Predictive inference comprehension in adults with traumatic brain injury (TBI): The effects of salience and working memory

Tamaryn D. Todd

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Department of Communication Disorders

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Abstract

Objective: The purpose of this study was to investigate the impact of salience on the comprehension of predictive inferences in adults with traumatic brain injury (TBI), by increasing the visual salience of the predictive sentence. This study also investigated whether a relationship existed between performance on a predictive inferencing comprehension task and working memory for this population. Increasing the salience of a crucial sentence in the predictive inferencing task may lead to better memory for the inferred information within the focused portion of the text (Gernsbacher & Jescheniak, 1995; Parkhurst, Law, & Niebur, 2002).

Method: Six participants with TBI and six non-brain injured peers (NBI) took part in the study. Each participant was administered an inference comprehension task which consisted of a series of 55 stories. Each story incorporated one of five conditions: 1) a *Recent salient* condition (inferred information immediately preceded the comprehension question and was visually salient); 2) a *Recent non-salient* condition (inferred information immediately preceded the comprehension question but was not visually salient); 3) a *Distant salient* condition (inferred information occurred early in the story and was visually salient); 4) a *Distant non-salient* condition (inferred information occurred early in the story and was not visually salient); and 5) a *Control* condition (no inferred information in the story). In addition there were 20 filler stories. The predictive sentence was bolded in half the stories in order to increase the visual salience of the stimuli. In addition, a measure of working memory span (Lehman-Blake & Tompkins, 2001) was administered.

Results: A significant main effect was found for Group, $F(1,11) = 7.6$, $p = 0.019$, with adults with TBI performing more poorly than matched controls. A significant main effect

was also found for Condition, $F(3,33) = 3.159$, $p = 0.038$, with all participants performing more poorly in the *Distant non-salient* condition. No statistically significant interaction between Group x Condition was observed, $F(3,33) = 0.469$, $p = 0.706$. Post-hoc comparisons revealed that all participants performed more poorly in the non-salient condition when the storage load was high (distant non-salient condition). Significant correlations were found for working memory span and the *Distant salient* condition ($r = 0.677$, $p < 0.05$) and *Distant non-salient* condition ($r = 0.646$, $p < 0.05$).

Conclusion: The results have both theoretical and clinical implications. Theoretically, the role of attention in working memory is of interest in language comprehension (e.g. Montgomery, Evans, & Gillam, 2009). This study may further contribute to studies of allocation of attention using increased salience to enhance comprehension. Clinically, the use of enhancing the salience of key information is a practical strategy that can be employed.

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Chapter 1

Literature Review

1.0 Introduction

Traumatic brain injury (TBI) is defined as "an injury to the brain resulting from externally inflicted trauma" (Accident Compensation Corporation, 2006, p. 21). It has been estimated that between 16 000 and 22 500 individuals in New Zealand sustain a TBI each year (Accident Compensation Corporation, 2006). Due to advances in medical care, most of these people will survive the original impact of a TBI but will be left with ongoing difficulties due to the injuries sustained (Accident Compensation Corporation, 2006). The consequences of TBI are broad and varied and often include complex impairments affecting linguistic and cognitive functioning (Adamovich, 2005; Biddle, McCabe, & Bliss, 1996; Constantinidou, Thomas, Best, & Ashley, 2004; McDonald & Flanagan, 2004; Murdoch, 2010).

Individuals who have sustained a TBI often find their ability to function independently within various settings, including home, work and social situations is impeded by the consequences of their injury (Adamovich, 2005; Constantinidou, et al., 2004; King & Tyerman, 2008; McDonald, 2000; Ylvisaker, 1992; Ylvisaker, Szekeres, & Feeney, 2001; Ylvisaker, Urbanczyk, & Feeney, 1992). One consequence that is highly likely to have an impact on functioning in a variety of settings is language impairment. The presence of persisting language difficulties has been highly reported following TBI (Murdoch, 2010) The nature of the language impairment is not always clear however. An individual who has sustained a TBI will often show impairment in their ability to use language in daily

situations despite basic structural components of language remaining intact (Martin & McDonald, 2003). It has been suggested that cognitive constructs such as attention and memory may be more likely to be contributing to the language deficits that are observed following TBI (Beukelman & Yorkston, 1991; Coelho, DeRuyter, & Stein, 1996; Murdoch, 2010; Murdoch & Theodoros, 2001). This study will examine one type of language deficit that has been described in TBI, inference comprehension. Specifically, the ability of individuals with TBI to understand inferences under different conditions that alter cognitive load will be evaluated.

1.1 Language following TBI

Language difficulties following TBI are commonly referred to as 'cognitive-communicative impairment' (Beukelman & Yorkston, 1991; Coelho, et al., 1996; Leblanc, de Guise, Feyz, & Lamourreux, 2006; Murdoch & Theodoros, 2001).This term encompasses the cognitive constructs that are often impaired in individuals who have sustained a TBI (Hartley, 1995; Murdoch & Theodoros, 2001; Ylvisaker, et al., 2001). Domains of cognition that are susceptible to impairment include attention, executive functioning, reasoning, problem solving, perception, learning and memory (Adamovich, 2005; Beukelman & Yorkston, 1991; Coelho, et al., 1996; Constantinidou, et al., 2004; Hartley, 1995; Ylvisaker, et al., 2001). Effective communication involves the interaction of these cognitive domains and linguistic processes (Hartley, 1995; Hinchliffe, Murdoch, & Chenery, 1998) in a complex synergy. When one or more of the domains is affected, the presence of communication difficulties is likely.

