SOLDIERS MARCHING DOWN THE GARDEN PATH: COMPREHENSION OF COMPLEX LANGUAGE IN VETERANS WITH MTBI

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Background: There have been many reports of mild traumatic brain injury in soldiers returning from tours in Iraq and Afghanistan as a part of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). These soldiers, who suffer from mild traumatic brain injury (mTBI), are having trouble returning to work, school, and developing relationships with others due to problems associated with TBI. A typical TBI patient with damage to the frontal lobe will find difficulty with many areas of executive functioning. These areas include working memory, inhibition, planning, attention and social cognition. Another effect that mTBI can have on an individual is problems with the comprehension and production of complex connected language and verbal fluency. A particular type of sentence, known as the garden-path sentence, requires many of the same executive functions which are typically impacted by TBI, in order to arrive at the correct interpretation of the sentence. The following experiment presents these sentences, followed by a comprehension question, to both impaired veterans with clinically diagnosed mTBI and those without brain injury. It is predicted that this task will be more difficult, and take longer to complete, for the impaired individuals. If the results confirm this prediction, the test will be able to distinguish between those with and those without TBI. Eventually, this task may be used in the future as a new diagnostic tool which is more sensitive to the presence of a mild form of TBI than the current diagnostic tests.

Aims: This investigation examined the comprehension of complex language in soldiers from Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) who have been diagnosed with a mild traumatic brain injury upon return from deployment. In particular, this study examined whether soldiers with mild traumatic brain injury exhibited particular difficulty with the comprehension of complex garden-path sentences compared with unimpaired individuals.

Methods and Procedures: All experimental subject testing was performed at the VA Pittsburgh Healthcare System (VAPHS). The data for control subjects were obtained from a previous experiment performed in Ontario, Canada at McMaster University. Participants were placed in a sound treated booth and all testing was done auditorily through binaural headphones. Each subject was presented with a series of complex garden-path sentences without any prosodic cues, or filler sentences of non-garden path structure, followed by a comprehension question about each sentence. For example, "While the hunter hunted the deer ran into the woods" is followed by the question, "Did the hunter hunt the deer?" Subjects used their left hand to answer 'yes' or 'no' to the question using the keyboard and then the space bar in order to hear the next sentence, making this experiment self-paced. All stimuli are presented at a comfortable 70 dB hearing level. All responses and reaction times were recorded by E-Prime software version 1.0.

Outcomes and Results: In this study, veterans with mTBI were significantly less accurate than the control subjects for some of the sentences, demonstrating a complex language difficulty within the population. Contrary to the hypothesis, the garden path sentence was not significantly harder than the other sentences and clause order did not matter. The TBI subjects were also not

significantly slower than the control subjects for most cases, which rejects the original hypothesis. Also, the veterans with mTBI showed no sign of fatigue or learning difficulties.

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PREFACE

This thesis would not have been possible without, first and foremost, my thesis advisor, Dr. Michael Dickey. His encouragement and enthusiasm throughout the past two years has helped drive me through this entire process. In the end, he helped me accomplish something that I am so proud of and I owe so much of my success with this project to him. It is difficult for me to even express how much he has inspired me through his interest and passion for research and language.

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1.0 INTRODUCTION

There have been many reports of mild traumatic brain injury in soldiers returning from tours in Iraq and Afghanistan as a part of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). Some reports indicate that nearly 10-20% of all OEF/OIF veterans have been diagnosed with some form of mTBI since they have returned from deployment (Hoge, C., McGurk, D., Thomas, J., Cox, A., & Engel, C., 2008; Tanielian & Jaycox, 2008; Warden, D., Bleiberg, J., Cameron KL., 2005). Every year, TBI is the leading cause of death and disability in the United States (McCrea, 2008). It is one of the greatest public health problems in the United States and worldwide. More specifically, this study concentrates on the severity rated "mild" traumatic brain injury which constitutes 70-90% of all treated TBI cases (McCrea, 2008). Even these numbers may be underrepresented because of an overall lack of a universal diagnostic tool/classification system for diagnosing mTBI. Currently, the Glasgow Coma Scale is the most basic approach for grading TBI severity; however, it is not specific enough to fully diagnose a patient with a more mild case of TBI. There is no single, objective diagnostic tool for evaluating mild traumatic brain injury unfortunately and diagnosis relies heavily on self-reported symptoms and subjective measures. According to the Defense and Veterans Brain Injury Center, the symptoms of mTBI include complaints of poor concentration, memory difficulty, intellectual impairment, irritability, fatigue, headache, depression, anxiety, dizziness, blurred vision, light sensitivity and sound sensitivity (DVBIC, 2006). Soldiers who suffer from mild traumatic brain

