of the TBI and NBI dyads were not comparable. The examiner used more smooth shifts interacting with members of the TBI group than those of the NBI group, suggesting that the examiner assumed more of the onus for sustaining conversation with the former cohort. Overall, findings indicate that individuals with TBI have difficulty initiating and managing topics in interactive contexts, prevailing upon their conversational partners to assume a greater communicative burden.

Systemic Functional Linguistics. Systemic functional linguistics (SFL) is a theory that describes language use as involving a system of choices (Halliday, 1985). Every utterance requires choices be made regarding content and manner of expression. The decisions are influenced by the conversational partner and situation, which represent the communicative context. The notion of context in SFL is comprised of three elements—field, mode, tenor. *Field* refers to the type of social interaction that is occurring (e.g., lecture or chatting with friends). *Mode* refers to the discourse modality used (e.g., oral or written). *Tenor* encompasses who the participants are, their relationship to one another, and roles (e.g., teacher and student, two siblings, waiter and restaurant patron). *Genre* and *ideology* are two other important concepts in

SFL. Genre refers to the influence of the culture on language and ideology to the influence of personal biases and views on language. SFL utilizes three types of conversational analyses—*exchange structure analysis*, *generic structure potential*, and *mood and modality analysis*. Of the three, only exchange structure analysis stresses the dyadic interaction and dynamics of tenor. It has been suggested that tenor relationships greatly impact the choices made during conversation (Togher, Hand, & Code, 1999). As such, only exchange structure analysis will be elaborated here.

Exchange structure analysis identifies who possesses the knowledge in the dyad and how the information is delivered to the conversation partner. This measure has been used to assess conversational performance in a number of daily communicative tasks with different communicative partners in one's community (Togher, Hand, & Code, 1997; Togher et al., 1999). Of interest is how the conversational partners respond to individuals with TBI in comparison to normal controls. In encounters with the police, TBI group gave more information, some of which was inappropriate for the context, than the NBI group. Bus station employees and therapists elicited less information from the individuals with TBI than the police, which was attributed to the police using more interrogatives. Mothers tended to request more information from the NBI group than the TBI cohort. Participants with TBI were noted to ask for clarification more frequently in interactions with therapist and police. In general, the characteristics of conversational discourse among the individuals with TBI changed based on the conversational partner. The identification of dynamics between communicators is important, particularly when there is unequal power distribution (e.g., one partner has more knowledge relevant to the interaction as in the doctor-patient relationship).

Pragmatic rating scales and checklists. Less structured and less formal approaches to conversation discourse analysis are pragmatic rating scales and checklists, which vary in range and degree of abilities covered. The pragmatic measures include Clinical Discourse Analysis (CDA; Damico, 1985), the Pragmatic Protocol (Prutting & Kirchner, 1987), the Profile of Functional Impairment in Communication (PFIC; Linscott, Knight, & Godfrey, 1996), and the La Trobe Communication Questionnaire (Douglas, O'Flaherty, & Snow, 2000). Some pragmatic procedures assess nonverbal (e.g., eye contact, gesture) and verbal (e.g., turn-taking, topic maintenance) abilities. Other measures quantify particular verbal and textual features. The PFIC and La Trobe Questionnaire are linguistically focused but incorporate items for nonverbal communication abilities.

Individuals with TBI exhibit a number of difficulties on pragmatic rating scales and checklists. A modified version of the CDA (CDA-M; Snow, Douglas, & Ponsford, 1997) revealed errors on conversational variables of content and organization not observed in the NBI group. In particular, individuals who had sustained severe TBI demonstrated deficiencies in efficiently conveying meaningful messages. In a longitudinal study, the CDA-M was sensitive to TBI not only in differentiating between TBI and NBI groups but also in identifying subsets within the TBI group (Snow et al., 1998). Based on Gricean conversational maxims related to quantity and manner, McDonald's rating scales identified differing patterns of deficit in two individuals with TBI (McDonald, 1993). Although both performed poorly on dimensions of manner (i.e., clarity, organization and effectiveness), they demonstrated dissociations on the quantity axis, which involved ratings of repetitiveness and amount of detail provided. In terms of repetitiveness, one participant was judged as being very repetitive while the other performed within normal limits. On the detail subscale, the individual who was deemed very repetitive had

ratings in the average range while the other was characterized as providing too little detail. These findings were further delineated by propositional analyses, which revealed impairments in organizing semantic content.

Overall, pragmatic rating scales and checklists provide useful information and can serve as external validation of more structured approaches to conversational analysis. Administration of rating scales and checklists is generally easier and more quickly accomplished than more formalized methods of conversational analysis. While they offer clinical utility, reliability of pragmatic measures hinges upon careful examiner training and often lack solid theoretical grounding (Coelho et al., 2005; Togher et al., 1999).

Cognitive Explanations for Discourse Impairments in Traumatic Brain Injury

The research canon on neurogenic communication disorders has shown that discourse production deficits are frequent and widespread consequences of TBI. However, questions remain regarding the underlying cause of impairments in discourse production. While cognitive deficits have long been suspected, the exact identity and nature of these processes has yet to be determined. Emerging evidence from research examining the relationship between discourse production and aspects of cognition in TBI as well as other clinical populations suggests sequencing and inferencing, working memory, and executive functions may play a role. Research on specific clinical populations with cognitive-communicative disorders, such as schizophrenia and frontal lobe damage, may have implications for TBI given commonalities between the natures of the disorders.

Sequencing and Inferencing

Disruptions in sequencing and inferencing ability have been associated with impaired discourse processing in TBI (Body et al., 1999; Sohlberg & Mateer, 2001). Sequencing refers to the ordering of information, often based on logical and temporal rules. Inferencing refers to the ability to extrapolate information from a context in which the information is not explicit or directly stated. Studies examining discourse macrostructure and superstructure have consistently demonstrated that TBI diminishes the ability to organize and abstract information. Impairments in story grammar reflect an inability to effectively structure semantic content. In addition to story grammar deficits, other problems in sequencing and ordering discourse have also been reported. A study implementing an interactive procedural discourse task demonstrated that participants with TBI had difficulty with sequencing explanations (McDonald, 1993). The two participants' discourse samples opened with irrelevant propositions and did not follow the same order as the NBI participants. In one case, impulsivity was thought to be the underlying problem, and, in the other, poor self-monitoring. The findings from quantitative organizational measures were validated by listener judgments on a pragmatic rating scale, on which the discourse of TBI participants was deemed as confusing, disorganized, and ineffective.

A study of narrative discourse in mild and moderate TBI brought to light deficits with sequencing content and distilling story implications (Tucker & Hanlon, 1998). Participants were asked to arrange a set of pictures that formed a story and subsequently tell a story congruous with the picture arrangement. All NBI participants performed at ceiling level on both tasks. However, only 88% and 76% of the respective mild and moderate TBI groups correctly sequenced the pictures, and only 73% and 60% of the respective groups narrated a correct story.

Even when the appropriate sequence was presented to the TBI group, they continued to have difficulty narrating a story corresponding to the events of the picture sequence. There were no differences among groups on the generation of implied meanings with the story likely due to the large variance. However, there was a noticeable trend for the moderate TBI group to abstract fewer inferences than the mild TBI group and the mild TBI group to abstract fewer inferences than the moderate TBI group.

Communicative impairments in schizophrenia share common characteristics with those in TBI and may help to shed light on discourse production deficits in TBI. A multi-analysis discourse study of 29 individuals with schizophrenia found that the clinical group exhibited deficits at both microstructural and macrostructural levels (Marini et al., 2008). Yet, when macrolinguistic variables, such as local and global coherence, were held as covariates in the analysis, no differences were found between the schizophrenia and comparison groups. This suggests that macrolinguistic measures more likely accounted for the discourse impairments, similar to descriptions of discourse following TBI. Deficits in action planning, ordering and sequencing were identified as possibly underlying factors in addition to impairments in pragmatics and attention.

Event sequencing and inferencing has been further studied in relation to executive functions and Theory of Mind (ToM). ToM refers to the ability to attribute another individual's mental states or, simply, to view things from another person's perspective (McDonald et al., 2014). A study of 40 individuals with schizophrenia separated participants into two groups: 1) participants with formal thought disorder (FTD) and 2) those without FTD (Zalla et al., 2006). Characteristics of FTD include disorganized speech, circumstantiality, tangentiality, illogicality and incoherence (Andreasen, 1984), communicative deficits also frequently observed in the

wake of TBI. Participants were asked to sequence a variety of picture sets, including those related to character actions, daily social routines, ToM stories, and physical events. The FTD group had difficulty sequencing across picture set categories, performing worse than the non-FTD and comparison groups. Their performance pointed to problems in event sequencing and inferential reasoning of a general nature. By contrast, the non-FTD group demonstrated a specific impairment in ToM.

The nature of TBI, particularly closed-head injury, renders the frontal lobes extremely vulnerable to primary and secondary impact damage (Sohlberg & Mateer, 2001). Consequently, frontal lobe functioning is frequently disrupted following TBI. Given this, it is reasonable to consider research in individuals with focal prefrontal cortex lesions. A study of 17 individuals with frontal lobe lesions (FLL) and 7 individuals with amnesia examined on-line (during encoding) and off-line (during later retrieval) inferencing ability for story comprehension. The participants with FLL demonstrated an inability to answer inference questions when presented concurrently with the story but did not differ in response pattern compared to NBI participants when questions were presented an hour later. In contrast, the participants with amnesia had converse performance. Additionally, the FLL group made sequencing errors during recall that neither the amnesic nor the NBI group committed. Given that the story task had a low working memory load, impaired performance was attributed to a specific deficit in inferring relationships within complex events. This finding may explain the difficulty individuals with TBI have establishing local and global coherence. Impaired inferential ability may also underlie story grammar deficits given that the logical relationships between characters and events often must be deduced.

Sequencing deficits were further investigated in a study of individuals with prefrontal cortex (PFC) lesions and individuals with Broca's aphasia (BA) (Sirigu et al., 1998).

Sequencing ability was postulated to be modular and dependent on the type of information being ordered. Two sequencing tasks were used, one involving sequencing of words and word phrases to form a sentence and the other involving sequencing of actions to form a narrative. The NBI group performed at ceiling level on both tasks. The BA group had significantly more errors ordering sentences than the PFC group. However, the BA group was comparable to the NBI group on the script sequencing task while the PFC group performed comparably to the NBI on the sentence ordering task. Although the PFC group assigned actions to the appropriate script theme, they struggled to order the actions correctly. The PFC group was significantly worse than both BA and NBI groups on the script sequencing task. Of note, participants with aphasia were noted to self-monitor but could not self-correct. The PFC group did not self-monitor and were noted to provide reasons for performance when asked after the fact. The double dissociation suggested that sequencing is a domain-specific or knowledge-specific skill. Both groups could sequence, but success was dependent on the knowledge tapped to perform the task.

Working Memory

Of the multitude and diversity of TBI sequelae, memory difficulties stand as the leading subjective complaint among patients and caregivers (Murray, Ramage, & Hopper, 2001). Given that brain damage following TBI typically involves diffuse axonal injury and significant frontal lobe damage, it is not surprising that memory systems that depend on the frontal lobes and their extensive connections to other areas of the brain are disrupted. Nontraditional analyses have

revealed subtle impairments of attention and working memory present one-year after the injury (Vanderploeg, Curtiss, & Belanger, 2005). In a functional outcome study of 60 participants with mild to severe TBI, individuals continued to demonstrate problems with memory, including working memory, even 10 years after the injury (Ponsford, Draper, & Schönberger, 2008).

There is some debate as to whether the memory impairments associated with TBI are truly distinctive from those associated with global amnesia or if they are manifestations of the same disorder with TBI involving other cognitive deficits (McDonald, Togher, & Code, 1999). Global amnesia results from damage to the medial temporal lobes and diencephalic structures, and it is a selective impairment of memory. TBI typically involves damage to frontal regions of the brain and does not selectively impair memory. Similarities between memory problems in individuals with TBI and those in individuals with frontal lobe damage have been noted, suggesting that the memory impairments observed in TBI may be due to an underlying general cognitive disorder (Vakil, 2005).

Based on mixed findings in the research literature, the relationship between memory and communication remains tentative. In a longitudinal study of 12 participants with TBI, no correlation was established between performance on memory tasks and ratings of social competence during naturalistic interactions (Marsh & Knight, 1991). The process that has shown the most potential in accounting for communicative impairments following TBI is working memory (WM; Murray et al., 2001). In a study of 55 individuals with closed-head-injury, WM measures moderately correlated with narrative discourse analyses (Youse & Coelho, 2005). Story retelling tasks accounted for more of the significant correlations than story generation tasks. Because story retelling involves operations of information processing and storage as opposed to information processing alone in story generation, demands on WM are

likely greater in the former. As such, story retelling procedures may be more informative in elucidating the connection between WM and communication.

An earlier investigation of 11 individuals with TBI examined the relationship between memory and discourse measures in story retelling, story generation, and procedural tasks (Hartley & Jensen, 1991). Significant correlations were found between the digit span backward task and cohesion measures from story generation. A logical memory subscale, tapping episodic memory, correlated with story retelling. A study of adolescent TBI identified WM as a constraining factor in the comprehension of low-familiarity proverbs (Moran, Nippold, & Gillon, 2006). The results suggested that processing of figurative language is influenced by WM load, particularly in novel contexts. In another study of adolescents with TBI, WM load was examined in relation to syntactic processing (Turkstra & Holland, 1998). Participants were presented with two versions of a grammar subtest, one of which was altered to reduce information processing and storage loads. The TBI group not only performed poorly on both indices but fared worse on the unmodified version. However, their syntactic abilities on the measures tested were within normal limits during discourse production tasks. The evidence suggested that controlling for WM may result in better performance on receptive linguistic measures.

The relationship between discourse macrostructure and WM were further probed in a study of children with mild and severe TBI (Chapman et al., 2006). Participants were asked to produce gist summaries of a story narrative, which were evaluated on cohesion and coherence measures. They also answered questions drawing upon factual and inferential story content. WM was assessed using “n-back” tasks, in which individuals must recall information that occurred “n” stimuli prior to the time of probe. Both TBI groups produced poorer story

transformations, and the severe TBI group performed worse than the mild and comparison groups on content questions and WM tasks. Performance on the WM task was significantly correlated with summarization ability, understanding of explicit discourse content, and processing of implicit discourse content. Impaired summarization ability was ascribed to deficits in top-down processing. Children with TBI were surmised to rely more on inefficient bottom-up processing to produce their summaries, merely removing information from the original story rather than abstracting main ideas.

Executive Functions

The impact of impaired executive functions on functional recovery following TBI is widely documented in the literature (Richardson, 2000; Sohlberg & Mateer, 2001; Ylvisaker & Szekeres, 1989). The success of community reintegration is contingent upon executive functions more so than any other cognitive process (Sohlberg & Mateer, 2001). The communicative impairment seen in severe TBI is the result of disruption to executive processes (Ylvisaker & Szekeres, 1989). Seven aspects of executive functions critical for effective communication have been identified as 1) self-awareness and goal-setting, 2) planning, 3) self-directing/initiating, 4) self-inhibiting, 5) self-monitoring, 6) self-evaluation, and 7) flexible problem solving (Ylvisaker & Szekeres, 1989).

“Dysexecutive syndrome” is a term often used to label the impairments observed following frontal lobe damage. There is some disagreement as to whether the label accurately reflects the concept. Some have rejected the notion of a dysexecutive syndrome, citing that there is no evidence of a central executive (Stuss & Alexander, 2007). Rather, they attribute the

symptoms of dysexecutive syndrome to three separate attentional processes in the frontal lobes—initiating and sustaining attention, task-setting, and monitoring. Although these findings were derived from participants with focal frontal damage, it may have implications for TBI given the incidence of frontal involvement in TBI. Of note, however, are the similarities between the attentional processes identified in the study and the seven areas of executive function previously identified. Although the debate regarding the designation of dysexecutive syndrome is beyond the scope of this paper, the characteristics of the problem appear common to both sides of the discussion—namely, that there is a breakdown in self-regulatory processes.

Macrostructural and superstructural aspects of discourse have demonstrated sensitivity to impairments of executive functions. In a study of narrative discourse in 32 adults with TBI, there was a moderately large correlation between story grammar measures and the percentage of perseverations on the Wisconsin Card Sorting Test (WCST) but no significant correlations between the WCST and indices of productivity or cohesion (Coelho, Liles, & Duffy, 1995). In a follow-up study of 55 adults with TBI, moderate correlations were noted between WCST factors and measures of productivity, grammatical complexity, and story grammar (Coelho, 2002). Consistent with the previous study, no correlations were found between WCST and cohesion scores. Findings in the adult TBI literature are analogous to those in pediatric TBI studies. A 3-year longitudinal study of children with severe and mild TBI demonstrated the long-term consequences of TBI on discourse production and executive functions (Brookshire et al., 2000). Low-to-moderate correlations were found between the WCST and all informational measures—core propositions, gist, and story grammar. The WCST also was low-to-moderately correlated with two linguistic measures—productivity and grammatical complexity. Another measure of executive function, word fluency, was moderately correlated with core propositions and gist as

well as with grammatical complexity. There was also a low-to-moderate correlation between the Tower of London test and productivity.

Complementing studies of monologic discourse, executive functions have been examined in interactive communicative contexts. A longitudinal study of 24 individuals with TBI found modest correlations between performance on word fluency, trail making, and verbal learning tests and conversational discourse measures, as measured on the modified version of the Clinical Discourse Analysis (Damico, 1985) rating scale (Snow et al., 1998). In one study engaging close relatives as communicative partners, pragmatic ability of 43 individuals with TBI was assessed and examined in relation to measures of executive function (Douglas, 2010). The pragmatic measure of interest was the La Trobe Communication Questionnaire (LCQ), the items for which are based upon Gricean conversational maxims (Douglas et al., 2000). Executive functions were indexed using tasks of verbal fluency, new learning and manipulation of information, and efficiency of language comprehension. All three measures of executive functions were significantly correlated with LCQ ratings, and, in a subsequent regression analysis, accounted for approximately one-third of the variability in pragmatic performance. Verbal fluency scores were noted as the only significant explanatory in LCQ scores.

As a whole, the relationship between executive functions and discourse production is supported in the literature. The majority of significant findings encompassed macrolinguistic and superstructural levels of discourse. Global aspects of discourse formulation are purported to draw upon schema or structured event complexes (SECs) that direct goal-oriented behavior (Grafman, 1995), such as engaging in conversation or telling a story. From this perspective, self-regulatory processes would be critical in the achieving the goal. However, the correlational findings from the discourse literature have generally been modest in magnitude, cautioning

against attributing executive functions as the primary factor underlying impairments in discourse production. Further research is needed to identify the processes that account for the remaining variability.