Despite the presence of cognitive communication deficits in TBI, performance on language measures depends on the nature of the language task being performed. For instance, there is a general consensus that standardized measures of language, which are typically aphasia assessment batteries, are insensitive to the deficits which individuals with TBI exhibit (Biddle, et al., 1996; Hinchliffe, et al., 1998; McDonald, 2000; Murdoch, 2010) because they fail to investigate beyond sentence level and only assess primary language function (Hinchliffe, et al., 1998). Areas of impaired language functioning are highlighted when individuals with TBI are assessed on measures of functional communicative interactions and 'higher-level language tasks' that involve the integration of language domains such as syntax and semantics with cognitive domains such as memory. These 'higher-level' language tasks include comprehension of figurative language (e.g. idioms and metaphors), ambiguous sentences (i.e. sentences where the meaning is influenced by the context) and inferences (where comprehension involves filling in missing information) (Biddle, et al., 1996; Hinchliffe, et al., 1998; McDonald, 2000; Murdoch, 2010). Although all of these "high-level language abilities are critical for communicative competence, in this study, inference comprehension will be the focus of the research.

An inference occurs any time that one goes beyond the literal material which has been read or heard in order to understand what is being communicated (Eysenck, 2001; Harley, 2001; McDonald, 2000; McKoon & Ratcliff, 1992). Understanding an inference involves the comprehension of implied, rather than explicitly stated, information (McKoon & Ratcliff, 1992; Moran & Gillon, 2005). Inferences are of interest for several

reasons: 1) they occur frequently in academic, vocational, and social situations; 2) they have been shown to require cognitive resources (McKoon & Ratcliff, 1992); and, 3) inference comprehension has been shown to be impaired following TBI (Moran & Gillon, 2005). In order to understand how inferences are affected following TBI however, it is important to understand the differences between inference types.

Three main types of inferences have been identified in the literature: logical inferences, bridging inferences and elaborative inferences (Harley, 2001). Logical inferences are based on the semantic association of the words. For example, when one hears the sentence *Vlad is a bachelor* (Harley, 2001, p. 318), one infers that Vlad is a man because of the presence of the word bachelor which is a masculine term (Harley, 2001). Bridging inferences involve establishing a relationship between current information and preceding components of discourse and/or text (Clark, 1977; Singer, Russell, & Halldorson, 1990) in order to maintain coherence among ideas (Clark, 1977). An example of a bridging inference is *Vlad looked around the castle. The moat was dry* (Harley, 2001, p. 319). Harley (2001) explains that individuals assume that the moat mentioned in the previous sentence refers to a moat that must be around the castle that was mentioned in the first sentence. The most common form of bridging inference involves pronoun reference coherence (Harley, 2001) such as *The girl went to the shop. **She** bought some bread* (Moran, 2005).

In addition to the description of inferences into the three categories described above McKoon and Ratcliffe (1992) classified inferences according to the cognitive resources

required to process them. They organized inferences into two categories: 'minimal' and 'elaborative.' Minimal inferences rely on fewer processing resources and are therefore less cognitively demanding (Lehman-Blake & Tompkins, 2001). This category of inferences is believed to be processed automatically (Lehman-Blake, 2009; Lehman-Blake & Tompkins, 2001; McKoon & Ratcliff, 1992), occur during comprehension (Harley, 2001) and aid in sentence and text coherence (Calvo, 2001; Harley, 2001). The bridging inference described above is an example of a minimal inference. Elaborative inferences on the other hand, occur when individuals apply their world knowledge in order to extend information provided (Harley, 2001; McDonald, 2000). Elaborative inferences are believed to place high demands on an individual's cognitive resources as they require conscious strategic processing in order to apply their world knowledge (Calvo, 2001; Lehman-Blake & Tompkins, 2001; McKoon & Ratcliff, 1992; Saldert & Ahlsén, 2007) and generally are only made during recall (Anderson, 2000).Theme generation, character attitude and motivation and outcome prediction are all examples of elaborate inferences that individuals must make when comprehending a text (Lehman-Blake & Tompkins, 2001; Saldert & Ahlsén, 2007).

1.2 Inference comprehension and TBI

As noted earlier, inference comprehension is believed to be one of several 'high-level' language processes affected by TBI (Hinchliffe, et al., 1998; Lehman-Blake & Tompkins, 2001; Moran & Gillon, 2005; Murdoch, 2010). Inference comprehension abilities in adults who have sustained a TBI are of particular interest as it has been argued that "…virtually every aspect of language comprehension is inferential" (Singer, 2007, p.

343). Inference comprehension is required in many aspects of daily living (McDonald & Flanagan, 2004; Moran & Gillon, 2005; Turkstra, 2008) with inferencing taking place continuously for the purpose of language comprehension (Ferstl, Guthke, & von Cramon, 2002; Harley, 2001). With this in mind, it would appear that inference comprehension is a crucial element of the social aspects of daily life (McDonald & Flanagan, 2004; Moran & Gillon, 2005; Turkstra, 2008). Social interactions are largely based on making inferences from what other people say (Harley, 2001). The inability to generate accurate inferences is a pragmatic communication deficit commonly observed in individuals who have sustained a TBI (McDonald & Flanagan, 2004; Turkstra, 2008).

Although it is agreed that inference comprehension is likely to be influenced following TBI, Moran & Gillon (2005) speculated that perhaps performance could be improved under differing conditions. Moran & Gillon (2005) reviewed several factors which constrain and facilitate the comprehension of inferences. First they noted that the type of inference being processed can influence inference comprehension (Moran & Gillon, 2005). For instance, minimal inferences are less cognitively demanding, require fewer processing resources (Lehman-Blake & Tompkins, 2001) and occur automatically (Lehman-Blake, 2009; Lehman-Blake & Tompkins, 2001; McKoon & Ratcliff, 1992). Elaborative inferences, on the other hand place high demands on processing resources and require conscious processing (Calvo, 2001; Lehman-Blake & Tompkins, 2001; McKoon & Ratcliff, 1992; Saldert & Ahlsén, 2007) so are likely to be more difficult. Contextual bias and familiarity were also noted as factors which can facilitate or constrain inference comprehension (Moran, 2005). Contextual bias refers to how likely

an inference is based on the context which it is made. The strength with which the context suggests a particular inference is a deciding factor as to whether the inference will be understood or not. Familiarity refers to the listener's familiarity with the lexical and contextual content of the inference (McKoon & Ratcliff, 1992).