injury are, "significantly more likely to report poor general health, missed workdays, medical visits, and a high number of somatic and post concussive symptoms" (Hoge et al., 2008: 453). This is often a direct result of these patients not receiving the rehabilitation that they need in order to gain functional independence. Research on the rehabilitation outcomes of soldiers with blast injuries found that patients who have varying degrees of severity for their injuries all make considerable progress over the course of the hospitalization (Sayer, N., Chiros, C., Sigford, B., Scott, S., & Clothier, B., 2008). Research also shows that those who receive educational intervention and follow-up medical attention early after mild TBI reported fewer symptoms than those who did not (Terrio, H., Brenner, L., Ivins, B., Cho, J., & Helmick, K., 2009). This finding indicates that proper rehabilitation is important for the soldiers who have experienced a traumatic brain injury. This is a serious problem and is affecting the lives of many young individuals.

As a result of the disorder being so prevalent in this population due to a high incidence of blast injuries in these wars, all soldiers who return from deployment and have suffered from some form of concussion are required to complete a neuropsychological screening. These tests determine the necessity of treatment, but it seems they tend to identify only more severe cases of the disorder. For example, at the VA Pittsburgh Healthcare System, approximately half of OEF/OIF veterans who fail the VA/DOD TBI screen obtain normal-range neuropsychological test scores, but complain of persistent problems (Edward Kendjelic, Ph.D., personal communication). This means that there are people who have suffered from a mild TBI and notice persistent problems upon return to civilian life, yet they are not receiving treatment because the current tests are not sufficiently sensitive to diagnose the presence of this very mild traumatic brain injury. The solution seems to be to find a test that will be sensitive enough to detect the underlying problems which result from mTBI, and obtain definitive data that will

allow these soldiers, who are passing the current tests but still experiencing problems, to receive treatment.

1.1 MILD TRAUMATIC BRAIN INJURY AND ITS EFFECTS ON EXECUTIVE FUNCTIONING AND LANGUAGE

The National Institute of Health defines traumatic brain injury (TBI) as an acquired disorder resulting from sudden trauma to the brain, caused by motor vehicle accidents, sport-related, or any other injury which causes the head to suddenly and/or violently hit an object. The three levels of severity include mild, moderate, and severe. The World Health Organization defines mTBI as having one or more of the following: confusion or disorientation, loss of consciousness for 30 minutes or less, posttraumatic amnesia for less than 24 hours, or other transient neurological abnormalities such as focal signs, seizure, or intracranial lesion not requiring surgery. An individual must also have a Glasgow Coma Scale score of 13-15 after 30 minutes post injury or later upon presentation for health care. Factors that can affect the potential for problems after the injury include severity of the injury, location of the injury, and the age and general health of the individual. The signs and symptoms of TBI can be subtle, and can be either physical or cognitive. Some of the common physical symptoms post-injury include: headaches, light-headedness, dizziness, or loss of balance, urge to vomit (nausea), increased sensitivity to light, sounds, or distractions, fatigue, blurred vision, and ringing in the ears (DVBIC, 2009). Other common problems that can occur after the injury

include difficulties with, "cognition (thinking, memory, and reasoning), sensory processing (sight, hearing, touch, taste, and smell), communication (expression and understanding), and behavior or mental health (depression, anxiety, personality changes, aggression, acting out, and social inappropriateness)" (NIH, 2009).

As opposed to a severe or moderate TBI, mild TBI is much more difficult to identify and diagnose because of a lack of definitive objective diagnostic tools and one single definition for the disorder. The following sections will describe the consequences of TBI on cognition, reaction time, and language. It will also illustrate the controversy over defining mTBI and the issues that complicate the disorder.

