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Implicit causality bias in adults with traumatic brain injury

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ABSTRACT

Introduction: Individuals with moderate or severe traumatic brain injury often experience impairments in pragmatic language functions. Pragmatic language has been studied primarily in connected language genres such as narratives. It may be, however, that individuals with traumatic brain injury also miss microscopic cues, such as social cues embedded in single word meanings or sentence structure. The current study examined one type of sentence-level pragmatic language cue: implicit causality bias. Implicit causality bias is the attribution of an interpersonal transitive verb action to either the subject noun phrase or object noun phrase of a sentence, and is an inherent property of English-language verbs.

Method: In this study, 19 adults with traumatic brain injury and 18 typical adults were asked to provide sensible and spontaneous completions to 96 sentence fragments. Each fragment contained one interpersonal transitive verb and two noun phrases to which the cause of the verb could be attributed.

Results: Adults with traumatic brain injury showed significantly less implicit causality bias than typical adults, and also made more errors in assigning the causality of a clause.

Conclusions: These results challenge assumptions regarding intact implicit processing in adults with traumatic brain injury, and reveal mechanisms by which communication could fail in everyday social interactions.

1. Introduction

Individuals with moderate or severe traumatic brain injury (TBI) often show impairments in pragmatic aspects of communication (Coelho, Liles, & Duffy, 1994; Mentis & Prutting, 1987; Milton & Prutting, 1987), particularly in *pragmatic inference* (Dennis & Barnes, 1990; McDonald, 1993). Pragmatic inference is the process of integrating context cues and knowledge, to add meaning to information that has been explicitly provided. A common pragmatic inference problem for people with TBI is understanding speech acts such as sarcasm, which requires the listener to infer that a speaker means the opposite of what he or she says (McDonald, 1992, 1999, 2000). Individuals with TBI also may miss the implied gist of narratives (e.g., missing the moral of a story), or fail to bridge semantic gaps (e.g., hearing "The children were cooking dinner" and then "The family had to order pizza," and inferring that something must have happened to the dinner; Chapman et al., 2006; Dennis & Barnes, 1990). Comprehension of sarcasm and other implied information requires *elaborative inference*, i.e., inferring meaning via controlled and strategic use of information such as world knowledge and social norms (Johnson & Turkstra, 2012). Elaborative inference is described as having a high cognitive load (Swinney & Osterhout, 1990), because the person must access information outside of current working memory contents and hold and manipulate this

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information in working memory (Moran & Gillon, 2005; Swinney & Osterhout, 1990). Given the prevalence of working memory impairments among adults with TBI, it is not surprising that elaborative inference is often impaired in this group, both on laboratory tasks (Bibby & McDonald, 2005; Channon & Watts, 2003; Dennis & Barnes, 2000; Dennis, Purvis, Barnes, Wilkinson, & Winner, 2001; Ferstl, Guthke, & von Cramon, 2002; Martin & McDonald, 2005; Moran & Gillon, 2005) and in conversations with everyday partners (Johnson & Turkstra, 2012), and that inference accuracy has been linked explicitly to working memory scores (e.g., Dennis & Barnes, 2000; Moran & Gillon, 2005; Turkstra, 2008).

By contrast, *automatic inferences* are low-cognitive-demand inferences that require little world knowledge or strategic use of information, and are made rapidly and accurately by typical adults (McKoon, Greene, & Ratcliff, 1993; Swinney & Osterhout, 1990). Automatic inferences include presupposition (e.g., understanding that the phrase "Jane knows that lunch was delivered" entails that lunch was delivered; Dennis & Barnes, 2000), and also implicit semantic associations, such as that the phrase "Jane knows that lunch was delivered" implies that it is lunch-time (McKoon et al., 1993). There have been very few studies of automatic inference in TBI, and results are mixed. Bergemalm and Lyxell (2005) tested automatic inference by asking adults with or without TBI to complete sentences with missing words (e.g., May…order…later?), and found no significant difference between groups. Sentences were common phrases from restaurants or shops, however, and might have been known to participants, so results could have reflected cued recall of social scripts rather than inference. Johnson and Turkstra (2012) measured inference in extemporaneous conversations between adults with or without TBI and their self-nominated familiar partners, and again found no difference between groups and very low error rates overall. As in the Bergemalm and Lyxell (2005) study, however, familiarity of topics could have provided cues to support inference. Interactions were in person, so non-verbal cues also could have played a role, although elaborative inference errors were still significantly higher in the TBI group.