A third factor, text distance was shown to constrain inference comprehension; it refers to the amount of time between the introduction of an inference and assessment of an individual's comprehension of that inference (Lehman-Blake & Tompkins, 2001; Moran, 2005). Increased text distance results in an increase in storage demands on working memory (Daneman & Carpenter, 1980; Lehman-Blake & Tompkins, 2001; Moran & Gillon, 2005).

Moran and Gillon's (2005) study focused on the influence of text distance on elaborative inference comprehension of six adolescents with TBI. Specifically they looked at predictive inferences. Predictive inferences involve an individual seeing or hearing linguistic information and, based on the integration of context and the linguistic information, predicting an outcome (Moran, 2005). Moran and Gillon (2005) examined the adolescents' ability to generate inferences that were presented under two different conditions. In both conditions, participants were expected to read a paragraph and generate an inference from a predictive sentence. An example of a paragraph is as follows:

> John was really looking forward to going on holiday.
>
> He had been working really hard and needed a rest.

John had the car packed and was ready to go.

John threw his rod and reel into the car. (predictive sentence)

Participants were then asked to infer where John was going on holiday. The dependent variable was the accuracy of response to the comprehension questions between the two conditions, distant and recent. This design allowed the researchers to evaluate the effect of recency of mention on the participants' ability to comprehend the inferences. The results indicated that individuals with TBI could comprehend and generate inferences when the predictive sentence occurred just prior to the comprehension question (Where was John going on holiday) but had significant difficulty in generating the inference when the predictive utterance occurred earlier in the passage. These findings indicated to the researchers that individuals with TBI had difficulty storing the predictive sentence over time; they therefore could not generate inferences when storage demands were increased. The researchers interpreted their findings based on a working memory hypothesis of language comprehension. That is, they suggested that individuals with TBI have poor working memory and that by increasing or decreasing working memory load, language performance could be enhanced In order to understand how this would be the case it is important to consider working memory and the factors that facilitate and constrain language comprehension within a working memory model.

1.3 Working Memory and TBI

Working memory provides the vehicle by which many cognitive functions operate, including reasoning, problem solving and language comprehension (Braver et al., 1997;

Constantinidou, et al., 2004; Just & Carpenter, 1992; Miyake & Shah, 1999; Roncadin, Guger, Archibald, Barnes, & Dennis, 2004). Working memory refers to an individual's ability to store and process information simultaneously (Baddeley, 1986; Calvo, 2001; Just & Carpenter, 1992; Miyake & Shah, 1999; Roncadin, et al., 2004). The processes and mechanisms involved in working memory can be utilized to support storage and processing of information complex cognitive activities, such as language comprehension (Gathercole, 2007). When an individual is listening to someone speaking, s/he is remembering what is being said while processing the new and incoming information. Old information must be processed and integrated with new, incoming information (Just & Carpenter, 1992; Roncadin, et al., 2004). Working memory involves the integration of information derived from both long-term (LTM) and short-term memory (STM) (Baddeley & Logie, 1999; Just & Carpenter, 1992).

Deficits in working memory occur frequently following TBI (Adamovich, 2005; Beukelman & Yorkston, 1991; Constantinidou, et al., 2004; Hartley, 1995; Hinchliffe, et al., 1998; Moran & Gillon, 2004, 2005; Murdoch, 2010; Murdoch & Theodoros, 2001; Ylvisaker, et al., 2001). They have been reported in the paediatric (Hanten, Levin, & Song, 1999; Levin et al., 2002; Roncadin, et al., 2004), adolescent (Moran & Gillon, 2004, 2005) and adult TBI literature (Adamovich, 2005; Hinchliffe, et al., 1998; Ylvisaker, et al., 2001). It has been postulated that these memory deficits occur due to "ineffective encoding of information, inadequate storage of information, difficulty retrieving information, and the inability to cope with interferences" (Adamovich, 2005, p. 229). Moran and Gillon's (2005) study explored the inadequate storage component of

working memory deficits. The auditory comprehension deficits commonly seen in individuals who have sustained a TBI have been shown to be strongly correlated with memory deficits which typically affect the TBI population (Hinchliffe, et al., 1998; Moran & Gillon, 2005; Murdoch, 2010; Murdoch & Theodoros, 2001). One component of auditory comprehension involves inference comprehension and has been shown to be related to working memory capacity in TBI and other clinical populations, such as RHD (Lehman-Blake & Tompkins, 2001; Moran & Gillon, 2005; Tompkins, Bloise, Timko, & Baumgaertner, 1994).

Inference comprehension has been shown to be influenced by working memory (Moran & Gillon, 2005). Moran and Gillon's (2005) findings are consistent with other studies that have demonstrated that storage load can constrain working memory capacity (Carpenter, Miyake, & Just, 1994; Lewis, Vasishth, & Van Dyke, 2006; MacDonald, Just, & Carpenter, 1992; Miyake, Carpenter, & Just, 1994). The adolescent participants with TBI from Moran and Gillon's (2005) study only differed in performance to their peers without brain injury when the inferences that required increase storage demands were presented. The performance of these individuals on inferencing comprehension tasks is impaired when storage demands are increased which place higher demands on their working memory capacities. It would seem plausible to argue, based on these findings, that the impaired performances of adolescents with TBI on inference comprehension tasks that require a greater storage load stems from a working memory deficit rather than a deficit in general inference comprehension abilities (Moran & Gillon, 2005).