In summary, examination of discourse in traumatic brain injury (TBI) can reveal subtle communicative impairments undetected on traditional language tests designed to diagnose aphasia. Linguistic abilities are relatively preserved, and the majority of people with TBI are not aphasic. However, breakdowns in discourse ability are hallmarks of the cognitive-communicative impairments of TBI. Discourse impairments have profound consequences, affecting community reintegration, work re-entry, social adjustment, and overall quality of life. Discourse deficits are persistent and often do not resolve over time. People with TBI continue to demonstrate impairments in discourse production two years post-injury and beyond. Our studies identified impaired discourse production more than three decades later (Lê, Coelho, Mozeiko, Krueger, & Grafman, 2011a). The chronicity of discourse deficits underscores the need for targeted discourse intervention. The development of meaningful, theoretically-based discourse interventions hinges upon a sound model of discourse.

However, gaps in considering cognitive factors in discourse ability currently present challenges to modeling discourse and, consequently, treating discourse impairments in individuals with TBI. Information gained from the current research has both theoretical and clinical implications. Expanding knowledge of the processes that govern discourse in TBI is critical groundwork for refitting normative discourse models to capture comprehension and production abilities across typical and brain-injured populations and for identifying potential avenues for treatment of discourse impairments.

The infrequency of aphasia in the TBI population has led researchers to search for nonlinguistic explanations for their communicative deficits (Hagen, 1981; Thomson, 1975). Therefore, a cognitive model of discourse production, representing the elements of discourse and the deployed cognitive processes, would be well-suited for explaining the deficits seen after TBI and serving as the basis for theoretically based intervention. A better understanding of discourse production in TBI would also necessitate an examination of discourse comprehension and its role in discourse production (Mar, 2004). The cognitive underpinnings of discourse production have been understudied, and the role of discourse comprehension in generating discourse is yet unknown. The limited research on factors underlying discourse production has impeded development of a discourse production model capable of explaining impairments associated with cognitive-communicative disorders. By examining specific cognitive processes and discourse comprehension, the current research study was an attempt to move the field towards a model of discourse production that is theoretically driven and potentially clinically useful in treating discourse impairments.

Cognitive Models of Discourse Comprehension

A potentially fruitful starting point for the development of a cognitive model of discourse production model would be to examine cognitive models of discourse comprehension. A caveat in investigating the cognitively-based discourse comprehension models is that the development of these models focused on representing discourse ability in neurotypical populations. Mar (2004) has provided a succinct review of three cognitive models of discourse comprehension: 1) the Construction-Integration Model (Kintsch, 1988; van Dijk & Kintsch, 1983), 2) the Immersed

Experiencer Framework (Zwaan, 2004) and 3) the Structure Building Framework (Gernsbacher, 1990).

The Construction-Integration (CI) Model (Kintsch, 1988; van Dijk & Kintsch, 1983), describes comprehension as a bottom-up process that is influenced by strategic top-down processes. In the CI model, an utterance triggers automatic and broad activation of information that is divorced from context. Higher-level control processes function inhibit irrelevant information. van Dijk and Kintsch (1983) proposed that comprehenders build three different mental models of the discourse, or text, in the process of comprehension: 1) the textbase, which represents the actual words and propositions of the discourse, 2) a semantic model, which represents the meaning of the discourse and 3) the situation model, which represents the situation or context of discourse. The situation model is the result of the integration of information in the textbase with previous knowledge held in long-term memory.

The Immersed Experiencer Framework (IEF; Zwaan, 2004) stipulates that words trigger activation of experiences with their referents. A sequence of three steps is associated with the process of comprehension: 1) incoming words activate functional webs, which are also activated in experiencing the referent, 2) functional webs are integrated in a mental simulation of the event of interest in process referred to as construal and 3) transitions from one construal to the next construal occurs in processed referred to as integration and are assumed to be experientially based (Zwaan, 2003).

Like the IEF above, the Structure Building Framework (SBF; Gernsbacher, 1990) also describes comprehension as a three-step process. First, comprehenders lay the foundation for representing incoming information. Second, new information is mapped onto the existing (activated) representation if the new information is related to information in the current

representation. Third, if new information is unrelated to the information in the activated representation, then there is a shift to build a new representation to accommodate the novel information.

Impairments of discourse production following TBI have been well studied, but no theoretical model has been empirically tested to account for the deficits (Coelho, 2007b). Even neurotypical accounts of language production are strikingly absent in the field of psycholinguistics (Garnham, 1994; Mar, 2004). Although there are a few computational models of discourse production (e.g., Davey & Longuet-Higgins, 1978; Power, 1975), the level of detail involved in such models is prohibitive for testing brain-process relationships (Mar, 2004). The Construction-Integration Model (van Dijk & Kintsch, 1983), described above as a cognitive model of discourse comprehension, has been posited by its creators to apply to discourse production as well. van Dijk (1985) proposed that discourse production begins with the situation model, from which speakers “read off” relevant propositions to construct the textbase, the actual words and utterances. Models, such as the Construction-Integration Model, focus mainly on representing discourse elements and less the *process* of generating discourse. Significantly, these discourse models fail to address the cognitive-communicative breakdowns in neurologic populations. In addition, despite several neurotypically based models of discourse comprehension, discourse comprehension following TBI has received little attention. Discourse production processes are speculated to subsume those of discourse comprehension (Cook, Chapman, & Gamino, 2007; Mar, 2004; Stein & Glenn, 1979). Such views suggest the primacy of discourse comprehension and that discourse production deficits likely reflect problems of discourse comprehension. Some have challenged this view, citing the lack of gains in production from language treatments targeting comprehension and vice versa (Ruder & Finch, 1987). For

example, a single-subject TBI treatment study found that there was limited carryover into discourse production from targeting comprehension of story grammar structures (Cannizzaro & Coelho, 2002). Whether these findings are representative of discourse in TBI remains an empirical question. As such, the relationship between comprehension and production is an ongoing topic of debate and investigation in the field (Treiman, Clifton, Meyer, & Wurm, 2003). Therefore, a model that accounts for both generative and receptive discourse processes holds promise for testing these assumptions and for explaining the nonaphasic cognitive-communicative impairments of TBI.

Requirements for a Model of Discourse Production

While a number of models explaining discourse comprehension have been proposed, no formal model of discourse production has been introduced to date that can account for the nonaphasic cognitive-communicative impairments following TBI. Extant models of discourse comprehension based on normative populations often fail to explain changes in neurologic populations while formal discourse production models are virtually absent in the literature. Challenges to the development of a discourse production model include the need for more research on discourse production itself and the complexity of discourse production, which likely subsumes comprehension processes and requires generative processes (Mar, 2004). A discourse production model applicable to TBI must consider the likely cognitive substrates of discourse ability and describe how disruption of cognitive processes leads to discourse impairments. A potential model of discourse production may be adopted from the extant models of discourse comprehension.

The Structure Building Framework. A model of discourse that merits consideration is the Structure Building Framework (SBF; Gernsbacher, 1990). The Structure Building Framework (SBF) is a cognitive discourse processing model that involves construction of mental representations (i.e., structures) through three key building processes: 1) laying a foundation, 2) mapping relevant information onto that foundation, and 3) shifting, as needed, to initiate a new substructure when incoming information is unrelated to the currently activated substructure. The SBF provides a way to understand how discourse comprehension and, potentially, discourse production may occur and how cognitive processes are marshaled specifically during discourse.

A critical assumption of the SBF is that the cognitive processes and mechanisms are domain-general and not specific to language. Two general mechanisms function in building mental structures: enhancement of relevant information and suppression of irrelevant information. Activation of memory nodes (i.e., memory cells) by incoming stimuli allows the formation of mental structures. The activated memory nodes serve as the foundation on which to build further representations. Incoming information is then mapped onto the foundation if the information is relevant to and coherent with the current mental representation. Otherwise, the activated memory nodes are suppressed and new ones are enhanced to support the new mental structure emerging from the novel stimuli.

Although the SBF does not elaborate upon the specific cognitive processes involved in building mental representations, the involvement of working memory and declarative memory is strongly implicated in the suppression and enhancement processes. It can be argued that the memory representations themselves are an activated subset of declarative memory. Prior knowledge and information about the world held in declarative memory make it an ideal candidate for the SBF's foundation on which to incorporate new information. The temporary

activation of memory representations and the mapping process in the SBF suggest the involvement of a mechanism that allows for the short-term comparisons of information necessary in language comprehension. Indeed, Oberauer and Lange (2009) has argued that language comprehension depends upon the construction and maintenance of relational representations in working memory. These representations require temporary bindings. Oberauer and Lange (2009) posit that the mechanism for these bindings is a key function of working memory. Given this specific role of working memory, suppression may be viewed as the consequence of decreased coherence in the relational representations in working memory and enhancement as the consequence increased coherence in the relational representations.

Working memory and discourse in the Structure Building Framework. Although details of WM constructs differ, there is general consensus that WM is a system for simultaneous storage and processing of information governed by executive control processes (Baddeley, 1986; Engle & Kane, 2004; Oberauer, 2005). Of the various memory processes, WM has shown the most potential in accounting for communicative impairments following TBI (Murray, Ramage, & Hopper, 2001). Enhancement and suppression control mechanisms in the SBF are central to effective structure building. The current research study posits that the SBF implicates WM involvement in temporarily storing story information for mapping onto episode structures.

The relationship between WM and discourse is an area of ongoing disambiguation in the field. Studies reflecting this debate, discussed in previous sections, are recapitulated here. In one study, story grammar measures did not correlate significantly with digit span (Youse & Coelho, 2005) although it may be argued that digit span lacks a processing component to be truly a WM task. Another study indicated that “n-back” task performance varied with narrative discourse content measures (Chapman et al., 2006). Hay and Moran (2005) found strong

correlations between WM capacity, as measured by nonword repetition and listening span tasks, and both narrative structure and content measures. However, our pilot studies have found small to moderate correlations between WM capacity, as measured by letter-number sequencing, spatial span, and digit span tasks (inclusive of backwards span tasks), and similar discourse measures (Lê, Coelho, Mozeiko, Krueger, Grafman, 2011a). WM was found to constrain comprehension of low-familiarity proverbs (Moran, Nippold, & Gillon, 2006), suggesting that reduced WM capacity affects figurative language comprehension in TBI. Individuals with TBI also perform more poorly on other language comprehension tasks with high WM loads, such as inferencing and discourse comprehension, than those with lower WM loads, such as word comprehension (Moran & Gillon, 2004).

Inferencing ability and discourse in the Structure Building Framework. In order to make appropriate inferences, one must draw on previous knowledge to compare new information. In the SBF, difficulty with inferencing may be explained by mapping new information erroneously onto unrelated substructures, which could stem from difficulty suppressing competing substructures or problems enhancing the most coherent substructure. Reports of inferencing problems are frequent in the TBI literature. Individuals with TBI have difficulty making mental (i.e., Theory of Mind) and non-mental inferences (Hinchliffe, Murdoch, & Chenery, 1998; McDonald, 1999). However, when WM demands of inferencing tasks are controlled, individuals with TBI have performed comparably to NBI participants (Moran & Gillon, 2005). The right hemisphere damage (RHD) literature may shed further insights on the relationship between WM and inferencing. Inference comprehension in RHD has correlated with WM under high but not low resource-demanding conditions (Tompkins, Bloise, Timko, & Baumgaertner, 1994). In contrast, WM has correlated with social inferencing in some studies,

but the modest magnitude of the correlations indicates that WM does not entirely account for inferencing ability (Bibby & McDonald, 2005; Turkstra, 2008). A review study found that executive functions were correlated with Theory of Mind (ToM) ability but that no singular executive process could be attributed to ToM (Aboulafia-Brakha, Christe, Martory, & Annoni, 2011). This suggests that individuals with TBI may have difficulty with inferencing apart from the WM component. As a type of inference ability, ToM requires relational representations to extrapolate mental states of others from contextual information. Although WM may not account for all the variance in ToM, it is strongly implicated in holding these representations active similar to its involvement in language comprehension.

Consistent with findings on the relationship between cognitive capacity and complex language processing (Lehman-Blake & Tompkins, 2001; Chapman et al., 2006; Just & Carpenter, 1992), this research study took the perspective that the SBF is capacity-constrained with limited available cognitive resources to form representations for comprehending and producing discourse. The current research study aimed to investigate the nature of the cognitive substrates (i.e., domain-general versus domain-specific) and the extent to which they account for discourse ability. This information is critical for understanding the mechanisms of discourse.

While the SBF originated to explain discourse comprehension, the same mechanisms are purportedly involved in discourse production (Gernsbacher, Tallent, & Bolliger, 1999). The SBF is the only cognitive model that has been applied to discourse comprehension and production in neurologic and psychiatric populations, namely right hemisphere damage (RHD) and schizophrenia. Deficient suppression has been linked to overall measures of discourse comprehension as well as resolution of inferential ambiguity following RHD (Tompkins, Lehman, & Baumgaertner, 1999; Tompkins, Lehman, Baumgaertner, & Fassbinder, 2002).

Suppression may be measured by reaction times in deciding that a dominant interpretation of word or situation is incorrect. Thus, the dominant interpretation must be suppressed. For example, Tompkins and colleagues (2002) presented two-sentence paragraph stimuli to participants in which the first sentence induced a particular inference while the second sentence induced another inference, causing participants to make an inference revision. Suppression was measured by the reaction time in deciding if a particular probe word, representing one of the inferences, fit the meaning of the paragraph.

Discourse production deficits frequently characterize schizophrenia. Neuropsychological profiles of schizophrenia reveal impairments of frontal lobe functions, much like TBI (Sanz de la Torre, Barrios, & Junqué, 2005). Therefore, insights into discourse in schizophrenia may shed light into discourse in TBI. Improper laying of the foundation for referents has provided a way to explain the tendency in schizophrenia to inappropriately introduce new referents during storytelling, and shifting without adequate mapping of relevant thematic information has been an explanation for the production of increasingly incoherent discourse in response to increasingly complex elicitation stimuli (Gernsbacher et al., 1999). Preliminary clinical application of the SBF in RHD and schizophrenia strengthens its candidacy for explaining deficits in TBI.

CHAPTER II

Motivation for the Current Study

Executive functions, such as working memory (WM), are frequently disrupted in TBI and have emerged as potential substrates of discourse (Brookshire, Levin, Song, & Zhang, 2004; Coelho, 2002; Mozeiko, Lê, Coelho, Krueger, & Grafman, 2011). A related factor in discourse ability is inferencing, an often diminished skill in TBI (Hinchliffe, Murdoch, & Chenery, 1998; McDonald, 1999). This research study aimed to investigate verbal and nonverbal WM and predictive inferencing in storytelling ability using the SBF as a potential explanatory model. The novelty of this dissertation study lies in three aspects. The first is the experimental testing of a cognitive model of discourse by examining specific cognitive and communicative factors thought to underlie narrative discourse ability. The second novel aspect is the determination of the domain-specificity of WM in relation to discourse. As discussed in previous sections, several studies have examined the role of working memory in discourse by using verbal WM tasks (Chapman et al., 2006; Youse & Coelho, 2005). Few have investigated the contribution of nonverbal WM tasks (Lê, Coelho, Mozeiko, Krueger, Grafman, 2011a). The consideration of nonverbal WM tasks in conjunction with verbal WM tasks is critical for testing the SBF's assumption that discourse draws upon domain-general cognitive processes. The third novel aspect is the analysis of discourse comprehension alongside discourse production in TBI. The examination of both discourse comprehension and production will help to define the relationship between them. Whether or not discourse comprehension and discourse production operate as one system or two parallel systems is currently an open question in the literature.

Rationale for the use of narratives and narrative discourse measures

Although conversation may seem to have greater ecologic validity, monologic discourse (i.e., non-interactive), such as story narratives, may be more clinically useful in assessing discourse in TBI. Narrative structure is pervasive in daily communication with storytelling embedded in social exchanges (Mar, 2004; Schank & Abelson, 1995). Monologic discourse measures are better predictors of social integration than either conversational or psychosocial variables, suggesting conversational tasks may not be taxing enough to ascertain the underlying cognitive-communicative skills necessary for successful community re-entry (Galski et al., 1998). Furthermore, discourse elicitation through the use of stories identifies a target outcome which serves as the standard for comparison whereas conversational tasks do not provide an equivalent archetype against which to set elicited interactions. Thus, monologic discourse affords ecologic validity and methodological advantages, which facilitate the prediction and monitoring of recovery following TBI and provide the rationale for this study's focus on narrative discourse.

Global (i.e., macrolinguistic) measures of narrative discourse are more sensitive to TBI than word- or sentence-level measures (e.g., productivity, grammatical complexity, cohesion; Coelho, 2007a; Glosser & Deser, 1991). For this reason, the current research study involved global measures of discourse organization (story grammar) and content (story completeness). Story grammar guides comprehension and expression of logical relationships (temporal and causal) between people and events (Merritt and Liles, 1987). Story grammar analysis, a global measure of narrative discourse, examines a story's organizational framework. Individuals with

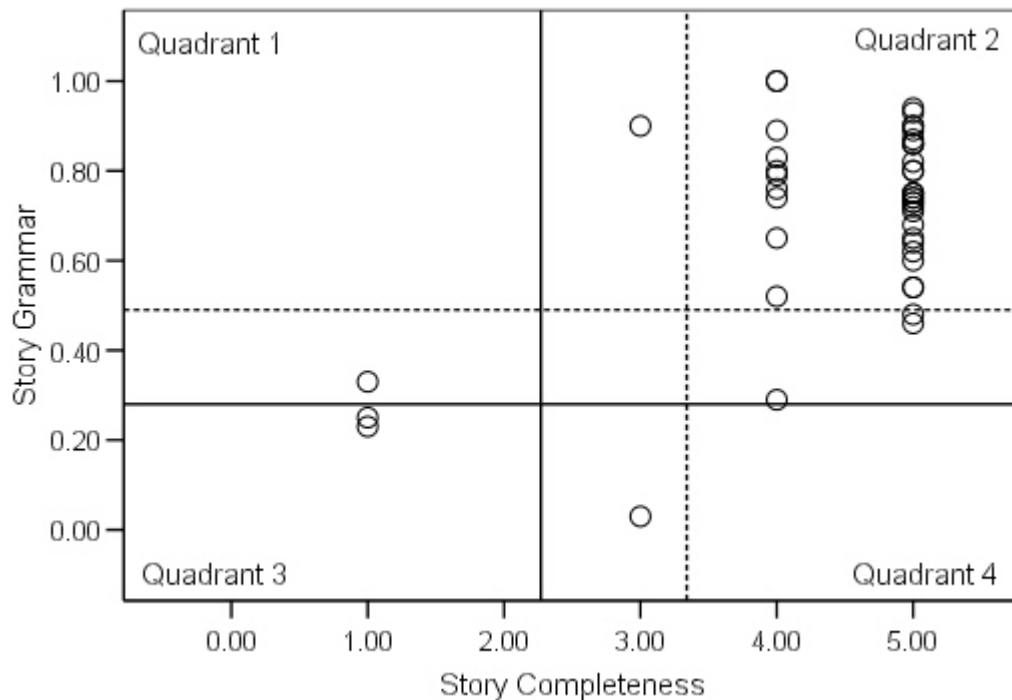
TBI consistently demonstrate difficulty with story grammar (Coelho, 2002; Hay & Moran, 2005). In addition to deficits of narrative organization, individuals with TBI often have deficient narrative content, reflected in difficulty judging importance of information and omission of critical information and relevant details (McDonald, 1993; Tucker & Hanlon, 1998).