In a third study, Dennis and Barnes (2000) asked children with mild or severe TBI to judge the truth of sentences that contained factive predicates such as *know* and *realize,* as in the example in the previous paragraph; non-factive predicates (e.g., "Jane *believes* that lunch was delivered" does not entail that lunch was delivered); implicative predicates (e.g., "Jane *remembered* that lunch was delivered" entails that lunch was delivered); and non-implicative predicates (e.g., "Jane *wants to* remember that lunch was delivered" does not entail that lunch was delivered). Inferences based on these predicates are automatic for school-aged children, as evidenced by near-ceiling scores in the typically developing children included in the study (M = 22.9/24). Accuracy was significantly lower in children with severe TBI (M = 18.6), but not in those with mild TBI (M = 20.4), and pragmatic inference scores were significant predictors of scores on a standardized test of speech acts. That is, word-level automatic inference processes were impaired, and predicted performance on a connected language test.

In summary, there is strong evidence that elaborative inference processes can be impaired in individuals with TBI, but the story for automatic inference is less clear. As automatic inferences are a key component of everyday communication, and errors could lead to communication breakdowns, it was important to address this gap in knowledge.

In this study, we examined automatic inference in response to cues embedded in single words, specifically in verbs. Many verbs naturally embody underlying causes, accompaniments, and results that can appear in any context without being formally introduced or defined (Chafe, 1972). Understanding these features of verbs is critical in everyday communication. Many simple, active sentences are composed of two noun phrases (NPs), which are either nouns or constructions that function syntactically as nouns. Simple transitive sentences follow the form *subject-verb-object, or NP1-verb-NP2* (e.g., "Susan helped David."). In this grammatical context, certain verbs imply attributes to either the subject (NP1) or object (NP2) of the sentence. For example, the cause of the sentence "The mother scolded her son" is not explicitly stated. However, the verb "scold" naturally implies that the second noun phrase (NP2) is the cause of the statement, specifically that the son's behavior is the cause of his mother's scolding (Ferstl, Garnham, & Manouilidou, 2011). Sentence (1) below is an example in which the cause of the verb is attributed to the second noun phrase (NP2), which is the expected attribution; whereas sentence (2) contradicts expectations by attributing the cause of the verb to the mother, thereby treating the verb as a NP1 type verb (Garvey & Caramazza, 1974).

(1) The mother scolded her son because *he* (NP2) admitted his guilt.
(2) The mother scolded her son because *she* (NP1) discovered his guilt.

The phenomenon shown in this example is referred to as *implicit causality* (IC), which reflects intuitions about the causal agent of an event that are embedded within a verb's semantics (Hartshorne, 2014). These intuitions have been interpreted as linguistic structures (e.g., semantic features of verbs), reflections of general world knowledge, and high-level cognitive functions (Ferstl, Walther, Guthke, & von Cramon, 2005; Hartshorne, 2014). Work by Rohde et al.'s shows that IC verbs yield expectations about discourse direction, particularly regarding explanations and elaborations (Rohde, Kehler, & Elman, 2006). They have demonstrated that surface-level accounts of pronoun resolution and interpretation do not account for the range of findings in the literature (e.g., NP1 preference: Crawley, Stevenson, & Kleinman, 1990; grammatical parallelism: Sheldon, 1974; thematic role preference: Stevenson, Crawley, & Kleinman, 1994). However, pronoun biases unexplained by grammatical, thematic, or event-related accounts, can be modeled by the unfolding discourse (Rohde, Kehler, & Elman, 2007). The term "bias" is often paired with IC because it is necessary to make *judgments* about a statement's cause in order to measure IC (Ferstl et al., 2011). IC bias is a unique construct because it links a conceptual network of causal relationships to the concrete linguistic process of pronoun resolution, or determining the pronoun to which a verb refers (Hartshorne & Snedeker, 2013).

Accurate IC bias is an essential skill for comprehending text and spoken language (Caramazza, Grober, Garvey, & Yates, 1977; McKoon et al., 1993). To understand language in everyday contexts, we must have the skills to understand causal relations between events and states described within that language (Ferstl et al., 2011; Stuss & Alexander, 2000). Garvey and Caramazza (1974), who