1.4 Salience and inference comprehension

The study conducted by Moran and Gillon (2005) provided evidence that individuals with TBI are able to generate inferences when the storage demands are reduced. Reduced storage load, is only one factor that may facilitate working memory and therefore language comprehension (Moran, 2005) however there are others that have also been shown to facilitate working memory (e.g. familiarity reference). One procedure that may facilitate working memory is increasing the salience of the target stimulus (Gernsbacher & Jescheniak, 1995; Givón, 1992; Klin, Weingartner, Guzman, & Levin, 2004). Salience is worth exploring as it is a simple modification that can be made in written and spoken language to enhance comprehension for adults and children alike.

Klin and colleagues (2004) conducted four experiments in which they investigated factors that influenced readers' abilities to make anaphoric inferences. An example of an anaphor is *Vlad was happy;* ***he*** *loved the vampire. Vlad* is the anaphor's antecedent (what the anaphor is referring to) *and He* is the anaphor (Harley, 2001). The readers from the study were found to adjust the amount of processing they devoted to each text based on its perceived importance. Klin et al. (2004) found that drawing attention to relevant information by making it more salient, in this case the anaphor's antecedent, aided in the processing of the text for comprehension. These results supported the hypothesis postulated by Givón (1992). Givón (1992) proposed that different types of linguistic cues assisted comprehension because they drew the reader's attention to concepts and ideas crucial to the inference. Givón (1992) argues that if concepts are highlighted in some way

as being important, attention will be drawn to them. With increased attention, more thorough processing is likely to take place.

A way to draw a reader's attention to important concepts within a *written* text is to increase the visual salience of the stimulus (Itti & Koch, 2000; Ozcelik, Karakus, Kursun, & Cagiltay, 2009). A learner's attention is believed to be guided by low-level visual features, such as colour, utilizing a bottom-up mechanism (Itti & Koch, 2000; Ozcelik, et al., 2009; Parkhurst, Law, & Niebur, 2002). A bottom-up mechanism refers to the visual features of stimuli and is therefore based on visual salience (Itti & Koch, 2000; Ozcelik, et al., 2009; Parkhurst, et al., 2002).

Ozcelik and colleagues (2009) altered the visual salience of their stimulus by colour-coding the material shown to 52 undergraduate participants. Their aim was to investigate why learners performed better when using colour-coded material rather than monochrome material. The researchers hypothesised that their participants would pay more attention to, and thus spend more time processing, the coloured elements of the material because they were more visually salient. The results of their study indicated that colour-coding increased the retention of the material being learned. The researchers also included an eye-tracking component to their investigation which revealed that colour-coding attracted learners' attention to visually salient information.

1.5 Thesis aims and hypotheses

To date there appears to be a paucity of research in the area of inference comprehension and the effects of salience and working memory in adults with a TBI. This study has been designed in order to investigate the impact that salience may have on the comprehension of predictive inferences in adults with TBI by increasing the visual salience of the predictive sentence. This study will also investigate whether a relationship exists between performance on a predictive inferencing comprehension task and working memory for this population.

There are two primary aims for this research:

1. To determine the influence of increased salience on predictive inference comprehension;
2. To observe whether there is a relationship between predictive inferencing comprehension abilities and working memory.

The null hypothesis of this investigation is that there will be no difference in the participants' performance in the *Recent salient, Recent non-salient, Distant salient* and *Distant non-salient* conditions. The research hypotheses predict the following outcomes:

1. There will be no difference across participants in the performance under the *Distant salient* condition (where the predictive sentence is bolded) and the *Recent salient* and *Recent non-salient* conditions.

2. The participants who have sustained a TBI will perform more poorly on the inference comprehension task when under the *Distant non-salient* condition than when the inference comprehension task is presented in the *Distant salient*, *Recent salient* and *Recent non-salient* conditions.

3. A relationship between working memory capacity and performance on the inference comprehension task will be observed. Participants with a depressed working memory score are expected to perform more poorly on the inference comprehension task than participants with a higher working memory score.

Chapter 2

Methods

2.1 Participants

Seven adults with TBI and seven individuals with no brain injury (NBI) participated in the study. Participants in the TBI group and the NBI group were matched based on age, gender and educational history. One participant was excluded from the study based on the fact that he was unable to follow the experimental instructions and answer the comprehension question. Participants ranged in age from 47 years to 56 years (mean age 51 years). All TBI participants reported having sustained a severe head injury. The participant group with TBI consisted of two males and four females. Biographical details of the participants are presented in Table I.

Table I: ***Participant demographics***

Participant	Sex	Age	Age at injury	Nature of accident	Control Age
1	M	55;7	19	MVA	52;10
2	F	48;7	22	MVA	47;1
3	F	56;8	47	Assault	54;11
4	M	47;2	19	MVA	49;5
5	F	48;11	28	MVA	50;0
6	F	56;5	23	Pedestrian vs car	55;8

Note: MVA = Motor Vehicle Accident; L = Left; R = Right

Participants were recruited from a previous research study, and all were from the Christchurch metropolitan area. All participants were native English speakers. Participants were excluded if they had identified cognitive deteriorating conditions, emotional or behavioural disorders, and uncorrected sensory or motor deficits that may

have impeded their ability to perform the assessment tasks. The NBI participants were recruited to match the TBI participants based on gender, age and level of education (+/- 3 years).

2.2 Method

2.2.1 Procedure

The study was designed to examine the influence of visual salience on performance on a predictive inferencing comprehension task. The dependent variable that was measured was the accuracy of the participants' responses to inference comprehension questions. The testing sessions were made up of the experimental inference comprehension task and an ancillary working task. Testing took place in a quiet room either at the participant's house or in a clinic room at the University of Canterbury Speech and Hearing Clinic. The testing sessions lasted between 40 and 270 minutes. Participants from the experimental group were offered frequent breaks between tasks and were also given the option to complete the tasks over two sessions.