CHAPTER III

Pilot Data

To address both aspects of narrative discourse (i.e., organization and content), pilot work for this research study included the development of a new discourse tool, called the Story Goodness Index (SGI), which combines story grammar analysis with story completeness, a new content measure (Lê, Coelho, Mozeiko & Grafman, 2011). The SGI offers a way to view a storyteller's ability to organize a story in relation to the storyteller's narrative content. A subsequent validation study of the SGI in 171 individuals with TBI and 42 non-brained-injured (NBI) comparison participants found that it was sensitive and reliable, and identified subgroups of storytelling ability (Lê, Coelho, Mozeiko, Krueger & Grafman, 2011b). Figure 1 depicts performance for the NBI group and Figure 2 the TBI group (The dashed lines and solid lines are based on NBI group performance and represent 1 SD and 2 SD below the mean, respectively). The SGI classified narrative performance into four quadrants: stories that were: 1) organized and incomplete, 2) organized and complete, 3) disorganized and incomplete, or 4) disorganized and complete. Narrative discourse performance for the TBI group was distributed across all quadrants while the NBI comparison group clustered distinctly in Quadrant 2 (organized, complete), which prompted questions as to the factors that could account for performance in producing narrative content and narrative organization.

Figure 1. Goodness of story narratives plotted as a function of story grammar and story completeness for the comparison group.



Quadrants were defined by cut-off points at 1 SD (dashed line) and 2 SD (solid line) below the mean for both story grammar and story completeness measures. Using 1 SD values, the distribution of scores was 2% in Quadrant 1, 83% in Quadrant 2, 9% in Quadrant 3, and 7% in Quadrant 4. 2 SD cut-off points resulted in 2%, 91%, 4%, and 2% in the respective quadrants. Reprinted from "Measuring Goodness of Story Narratives," by K. Lê, C. A. Coelho, J. Mozeiko, F. Krueger and J. Grafman, 2011, *Journal of Speech, Language, and Hearing Research*. Reprinted with permission.

Figure 2. Goodness of story narratives plotted as a function of story grammar and story completeness for the TBI group.

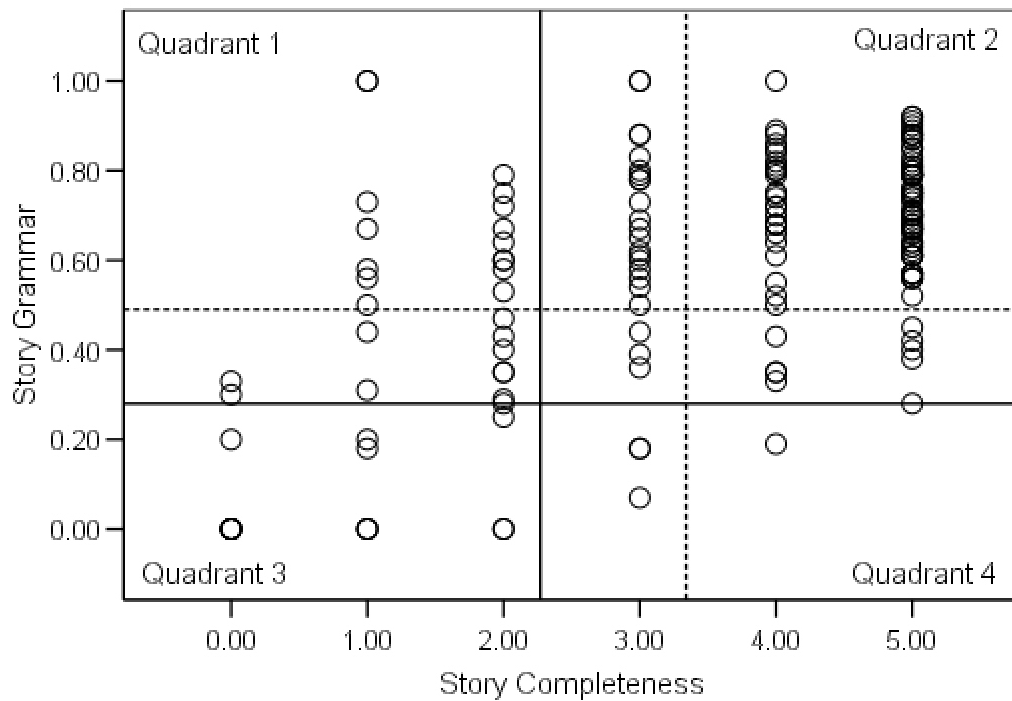


Figure 2. Goodness of story narratives plotted as a function of story grammar and story completeness for the brain-injured group. Quadrants were defined by cut-off points at 1 SD (dashed line) and 2 SD (solid line) below the mean for both story grammar and story completeness measures. Using 1 SD values, the distribution of scores was 21% in Quadrant 1, 54% in Quadrant 2, 19% in Quadrant 3, and 6% in Quadrant 4. 2 SD cut-off points resulted in 15%, 73%, 9%, and 3% in the respective quadrants. Adapted from “Measuring Goodness of Story Narratives,” by K. Lê, C. A. Coelho, J. Mozeiko, F. Krueger and J. Grafman, 2011, *Journal of Speech, Language, and Hearing Research*. Adapted with permission.

Additional previous work for this dissertation study included a follow-up study to examine the cognitive substrates of the SGI and provided pilot data for the current research study (Lê, Coelho, Mozeiko, Krueger & Grafman, 2012). The TBI group distribution across all quadrants in the validation study led to questions regarding the factors that could account for the differences in storytelling ability on the SGI. The research literature indicated that aspects of executive functions (EF) and memory would be fruitful to investigate (Chapman et al., 2006; Coelho, 2002).

In the follow-up study (Lê et al., 2012), it was hypothesized that EF and memory measures would significantly predict discourse outcomes of story completeness and story grammar. Three cognitive measures (i.e., a card sorting test that measures EF, working memory index and immediate memory index) were entered into a step-wise multiple linear regression model for each discourse measure. Two sets of regression analyses were performed, the first with the EF measure, the Sorting Test, as the first predictor and the second with it as last. The first set of regression models identified EF and immediate memory as the only significant predictors. The second set identified all cognitive variables as significant predictors.

Findings demonstrated that the cognitive variables predicted story completeness and story grammar performance although there were differences in the amount of explained variance. Since EF is thought to subsume working memory (WM) processes, entering EF as the first predictor likely negated the WM contribution when WM was entered after EF. The results suggested that discourse ability draws upon a number of underlying skills and underscored the importance of using discrete cognitive tasks rather than broad cognitive indices in identifying the cognitive substrates of discourse. Hence, specific cognitive and communicative tasks were selected for the current research study.

Purpose of the Study

The goal of this research study is to advance our knowledge of cognitive-communicative disorders following traumatic brain injury (TBI) by identifying the cognitive and communicative processes underlying discourse ability and investigating the relationship between discourse comprehension and discourse production. This research study will examine the role of verbal and nonverbal working memory (WM) and inferencing in narrative discourse and test key assumptions posited by a cognitive model of discourse, the Structure Building Framework (SBF; Gernsbacher, 1990). A central postulate of the SBF is that the cognitive processes and mechanism underlying discourse ability are domain-general rather than language-specific.

The specific questions and hypotheses of this research study are:

1. What is the contribution of working memory and inferencing to narrative discourse comprehension, as measured by a standardized test and an experimental task, in TBI?

Hypothesis 1A: Working memory and inferencing will be significant predictors of narrative discourse comprehension.

Hypothesis 1B: Given the SBF's assumption of domain-generalality, verbal working memory will not account for narrative discourse comprehension beyond that of nonverbal working memory and vice versa.

Hypothesis 1C: Inferencing will have a unique contribution to narrative discourse comprehension beyond a shared variance with working memory.

The corresponding multiple regression models and hypothesis equation statements for Question 1 are listed below:

$$\text{Discourse Comprehension Test} = b_{01} + b_{11}\text{Verbal WM} + b_{21}\text{Nonverbal WM} + b_{31}\text{Inferencing} + \square$$

$$H_0: b_{11} = b_{21} = b_{31} = 0$$

$$H_{1A}: b_{11} \neq 0, b_{21} \neq 0, b_{31} \neq 0$$

$$H_{1B}: r_{\text{verbal WM, nonverbal WM}} \neq 0 \text{ such that, if } b_{11} \neq 0, \text{ then } b_{21} = 0 \text{ and, if } b_{21} \neq 0, \text{ then } b_{11} = 0.$$

$$H_{1C}: r_{\text{verbal WM, inferencing}} \neq 0 \text{ and } r_{\text{nonverbal WM, inferencing}} \neq 0, \text{ but } b_{31} \neq 0$$

$$\text{Picture story comprehension} = b_{02} + b_{12}\text{Verbal WM} + b_{22}\text{Nonverbal WM} + b_{32}\text{Inferencing} + \square$$

$$H_0: b_{12} = b_{22} = b_{32} = 0$$

$$H_{1A}: b_{12} \neq 0, b_{22} \neq 0, b_{32} \neq 0$$

$$H_{1B}: r_{\text{verbal WM, nonverbal WM}} \neq 0 \text{ such that, if } b_{12} \neq 0, \text{ then } b_{22} = 0 \text{ and, if } b_{22} \neq 0, \text{ then } b_{12} = 0.$$

$$H_{1C}: r_{\text{verbal WM, inferencing}} \neq 0 \text{ and } r_{\text{nonverbal WM, inferencing}} \neq 0, \text{ but } b_{32} \neq 0$$

2. What is the contribution of working memory and inferencing to narrative discourse production, as measured by story grammar and story completeness, in TBI?

Hypothesis 2A: Working memory and inferencing will be significant predictors of narrative discourse production.

Hypothesis 2B: Given the SBF's assumption of domain-generalty, verbal working memory will not account for narrative discourse production beyond that of nonverbal working memory and vice versa.

Hypothesis 2C: Working memory will carry a greater portion of the overall variance in story completeness compared to story grammar given that deficits on story completeness reflect problems activating memory nodes for mapping narrative information in the SBF. Inferencing will carry a greater portion of the variance for story grammar than for story completeness given that difficulty creating temporal and causal links involved in story grammar reflect problems with laying the foundation and shifting to form new substructures in SBF.

The corresponding multiple regression models and hypothesis equation statements for Question 2 are listed below:

Story completeness = $b_{03} + b_{13}\text{Verbal WM} + b_{23}\text{Nonverbal WM} + b_{33}\text{Inferencing} + \square$

H_0 : $b_{13} = b_{23} = b_{33} = 0$

H_{2A} : $b_{13} \neq 0, b_{23} \neq 0, b_{33} \neq 0$

H_{2B} : $r_{\text{verbal WM}, \text{nonverbal WM}} \neq 0$ such that, if $b_{13} \neq 0$, then $b_{23} = 0$ and, if $b_{23} \neq 0$, then $b_{13} = 0$.

H_{2C} : $b_{13} + b_{23} > b_{14} + b_{24}$

Story grammar = $b_{04} + b_{14}\text{Verbal WM} + b_{24}\text{Nonverbal WM} + b_{34}\text{Inferencing} + \square$

H_0 : $b_{14} = b_{24} = b_{34} = 0$

H_{2A} : $b_{14} \neq 0, b_{24} \neq 0, b_{34} \neq 0$

H_{2B} : $r_{\text{verbal WM}, \text{nonverbal WM}} \neq 0$ such that, if $b_{14} \neq 0$, then $b_{24} = 0$ and, if $b_{24} \neq 0$, then $b_{14} = 0$.

H_{2C} : $b_{34} > b_{33}$

3. What is the extent to which narrative discourse comprehension accounts for narrative production as measured in this study in TBI?

Hypothesis 3A: Narrative discourse comprehension will be significant predictors for story grammar and story completeness given that the SBF applies to both narrative discourse comprehension and narrative discourse production.

Hypothesis 3B: The amount of variance in narrative discourse production explained by narrative discourse comprehension will be small to moderate given that pilot studies support the notion that discourse comprehension and production may operate as two parallel systems that draw upon the same cognitive processes but to differing degrees.

The corresponding multiple regression models and hypothesis equation statements for Question 3 are listed below:

Story completeness = $b_{05} + b_{15}\text{Discourse Comprehension Test} + b_{25}\text{Picture story comprehension} + \square$

$H_0: b_{15} = b_{25} = 0$

$H_{3A}: b_{15} \neq 0, b_{25} \neq 0$

$H_{3B}: R^2 \leq .25$

Story grammar = $b_{06} + b_{16}$ Discourse Comprehension Test + b_{26} Picture story comprehension + \square

$$H_0: b_{16} = b_{26} = 0$$

$$H_{3A}: b_{16} \neq 0, b_{26} \neq 0$$

$$H_{3B}: R^2 \leq .25$$

CHAPTER IV

Methods

Methodological Overview

This research study employed multiple regression analyses to address three specific aims. The study involved one TBI cohort and one cohort of non-brain-injured (NBI) participants matched for age and education. All participants completed two working memory (WM) tasks, one inferencing task, two narrative discourse comprehension tasks and one discourse production task (analyzed using two measures). Altogether, there were seven measures of interest in the study that are described in detail in this chapter. Analysis 1 addressed Hypothesis 1: *What is the contribution of working memory and inferencing to narrative discourse comprehension as measured by a standardized test and an experimental task in TBI?* and examined verbal and nonverbal WM and inferencing as predictors for narrative discourse comprehension. Analysis 2 addressed Hypothesis 2: *What is the contribution of working memory and inferencing to narrative discourse production as measured by story grammar and story completeness in TBI?* and examined verbal and nonverbal WM and inferencing as predictors for narrative discourse production. Analysis 3 addressed Hypothesis 3: *What is the extent to which narrative discourse comprehension accounts for narrative production as measured in this study in TBI?* and evaluated narrative discourse comprehension tasks as predictors for performance on discourse production tasks.

Participants

There were 44 participants in total in this research study divided into two cohorts: 21 individuals with TBI and 23 NBI comparison participants. All participants were monolingual native English speakers, screened for hearing acuity, visual acuity and visual perceptual deficits. In order to qualify for the study, all participants must have been 16 years of age or older. The goal of the research study was to understand the cognitive and communicative processes underlying discourse ability in adults with TBI. As such, the research questions investigated the consequences of TBI on relatively mature networks of the linguistic and cognitive systems. At age 16 and beyond, individuals are capable of performing sophisticated analyses when presented with narratives, such as generalizing story meaning or extrapolating abstract themes (Larson & McKinley, 1987). Because of this, children ages 15 and younger were excluded from the study as their development of the linguistic and cognitive systems relative to narratives is ongoing. Additionally, individuals were excluded if there was a significant history of other neurological (e.g., stroke, dementia) or psychiatric illness or if there was presence of a significant motor speech disorder as determined by a speech-language pathologist.

Aside from the requirement that human subjects be, at least, young adults, participants were not excluded on the basis of age, gender, race, and ethnic background. The aim for gender representation in the sample for this study was to achieve equivalence to that in the TBI population in Connecticut, which has approximately a 2:1 ratio of males to females with TBI (CT Department of Public Health, n.d.).

Since the mechanism of penetrating heading injury (PHI) is different from closed head injury (CHI) and typically results in focal brain injury and since CHI is more representative of

civilian TBI, individuals with PHI were excluded. Although the participants in pilot studies for the current study had PHI, their injuries were due to multi-focal lesions caused by projectile shrapnel. Their injuries were distributed throughout the brain paralleling the diffuse damage in CHI. The focal nature of civilian PHIs is distinct from the PHIs in the pilot studies.

Screening Procedures. Visual acuity was screened using a Snellen chart. A pass was considered 20/30 vision with or without corrective lenses. Participants were asked regarding the presence of color blindness. A pass was considered a “no” answer. Visual perceptual deficits were screened using the picture description task from the Western Aphasia Battery-Revised (WAB-R; Kertesz, 2006). Individuals had to provide descriptions of characters, objects and actions in all four quadrants of the picture. Hearing was screened using a portable audiometer with testing at 500, 1000, 2000 and 4000 Hz. A pass was considered 35dB HL or less at 500 and 1000 Hz and 40 dB or less at 2000 and 4000 Hz in the better ear. A mild hearing loss was acceptable since no task in the study depended on the auditory modality alone. Language abilities were screened using the WAB-R (Kertesz, 2006) to ensure adequate auditory comprehension and verbal expression.

Participants with traumatic brain injury. In order to qualify for the TBI cohort, participants with must have met the following criteria:

- a) Positive history of a single closed-head-injury as determined by medical record and be, at least, 3-months post-injury. Individuals who were less than 3-months post-injury were judged to be too acute in the recovery phase to participate.
- b) Ranchos Los Amigos Level of Cognitive Functioning Scale - Revised (LCFS; Hagen, 1998) of VII (automatic-appropriate) or above; individuals scoring below RLA VII were not included since they are characterized as confused and inconsistently oriented to time

and place and, thus, unlikely to have understood the experimental tasks. The LCFS was useful because it provided an additional measure of severity that reflected current cognitive functioning relative to activities of daily living as opposed to initial injury severity.

c) Galveston Orientation and Amnesia Test (GOAT; Levin, O'Donnell, & Grossman, 1979) score of 75 or above to ensure participants were not experiencing post-traumatic amnesia and to screen for dementia.

d) Aphasia Quotient (A.Q.) above 93 on the Western Aphasia Battery - Revised (WAB-R; Kertesz, 2006) to rule out presence of aphasia.