1.1.1 MTBI and PTSD

Another factor that must be taken into consideration is the correlation between post traumatic stress disorder and traumatic brain injury. According to Hoge et. al. (2008), 44% of soldiers who reported loss of consciousness met the criteria for post traumatic stress disorder. This complicates the diagnosis of mTBI and the treatment plan because it slows down the recovery and puts additional stress on the individual. The two overlapping conditions show that poor performance on tests may be not only attributed to the mTBI, but also to the mental health conditions that are a result of PTSD. Research shows that PTSD affects neuropsychological performance adversely over time (Marx et. al. 2009). They found a correlation between PTSD and attentional functioning, which is minimal at first, but becomes stronger over time. Because of the risk of co morbidities, an effort must be made to eliminate the affect of PTSD on performance.

1.1.2 Mild Traumatic Brain Injury and Cognition

A typical TBI patient may have focal or diffuse cerebral damage, which can result in difficulty with many areas of cognition – especially executive functioning. Executive functioning is an umbrella term for various functions including: planning, working memory, inhibition, and mental flexibility (Chan, R., Shum, D., Toulopoulou, T., Chen, E., 2008). Two distinct theories seek to explain the cognitive problems associated with mTBI. One theory is that the symptoms represent a general, diffuse slowing of all mental processes. The other theory holds the difficulty to be in more specific areas of cognition, such as memory and attention. In this section, specific areas of cognition that are affected by mTBI are discussed; the general slowing of information processing will be discussed in the next section.

In 1992, a study was done in order to try to characterize symptoms following mild head injury. This study was done by comparing those who have experienced TBI to those with no history of TBI. The experiment asked participants with no history of traumatic brain injury to discuss their expectations of what the symptoms would be like and compared them with the actual symptoms of TBI patients. The results demonstrated that individuals with mTBI reported difficulties with memory, concentration, and "thinking clearly" at a significantly higher rate (40% higher or more) than the general population (Mittenberg, W., DiGiulio, D. V., Perrin, S., & Bass, A. E., 1992). These areas of self-reported difficulty provide a sample of the kinds of cognitive complaints that are common following mild TBI. More specifically, problems associated with TBI include deficits in working memory, inhibition, planning, attention, and social cognition. These problems can be short term and are able to be relieved within minutes post-injury, but other problems may last for years (Binder, et. al., 1997, Cicerone & Kalmar 1995, Levin, et. al., 2005).

Many studies have examined the effect of TBI on memory. Memory difficulties may be caused by bruising on the temporal lobe of the brain – the area that stores memories – or from poor concentration and fatigue (DVBIC, 2009). A recent study examined the proportion of soldiers in a brigade combat team with deployment-acquired TBI and aimed to describe the nature of sequelae associated with such injury. Using the Warrior Administered Retrospective Casualty Assessment Tool (WARCAT), results indicate that some symptoms – such as headaches, dizziness, and balance problems – tend to be more prevalent and resolve with time. However, other symptoms, such as irritability and memory problems, were more persistent (Terrio, et. al., 2009). The outcomes were reported up to one year post-injury from a Brigade Combat Team that was deployed to Iraq for one year. Other studies have shown post concussive symptoms to last for up to four years post injury (Levin, et al. 2005). Another result of Terrio and colleagues' study demonstrated that nearly half of the reported memory problems were new symptoms, which were not present at the time of injury. This finding indicates that memory problems associated with TBI may take time to develop and could become a lingering problem long after the actual injury. A proposed explanation of these findings suggests that the later onset of memory problems and irritability may be related to challenges that arise when individuals return home and are no longer in a combat setting. Not only do TBI patients self report difficulties remembering intentions, but they also have been shown to perform more poorly than unimpaired individuals on tests of prospective memory. Prospective memory refers to the ability to remember a planned task in the future through self-initiation (Kinsella, 1998); for example paying the bills or taking medication. The impact that these memory complaints could have for individuals with TBI may thus extend to difficulties with everyday functioning.

Besides memory problems, an individual is just as likely to suffer from problems with attention after sustaining a traumatic brain injury (Hart, 1994). However, depending on the area of the brain that is affected by the TBI, different aspects of attention may be affected. The three major aspects of attention that can be impacted include: orienting attention, selecting and controlling attentional processes, and sustaining attention (Kinsella, 1998). Practicing clinicians use the Stroop Color Word Test (Stroop, 1935) in order to test dealing with distraction or interference. This task can be used as a measure of controlled or voluntary attention. Studies have shown evidence of deficits in individuals with mild TBI when the task becomes cognitively more demanding (Kinsella 1998). This inability to decipher important information – and at the same time inhibit unwanted information – is relevant to the current experiment, to be discussed later.