2.2.2 Experimental task

The inference comprehension task that was administered to participants evaluated the understanding of predictive inferences. The inference comprehension task was adapted from Lehman-Blake and Tompkins (2001) and Moran and Gillon (2005). The task consisted of a series of 55 stories. Each story incorporated one of five conditions: a *Recent salient* condition (a total of 7 stories), a *Recent non-salient* condition (7 stories), a *Distant salient* condition (7 stories), a *Distant non-salient* condition (7 stories) and a

Control condition (7 stories). In addition there were 20 filler stories. All stories were made up of four sentences. For the two "*Recent*" conditions the first three sentences provided setting information and the final sentence was the predictive sentence which inferred a specific outcome. The predictive sentence was bolded in half the stories in order to increase the visual salience of the stimuli. The seven stories that contained bold sentences in the recent position made up the *Recent salient* condition. The *Recent non-salient* condition was comprised of the remaining seven stories that did not contain bolded predictive sentences. For the "*Distant*" conditions, the predictive sentence was placed in the second position in the story. This manipulation meant that there was a greater difference between the expected time that the inference was made and the time that the participants were required to respond. The participants would be required to store the generated inference over a longer duration than in the two *Recent* conditions, allowing for the evaluation of a recency of mention effect on the ability to understand inferences (Lehman-Blake & Tompkins, 2001). As in the *Recent* conditions, the predictive utterance was either bolded (*Distant salient*) or not (*Distant non-salient*). The *Control* condition stories also contained four sentences but did not include a predictive sentence. The predictive sentence was replaced by factual information. Examples of the stimuli are as follows:

● *Recent salient* condition:

(1) Andrew arrived at the event early Saturday morning (Setting).

(2) He had been preparing for the competition for several months (Setting).

(3) Andrew's team mates were cheering loudly (Setting).

(4) **At the sound of the horn, Andrew dived into the water** (Predictive).

● *Recent non-salient* condition:

(1) Andrew arrived at the event early Saturday morning (Setting).

(2) He had been preparing for the competition for several months (Setting).

(3) Andrew's team mates were cheering loudly (Setting).

(4) At the sound of the horn, Andrew dived into the water (Predictive).

● *Distant salient* condition:

(1) **Andrew dived into the water** (Predictive).

(2) He arrived at the competition early Saturday morning (Setting).

(3) He had been preparing for the event for a few months (Setting).

(4) Andrew's team mates were clapping loudly (Setting).

● *Distant non-salient* condition:

(1) Andrew dived into the water (Predictive).

(4) He arrived at the competition early Saturday morning (Setting).

(5) He had been preparing for the event for a few months (Setting).

(4) Andrew's team mates were clapping loudly (Setting).

● Control condition:

(1) Andrew arrived at the competition early Friday morning (Setting).

(2) He had been preparing for the event for several months (Setting).

(3) Andrew's friends were clapping loudly (Setting).

(4) He ran faster than any of the other competitors (Factual).

Twenty filler stories were also included in the task. They did not contain any inferences or highlighted salient information and were presented intermittently among the different conditions. All stories were presented line by line on a laptop computer. The participants controlled the presentation of the stimulus by pressing the spacebar key to reveal each subsequent line until the story appeared on screen in its entirety. The stories were presented in three blocks with a rest break within each block. Following the presentation of a complete story, a comprehension question appeared on the screen. Participants were instructed to read the question and then respond verbally to answer the question. The participants were asked what they thought would happen or what had happened and their responses were recorded using an Olympus WS-450S digital voice recorder. The order in which these sentences were presented was randomized for each participant to control for order effects.

2.2.3 Ancillary task

A measure of working memory was included in order to evaluate the working memory abilities of the participants. The task was also included in order to examine whether a relationship exists between working memory and inference comprehension. The working memory measure consisted of a working memory reading span task that was developed by Daneman and Carpenter (1980) and adapted by Tompkins et al. (1994). The reading span task provides a measure of the processing and storage elements of working memory

(Tompkins, et al., 1994). The processing component of the working memory reading span task involved reading a sentence and judging whether the statement is true or false. The storage component of the task involved trying to remember the final words of the sentences for later recall. For the task, the participants were required to read stimuli sentences. The stimuli consisted of twelve sets of sentences, which varied in length between three and five words. The sentences were divided into three sets of two sentences, three sets of four sentences, and three sets of five sentences. Every set was introduced by a set number which appeared on the laptop screen. The sentences from each set were made up of active declarative sentences and ended in different words. After reading each statement sentence, the participants were encouraged to verbalise whether the statement was either 'True' or 'False'. Examples of the task stimuli are as follows:

You sit on a chair (T)

Trains can fly (F)

The sentences were presented individually on a laptop computer. Participants pressed the spacebar key to reveal the next sentence. At the completion of each set, a sentence would appear to indicate the end of the set and the beginning of the next. Participants were at this point instructed to recall the last words from each of the sentences in that set. The participants were given several practice items at the two sentence level. The participants were informed that the number of sentences per set would increase as they progressed through the task. The participants' responses to both the comprehension and recall components of the task were recorded using an Olympus WS-450S digital voice recorder. A working memory span score was calculated based on the total number of words that were recalled.

Chapter 3

Results

This study compared the performance of adults with TBI and their peers on an inference comprehension task. Comprehension was measured under four conditions: *Recent salient, Recent non-salient, Distance salient* and *Distant non-salient*.