Where available, scores from the Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) were reported to estimate level of TBI severity at the time of injury or in the acute stages of recovery. In one case, one individual was 39 years post-onset of TBI, and medical records were not available. In this instance, the participant self-reported the circumstances of the TBI, which involved ejection through the windshield of car during a motor vehicle accident followed by loss of consciousness for three to four days. Family members confirmed this individual's reports of the accident, and it was determined that the individual fit the criteria for inclusion in the study.

The TBI group comprised 15 males and 6 females, ranging from 20 to 68 years of age with an average age of 39.19 years. Demographic characteristics of the participants with TBI are presented in Table 1, and injury-related characteristics are presented in Table 2. Time post-onset ranged from 5 months to 471 months (39.25 years) with a mean of 103 months (8.60 years). Causes of injury were primarily due to motor vehicle accidents (13 participants). Three participants sustained TBIs from falls. Three participants incurred TBIs from unintentional blunt trauma, comprising a skiing accident, a weight-lifting accident and person-to-person collision.

Assault accounted for the injuries of two participants. Sixteen individuals identified as Caucasian, four as African-American and one as Hispanic. Education ranged from 12 to 21 years with a mean educational level of 15.10 years.

GCS scores were not consistently reported in the medical record and were only available for 8 individuals and ranged from 3 to 15. Loss of consciousness (LOC) was quite variable with some individuals experiencing no LOC while the greatest duration of LOC was 90 days. Likewise, post-traumatic amnesia (PTA) was also variable across the TBI group. Nine participants had no PTA. For those with PTA, durations ranged from less than 24 hours to approximately one year. LCFS scores varied from 7 to 10 with a mean of 8.95. GOAT scores were well above levels that would indicate amnesia or dementia, ranging from 85-100 with a mean of 97.62. Performance on the WAB-R ranged from 94.8 to 100 with a mean of 98.39.

Table 1				
<i>Demographic Characteristics of Participants with Traumatic Brain Injury</i>				
Participant	Age (Years)	Sex	Education (Years)	Race/Ethnicity
1	31	M	18	Caucasian
2	27	M	14	Caucasian
3	37	F	18	Caucasian
4	29	M	12	Caucasian
5	20	M	14	Caucasian
6	28	M	18	African-American
7	26	M	13	African-American
8	28	M	13	Caucasian
9	56	M	17	Caucasian
10	43	F	16	Caucasian
11	42	M	14	Caucasian
12	41	M	21	Caucasian
13	32	M	13	Hispanic
14	50	M	14	Caucasian
15	28	M	12	African-American
16	68	F	13	African-American
17	35	F	16	Caucasian
18	49	F	12	Caucasian
19	54	F	17	Caucasian
20	37	M	20	Caucasian
21	62	M	12	Caucasian
Range	20-88		12-21	
Mean	39.19		15.10	

Note. Education was measured as the total number of years of education, regardless of degree completion.

Table 2

Injury-Related Characteristics of Participants with Traumatic Brain Injury

Participant	Time post-onset (Months)	GCS	LOC	PTA	LCFS	GOAT	Cause of injury and injury characteristics
1	43	3	7 days	42 days	10	100	MVA – R frontal SAH
2	86	5	21 days	120 days	7	85	MVA – L frontal & R temporal contusions
3	213	NA	5 days	None	10	100	MVA – NS
4	134	6	28 days	150 days	7	88	Unintentional blunt trauma – R frontal & R parietal
5	41	4	10 days	63 days	9	95	MVA – NS
6	16	NA	None	None	10	100	Unintentional blunt trauma – NS
7	9	NA	Yes, NS	35 days	10	100	MVA – NS
8	45	NA	42 days	365 days	7	95	MVA – hematoma, location NS
9	15	14	<1 hr	4 days	9	100	Fall – R SAH, L epidural hematoma
10	82	13	5 min	8 days	9	99	MVA – R contusion, bifrontal SAH
11	10	3	10 days	21 days	8	100	MVA – R hematoma, R SDH
12	210	NA	<24 hr	30 days	10	100	Assault – L occipital subarachnoid contusion
13	6	15	None	<24 hr	8	100	Fall – R epidural hematoma & SDH
14	364	NA	90 days	None	9	100	MVA – frontal
15	9	NA	26 days	None	9	100	Assault – NS
16	5	NA	None	None	10	99	Fall – NS
17	11	NA	<5 min	<24 hr	10	100	Unintentional blunt trauma – R frontal contusion
18	383	NA	48 days	None	7	100	MVA – NS
19	5	NA	<5 min	None	9	95	MVA – NS
20	7	NA	<1 min	None	10	99	MVA – NS
21	471	NA	4 days	None	10	95	MVA – NS
Range	5-471				7-10	85-100	
Mean	103.10				8.95	97.62	

Note. GCS = Glasgow Coma Scale (Teasdale & Jennett, 1974); LOC = Loss of consciousness; PTA = Duration of post-traumatic amnesia; LCFS = Ranchos Los Amigos Level of Cognitive Functioning Scale – Revised (Hagen, 1998); NA = Not available, NS = Not specified, L = left, R = right, MVA = Motor vehicle accident, SAH = subarachnoid hemorrhage, SDH = subdural hemorrhage.

Non-brain-injured comparison participants. The NBI comparison group had no history of speech and language disorders. Efforts were made to individually match the NBI participants as closely as possible according to age and education to the participants with TBI and to group match the cohorts according to gender and race.

The NBI group comprised 11 males and 12 females, ranging from 18 to 67 years of age with an average age of 35.48 years. Demographic characteristics of the NBI comparison participants are presented in Table 2. There were 21 individuals who identified as Caucasian and two individuals who identified as African-American. Education ranged from 12 to 18 years with a mean educational level of 13.78 years. Performance on the WAB-R ranged from 97.2 to 100 with a mean of 99.3.

Comparison of Participant Groups. Demographic variables between the TBI and NBI groups were compared using independent samples *t*-tests (Table 3). There were no significant differences in age or education. There was statistically significant difference on the WAB-R. However, the means of the group differed by less than one point. Both the TBI and NBI groups scored quite high on the WAB-R as neither group was expected to have fundamental linguistic deficits. Examination of WAB-R subtest scores revealed that mean subtest scores differed by less than one point between groups with the exception of the word fluency task where the difference between groups was 1.62 points. Of all the tasks, the word fluency task on the WAB-R is arguably the most cognitively demanding as word fluency is purported to involve a number of cognitive domains and processes, including semantic memory, working memory and speed of processing (Daneman, 1991; Henry, Crawford, Philips, 2004; Shao, Janse, Visser, & Meyer, 2014), which can all be disrupted following TBI. The clinical significance of the difference between groups on the WAB-R is very small from a linguistic standpoint and very likely

reflected differences in underlying cognitive abilities rather than differences in fundamental linguistic ability.

Table 2				
<i>Demographic Characteristics of Non-Brain-Injured Comparison Participants</i>				
Participant	Age (Years)	Sex	Education (Years)	Race/Ethnicity
1	22	F	15	Caucasian
2	35	M	16	Caucasian
3	58	F	12	Caucasian
4	44	F	16	Caucasian
5	18	F	12	Caucasian
6	58	F	18	Caucasian
7	19	M	12	Caucasian
8	18	M	12	African-American
9	19	F	13	Caucasian
10	19	F	13	Caucasian
11	23	M	16	African-American
12	20	M	13	Caucasian
13	34	F	18	Caucasian
14	29	M	12	Caucasian
15	23	F	12	Caucasian
16	45	F	12	Caucasian
17	47	F	12	Caucasian
18	62	M	13	Caucasian
19	49	M	12	Caucasian
20	39	M	16	Caucasian
21	35	M	18	Caucasian
22	33	M	12	Caucasian
23	67	F	12	Caucasian
Range	18-67		12-18	
Mean	35.48		13.78	

Table 3

Demographic Data for Matched Groups

Measure	TBI			NBI				
	<i>M</i>	<i>SD</i>	Range	<i>M</i>	<i>SD</i>	Range	<i>df</i>	<i>P</i>
Age (Years)	39.19	13.05	20-88	35.48	15.68	18-67	42	.40
Education (Years)	15.10	2.77	12-21	13.78	2.26	12-18	42	.09
LCFS	8.95	1.16	7-10					
GOAT	97.86	4.19	85-100					
WAB-R	98.39	1.50	94.80-100	99.27	.86	97.20-100	42	.02

Note. LCFS = Ranchos Los Amigos Level of Cognitive Functioning Scale – Revised (Hagen, 1998); GOAT = Galveston Orientation and Amnesia Test (Levin, O’Donnell & Grossman, 1979); WAB-R = Western Aphasia Battery – Revised (Kertesz, 2006).

Use of Human Subjects. This study was approved by the Institutional Review Board (IRB) at the University of Connecticut under protocol #H12-206HH. The Cooperative Agreement between the University of Connecticut and Hartford Hospital allowed for the University of Connecticut to stand as the IRB of record for aspects of the research study involving Hartford Hospital. A separate agreement was secured between the University of Connecticut and the University of Connecticut Health Center (UCHC) to allow for recruitment at the Hospital for Special Care for which the UCHC IRB stands as the IRB of record.

Non-brain-injured (NBI) participants were recruited through friends and family members of participants with TBI, community members and the University of Connecticut. Friends and family members of participants were recruited because they often represent the best comparison participants in that friends and family members often share similar backgrounds and upbringing. Thus, in this way, they are often “experience-matched” to participants with TBI. Participants

with TBI were recruited from Hartford Hospital in Hartford, CT, the Hospital for Special Care in New Britain, CT and the Brain Injury Alliance of Connecticut (BIAC). IRB-approved announcements were posted on the BIAC website and sent via campus e-mail at the university. IRB-approved flyers were distributed to colleagues and individuals who expressed interest in the study.

Participants were compensated thirty dollars for completion of the study, five dollars for the screening procedures and twenty-five dollars for the core study tasks.

Procedure

Data collection. All data for each participant were collected in approximately 2.5-3 hours over one to three sessions with breaks. The examiner who conducted all sessions was a licensed speech-language pathologist with clinical experience working with individuals with neurogenic communication disorders. There were two parts to the research study: 1) screening procedures and 2) core study procedures in which participants carried out the memory and story tasks. Sessions occurred within approximately one week of each other to control for potential changes in TBI recovery given longer intervals. Core study procedures were counter-balanced to control for order effects with participants in each group randomly assigned to one of two task presentation sequences.

Core study tasks were presented using E-Prime software on a laptop computer with a 15.5 inch screen display. Testing took place in a quiet room typically in the participant's home. Some participants were tested in a quiet room in a local library or in the Department of Speech,

Language and Hearing Sciences at the University of Connecticut. All sessions were audio- and video-recorded.

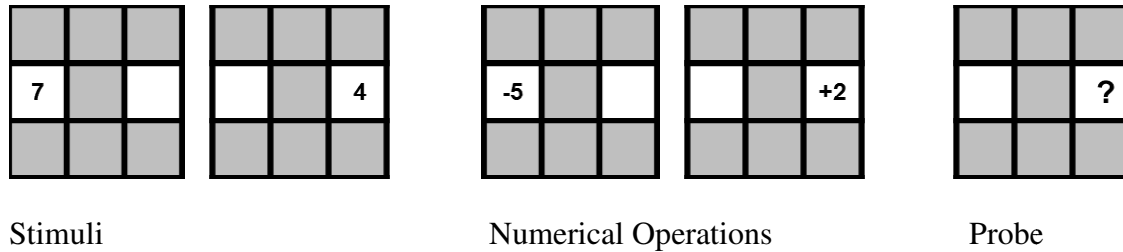
Stimuli

Working memory. Working memory (WM) was measured with WM updating tasks, which involve storage and revision of information. WM updating is highly correlated with complex WM span tasks and intelligence measures (Friedman et al., 2006; Schmiedek, Hildebrandt, Lövdén, Wilhelm, & Lindenberger, 2009). WM updating allows for the use of parallel versions of the task that differ only in domain. Performance differences between versions may then be related to domain rather than other task parameters.

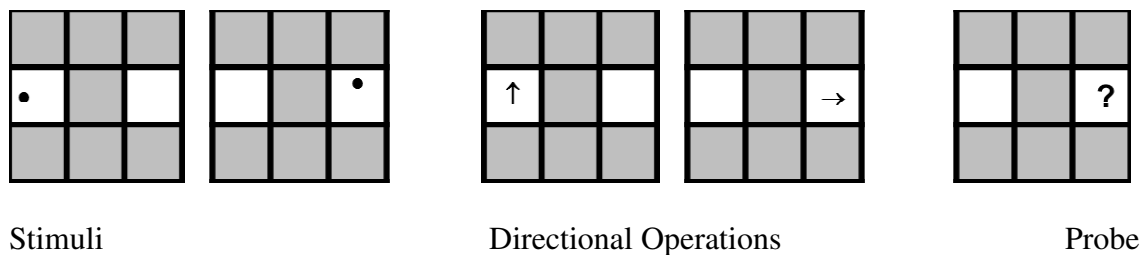
The WM updating task used in this study was an adaptation by Oberauer and colleagues (2000; Figure 3) from Salthouse, Babcock, and Shaw (1991) with permission granted by Dr. Oberauer. There were two versions of the WM updating task, verbal and nonverbal. Participants in the study by Oberauer and colleagues (2000) were neurotypical, and mean accuracy on the verbal WM task was 72% and on the nonverbal WM task was 52%. Given the difficulty of the task for the neurotypical participants, the WM updating task was modified in this study to ensure feasibility of administration to participants with traumatic brain injury. Modifications to the task are specified below.

Figure 3. Examples of working memory updating tasks

Verbal (numerical) version



Nonverbal (spatial) version



Stimuli were presented on a 3x3 grid on a computer. “Active” cells contained stimuli; inactive cells were grey blocks. For each item in the verbal (numeric) version, numbers were presented successively in each active cell. Then, a new grid appeared with numerical operations (e.g., +1, -4) in selected active cells. Each operation was performed on the value within that cell. The number of operations per cell varied for each item presentation. Participants then reported the final value of a selected probe cell by pressing a computer key. In the original task, two to three probes were used depending on the number of active cells. The WM updating task for this study employed one to three probes given a modification of an additional set of items that was added in which there was only one active cell. An item with one active cell could only have one probe. In the nonverbal (spatial) version, dots appeared in one of nine positions in a cell. The

operation involved mentally moving the dot to a new location as cued by a directional arrow. Probes involved reporting the final dot position. In the original task, stimuli were presented for 1300 ms. In the current study, stimuli were presented for 2000 ms. Interstimulus interval (ISI) was not specified in the original task by Oberauer and colleagues. Selection of the ISI for this study was based on Hancock and colleague's (2007) examination of different ISI levels on working memory performance in older adults. 1500 ms was selected as the ISI since 1) longer ISIs were found to result in greater accuracy and 2) ceiling effects were not expected to be as prevalent compared to longer ISIs.

Each version of the WM task, verbal and nonverbal, had two practice trials and 20 test items divided into four sets of five items each. Participants did not have to meet a specific accuracy criterion to proceed to the experimental trials. As mentioned, an additional set of items was included with the original three sets over concerns that beginning the task with two active cells would be too challenging for some participants with TBI. As such, a new set was added that contained only one active cell. The number of active cells (i.e., cells that contained stimuli) and operations were calibrated a priori to ensure items were equated in difficulty in the original study (Oberauer et al., 2000). The addition of the fourth set with a single active cell to both verbal and nonverbal versions was not considered a significant threat to the calibration of items. In the verbal version, Set I had once active cell (one to five operations), Set II had two active cells (two to six operations), Set III had four active cells (one to five operations) and Set IV had six active cells (one to three operations). In the nonverbal version, Set I had once active cell (one to five operations), Set II had two active cells (two to six operations), Set III had three active cells (one to five operations) and Set IV had four active cells (one to three operations). There were a total of 45 probes. The WM score was the percentage of correct responses on each

version.

Predictive inferencing. Inferencing was measured using Moran and Gillon's (2005; Figure 4) adaptation of Lehman-Blake and Tompkins's (2001) predictive inferencing task. Use and adaptation of stimuli was granted by Dr. Lehman-Blake. The task consisted of seven sets of short stories of familiar activities (e.g., cleaning house). Each set contained three versions of the story: 1) Distant, 2) Recent and 3) Control. The Distant and Recent stories each contained four sentences: three related to setting and a predictive sentence suggesting a particular outcome. In the Distant condition, the predictive sentence was the second sentence in the story. In the Recent condition, the predictive sentence was the last sentence in the story, immediately preceding the probe question. As such, the Distant condition required longer storage of the inference than in the Recent condition. The Control stories contained four sentences and no predictive sentence. The last sentence in the Control condition contained the outcome. Twenty-six filler stories of the same length that did not have predictive sentences were also randomly presented. The filler stories were used to deter participants from identifying patterns in the stories. There were 47 stories altogether, 21 experimental stories and the 26 filler stories. The 47 stories were divided into two sets, one with 23 stories and the other with 24 stories. Each set was further divided into subsets, one with 11 stories and the others with 12 stories. Story presentation was randomized with the condition that no two experimental versions appeared in the same subset.

Participants were provided with the text of each story to follow along on a computer. Each story was presented sentence by sentence, and participants were allowed to self-pace through each sentence presentation. Stories were simultaneously read aloud to participants via corresponding audio clip for each sentence. Immediately after story presentation, participants were asked to answer a question regarding what they expected to occur or what had occurred.

Number of correct answers for the stories with a predictive sentence served as the total inferencing score. Subscores were obtained for the Distant and Recent conditions.

Figure 4. Example of predicting inference task stimuli

Distant	Recent	Control
1) Mary had spent the day organizing her new desk (Setting).	1) Jill had spent the day organizing her new desk (Setting).	1) Susan had spent the day organizing her new desk (Setting).
2) She took out a piece of paper and a pen (Predictive).	2) She wanted to let her brother know about her promotion (Setting).	2) She wanted to let her brother know about her promotion (Setting).
3) She wanted to let her brother know about her promotion (Setting).	3) Jill knew he would be happy for her (Setting).	3) Susan knew he would be happy for her (Setting).
4) Mary knew he would be happy for her (Setting).	4) She took out a piece of paper and a pen (Predictive).	4) Susan called her brother and told him all about her new position.
Question: How did _____ let her brother know about her promotion?		