In a study done with children with TBI, findings show that symptoms can last for years after sustaining the traumatic brain injury (Levin H.S., Hanten G., 2005). Working memory is impaired in children who are on average 4 years post-TBI. Resistance to interference by distraction was impaired in a sample of children representing a wide range of TBI. Rule breaking and problems of high complexity involving planning have been related to traumatic brain injury severity. Children with traumatic brain injury also had difficulty repairing anomalous sentences, which suggests that metacognitive control was affected. Finally children with traumatic brain injury have difficulty selecting a specific solution to dilemmas (Levin et al. 2005). This pattern of findings shows that the time post-injury in which TBI-related impairments may exist can range from immediately after the TBI to years afterward. While this study focused on children, and is different from the population that the current study will examine, other sources also demonstrate similar findings in regards to the long term effects of

TBI. Twenty percent or more of individuals with mTBI (210,000 individuals with mTBI per year, given current incidence rates) report problems persisting a year or more post-injury (Binder, et al., 1997). These persistent symptoms can result in long-term functional limitations, with as many as forty percent of hospitalized TBI survivors reporting one or more unmet rehabilitation needs at one year post-injury (Corrigan, et al., 2004).

In general, a closed head injury can have a major effect on an individual's cognitive status. Many studies have examined the effects of TBI and cognition and found that memory, attention, and inhibition are compromised. Some of the physical problems associated with TBI including headache and dizziness are alleviated immediately or soon after the injury. However, some studies have shown that problems such as planning and working memory can remain impaired for as many as four years post-injury.

1.1.3 TBI and Reaction Time

TBI has also been argued to produce a generalized slowing of information processing and impacts various attentional and cognitive processes such as encoding, verbal comprehension, and adaptive responding to novel situation (Tombaugh, T.N., Rees, L., Stormer, P., Harrison, A.G.,& Smith, A., 2007). If so, reaction times should be sensitive to the effects of TBI. Tombaugh et al. (2007) used various reaction time measures through the computerized test of information processing (CTIP) to assess the effects of mild and severe TBI on speech of information processing. The results suggest that reaction time measures are more sensitive to the long term effects of head injury than are most traditional neuropsychological tests.

Tombaugh et al. (2007) examined three different reaction time measures that increased in difficulty with each task. The first test was a simple RT, which was pressing a button in

response to a sound or image. The level of difficulty increased when an element of choice was introduced to the task. The most difficult task involved semantic processing elements introduced in the choice paradigm. More specifically, the individual needed to decide if a word represented a member of one of four categories. On each trial, one of four categories (Weapon, Furniture, Bird, or Fruit) was randomly presented on the screen. The category names remained presented on the screen and then a word appeared below the category that either represented or did not represent a member of that category. Mean reaction times for the control group, mild TBI group, and severe TBI group followed the same pattern of slower RT with increased difficulty. The results show that as the difficulty of the test increased from simple reaction time to semantic reaction times – where the elements of choice and language increased the complexity of the task – the reaction time in general increased (slowed). The three groups performed similarly for the simple RT task; but as the difficulty increased, the difference between the three groups' performance increased, with the severe TBI group having the slowest RT and the controls having the fastest. In both the simple and choice RT tasks, the mild TBI group performed similarly to the control group. It wasn't until the semantic RT task was introduced that the mild TBI group performed significantly worse than the control group. This is very relevant for the current study because it gives reason to believe that using language related reaction time measures – for those with mild TBI – will distinguish them from a control population. Given that the proposed research project focuses on complex language, the RT measures will be important indicators of the experiment's successes and failures. Additionally, other research suggests that reaction time procedures reveal cognitive impairment even when normal performance is shown on traditional neuropsychological measures (Bleiberg, J., Halpern, E. L., Reeves, D., & Daniel, J. C., 1998).

Another problem associated with TBI is fatigue (DVBIC, 2009). This is relevant for the current study because the challenging stimulus and approximate 30-minute administration time would potentially cause the participant to become fatigued. In order to measure this possibility, it will be important to examine the reaction times from the beginning of the test to the end of the test to see if there is a general slowing throughout the 30 minutes.