3.1 Statistical analysis

To determine the differences and evaluate the effects of increased salience on predictive inference comprehension on adults with and without TBI, a multiple two-way analysis of variance was calculated. A significant main effect was found for Group, $F(1,11) = 7.6$, $p = 0.019$, with adults with TBI performing more poorly than matched controls. A significant main effect was also found for Condition, $F(3,33) = 3.159$, $p = 0.038$, with all participants performing more poorly in the *Distant non-salient* condition. No statistically significant interaction between Group x Condition was observed, $F(3,33) = 0.469$, $p = 0.706$. Multiple comparison procedures were conducted for the four conditions. Significant differences were observed for *Recent salient* verses *Distant non-salient* and *Recent non-salient* verses *Distant non-salient* conditions. There was no statistically significant difference between the *Recent salient, Recent non-salient* and *Distant salient* conditions. The performance of the participants with TBI and the matched controls is summarised in Table II.

Table II. Group performance on predictive inferencing task under each condition

	Adult TBI				Matched control			
	Recent S	Recent NS	Distant S	Distant NS	Recent S	Recent NS	Distant S	Distant NS
Mean	6.3	6.3	6.1	5.5	7.0	7.0	6.7	6.5
SEM	0.246	0.246	0.246	0.246	0.227	0.227	0.227	0.227

Note: Recent S = Recent salient, Recent NS = Recent non-salient, Distant S = Distant salient, Distant NS = Distant non-salient

3.2 Ancillary task

Working memory span score was calculated based on the total number of words that were recalled (see Table III). Mean accuracy scores on the Working Memory Span Task (Tompkins, et al., 1994) for the participants with TBI and their matched controls were 21.0 (SD = 5.6) and 27.3 (SD = 4.7). The performances on the working memory task of the TBI and NBI participants were compared using the Mann-Whitney Rank Sum Test. The difference between the two groups was not statistically significant. The groups' scores were collapsed for subsequent analyses. Pearson Product Moment correlations were calculated to determine whether a relationship existed between Working Memory Span scores and the effects of visual salience on predictive inference comprehension. There was no significant correlation between working memory span and performance on either the *Recent salient* or *Recent non-salient* conditions ($r = 0.56$). Significant correlations were found for working memory span and the *Distant salient* condition ($r = 0.677$, $p < 0.05$) and *Distant non-salient* condition ($r = 0.646$, $p < 0.05$).

Table III: ***Performance on ancillary task***

Participant	Total Words Recalled	
	TBI	NBI
1	16	22
2	28	30
3	15	26
4	26	32
5	17	22
6	24	32

Chapter 4

Discussion

Predictive inference comprehension is of interest in the study of TBI because it is required in many aspects of daily living (McDonald & Flanagan, 2004; Moran & Gillon, 2005; Turkstra, 2008). The aim of this study was to determine the influence of increased salience on predictive inference comprehension for adults who had sustained a TBI. Specifically, four conditions were tested: 1) A *Recent salient* condition (low storage load and a salience cue); 2) a *Recent non-salient* condition (low storage load and no salience cue); 3) a *Distant salient* condition (high storage load but with the inclusion of a salience cue); and 4) a *Distant non-salient* condition (high storage load and no salience cue). Based on theories of working memory (Baddeley, 1986; Baddeley & Logie, 1999; Cowan, 2005; Just & Carpenter, 1992; Miyake & Shah, 1999), it was expected that condition four would be the most difficult and the remaining three conditions would be equal. In addition, the relationship between predictive inferencing comprehension abilities and working memory was explored.

Influence of Distance on Comprehension: Distant non-salient condition

Considering past research (e.g. Moran & Gillon, 2004), it was hypothesized that inference comprehension on tasks with a large storage load, would be difficult for individuals with TBI. This was confirmed in this study whereby the adults with TBI performed significantly poorer than their matched controls without brain injury when presented with inferences from the *Distant non-salient* condition. Likewise it was expected that the *Distant non-salient* condition would constrain comprehension more

than the remaining three conditions and therefore performance would be poorer. This was confirmed as a significant difference across task was noted with performance in the *Recent salient, Recent non-salient* significantly better than performance of the inference task in the *Distant non-salient* condition. Again these findings were consistent with Moran & Gillon (2004).

Influence of saliency: Distant Salient Condition

One of the most unique questions addressed in this study was whether salience would enhance comprehension, particularly in individuals with TBI. It was expected that the inclusion of a visually salient target would increase comprehension of the inferences because it would draw attention to the information that was required for making the inference. Altering visual salience helps to draw one's attention to important information (Itti & Koch, 2000; Ozcelik, et al., 2009) which may enhance comprehension (Moran, 2005). It was therefore predicted that individuals with TBI would perform as well on a task that had a large storage load (i.e. the *Distant* Condition) if the target information was made salient, as a task with a low storage load (i.e. the *Recent* Condition).

As predicted, there were no differences in performance for either group on *Distant salient* versus the two *Recent* conditions. The inclusion of the salient target was expected to draw attention to the relevant information, therefore having the same effect as having a reduced storage load. In accordance with the findings of Klin et al. (2004), the researchers found that drawing attention to the relevant stimuli aided in the processing of the predictive inference. Contrary to expectation, while there was a difference between the *Distant*

salient and *Distant non-salient* conditions, this difference was not statistically significant. This may be due to two reasons. Firstly, the small sample size may have affected the statistical significance between the *Distant salient* and *Distant non-salient* conditions. Or secondly, the storage demands of the *Distant salient* and *Distant non-salient* conditions were greater than previously anticipated by the researchers and increasing the visual salience of the predictive sentence was not powerful enough to overcome these storage demands.

Working memory and inference comprehension

A relationship was found between the performances on the working memory task and the performances on the inference comprehension task in the *Distant salient* and *Distant non-salient* conditions. No relationship was found between the *Recent salient* and *Recent non-salient* conditions and working memory capacity. This may be due to the fact that the *Distant salient* and *Distant non-salient* conditions required greater processing and storage than the *Recent salient* and *Recent non-salient* conditions, which placed greater demands on working memory capacity.