Discourse comprehension. Discourse comprehension was measured using the Discourse Comprehension Test (DCT; Brookshire & Nicholas, 1993), which is a valid, reliable standardized measure developed for use in neurologic populations that is sensitive to deficits of narrative processing (Kennedy & Nawrocki, 2003; Nicholas & Brookshire, 1995). Stories and questions are controlled for a number of variables, including number of words and sentences, grammatical complexity, listening difficulty, and passage dependency. The DCT included five pre-recorded stories with eight yes/no questions that require information varying in salience (main ideas vs. details) and explicitness (stated vs. implied information). There were two questions each requesting 1) stated main ideas, 2) implied main ideas, 3) stated details, and 4) implied details. WM scores have correlated with both the DCT inference score and overall

performance (Monetta, Grindrod, & Pell, 2008; Welland, Lubinski, Higginbotham, 2002). A DCT adaptation using longer stories was sensitive to inferencing deficits in TBI (Ferstl, Walther, Guthke, von Cramon, 2005). However, in a study of right-hemisphere damage (Tompkins, Meigh, Scott, Lederer, 2009), DCT performance did not correlate with high-level inferencing ability, suggesting that the DCT may not be sensitive to certain types of complex inferencing impairments. In pilot studies leading up to this current research study, the TBI group performed comparably to the NBI group on the overall DCT score and each question set (Lê, Coelho, & Grafman, 2011). These results implied that individuals with TBI do not have difficulty with discourse comprehension, as measured by the DCT.

A picture story comprehension measure was administered using visual stimuli with no words, similar to that for the discourse production task. A different picture story, *Sector 7* (Wiesner, 1999), comparable to the story retelling stimulus (used in the discourse production task) in number of frames (16), main characters, visual complexity and events was used for the discourse comprehension task. Like the story retelling stimulus, *Sector 7* contained surreal and absurd elements. The picture story in this task centered upon a boy who is befriended by a cloud on top of skyscraper on a school field trip and is subsequently transported to a cloud-making factory where he disrupts the order of business. Participants were allowed to self-pace viewing of the picture story. The picture story task provided a comprehension measure applicable to the production task. Comprehension questions regarding the story retelling stimulus were not posed to participants to control for possible “contamination” between comprehension and production processes as the influence between these processes is not yet well understood. Answering comprehension questions regarding a story may influence its subsequent retelling and vice versa.

Twenty questions were developed similar in construction to those of the DCT, varying in

salience and explicitness and controlled for number of words, number of unfamiliar words, grammatical complexity and stimulus dependency. Questions addressed characters and events and tapped story grammar knowledge and were presented in the same sequence as information in the stories. Picture stimuli were removed when questions were presented. No questions provide cues for answering subsequent questions.

Discourse production. For discourse production, participants were shown a 16-frame picture story, *Old MacDonald Had An Apartment House* (Barrett, 1998), with no soundtrack on a computer screen. The story was the same as that used for the original development of the Story Goodness Index (SGI) and involved the horticultural antics of a farmer dwelling in an urban setting. Participants were allowed to self-pace through the story. Immediately upon completion of viewing the story, each participant retold the story without picture stimuli present. Each retelling was video- and audio-recorded, transcribed and segmented into T-units (i.e., minimal terminable units). Narratives were analyzed along two dimensions—organization (story grammar) and content (story completeness)—using the SGI protocol. Story grammar analysis provided the measure of narrative organization. The analysis was a two-step process based on Merritt and Liles' adaptation of story grammar analysis (1987). First, the number of episodes was ascertained. A complete episode consisted of 1) an initiating event prompting a character to act, 2) an attempt related to the initiating event, and 3) a direct consequence of the attempt. A partial episode consisted of two of the three episode components. The second step determined the proportion of T-units within episode structure, calculated as the number of T-units within episodes divided by the total number of T-units in retelling. The possible score range was 0 to 1.00. The proportion measure is a well-established measure of organization in narrative discourse (Coelho, 2002).

For story completeness, an inventory of key components (events and characters) was created for each NBI participant. The inventories were pooled into a matrix to identify the critical components, defined as components mentioned by 80% or more of the NBI group. In the pilot studies, five critical components were identified. The same five critical components were identified in this research study. All narratives from both NBI and TBI groups were then reviewed for the presence of the critical components. The total number of critical components produced in each story was the story completeness score with possible scores ranging from 0 to 5. Plotted together, the story grammar and story completeness scores depicted story goodness performance.

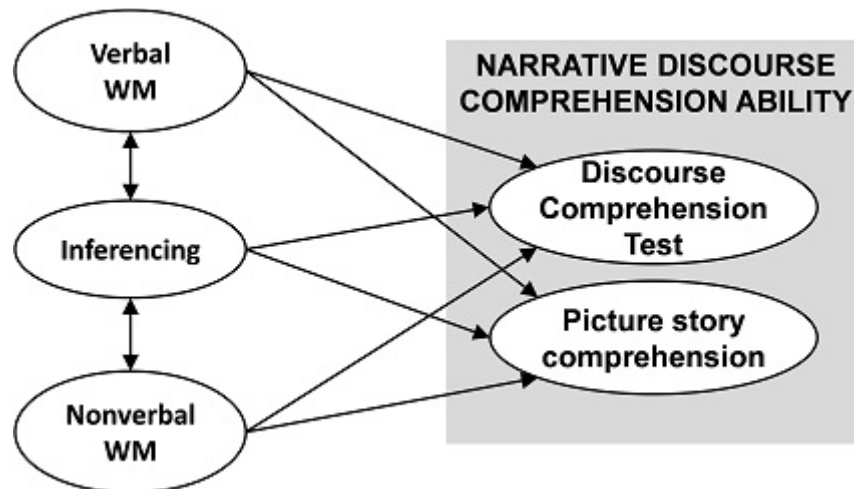
More than ten percent of transcripts ($n = 6$) were re-examined to obtain intra- and inter-rater reliability data. Point-to-point intra-rater reliability and inter-rater reliability for the story grammar measure was 92% and 83%, respectively. For the story completeness measure, intra-rater reliability and inter-rater reliability were 100% and 93%, respectively. In pilot studies, intra- and inter-rater reliability for the story grammar measure was 90% and 84%, respectively, and those for the completeness measure were each 100% (Lê, Coelho, Mozeiko & Grafman, 2011). The reliability scores for the story grammar and story completeness measures for the current study are comparable to those obtained in earlier studies.

Data Analyses

Analysis 1: Working memory (WM) and inferencing in narrative discourse

comprehension. Analysis 1 examined the role of WM and inferencing in understanding narrative discourse in TBI relative to three objectives: 1) determine the contribution of WM and inferencing to discourse comprehension, as measured by the Discourse Comprehension Test (DCT) and picture story comprehension, 2) test the Structure Building Framework (SBF; Gernsbacher, 1990) hypothesis that discourse comprehension draws upon domain-general cognitive processes by examining verbal and nonverbal WM in their relationship to discourse comprehension, 3) examine the extent to which inferencing predicts discourse comprehension over and above the contribution of WM (Figure 5).

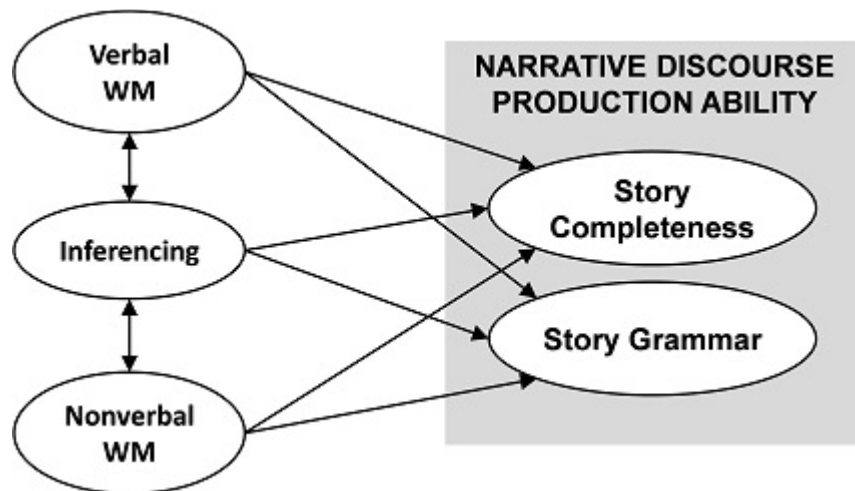
Figure 5. Conceptual model for Analysis 1



Analysis 2: Working memory (WM) and inferencing in narrative discourse

production. Analysis 2 examined the role of WM and inferencing in producing narrative discourse in TBI with the following objectives: 1) determine the contribution of WM and inferencing to story grammar and story completeness, 2) test the SBF hypothesis that discourse production draws upon domain-general cognitive processes by examining both verbal and non-verbal WM tasks in their relationship to discourse production, and 3) examine the extent to which inferencing predicts discourse production over and above the contribution of WM (Figure 6).

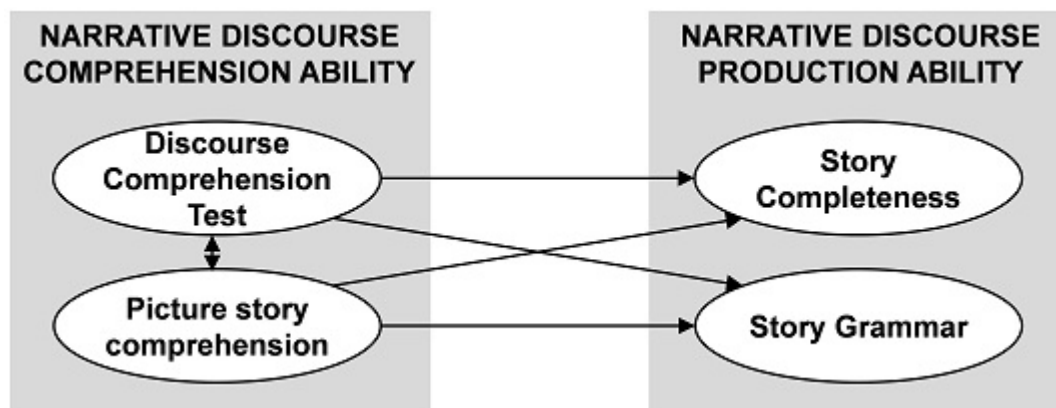
Figure 6. Conceptual model for Analysis 2



Analysis 3: Relationship between discourse comprehension and discourse production.

Analysis 3 examined the contribution of narrative discourse comprehension to narrative discourse production with the following objectives: 1) determine whether discourse comprehension and production were impaired and examine whether production deficits in story completeness and story grammar could occur without comprehension deficits, and 2) examine the relationship between discourse comprehension and discourse production measures. Scores from the DCT and picture story comprehension task were used to predict performance on story grammar and story completeness. In summary, Analysis 3 investigated the extent to which discourse comprehension predicted discourse production outcomes (Figure 7).

Figure 7. Conceptual model for Analysis 3



Statistical Analyses. Statistical analyses were performed with Predictive Analytics SoftWare (PASW) Statistics 18 software. T-tests were used to evaluate for differences between the TBI and NBI groups on the screening procedures (Table 3). T-tests were also used to determine differences between groups on the core study measures with the exception of the predictive inferencing task. Because multiple measures were obtained from the predictive inferencing task, a MANOVA was first performed to assess for differences between groups overall followed by examination of individual ANOVAs of the different measures. Pearson product-moment correlations were performed for predictors and outcome variables. The primary statistical analyses to address the central questions of this study were accomplished using multiple regression analysis.

CHAPTER V

Results

Descriptive Statistics

Working memory measures. The scoring range for each working memory measure was 0 to 45. Scores for WMU-V, the verbal version of the working memory updating task, and WMU-NV, the nonverbal version of the working memory updating task, are presented in Table 4.

TBI Group. The mean for WMU-V for the participants with TBI was 29.95 ($SD = 9.37$; Table 4). The mean for WMU-NV for the TBI group was 17.81 ($SD = 6.23$).

NBI Group. The mean for WMU-V for the NBI comparison participants was 34.39 ($SD = 6.62$; Table 4). The mean for WMU-NV for the NBI group was 21.04 ($SD = 8.78$).

Predictive inference measure. There were four measures of interest from the predictive inferencing (PI) task (Table 4). PI-Total was the total number of correct predictive inferences, reflecting collective performance in both Distant and Recent conditions. The range of possible scores for PI-Total was 0 to 14. PI-Distant was the number of correct predictive inferences produced in the Distant condition while PI-Recent was the number of correct predictive inferences made in the Recent condition. PI-Control reflected the number correct responses in the Control condition in which participants did not make a predictive inference but, rather, answered a question tapping explicit story information. The range of possible scores for each separate condition was 0 to 7.

TBI Group. The mean for PI-Total for the TBI group was 11.38 ($SD = 1.88$). The

participants with TBI had a mean of 5.43 ($SD = 1.25$) for the Distant condition, 5.95 ($SD = .86$) for the Recent condition, and 6.29 ($SD = .78$) for the Control condition.

NBI Group. The mean for PI-Total for the NBI group was 12.65 ($SD = 1.30$). The NBI participants had a mean of 6.00 ($SD = .85$) for the Distant condition, 6.65 ($SD = .57$) for the Recent condition, and 6.70 ($SD = .47$) for the Control condition.

Discourse comprehension measures. There were two scores reflecting discourse comprehension, DCT and PSC. DCT was the total number of correct responses on the Discourse Comprehension Test, which had a scoring range of 0 to 40. PSC was the total number of correct responses on the picture story comprehension task, which had a scoring range of 0 to 20.

TBI Group. The participants with TBI had a mean of 33.62 ($SD = 4.39$) on DCT and 16.33 ($SD = 2.06$) on PSC.

NBI Group. The NBI participants had a mean of 37.04 ($SD = 1.82$) on DCT and 17.91 ($SD = 1.88$) on PSC.

Discourse production measures. There were three measures for discourse production, T-units, Story Grammar and Story Completeness. T-units, the total number of T-units produced in story retelling, was an ancillary measure, the calculation of which was a necessary step for the story grammar score. T-units was not a measure of interest for this study. Story Grammar represented the proportion of T-units in episode structure, the range of scores for which were bound between 0 and 1.00. Story Completeness indicated the number of critical components mentioned in each story retelling, which varied between 0 and 5.

TBI Group. The TBI group had a mean of 17.05 ($SD = 11.91$) for T-units, .64 ($SD = .32$) for Story Grammar and 3.33 ($SD = 1.74$) for Story Completeness.

NBI Group. The NBI group had a mean of 17.30 ($SD = 9.67$) for T-units, .70 ($SD = .16$)

for Story Grammar and 4.48 (SD = .73) for Story Completeness.

Table 4				
<i>Means and Standard Deviations of Working Memory, Predictive Inference and Discourse Measures</i>				
Measure	TBI Group		NBI Group	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Working Memory Updating Measures				
WMU-V	29.95	9.37	34.39	6.62
WMU-NV	17.81	6.23	21.04	8.78
Predictive Inference Measures				
PI-Total	11.38	1.88	12.65	1.30
PI-Distant	5.43	1.25	6.00	0.85
PI-Recent	5.95	0.86	6.65	0.57
PI-Control	6.29	0.78	6.70	0.47
Discourse Comprehension Measures				
DCT	33.62	4.39	37.04	1.82
PSC	16.33	2.06	17.91	1.88
Discourse Production Measures				
T-units	17.05	11.91	17.30	9.67
Story Grammar	0.64	0.32	0.70	0.16
Story Completeness	3.33	1.74	4.48	0.73

Note. WMU-V = Working Memory Updating – Verbal; WMU-V = Working Memory Updating – Nonverbal; PI-Total = Predictive Inference – Total Inference Score; PI-Distant = Predictive Inference – Distant Condition; PI-Recent = Predictive Inference - Recent Condition; PI-Control = Predictive Inference – Control Condition; DCT = Discourse Comprehension Test (Brookshire & Nicholas, 1993); PSC = Picture Story Comprehension; T-units = Total number of T-units in story retelling; Story Grammar = Proportion of T-units in episode structure in story retelling; Story Completeness = Number of critical components in story retelling

Group comparisons

Working memory measures.

Verbal working memory updating. An independent samples *t*-test revealed that the difference in WMU-V scores between the TBI group and the NBI group was not statistically significant, $t(42) = 1.83$, $p = .08$, 95% CI [-.46, 9.34], but did have a medium-sized effect, $d = .56$ (Table 5).

Nonverbal working memory. An independent samples *t*-test revealed that the difference in WMU-NV scores between the TBI group and the NBI group was not statistically significant, $t(42) = 1.40$, $p = .17$, 95% CI [-1.44, 7.91], but did have a medium-sized effect, $d = .434$ (Table 5).

Table 5								
<i>Independent Samples T-Tests for Working Memory Updating Measures</i>								
Measure	TBI		NBI					
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	$t(42)$	p	95% CI	Cohen's <i>d</i>
WMU-V	29.95	9.37	34.39	6.62	1.83	.08	[-.46, 9.34]	.56
WMU-NV	17.81	6.23	21.04	8.78	1.40	.17	[-1.44, 7.91]	.43

Comparisons between verbal and nonverbal performance on working memory

updating. A paired samples *t*-test indicated that the difference in scores between the WMU-V and WMU-NV for the TBI group was statistically significant, $t(20) = 8.31$, $p = <.001$, 95% CI [9.10, 15.19] with a very large effect, $d = 2.01$ (Table 6). Similarly, a paired samples *t*-test

revealed a statistically significant difference in scores between the WMU-V and WMU-NV for the NBI group, $t(22) = 9.11$, $p = <.001$, 95% CI [10.31, 16.38]. As was the case for the TBI, this difference represented a very large effect, $d = 1.98$ (Table 6). Calculation of Cohen's d for each t -test took into account the correlation between performance on WMU-V and that on WMU-NV.

Table 6									
<i>Paired Samples T-Tests for Working Memory Updating Measures by Group</i>									
Measure	WMU-V		WMU-NV						
	M	SD	M	SD	t	Df	p	95% CI	Cohen's d
TBI	29.95	9.37	17.81	6.23	8.31	20	<.001	[9.10, 15.19]	2.01
NBI	34.39	6.62	21.04	8.78	9.11	22	<.001	[10.31, 16.38]	1.98

Predictive inference measures. Using Pillai's trace, there was a significant effect of group on the predictive inference measures, $V = .24$, $F(3, 40) = 4.26$ and $p = .011$. Univariate follow-up tests were performed with a Bonferroni-adjusted alpha level of .013 (.05/4) to account for multiple comparisons (Table 7). The difference between TBI and NBI groups on PI-Distant, $F(1,42) = 3.19$, $p = .081$, and PI-Control, $F(1,42) = 4.52$, $p = .039$, was non-significant although there was a medium-sized effect for the difference on PI-Distant, $d = -.54$, and on PI-Control, $d = -.66$. However, there was a statistically significant difference between groups on PI-Total, $F(1,42) = 6.89$, $p = .012$, with a large effect size, $d = -.80$, and PI-Recent, $F(1,42) = 10.18$, $p = .003$, also with a large effect size, $d = -.98$.