There are many suggestions that traumatic brain injury has a profound effect on slowing the ability to process information. It is believed that the slowed reaction times of TBI patients are a result of the inability to process information quickly. The consistency of evidence for the use of reaction time measures to differentiate individuals with TBI from unimpaired individuals, encourages use of reaction times as a diagnostic tool in the clinical setting. This is especially true when the stimulus is difficult and involves language. This gives reason to believe that if a mild traumatic brain injury does cause a general slowing effect, the results of the current investigation will show slowed reaction times for the impaired population. However, if the belief that individual areas of cognition are affected by mild traumatic brain injury, it will be accuracy – and not reaction times – that will decrease.

1.1.4 Mild Traumatic Brain Injury and Language

Another major effect that mTBI can have on an individual is problems with comprehension and production of complex connected language and verbal fluency (LeBlanc, J., De Guise, E., Feyz, M., Lamoureux, J., 2006). This function ties together with the other executive functions because in order to comprehend complex language, one must rely on working memory, learning, inhibition and sustained attention. Because understanding complex sentences requires many functions to work together, successful comprehension of these

sentences requires intact memory, learning, and inhibition. A handful of studies focusing on sentence-level comprehension following TBI have shown deficits, both in speed of processing (Comerford, V. E., Geffen, G. M., May, C., Medland, S. E., & Geffen, L. B., 2002) and comprehension accuracy (Butler-Hinz, S., Caplan, D., & Waters, G., 1990). Furthermore, some individual case studies (Whelan, B.M., Murdock, B.E., & Bellamy, N., 2007, e.g.) have suggested that individuals with mTBI perform significantly differently from unimpaired controls on behavioral language tasks, particularly on measures of response latency.

1.1.5 Cognitive Function and Deployment

A study was performed which assessed many of the same cognitive functions, which are typically impaired in TBI patients, in a group of soldiers both pre-deployment and post-deployment to Iraq. Based on the MOS-CF, a self-reported questionnaire examining the impact of cognitive problems on daily functioning, soldiers post-deployment reported "cognitive problems on daily functioning" (Vasterling et al. 2006). The results of the NES3 CPT with both commission and omission errors, tests which focus on sustained attention and working memory, measured a decrease in scores post-deployment. This decrease in performance shows that regardless of injury, there is the potential that deployment alone can affect sustained attention and working memory. In addition, the tests showed, "significant deployment effects on WMS3 Verbal Paired Associates 1 recall, WMS Visual Reproductions percentage retention, ANAM simple reaction time throughout scores, and POMS confusion and tension subscales" (Vasterling et al. 2006: 525). Non-deployers showed practice effects on two of the tasks in this experiment but those who were deployed showed little or no improvement. An interesting finding from this study is that deployment was associated with improved simple reaction time. This information is

very relevant to the current investigation because reaction time measures have been shown to be sensitive to the effects of TBI (Tombough et. al., 2006).

In summary, the results of this study show a decrease in learning and memory, an advantage in reaction time compared to those who were not deployed, reduced proficiency in sustained attention and memory, and increases in confusion and tension, in deployed soldiers. The decrease in learning, memory, and attention as a result of deployment alone may complicate the results of this study because it suggests that poor accuracy on the current task may be a result of deployment and not TBI. Additionally, the advantage in reaction time due to deployment contrasts the evidence suggesting that those with TBI have a slowed reaction time as a result of a general slowing of information processing. When interpreting the data for reaction time, it will be important to analyze the contradicting elements of deployment and injury for the subjects with TBI.

1.1.6 Current Diagnostic and Evaluative Tools for mTBI

It is widely recognized that in order to appropriately and operationally define mTBI, a unique approach is required. This is because it is necessary to establish a minimum threshold for injury and classifying the gradient of acute TBI injury severity along the traditional continuum from mild to severe. The Glasgow Coma Scale (GCS) is the most recognized and widely used method for grading TBI severity (McCrea, 2008). It is a point system that ranges from 3-15 and evaluates symptoms based on motor, verbal, and eye opening categories, with an mTBI diagnosis scoring in the range of 13-15. However, this scale is not sensitive to both common symptoms

such as headache, dizziness and nausea, or mental status such as confusion, disorientation, or poor concentration. Other methods for classifying the severity of TBI include merely defining the signs and symptoms of each severity. This study will use a definition based on published WHO criteria for mTBI diagnosis (Holm, et al., 2005) and DVBIC operational definitions for mTBI in a military setting (DVBIC, 2006), which will be included in the participant inclusion section of this paper. An example of one of these classifying systems, DVBIC operational definitions for mTBI in a military setting, appears in Appendix B.