Future research

The focus of this study was to determine the influence of increased salience on predictive inference comprehension for adults who had sustained a TBI. A few influences require consideration both for the purpose of interpreting the findings of the current study and in directing future research in the field of TBI and predictive inference comprehension.

The researchers involved in the current study identified that storage load remains a significant factor in predictive inference comprehension for adults who have sustained a TBI. However the influence of attention by increasing salience of a target was shown to affect performance as well. The role of attention and comprehension has just begun to be explored in individuals with language impairment (e.g. J. W. Montgomery, Evans, & Gillam, 2009). The role of attention in working memory, and particularly the influence of salience on language comprehension requires much more research. While the size of the participant sample was small in this study, statistically significant results were still obtained. Future research in this area would benefit from a larger sample size.

It is important to bear in mind the heterogeneity of the TBI population at large when trying to generalise results (Murdoch, 2010). A relatively long period of time had lapsed since the TBI participants had sustained their injuries and the current study taking place (average time since injury was 25 years). Since sustaining their injuries, each of the participants had received varying amounts and types of intervention. One consideration is that rather than conducting studies of language performance based on etiology, it may be more interesting to evaluate performance based on overall working memory ability. Working memory has been shown to be related to a number of cognitive and linguistic aptitudes (Cowan et al., 2005; J. Montgomery, Magimairaj, & O'Malley, 2008). Although the participants in this study all had moderate to severe injuries, there were differences across working memory performance. In fact, as a group there was no difference between the TBI group and the age-matched peers. It may be of more use in future research to examine large populations of individuals grouped according to high and low working

memory and examine the effect of salience and storage load on individuals with differing working memory capacities.

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Appendix A: Predictive inference comprehension task stimuli

Control Condition

1. Don set out his coat and his hat.

   He had been looking forward to this trip for weeks.

   Don had been busy at work and wanted a few days alone.

   He couldn't wait to go skiing.

Question: What was Don going to do?

2. Richard arrived at the competition early Friday morning.

   He had been preparing for the event for several months.

   Richard's friends were clapping loudly.

   He ran faster than any of the other competitors.

Question: What was Richard doing?

3. Fred had been raking leaves all morning.

   He had only one more pile of leaves to collect.

   Fred quickly put them in his last rubbish bag.

   The sun was shining as he tied the rubbish bag.

Question: What had Fred been doing?

4. Donna arrived home close to midnight.

   She had worked the late shift in a noisy hotel bar.

   Now she just wanted some peace and quiet.

Donna curled up under her blanket and read a book for two hours.

Question: What was Donna doing?

5. Pam had spent the day organising her new office.

   She wanted to let her brother know about her promotion.

   Pam knew he would be excited for her.

   She called her brother and told him all about her promotion.

Question: How did Pam let her brother know about her promotion?

6. Lori was almost finished with her Christmas presents.

   She had made a beautiful scarf for her father.

   Lori also wanted to give her mother a special gift.

   She purchased a silk blouse and wrapped it in a large box.

Question: What had Lori purchased?

7. Beth was cleaning her house on Thursday.

   She had already worked most of the day.

   Now Beth had one final task to do.

   She had dusted her bookshelves and then sat down to rest.

Question: What had Beth been doing?

Recent salient condition

1. Tim set out his jacket and cap.

   He had been looking forward to this trip for months.

   Tim had been busy at work and wanted some time alone.

   He put his rod in the car and drove to the lake.

Question: What was Tim going to do?

2. Patrick arrived at the event early Saturday morning.

   He had been preparing for the competition for several months.

   Patrick's teammates were cheering loudly.

   At the sound of the horn, Patrick dived into the water.

Question: What was Patrick doing?

3. Bill had been raking leaves all afternoon.

   He had only one more pile of leaves to collect.

   Bill quickly put them in his last rubbish bag.

   There was a flash of lightning and a rumble of thunder.

Question: What was going to happen to the weather?

4. Julie arrived home after midnight.

   She had worked the late shift at a noisy restaurant.

   Now Julie just wanted some peace and quiet.

   She climbed into bed and switched off the light.

Question: What was Julie going to do?

5. Jill had spent the day organising her new desk.

   She wanted to let her brother know about her promotion.

   Jill knew he would be happy for her.

   She took out a piece of note paper and a pen.

Question: How did Jill let her brother know about her promotion?

6. Gina was almost finished with her Christmas presents.

   She had already made a handsome scarf for her brother.

   Gina also wanted to give her sister a special gift.

   She picked up a needle and thread and began to work.

Question: What did Gina do?

7. Jane was cleaning house on Saturday.

   She had already worked most of the day.

   Now she had one more task to do.

   Jane went to the cupboard and took out a broom.

Question: What was Jane's last task?

Recent non-salient Condition

1. Dylan arrived home after midnight.

   He had worked the late shift in a loud restaurant.

   It had been a very busy night.

   Dylan turned off the light and climbed into bed.

Question: What was Dylan going to do?

2. Amy set out her jacket and beanie.

   She had been looking forward to this trip for months.

   Amy had been busy at work and wanted to have some fun.

   She put her skis in the car and drove to the snow.

Question: What was Amy going to do on her trip?

3. Steve had spent the day organising his new office.

   He wanted to let his sister know about his promotion.

   Steve knew she would be excited for him.

   He sat down at his desk and dialed her number.

Question: What did Steve do?

4. Betty was cleaning house on Saturday.

   She had already worked most of the day.

   Now she had one more task to do.

   Betty went to the cupboard and took out a broom.

Question: What was Betty's last task?

5. Peter had been raking leaves all afternoon.

   He had only one more pile of leaves to collect.

   Peter quickly put them in his last rubbish bag.

   There was a flash of lightning and a rumble of thunder.

Question: What was going to happen to the weather?

6. Natalie arrived home at 10pm.

   She had met up with friends for dinner.

   She didn't stay out late because she had work in the morning.