Table 7

Post-Hoc Analysis of Variance for Predictive Inference Measures Between TBI and NBI Groups

Measure	TBI Group		NBI Group				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i> (1,42)	<i>p</i>	<i>Cohen's d</i>
PI-Total	11.38	1.88	12.65	1.30	6.89	.012	-.80
PI-Distant	5.43	1.25	6.00	0.85	3.19	.081	-.54
PI-Recent	5.95	0.86	6.65	0.57	10.18	.003	-.98
PI-Control	6.29	0.78	6.70	0.47	4.52	.039	-.66

Discourse comprehension measures.

Discourse Comprehension Test. An independent samples *t*-test revealed that the NBI group had statistically significantly higher scores on DCT than the TBI group, $t(26.20) = 3.32$, $p = .003$, 95% CI [1.31, 5.54]. Levene's test for the equality of variances between groups was significant, and calculation of the *t*-statistic and *df* was adjusted accordingly to account for unequal variances between groups. The effect of the difference between groups on DCT was large, $d = -1.02$ (Table 8).

Picture story comprehension task. . An independent samples *t*-test revealed that the NBI group had statistically significantly higher scores on PSC than the TBI group, $t(42) = 2.66$, $p = .011$, 95% CI [.38, 2.78]. The effect of the difference between groups on DCT was large, $d = -.80$ (Table 8).

Table 8

Independent Samples T-Tests for Discourse Comprehension Measures

Measure	TBI		NBI						
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>df</i>	<i>p</i>	95% CI	Cohen's <i>d</i>
DCT	33.62	4.39	37.04	1.82	3.32	26.20	.003	[1.31, 5.54]	-1.02
PSC	16.33	2.06	17.91	1.88	2.66	42	.011	[-.38, 2.78]	-.80

Discourse production measures.

T-units. An independent samples *t*-test showed that there was no statistically significant difference in T-units between the participants with TBI and NBI comparison participants, $t(42) = .08$, $p = .937$, 95% CI [-6.32, 6.83]. Additionally, the effect size for the difference was very small, $d = -.02$ (Table 9).

Story Grammar. Similar to the results for the group comparison on T-units, an independent samples *t*-test demonstrated that the difference in Story Grammar between groups was not statistically significant, $t(28.55) = .81$, $p = .423$, 95% CI [-.09, .22]. Levene's test for the equality of variances between groups was significant for Story Grammar, and calculation of the *t*-statistic and *df* was adjusted accordingly to account for unequal variances between groups. The effect size for the difference on Story Grammar was small, $d = -.24$ (Table 9).

Story Completeness. In contrast to findings for the other two discourse production variables, an independent samples *t*-test indicated that the difference in Story Completeness between groups was statistically significant, $t(26.32) = 2.80$, $p = .010$, 95% CI [.30, 1.99]. The effect of this difference was large, $d = -.86$ (Table 9).

Table 9
Independent Samples T-Tests for Discourse Production Measures

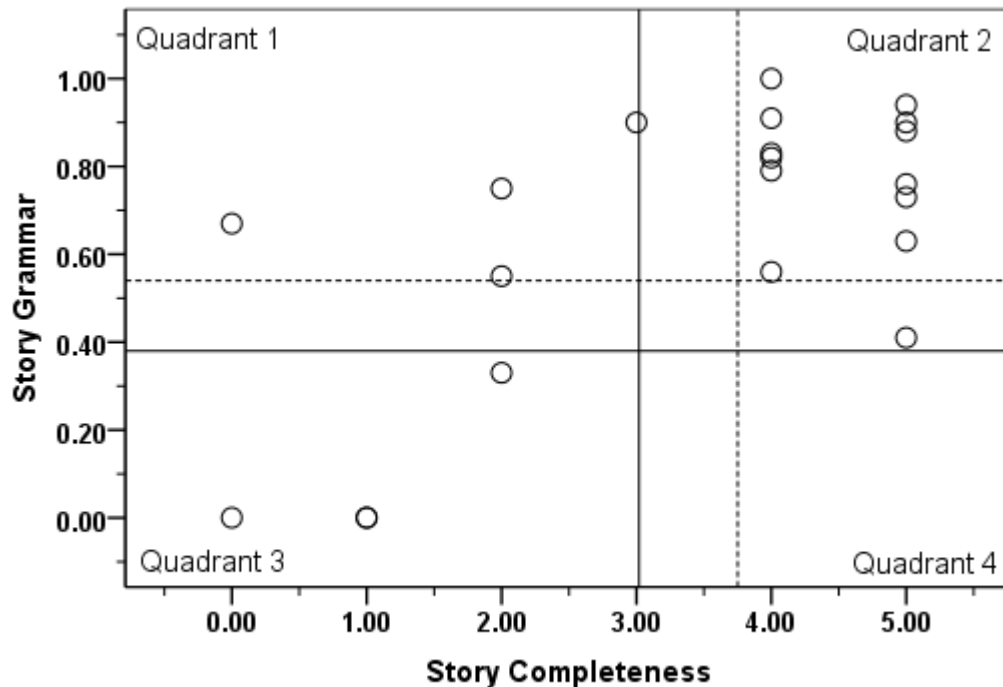
Measure	TBI		NBI						
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>T</i>	<i>df</i>	<i>p</i>	95% CI	Cohen's <i>d</i>
T-units	17.05	11.91	17.30	9.67	.08	42	.937	[-6.32, 6.83]	-.02
Story Grammar	0.64	0.32	0.70	0.16	.81	28.55	.423	[-.09, .22]	-.24
Story Completeness	3.33	1.74	4.48	0.73	2.80	26.32	.010	[.30, 1.99]	-.86

Story Goodness. The Story Goodness Index (SGI; Lê, Coelho, Mozeiko & Grafman, 2011) was used to depict storytelling ability by combining performance on Story Grammar and Story Completeness (Figure 8 and Figure 9). Using boundaries established at either 1 *SD* (dotted lines) or 2 *SD* (solid lines) below the mean of the comparison group for each discourse measure, the SGI classified participants into four quadrants of narrative discourse performance: 1) organized and incomplete storytellers, 2) organized and complete storytellers, 3) disorganized and incomplete storytellers and 4) disorganized and complete story tellers. The 1 *SD* boundary for Story Grammar (proportion of T-units in episode structure) was .54 while the 2 *SD* boundary was .38. The 1 *SD* boundary for Story Completeness was 3.75 critical components while the 2 *SD* boundary was 3.02. Story Grammar and Story Completeness scores served as coordinates for each data point (i.e., each participant's story retelling), guiding placement within the quadrants.

Using 1 *SD* boundaries, Quadrant 1 (Story Grammar > .54; Story Completeness ≤ 3.75) had two NBI comparison participants (9%). These individuals retold fairly organized by incomplete

stories. There was a larger representation of participants with TBI in Quadrant with 4 participants, representing 19% of the TBI group. Nearly three-quarters of the NBI group ($N = 17$, 74%) clustered in Quadrant 2 (Story Grammar $> .54$; Story Completeness > 3.75), representing the best storytellers in terms of story organization and content, whereas a slighter majority of the TBI group ($N = 12$, 57%) was contained in this quadrant. Quadrant 3 (Story Grammar $\leq .54$; Story Completeness ≤ 3.75) represented the poorest storytellers whose stories were not only disorganized but also sparse in context. Only one NBI participant (4%) was in Quadrant in comparison to four participants with TBI (19%). Quadrant 4 (Story Grammar $\leq .54$; Story Completeness > 3.75) encompassed individuals who retold relatively complete but disorganized stories, containing 13% ($N = 3$) of the NBI group and 5% ($N = 1$) of the TBI group.

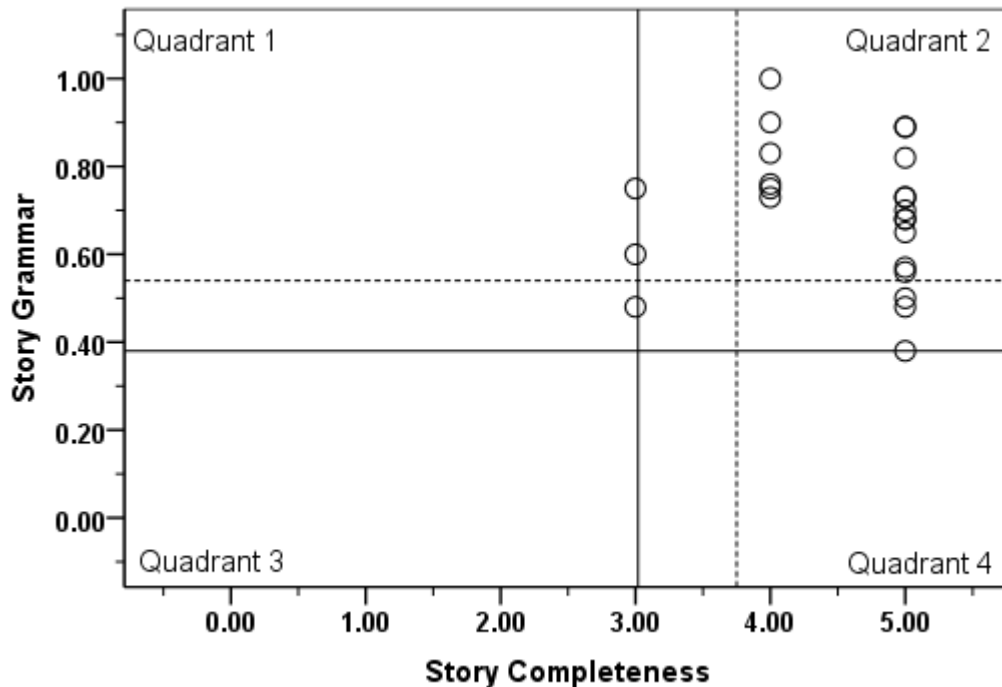
Figure 8. Goodness of story narratives plotted as a function of story grammar and story completeness for the TBI Group



Note. Adapted from “Measuring Goodness of Story Narratives,” by K. Lê, C. A. Coelho, J. Mozeiko, F. Krueger and J. Grafman, 2011, *Journal of Speech, Language, and Hearing Research*. Adapted with permission.

Shifting the quadrant boundaries to 2 *SD* cut-off points rendered 3 NBI participants (13%) and 4 TBI participants (19%) in Quadrant 1. Quadrant 2 subsumed an overwhelming majority of the NBI group ($N = 19$, 83%). Again, a slighter majority of the TBI group ($N = 13$, 62%) was represented in Quadrant 2. Quadrant 3 had no representation from the NBI cohort. In contrast, Quadrant 3 comprised four participants with TBI (19%). Conversely, Quadrant 4 included 1 NBI participant (4%) but had no representation from the TBI cohort.

Figure 9. Goodness of story narratives plotted as a function of story grammar and story completeness for the NBI Group



Note. Adapted from “Measuring Goodness of Story Narratives,” by K. Lê, C. A. Coelho, J. Mozeiko, F. Krueger and J. Grafman, 2011, *Journal of Speech, Language, and Hearing Research*. Adapted with permission.

Correlations

TBI Group. Pearson product-moment correlational analyses were performed for the seven measures of interest: WMU-V, WMU-NV, PI-Recent, DCT, PSC, Story Grammar and Story Completeness for the TBI group (Table 10). Although both PI-Total, the total number of correct inferences produced on the predictive inference tasks, and PI-Recent, the number of correct inferences produced in the Recent condition, were significantly different between groups, PI-Recent was selected as the predictive inference of interest given its more robust significance level and larger effect size. Furthermore, PI-Total was the sum of PI-Distant and PI-Recent.

Separate univariate analyses indicated that PI-Distant was not significantly different between groups, indicating that PI-Recent was the underlying source of the difference on PI-Total.

The working memory updating variables correlated with each other and only the discourse comprehension measures. WMU-V and WMU-NV were highly correlated with each other, $r = .70$ with $p < .01$, representing a large effect size. There were moderate correlations between WMU-V and DCT, $r = .52$, $p < .05$, and between WMU-NV and DCT, $r = .47$, $p < .05$. Moderate correlations that approached significance were found between WMU-V and PSC, $r = .41$, $.05 < p < .07$, and between WMU-NV and PSC, $r = .42$, $.05 < p < .07$. No significant correlations were found between the working memory updating variables and the predictive inference measure or between the working memory updating variables and the discourse production measures.

There were no significant correlations between the predictive inference measure and any of the discourse measures for both comprehension and production.

The discourse comprehension measures each correlated with both discourse production measures. Performance on the Discourse Comprehension Test (DCT) moderately varied with performance on the picture story comprehension task (PSC), $r = .62$, $p < .01$, and on the measure of story organization (Story Grammar), $r = .48$, $p < .01$. A large correlation was found between DCT and narrative content measure (Story Completeness), $r = .77$, $p < .01$. PSC was moderately correlated with both discourse production measures: Story Grammar, $r = .46$, $p < .05$, and Story Completeness, $r = .54$, $p < .05$.

Significant correlations were found between the two discourse production measures. Story Grammar and Story Completeness were moderately correlated with each other, $r = .66$, $p < .01$.

Table 10
Pearson Correlation Matrix for Working Memory, Predictive Inference and Discourse Measures in the TBI Group

	WMU-NV	PI-Recent	DCT	PSC	Story Grammar	Story Completeness
WMU-V	.70**	-.04	.52*	.41†	-.01	.22
WMU-NV		.01	.47*	.42†	.29	.21
PI-Recent			.22	.01	-.034	.28
DCT				.62**	.48*	.77**
PSC					.46*	.54*
Story Grammar						.66**

* $p < .05$; ** $p < .01$; † $.05 < p < .07$

NBI Group. Pearson product-moment correlational analyses were also performed for the seven measures of interest: WMU-V, WMU-NV, PI-Recent, DCT, PSC, Story Grammar and Story Completeness for the NBI group (Table 11) as a comparison. Some caution was warranted in interpretation of the results given that the NBI group often performed close to ceiling on several measures, and correlations that were statistically significant appeared to have been spuriously driven by a few data points when scatterplots were examined.

The working memory updating variables correlated with each other and one discourse comprehension measure. WMU-V and WMU-NV were moderately correlated with each other, $r = .66$ with $p < .01$, representing a large effect size. WMU-V varied moderately with PSC, $r = .42$, $p < .05$. Unlike the TBI group, WMU-V and Story Completeness were moderately correlated, $r = .58$, $p < .01$. No significant correlations were found between WMU-NV and other

measures of interest. There was small-to-medium effect of the relationship between WMU-NV and DCT that approached significance, $r = .39$, $.05 < p < .07$.

Analogous to the TBI group, the predictive inference measure, PI-Recent, was not significantly correlated with any measure of interest in the NBI group.

For the NBI participants, the discourse comprehension measures each correlated with each other but not with either of the discourse production measures. DCT correlated moderately with PSC, $r = .65$, $p < .01$. There was a moderate-sized relationship between PSC and Story Completeness that approached significance, $r = .40$, $.05 < p < .07$.

In contrast to the TBI group, there was no relationship between narrative organization (Story Grammar) and narrative content (Story Completeness).

Table 11

Pearson Correlation Matrix for Working Memory, Predictive Inference and Discourse Measures in the NBI Group

	WMU-NV	PI-Recent	DCT	PSC	Story Grammar	Story Completeness
WMU-V	.61**	-.20	.35	.42*	-.17	.58**
WMU-NV		-.34	.39†	.16	.08	.27
PI-Recent			-.33	-.24	.12	-.02
DCT				.65**	-.32	.29
PSC					-.33	.40†
Story Grammar						-.10

* $p < .05$; ** $p < .01$; † $.05 < p < .07$

Multiple regression analyses

Analysis 1: Working memory and inferencing in narrative discourse comprehension following TBI.

Working memory and predictive inferencing as predictors for performance on the Discourse Comprehension Test. Given the large correlation between the two working memory updating measures, the presence of collinearity in the regression analyses by including both WMU-V and WMU-NV as predictors was concerning. Indeed, a preliminary regression model was performed with both working memory variables and PI-Recent, which resulted in a nonsignificant regression model overall ($R^2 = .35$, $F(3, 17) = 3.02$, $p = .06$, although the model approached significance. Given the strengths of the relationships between the working memory updating variables and DCT in the correlational analyses, the lack of significance of the model was unexpected, and the effect of collinearity was strongly suspected in the outcome. Given that WMU-V had a somewhat larger correlation with DCT than WMU-NV, WMU-NV was jettisoned as a predictor to maintain the validity of the regression models.

Results indicated that WMU-V ($\beta = .53$, $p < .05$) contributed significantly to the prediction of DCT performance (Table 12). The model predicted 33% of the variance in DCT ($R^2 = .33$, $F(2, 18) = 4.39$, $p < .05$). PI-Recent was not a significant predictor for DCT.

Working memory and predictive inferencing as predictors for performance on picture story comprehension. Results indicated that neither WMU-V nor PI-Recent were significant predictors for PSC (Table 12). Overall, the model for PSC was non-significant.

Table 12

Summary of Multiple Regression Analyses for Working Memory Updating and Predictive Inference Variables Predicting Narrative Discourse Comprehension

	Discourse Comprehension Test (DCT)			Picture Story Comprehension (PSC)		
Variable	<i>B</i>	<i>SE B</i>	β	<i>B</i>	<i>SE B</i>	β
Constant	18.89	6.60		13.24	3.44	
WMU-V	.25	.09	.53*	.09	.05	.41
PI-Recent	1.23	.98	.23	.07	.51	.03
R^2	.33			.17		
F	4.39*			1.84		

* $p < .05$

Analysis 2. Working memory and inferencing in narrative discourse production following TBI.

Working memory and predictive inferencing as predictors for story grammar

performance. The regression analysis revealed that neither WMU-V nor PI-Recent were significant predictors for Story Grammar (Table 13). Overall, the model for Story Grammar was non-significant.

Table 13

Summary of Multiple Regression Analyses for Working Memory Updating and Predictive Inference Variables Predicting Narrative Discourse Production

	Story Grammar			Story Completeness		
Variable	<i>B</i>	<i>SE B</i>	<i>B</i>	<i>B</i>	<i>SE B</i>	β
Constant	.72	.58		-1.39	2.98	
WMU-V	<.01	.01	-.01	.04	.04	.31
PI-Recent	-.01	.09	-.03	.58	.44	.21
R^2	<.01			.13		
F	.01			.29		

Working memory and predictive inferencing as predictors for story completeness

performance. Like the findings for Story Grammar, the regression analysis showed that neither WMU-V nor PI-Recent were significant predictors for Story Completeness (Table 13). Overall, the model for Story Completeness was non-significant.

Analysis 3: Relationship between discourse comprehension and discourse production in TBI

Performance on the Discourse Comprehension Test and picture story comprehension task as predictors for story grammar performance. Results indicated that neither DCT nor PI-Recent were significant predictors for performance on the story organization measure, Story Grammar (Table 14). The model, predicting 28% of the variance in Story Grammar, was not significant overall but approached significance, $R^2 = .28$, $F(2, 18) = 3.41$, $p < .06$.

Performance on the Discourse Comprehension Test and picture story comprehension

task as predictors for story completeness performance. Results indicated that DCT ($\beta = .28, p < .01$) contributed significantly to story completeness scores (Table 14). The model predicted 60% of the variance in Story Completeness ($R^2 = .60, F(2, 18) = 13.46, p < .001$), which is a very large effect. PI-Recent was not a significant predictor for Story Completeness.

Table 14

*Summary of Multiple Regression Analyses for Narrative Discourse Comprehension Variables
Predicting Narrative Discourse Production*

	Story Grammar			Story Completeness		
Variable	<i>B</i>	<i>SE B</i>	β	<i>B</i>	<i>SE B</i>	β
Constant	-.80	.55		-7.51	2.27	
DCT	.02	.02	.24	.28	.08	.71**
PSC	.04	.04	.30	.09	.16	.10
R^2	.28†			.60***		
F	3.41			13.46		

** $p < .01$, *** $p < .001$, † $.05 < p < .06$

CHAPTER VI

Discussion

This research study was an investigation into the relationship between cognitive and communicative processes and narrative discourse ability and the relationship between narrative discourse comprehension and narrative discourse production in TBI. The systematic examination of these cognitive-communicative relationships granted an opportunity to test fundamental assumptions of a cognitive model of discourse, the Structure Building Framework (SBF; Gernsbacher, 1990). Performance on working memory, predictive inference, narrative discourse comprehension and narrative discourse production measures were compared between participants with TBI and NBI participants. Associations among the core variables of interest (i.e., WMU-V, WMU-NV, PI-Recent, DCT, PSC, Story Grammar and Story Completeness) were examined. Multiple regression analyses were performed to identify the factors that impact outcomes in understanding stories and story retelling in TBI.

Group Comparisons

Working memory. Performance on both verbal and nonverbal versions of the working memory updating task, WMU-V and WMU-NV, was comparable across the TBI and NBI groups. The lack of difference between the cohorts on working memory was unexpected. Individuals with TBI, ranging in severity from mild to severe, have demonstrated problems with working memory even a decade after injury (Ponsford, Draper & Schonberger, 2008). Several studies have found poorer performance on a variety of working memory tasks following TBI

(e.g., Chapman et al., 2006; Gorman, Barnes, Swank, Prasad & Ewing-Cobbs, 2012; Slovarp, Azuma & LaPointe, 2012). A possible explanation for the lack of differences between groups on the working memory performance is the somewhat small sample sizes. The difference between groups on WMU-V scores approached significance with $p = .08$. Thus, perhaps larger sample sizes would have provided more power to detect a difference. Alternatively, perhaps the working memory tasks were difficult and posed challenges equally to the TBI and NBI groups.

However, comparable performance between groups is not entirely a departure from the literature on working memory in TBI. Other studies have found equivalent behavioral performance on working memory tasks between participants with TBI and neurotypical participants (e.g., Rodriguez Merzagora, Izzetoglu, Onaral and Schultheis, 2014; Newsome, Scheibel, Steinberg, Troyanskaya, Sharma, Rauch et al., 2007). However, in a functional near-infrared spectroscopy study (fNIRS), Rodriguez Merzagora and colleagues (2014) found differences in hemodynamic response during a verbal n -back task despite the lack of differences in behavioral performance. Similarly, participants with TBI and orthopedically injured comparison participants who performed comparably on n -back tasks in a study by Newsome and colleagues (2007) showed differences in extent and regions of brain activation over time during these tasks. Although the participants with TBI in this study did not differ in behavioral performance on the working memory updating tasks from the NBI participants, it is possible that the TBI group had a different pattern of activity or different level of neural recruitment in carrying out the same task as the NBI group.

In contrast, there were differences between verbal and nonverbal versions of the working memory updating task within groups. On average, the participants with TBI and the NBI participants had better performance on WMU-V than on WMU-NV. This was a surprising

finding given that the working memory updating tasks used in this study were based on working memory updating tasks that had been calibrated for approximately equivalent levels of difficulty in neurotypical adults (Oberauer et al., 2000). Thus, it was thought that modifications to the working memory updating tasks from their original form may have driven the disparity between versions. For example, perhaps the 700 ms increase in stimulus presentation time to 2000 ms made the verbal (numerical) task too easy by reducing memory load and allowing participants time to develop strategies they might not have with less exposure to the stimulus.

A closer examination of the WMU-V and WMU-NV tasks in the study by Oberauer and colleagues (2000) revealed that the performances of their participants was comparable to those in the current research study. On average, their participants were 72% accurate on WMU-V and 52% accurate on WMU-NV. The correlation between scores on the two versions of the task was $r = .54$. A paired samples effect size was calculated for the difference in scores, resulting in Cohen's $d = 1.13$, which is considered a large effect. Although significance testing for the difference was not performed in the original study, there appears to be some divergence in task equality despite efforts to calibrate the items for similar levels of difficulty between versions. In the current study, the NBI group had 76% accuracy on WMU-V and 47% accuracy on WMU-NV, closely mirroring performance of the neurotypical participants in the study by Oberauer and colleagues (2000). Additionally, performance moderately correlated between versions with $r = .61$, which is comparable to the strength of the relationship between the versions in the original study. The effect of this difference was quite large with Cohen's d of approximately 2. Given the fairly congruent performance between the neurotypical groups in each study, modifications to the working memory updating task in the current research study likely had a minor, if any effect, on any overall task difficulty. Rather, the differences in performance between the verbal

and nonverbal versions would appear to originate, in part, from the original task construction and item calibration. The lack of comparable scores on WMU-V and WMU-NV would have been an obstacle in addressing the nature of working memory as domain-specific or domain-general if the study had been limited to *t*-tests alone. However, the inclusion of other statistical approaches enabled this study to test this assumption of the Structure Building Framework (SBF; Gernsbacher, 1990)

Predictive Inference. Overall, the individuals with TBI were less accurate than their NBI counterparts in making predictive inferences. The TBI group had lower scores for production of total inferences, which is composite score comprising performance on Distant (PI-Distant) and Recent (PI-Recent) conditions. A more in-depth examination of the scores revealed that the TBI group performed comparably to the NBI group in the Distant condition in which the predictive sentence was placed at the beginning of the story. In the Distant condition, participants were required to store the inference for a longer period of time than the Recent condition, in which the predictive sentence was placed at the end of the story, preceding the probe question. The overall findings for predictive inference are consistent with those Moran and Gillon (2005) in that participants with TBI performed more poorly than NBI participants in generating predictive inferences. However, Moran and Gillon (2005) found that the TBI group had lower scores in the Distant condition. The researchers attributed this finding to increased demands on the storage component of working memory in the Distant condition. Some caution is warranted in interpreting these findings as the sample size was rather small with six participants with TBI.

Using essentially the same stimuli as for this study but in a reading time paradigm, Lehman-Blake and Tompkins found that individuals with right-hemisphere damage (RHD)

demonstrated greater effects of recency of mention. In other words, the RHD group was better at generating predictive inferences when storage constraints on memory were low. The researchers posited an explanation for the findings using the SBF. In the SBF, comprehension involves the construction of mental representations (structures) onto which relevant information is mapped. If new information is presented that does not cohere with the current (activated) mental structure, then a new structure is formed to accommodate the novel information. The mental structure that was once activated is suppressed making the information within it less accessible. Thus, the individuals with RHD were thought to have more difficulty with making inferences in the Distant condition because the new setting information that followed the predictive sentence made the predictive information less accessible.

Findings for the current study offer an alternative interpretation given that the TBI group had lower scores in the Recent condition. The SBF comprises three key structure-building processes: 1) lay a foundation, 2) mapping as discussed above and 3) shifting to build new substructures. Because the TBI group performed comparably to the NBI group in the Distant condition, mapping of relevant information onto mental structures was presumably adequate. In the Recent condition, the predictive sentence follows three sentences with setting information. Thus, the TBI group may have had difficulty with suppressing the structure created for the setting information to adequately shift to create a new structure to map the novel predictive information.

Discourse Comprehension. The TBI group had poorer comprehension than the NBI in both auditory-verbal and visual presentations of story stimuli. These findings are consistent with a number of studies investigating discourse comprehension following TBI (e.g., Ferstl, Walther, Guthke & Von Cramon, 2005; Nicholas & Brookshire, 1995; Sohlberg, Griffiths & Fickas,

2014). The poorer performance of the TBI group on the discourse comprehension tasks is somewhat puzzling in light of the pilot studies conducted for the current research which demonstrated no differences on the DCT between TBI and NBI groups. A possible explanation is that the NBI group had more females, who have been found to have better performance than males on some language tasks (e.g., Bayles et al., 1999; Roivainen, 2011). Another consideration is that the participants with TBI in the pilot studies had chronic and remote injuries sustained more than three decades before testing. As such, perhaps over the course of time, the individuals with TBI had developed compensatory strategies for discourse comprehension whereas the participants with TBI in this study had, on average, more recent injuries and had not yet developed effective strategies for understanding discourse.

Discourse Production. The findings for the discourse production measures were somewhat consistent with previous literature. There were two measures of interest for narrative discourse production. The first was a measure of narrative organization, Story Grammar, and the second was a measure of narrative content, Story Completeness. The participants with TBI performed comparably to the NBI participants on Story Grammar. The superstructure of a text, alternatively referred to as the story schema, provides the broad framework that organizes discourse context. Story grammar is a reflection narrative discourse superstructure and converging evidence in the research literature supports the existence of discourse deficits at the superstructural level (Coelho, 2007a; Hinchcliffe et al., 2001; Moran & Gillon, 2010). Evidence from pediatric and adult investigations has shown that individuals with TBI frequently produce fewer story grammar components (Hay & Moran, 2005; Jorgensen & Togher, 2009). In another investigation, while TBI and NBI participants produced comparable numbers of total episodes, the TBI group had a lower proportion of T-units in episode structure (Coelho, 2002). The

proportion of T-units in episode structures, the story grammar used in this research study, was one of the more sensitive narrative discourse indices in discriminating discourse performance between TBI and NBI groups (Coelho, Youse, Le, & Feinn, 2003). Pilot studies for the current research study added further evidence of poorer story grammar following TBI.

In the pilot studies, the TBI group had a mean for Story Grammar of .61 with $SD = .25$, and the NBI group had a mean of .70 with $SD = .21$, resulting in a small-to-medium effect size. There was adequate power to detect this difference because the sample size was quite large with 171 participants with TBI and 46 NBI participants. The effect size for the difference in Story Grammar between groups would be difficult to detect using a smaller sample size such as the one in this study. The reduced power to manifest this difference is suggested by the 95% confidence intervals $[-.09, .22]$ for the difference in Story Grammar scores. With a larger sample size, the clustering of the groups would have been more well-defined in all likelihood, resulting in a greater separation of the confidence interval from zero.

The TBI group produced more incomplete stories than the NBI group as reflected by the Story Completeness. The effect of this difference was large and analogous to findings from the pilot studies. The results are in keeping with the literature on discourse ability in TBI, which indicated that narrative content is frequently deficient (Chapman et al., 2004; Glosser & Deser, 1991; Tucker & Hanlon, 1998, Van Leer & Turkstra, 1999).

Core Study Questions

Question 1: **What is the contribution of working memory and inferencing to narrative discourse comprehension as measured by a standardized test and an experimental task in TBI?**

Hypothesis 1A: *Working memory and inferencing will be significant predictors for narrative discourse comprehension.*

Working memory was a significant predictor for performance on the Discourse Comprehension Test (DCT) but not for picture story comprehension (PSC). The model with WMU-V and PI-Recent accounted for approximately one-third of the variance in DCT scores. Small-to-moderate correlations that approached significance were found between both working memory measures and PSC, suggesting the potential for a relationship between working memory and understanding picture stories.

There is a compelling literature that supports the notion that working memory constrains discourse comprehension in neurotypical comprehenders and comprehenders with TBI (e.g., Albrecht & O'Brien, 1993; Chapman et al., 2006; Gerrig & McKoon, 1998; Moran & Gillon, 2004; Myers & O'Brien, 1998). The Structure Building Framework (SBF; Gernsbacher, 1990) can be considered a memory-based model of discourse comprehension or, alternatively, text processing. A memory-based model of text processing proposes that discourse comprehension occurs through a process of resonance, which is the activation of information in long-term memory (LTM) by text information currently held in working memory (WM) for processing (Long, Johns & Jonathon, 2012). The newly activated knowledge is then used to construe

meaning of the text elements in WM. The degree to which representations are activated in LTM depend upon on how much they cohere with the information in WM (Gerrig & McKoon, 1998). The finding that working memory influenced performance on DCT outcomes is consistent with a memory-based discourse comprehension model. From the perspective of the SBF and given the central role of resonance, WM would be implicated in all three processes of building mental representations for comprehension: laying a foundation, mapping and shifting.

An ostensibly reasonable conclusion from the findings for working memory and the discourse comprehension tasks would be that perhaps the SBF and working memory are implicated in linguistically-based stories only without similar deployment for nonlinguistic media, such as picture stories. However, Gernsbacher has argued that the mechanisms underlying the formation of mental structures are general and not specific to discourse (1990). In a series of experiments, Gernsbacher demonstrated that the mechanisms and processes of the SBF also govern comprehension for picture stories (1985). A general comprehension phenomenon is the rapid forgetting of the exact form and difficulty in recall of recently processed information following the crossing of a structural boundary (e.g., change in point of view, change in location, change in time, sentence boundary, episode boundary; Anderson, Pichert, & Shirey, 1983; Daneman & Carpenter, 1983; Gernsbacher, 1990; Mandler & Goodman, 1982). Using picture stories, Gernsbacher found that comprehenders also forget the exact form of pictures despite generating accurate summaries of the picture stories they viewed indicating that they had comprehended the picture stories (1985). Gernbacher's findings bolster the case for the role of WM in activating knowledge from LTM in understanding stories presented through nonverbal media.

Inferencing did not contribute significantly to discourse comprehension outcomes on

either task. This was a surprising finding considering the well-established role of inferencing in discourse comprehension and that there is a preponderance of implicit elements on the DCT and PSC. There is general consensus in the literature that individuals with TBI have difficulty with understanding inferences across a variety of contexts, including conversation, theory of mind judgments and narratives (e.g., Johnson & Turkstra, 2012; McDonald, 2013; Moran & Gillon, 2005). The predictive inference task used in the current study was based on Moran and Gillon's (2005) adaptation of Lehman-Blake and Tompkins's (2001) predictive inference task. The participants with TBI in Moran and Gillon's (2005) study differed only from the non-brain-injured participants in the Distant condition as did Lehman-Blake and Tompkins's participants with right-hemisphere damage (RHD). These findings conflict with those of the current study, which found that individuals with TBI performed worse only on predictive inferences in the Recent condition. Because RHD is typically the result of focal damage in contrast to the diffuse damage associated with TBI, it is not altogether unexpected that performance on predictive inference differed. As discussed previously in the Group Comparisons section, the sample size was rather small in Moran and Gillon's study with six participants with TBI and may not have been representative of the TBI population.

Alternatively, perhaps the findings that the TBI group performance was worse in the Recent condition for predictive inference and that there was no significant relationship between generating predictive inferences in the Recent condition and discourse comprehension was a function of the specific cohort recruited. Although the poorer performance on predictive inference in the Recent condition may be a cohort-specific phenomenon, there does appear to be a pattern that individuals with TBI have difficulty with making predictive inferences in the context of discourse. In a recent study, individuals with TBI made more errors on elaborative

inferences, which encompass predictive inferences, than on automatic inferences in conversation (Johnson & Turkstra, 2012). This suggests that predictive and elaborative inferences are potentially fruitful areas for further investigation into the cognitive-communicative deficits following TBI.

Hypothesis 1B: Verbal working memory will not account for narrative discourse comprehension beyond that of nonverbal working memory and vice versa given the Structure Building Framework's (SBF) assumption of domain-generalty.

Although there were differences between performance on WMU-V and WMU-NV, verbal and nonverbal working memory were highly correlated. The working memory variables accounted for so much of the variance in each other that they were collinear. The extent of this correlation was to such a degree that multiple regression analysis could not be validly performed with the inclusion of both working memory variables in the model. The strength of the relationship between verbal and nonverbal working memory and the threat to valid model prediction posed by their collinearity supports the SBF's assumption of domain generality.

The argument that the mechanisms and processes underlying discourse comprehension are not specific to language would have been further strengthened had performance on the verbal and nonverbal versions of the working memory updating task been equated. However, the comparison of task versions is more reflective of task difficulty and does not speak to the relationship with discourse comprehension itself. Even though an argument can be made for the higher degree of difficulty associated with nonverbal working memory updating than for verbal

working memory updating in this study, the strength of each relationship with the discourse comprehension tasks was comparable.

Hypothesis 1C: Inferencing will have a unique contribution to narrative discourse comprehension beyond a shared variance with working memory.

Inferencing did not contribute significantly to outcomes of narrative discourse comprehension as discussed for Hypothesis 1A. There was no correlation between predictive inferencing and either DCT or PSC. It is possible that predictive inferences are less represented in the types of inferences generated on the DCT or the picture story comprehension task. Given that predictive inferences are elaborative and non-obligatory, they may not have necessarily been generated or generated to the same extent as coherence or automatic inferences, which are necessary for comprehension. In a study of RHD participants, Tompkins and colleagues (2009) found no correlation between high-level inferencing skills and the DCT, suggesting that dissociations between different types of inferencing tasks are possible. Furthermore, in light of the findings from the current study, the cognitive underpinnings for the various inference types may be different with some sharing cognitive substrates with the processes involved in DCT and PSC performance but not all. Alternative potential explanations for the lack of a relationship between predictive inferencing and discourse comprehension were discussed under Hypothesis 1A.