   Natalie turned on her lamp and picked up her book.

Question: What was Natalie going to do?

7. Mike set out his jacket and cap.

   He had been looking forward to this trip for weeks.

   He had arranged to meet some friends at the lake.

   Mike put his rod in the car and drove to the lake.

Question: What was Mike going to do on his trip?

Distant salient Condition

1. Joe packed his hat and his coat.

   He put his rod in the car and drove to the lake.

   He had been looking forward to this trip for a month.

   Joe had been busy at work and wanted a weekend alone.

Question: What was Joe going to do?

2. Andrew arrived at the competition early Saturday morning.

   He dived into the water.

   He had been preparing for the event for a few months.

   Andrew's team mates were clapping loudly.

Question: What was Andrew doing?

3. Jeff had been raking leaves all afternoon.

   There was a flash of lightning and a rumble of thunder.

   He had only one more pile of leaves to pick up.

   Jeff hastily put them in the last rubbish bag.

Question: What was going to happen to the weather?

4. Sally arrived home after midnight.

   She climbed into bed and switched off the light.

   She had worked the late shift in a noisy restaurant.

   Now Sally was ready for some peace and quiet.

Question: What was Sally going to do?

5. Eve had spent the day organizing her new desk.

   She took out a piece of note paper and a pen.

   She wanted to let her brother know about her promotion.

   Eve thought he would be happy for her.

Question: How did Eve let her brother know about her promotion?

6. Mary was almost finished with her Christmas presents.

   She picked up a needle and thread and began to work.

   She had already made a shirt for her father.

   Mary also wanted to give her sister a special gift.

Question: What did Mary do?

7. Ruth was cleaning her house on Saturday.

   She went to the cupboard and took out a broom.

   She had already cleaned most of the house.

   Now Ruth had one last task to do.

Question: What was Ruth's last task?

Distant non-salient Condition

1. Jessica arrived home at 9pm.

   She turned off the light and climbed into bed.

   She had worked the late shift in a local cafe.

   It had been a very busy night.

Question: What was Jessica going to do?

2. Charlie set out his jacket and beanie.

   He put his skis in the car and drove to the snow.

   He had been looking forward to this trip for months.

   Charlie had been busy at work and wanted to have some fun.

Question: What was Charlie going to do on his trip?

3. Kelly had spent the day organising her new office.

   She sat down at her desk and picked up the phone.

   She wanted to let her sister know about her promotion.

   Kelly knew she would be excited for her.

Question: How did Kelly let her sister know about her promotion?

4. Sue was cleaning house on Saturday.

   She went to the cupboard and took out a broom.

   Sue had already worked most of the day.

   Now she only had one more task to do.

Question: What was Sue’s last task?

5. Brad had been raking leaves all afternoon.

   There was a flash of lightning and a rumble of thunder.

   He had only one more pile of leaves to collect.

   Brad quickly put them in his last rubbish bag.

Question: What was going to happen to the weather?

6. Joy arrived home at 8pm.

   She turned on her lamp and picked up her book.

   She had met up with friends for dinner.

   Joy didn’t stay out late because she had work in the morning.

Question: What was Joy going to do?

7. Dean set out his jacket and cap.

   He put his rod in the car and drove to the lake.

   He had been looking forward to this trip for weeks.

   Dean had arranged to meet some friends at the lake.

Question: What was Dean going to do on his trip?

Appendix B: Working memory task record form

WM Task Participant: _____

SET 1
1. You sit on a chair (T) Answer: _____
2. Trains can fly (F) Answer: _____

Recall: _____

SET 2
1. A table is an animal (F) Answer: _____
2. Children like games (T) Answer: _____

Recall: _____

SET 3
1. Tigers live in houses (F) Answer: _____
2. Milk is white (T) Answer: _____

Recall: _____

SET 4
1. Sugar is sweet (T) Answer: _____
2. Auckland is in the South Island (F) Answer: _____
3. Horses run in the sky (F) Answer: _____

Recall: _____

SET 5
1. You can ride on a bus (T) Answer: _____
2. Cats can talk (F) Answer: _____
3. Apples grow on trees (T) Answer: _____

Recall: _____

SET 6
1. Pumpkins are purple (F) Answer: _____
2. Mice are smaller than lions (T) Answer: _____
3. Roses have thorns (T) Answer: _____

Recall: _____

SET 7

1. Twelve equals one dozen (T) Answer: _____
2. Bicycles are slower than cars (T) Answer: _____
3. A book can play (F) Answer: _____
4. Feathers can tickle (T) Answer: _____

Recall: _____

SET 8

1. Water is dry (F) Answer: _____
2. Cows like to eat grass (T) Answer: _____
3. Ducks have webbed feet (T) Answer: _____
4. Little boys wear dresses (F) Answer: _____

Recall: _____

SET 9

1. Chickens eat eggs (F) Answer: _____
2. Babies can drive (F) Answer: _____
3. A clock tells the time (T) Answer: _____
4. The sky is green (F) Answer: _____

Recall: _____

SET 10

1. Carrots can dance (F) Answer: _____
2. Fish swim in water (T) Answer: _____
3. You sleep on a bed (T) Answer: _____
4. You eat breakfast at night (F) Answer: _____
5. People have eyes (T) Answer: _____

Recall: _____

SET 11

1. An orange is a fruit (T) Answer: _____
2. February has sixty days (F) Answer: _____
3. A shoe has ears (F) Answer: _____
4. You wash with soap (T) Answer: _____
5. A car can race (T) Answer: _____

Recall: _____

SET 12

1. You keep books in ovens (F)	Answer: _____
2. Rabbits can read (F)	Answer: _____
3. A lobster has a shell (T)	Answer: _____
4. Chairs can eat (F)	Answer: _____
5. Dogs have four legs (T)	Answer: _____

Recall: _____