Question 2: What is the contribution of working memory and inferencing to narrative discourse production as measured by story grammar and story completeness in TBI?

Hypothesis 2A: Working memory and inferencing will be significant predictors for narrative discourse production.

Neither working memory nor inferencing ability contributed significantly to outcomes in discourse production. There was no relationship between working memory and Story Grammar or working memory and Story Completeness. Likewise, there was no relationship between predictive inferencing and Story Grammar and predictive inferencing and Story Completeness. This was an unexpected finding given that the pilot studies for the research study indicated that working memory would be a promising factor in elucidating the cognitive substrates of narrative discourse production. Results from one pilot study examining relationships between cognitive factors and narrative discourse outcomes indicated that WM moderately correlated with Story Completeness and more weakly correlated with Story Grammar (Lê et al., 2012). A conclusion drawn from the pilot study was that WM is deployed differently in the production of narrative content than in the construction of narrative organization. Although the nebulous relationship between WM and narrative discourse production continues to emerge in the field, WM appears to align more with narrative content than with narrative structure given findings from the pilot study and those in the literature (Chapman et al., 2006; Lê et al., 2012; Youse & Coelho, 2005).

The nature of the relationship between working memory and narrative discourse ability is an area of ongoing investigation. One factor to consider is that working memory is not a unidimensional concept but is, rather, multi-faceted comprising multiple components, such as

storage and transformation, coordination and supervision (Oberauer et al., 2000). Another consideration is that different working memory tasks tap these components differently. For example, the working memory updating task selected for this study can be viewed as having both storage and transformation and coordination components. What is meant by coordination is the transformation of incoming information into structures or mental representations (Oberauer et al., 2000), which has parallels to building processes in the SBF (Gernsbacher, 1990). However, a task like backward digit span only has a storage and transformation component as there is little need to build mental structures from the elements to carry out the task. It stands to reason that different aspects of discourse ability may draw upon different components of working memory and to various degrees. Alternatively, narrative discourse production may deploy processes involving other memory domains more heavily, such as declarative memory.

In the current study, the finding that WM predicted performance on a narrative discourse comprehension task but did not predict narrative discourse production outcomes suggests that the cognitive processes and mechanisms underlying each process differs. The finding does not preclude some shared cognitive substrates as this study examined only two key factors, working memory and inferencing, but suggests that some substrates are deployed differently and to different extents. In a pilot study for the current research project, there were moderate correlations between immediate declarative memory (short-term memory) and narrative discourse measures of story grammar and story completeness, which suggests that narrative content and organization is dependent, in part, upon short-term recall of explicit information in declarative memory (Lê et al., 2012).

Declarative memory has not received much attention in the study of discourse ability following TBI, but findings from discourse investigations in individuals with hippocampal

amnesia may inform those in TBI. In a study involving a participants and familiar partners carrying out a collaborative learning task, participants with amnesia initiated fewer episodes and fewer episodes were produced in sessions with participants with amnesia overall in comparison to the neurotypical participants and pairings between neurotypical participants and their familiar partners (Duff, Hengst, Tranel & Cohen, 2009). Qualitatively, the participants with amnesia produced episodes that lack the richness of communication (e.g., rote and repetitive utterances, absence of thematically linked episodes) observed in neurotypical peers. Thus, impairments in declarative memory would appear to disrupt not only the structure of discourse but also the content, emerging as a potentially worthwhile cognitive substrate for aspects of narrative discourse production.

In contrast to working memory, there is general agreement in the literature that individuals with TBI have inferencing deficits as discussed under Hypothesis 1A and Hypothesis 1C. Inferencing is critical to the extrapolation of meaning and discourse processing, and, therefore, it is reasonable to assume that impairments of inferencing would affect discourse processing. If the same processes and mechanisms involved in discourse comprehension subserve discourse production, then impairments of inferencing should also disrupt generative discourse processes.

A study of narrative discourse in mild and moderate TBI brought to light deficits with sequencing content and distilling story implications in narrative discourse production (Tucker & Hanlon, 1998). Participants were asked to arrange a set of pictures that formed a story and subsequently tell a story congruous with the picture arrangement. Both TBI groups performed worse on sequencing and narrating the picture story than the NBI participants, who performed at ceiling level on both tasks. Even when the appropriate sequence was presented to the TBI

group, they continued to have difficulty narrating a story corresponding to the events of the picture sequence. There were no differences among groups on the generation of implied meanings with the story likely due to the large variance. However, there was a noticeable trend for the moderate TBI group to abstract fewer inferences than the mild TBI group and the mild TBI group to abstract fewer inferences than the moderate TBI group. The study suggests that individuals with TBI have difficulty extrapolating meaning to generate a narrative even when the essential information is readily accessible. This finding has parallels to studies of individuals with amnesia who demonstrate declarative memory deficits in short-term or immediate recall tasks when the information required to carry out the task is virtually at hand (Duff & Brown-Schmidt, 2012; Warren, Duff, Tranel & Cohen, 2010; Zeman, Beschin, Dewar & Della Sala, 2013).

The current study did not uncover a relationship between predictive inferencing and the narrative discourse production measures. The possible reasons for the lack of a relationship are essentially the same as the rationale for the lack of relationship between predictive inferencing and the narrative discourse comprehension measures discussed under Hypothesis 1A and 1C. To reiterate briefly, the nonsignificance of predictive inferencing as a predictor for story grammar and story completeness may have been a cohort-specific phenomenon that is not reflective of the TBI population at large. Given the various inference types, it is possible that another type of inference or perhaps a broader category of inferences (e.g., examining elaborative inferences) would better account for performance on story grammar and story completeness.

Hypothesis 2B: Verbal working memory will not account for narrative discourse production beyond that of nonverbal working memory and vice versa given the SBF's assumption of domain-generalality.

As discussed above, there was no relationship between working memory and discourse production. Neither version of the working memory updating task correlated with Story Grammar or Story Completeness, which lends support to the SBF's assumption of domain-generalality. In other words, because verbal working memory did not vary with the narrative discourse production measures, nonverbal working memory also did not vary with the production measures given the extent of the correlation between WMU-V and WMU-NV. In general, the findings for this study indicated that the strength of the relationship between verbal working memory and each discourse variable closely mirrored that for nonverbal working memory and the same discourse variable. The findings are analogous to those found for the relationship between working memory and discourse comprehension measures in that the verbal working memory and nonverbal working variables do not appear to behave differently in the strengths of their relationship to the narrative discourse measures.

Hypothesis 2C: Working memory will carry a greater portion of the overall variance in story completeness compared to story grammar given that deficits on story completeness reflect problems activating memory nodes for mapping narrative information in the SBF. Inferencing will carry a greater portion of the variance for story grammar than for story completeness given that difficulty creating temporal and causal links involved in story grammar

reflect problems with laying the foundation and shifting to form new substructures in SBF.

The regression models predicting Story Grammar and Story Completeness were not significant. Therefore, working memory did not account for a greater proportion of the variance in story content, and inferencing did not account for a greater proportion of the variance in story organization. Potential explanations for these findings were explored under Hypothesis 2A.

Question 3: What is the extent to which narrative discourse comprehension accounts for narrative production as measured in this study in TBI?

Hypothesis 3A: Narrative discourse comprehension will be significant predictors for story grammar and story completeness given that the SBF applies to both narrative discourse comprehension and narrative discourse production.

Each narrative discourse comprehension measure correlated with both narrative discourse production measures. However, when DCT and PSC were placed as predictors in regression models for each discourse production measure, only the model predicting story completeness outcomes was significant. DCT emerged as the sole significant predictor. Because of the medium-to-large correlation between DCT and PSC, the DCT likely subsumed the shared variance.

The model predicting Story Grammar from DCT and PSC was not significant but approached significance with the model accounting for almost 30% of the variance in narrative organization. Given how closely the model approached significance, it is possible that the

sample size was too small to achieve significance given the smaller effect size compared to Story Completeness. Alternative explanations for these findings are considered below under Hypothesis 3B.

Hypothesis 3B: The amount of variance in narrative discourse production explained by narrative discourse comprehension will be small to moderate given that pilot studies support the notion that discourse comprehension and production may operate as two parallel systems that draw upon the same cognitive processes but to differing degrees.

The SBF posits that the processes and mechanisms involved in discourse comprehension are the same as those involved in discourse production (Gernsbacher, Tallent & Bolliger, 1999). In general, the findings support the hypothesis that discourse comprehension and discourse production operate as two parallel systems that marshal similar cognitive processes and mechanisms but to differing degrees. However, the details relative to the amount of variance accounted for differ. The narrative discourse comprehension measures accounted for 60% of the variance in Story Completeness, which is a substantial amount. Therefore, the contribution of narrative discourse comprehension to Story Completeness was not small-to-moderate as predicted but quite large. Nevertheless, 40% of the variance in Story Completeness is ascribed to other factors. Although some portion of that variance will be unpredictable and attributable to error, there remains a portion of unexplained variance that bolsters the assertion that the cognitive underpinnings of narrative discourse comprehension are not all deployed in the same manner for producing narrative content.

The regression model predicting Story Completeness from the narrative discourse comprehension measures supports the SBF assumption of shared cognitive substrates between discourse comprehension and discourse production processes particularly involving narrative content. Findings from the regression analysis predicting Story Grammar from the narrative discourse comprehension measures may be interpreted from a few different perspectives. If there truly is no relationship between discourse comprehension and story grammar, then an argument could be made that narrative organization is not derived from the interpretation of meaning within a story. Such as scenario could potentially weaken the case for the SBF but not necessarily so.

Performance on the DCT and the picture story comprehension task reflect the comprehender's understanding of narrative content. It is highly likely that the same mental representations that were formed during the comprehension process must be activated during the production process to generate the essential elements of the story, captured by the story completeness measure. Because the DCT and picture story comprehension task are more content-centered measures and do not formally consider episode formation and other aspects of narrative organization during the comprehension process, their relationship to an organizational measure like story grammar would, understandably, be more subtle. A task, such as sequencing a picture story, may tap narrative organization abilities more directly and have greater potential for predicting story grammar outcomes.

The SBF's assumption that narrative discourse comprehension and narrative discourse production are subserved by the same cognitive processes and mechanisms is supported by neuroimaging findings of shared regions of brain activation between the two processes. Narrative comprehension and production have been associated with medial prefrontal cortex,

lateral prefrontal cortex, temporoparietal region, anterior temporal region and posterior cingulate cortex (Mar, 2004). In a review study, Mar (2004) speculated that discourse production is more complex than discourse comprehension in that production subsumes the processes deployed for comprehension and necessitates semantic selection. Although an argument can be made for the role of semantic selection in comprehension processes via activation of representations in LTM, the key implication is that comprehension and production processes have similar cognitive substrates but are not “mirror images” of each other and that comprehension would not be expected to account for production in its entirety.

Limitations of the Study

Working memory updating tasks were not equated in difficulty. Participants in both the TBI and NBI groups performed better on the verbal version of the working memory updating task than on the nonverbal version. Support for the SBF’s assumption of domain-generality of the cognitive processes involved in discourse would have been strengthened if the tasks had been better calibrated for equivalence between versions.

Memory component of the Discourse Comprehension Test (DCT) complicates the interpretation of working memory as a predictor for discourse comprehension. Standard administration of the DCT involves presentation of the story followed by the questions. Participants did not have access to the written and auditory stimuli for the story, and, thus needed to remember the information in order to answer the comprehension questions. As such, the DCT’s relationship to working memory may have been driven by the memory requirements of task administration rather than narrative comprehension.

Lack of narrative comprehension and production measures for the same tasks.

Because the influence of narrative comprehension on narrative production and vice versa continues to be an area of investigation, this study placed a constraint on the pictures tasks in that only one aspect of discourse (comprehension or production) could be measured for any one set of stimuli. For example, only comprehension was measured using the pictures in the Picture Story Comprehension task. Thus, the study was unable to directly compare comprehension of the picture story to its production. Additionally, it is not known if the participants understood the sequence of pictures as a story or if they were understood as isolated images without the logical and temporal connections of a story.

Constraint of using several multiple regression analyses. This study used three multiple regression analyses to address the research questions. Running separate multiple regression analyses does not allow for the measurement of the relationships between all variables simultaneously. Structural equation modeling (SEM) is an approach that would permit a more elegant and holistic approach to answering the research questions but would require a much larger sample size than would have been feasible.

Conclusions, Clinical Implications and Future Directions

This research study attempted to identify some of the cognitive and communicative substrates of discourse ability in TBI and to test aspects of the SBF. Working memory was found to contribute to a well-established and standardized measure of discourse comprehension, but predictive inferencing did not. In this study, neither working memory nor inferencing predicted global organizational (story grammar) and content (story completeness) aspects of

narrative discourse production. Although discourse comprehension did not predict narrative organization, there was a trend towards this prediction. Moreover, discourse comprehension was predictive of narrative content. The findings can be interpreted as supporting SBF assumptions of domain-generalty of cognitive processes and mechanisms involved in discourse and partially supporting assumptions that the same cognitive substrates are marshalled for comprehension and production processes.

Although it would be premature to derive discourse interventions from the current findings, this research study has important clinical implications. This investigation offered evidence to support the potential of a theoretically-based cognitive model of discourse that may guide assessment and treatment. The findings suggest the potential for improvements in discourse comprehension by treating aspects of working memory, such as attention, and the potential for improvements in the production of story content by treating discourse comprehension. Certainly more information is warranted, but these cognitive and communicative factors are promising areas for further investigations.

Future directions from the current research should continue to identify not only other cognitive and communicative factors involved in discourse but to examine multiple measures of the factors identified in this study. For example, the inclusion of multiple measures of working memory, tapping its various functional components, would be useful in specifying which aspects of working memory are marshalled during discourse comprehension and production. Such an approach may prove useful for unpacking the global organization discourse given the lack of significant predictors for story grammar in this study.

The activation of mental representations in the SBF heavily implicates the role of declarative memory in discourse processing. The relationship of declarative memory and

discourse production in TBI has not been well-studied but has received more attention in clinical populations that are relevant to TBI, such as individuals with amnesia (e.g., Duff, Hengst, Tranel & Cohen, 2009). Additionally, pilot work for the current research study revealed that an index of declarative memory was a significant predictor for both story grammar and story completeness, suggesting that examination of other memory domains in addition to working memory may be illuminating to the study of discourse in TBI and to the continued testing of the SBF as potential discourse model for TBI (Lê et al., 2012).

TBI is a common agent of discourse impairments. The fluent language disorder that occurs following TBI is quite different from aphasia although it shares characteristics with other neuropathologies, such as frontal lobe lesions, schizophrenia and right-hemisphere damage. As the currency of everyday communication, discourse is critical for community reintegration, work re-entry, and overall quality of life. Impairments of discourse are “perhaps the most socially punishing and chronic communication problems associated with acquired brain injury” (Sohlberg & Mateer, 2001, p. 306). The persistence of discourse impairments prevails upon the field to develop meaningful and theoretically-based discourse intervention. Given the need to integrate information on discourse production and comprehension into an explanatory construct to guide treatment, the Structure Building Framework (SBF) emerged as a reasonable candidate, affording a model that has the potential to be clinically useful and empirically testable.

Appendices

Appendix A: Story retelling coding and scoring procedures

(Reprinted from “Measuring Goodness of Story Narratives,” by K. Lê, C. A. Coelho, J. Mozeiko, F. Krueger and J. Grafman, 2011, *Journal of Speech, Language, and Hearing Research*.

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Story grammar coding: IE = initiating event, A = attempt, DC = direct consequence, NS = no score (T-units were not scored if it was determined they did not fit the definition of one of the three story grammar elements).

Story completeness scoring: One point was awarded for the presence of each of the following story components:

1. The couple/farmer moving to city and/or finding an apartment and/or having an apartment building (i.e., statement regarding urban living)
2. The farmer having a garden/farm indoors
3. Tenants/neighbors becoming upset and/or moving out due to the farmer’s indoor activities
4. The owner/inspector arriving and attempting to resolve situation (e.g., couple is evicted and/or the owner has a brainstorm)
5. Construction/buying of vegetable stand/greenhouse/market, business partnership partnership between the farmer/owner

Appendix B: Examples of coded transcripts

A transcript with high scores on story grammar and story completeness

T-units	T-units in Episodes	Total Episodes	Complete Episodes	Incomplete Episodes	Story Completeness
10	7	3	1	2	5

1. Ok well it was about [um] Old MacDonald and his wife [of] having a farm fame. (NS)
2. And [uh] apparently they had an apartment complex (NS)
3. and at first everything was quite idyllic. (NS)
4. [Uh] but apparently they were growing different crops in every single area of the apartment building and [uh] keeping livestock in there as well which was a obviously a bit of a nuisance to their neighbors. (A-1, DC-1)
5. [Uh] they had giant roots breaking through the ground and going into other people's apartments, [Uh] bad cows pushing people around the building, (DC-1)
6. [uh] they had radishes and things growing in people's tubs, things of that nature (A-2)
7. and [uh] obviously this was creating a bit of a living situation [uh] to the point where the [uh] address book outside the apartment literally just had [uh] which crop was growing on which floor (DC-2)
8. and a [uh] rather grumping and plutocrat looking gentleman comes in there [and I don't know who he was] presumably some kind of landlord or [uh] maybe a city official or something who [uh] was not pleased with a residential space being used to grow farm [uh] livestock and [uh and] crops [uh] (IE-3)

9. so he comes up with the far more sane idea of simply having them [uh] maybe bring this to a general store where they could sell and grow their wares in a more [uh] natural environment as opposed to having them overtaking an entire residential area. (A-3)
10. And [uh] it appeared to be a reasonably happy ending for all parties involved. (DC-3)

A transcript with low scores on story grammar and story completeness

T-units	T-units in Episodes	Total Episodes	Complete Episodes	Incomplete Episodes	Story Completeness
5	0	0	0	0	1

1. Ok it was Old MacDonald had an apartment building. (NS)
2. the picture, there was one [that I've seen or similar to one I've seen in the past of an old of you know of] the couple [um I just don't you know] with carrots coming out of the ceiling and things that wouldn't really be [poss] feasible [whatever that would wouldn't happen um.] (NS)
3. There were [there were] plants on the table (NS)
4. [the] in the first photo is wasn't grown much (NS)
5. and then the next photo it was very full in [I believe] red maybe not colored [but it just didn't it was sort of far off for me to all take in.] (NS)

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