The controversy over defining mTBI is important to the current study because it shows a lack of objective measures in the field for diagnosing mTBI. If the current study can differentiate an individual with mTBI from an unimpaired individual, and possibly from a more severe case of TBI, this would result in an objective and measurable test for diagnosis of mTBI.

1.1.7 Summary

Traumatic brain injuries can range along a continuum of severity from severe to moderate to mild. This study focuses on veterans who have suffered from a mild TBI, which is more difficult to classify using traditional scales due to ceiling effects and limited sensitivity, and is not as well understood as more severe cases (McCrea, 2007). And yet, more than 80% of all TBI cases are categorized as mTBI.

Mild traumatic brain injury is very prevalent in the population of soldiers returning from the wars in Iraq and Afghanistan. Among the over 1,600,000 veterans who have served in OEF/OIF conflicts since October 2001, the number of individuals affected by mTBI may be as high as 320,000, given the mTBI prevalence rates reported for this group (Lew, H., 2008). While mTBI can be caused by other incidents more common to civilians, such as motor vehicle

accidents, the injury will still produce the same deficits in cognition, executive functioning, and language. These problems have been shown to last for many years post-injury (Levin, et al., 2005). This means that if a soldier does not receive treatment following mTBI, it is possible for the problems to persist and continue to affect school, work, and every day functioning at home for many years post-injury. However, deficits in cognitive and communicative function following mTBI are often difficult to detect using traditional neuropsychological or speech-language assessment tools (Bleiberg, et al., 1998; Tucker & Hanlon, 1998). Because some of the consequences of this disorder are subtle and not easily detected, the current tests that are being used may not tap into the complex functions which are commonly affected by the mild form of TBI. This would result in individuals going undiagnosed, but still having difficulty in their everyday lives. It is necessary to find a way to test for mTBI which will be sensitive enough to diagnose even the mildest cases.

1.2 GARDEN PATH SENTENCES AND THEIR CONNECTION TO EXECUTIVE FUNCTION

This study focuses on a type of complex sentence, called garden-path sentences to test the executive functioning of the subjects, both unimpaired as well as those diagnosed with mTBI. The name “garden-path” derives from the fact that the ambiguity of the sentence leads the mind down the path to the wrong interpretation. To a normal, unimpaired individual, these sentences are difficult to understand and require an intact working memory, inhibitory system, attention

span, as well as other executive functions. Because these areas of cognition tend to be damaged in individuals with mTBI, it is predicted that veterans with mTBI will have a more difficult time comprehending these sentences than unimpaired controls.

1.2.1 What is a Garden Path Sentence

The "garden path" is a reference to the saying "to be led down the garden path" meaning to be mislead. A garden path sentence is a sentence where the intuitive interpretation is an incorrect one, ultimately leading the responder to an improper parse (structural analysis). These sentences are used in psycholinguistics in order to demonstrate how human beings process language. As a person reads a garden path sentence, he begins to build up meaning by processing one word at a time. Once he gets to a certain point in the sentence, where the next word or phrase does not agree with the path the responder has been led down, it becomes clear that he has been building an incorrect interpretation. These sentences are more common in written language than in spoken language because stress and prosody often serve to remedy ambiguities encountered in text (Bever, 1970). The garden-path sentence that will be examined in this study is a specific sub-type that is classified as early closure/late closure.

In a typical individual, the garden-path sentence, "While the man hunted the deer ran into the woods" can be difficult to comprehend. The sentence begins with the initial clause "while the man hunted the deer." The reader begins to believe that the deer is the object that the man is hunting. Once the reader encounters the disambiguating verb 'ran', the individual must go back and reanalyze the initial interpretation. The initial interpretation must be inhibited in order to arrive at the ultimately correct interpretation of the sentence (Christianson, K., Hollingworth, A., Halliwell, J. F., & Ferreira, F., 2001). The reader must then realize that a deer is running into the

woods at the same time that a man is hunting, however the man is not necessarily directly hunting the deer.

Christianson et al. showed in 2001 that the reanalysis of such sentences is not always complete. This process has been termed a "good-enough" representation where the listener or reader will not necessarily process the sentence fully but will instead feel satisfied with a partial understanding of the sentence. The authors came to these conclusions based on four separate experiments.

Experiments 1a and 1b showed that when listeners answer 'yes' to the comprehension question, 'Did the man hunt the deer?' it is most likely a result of an incomplete reanalysis. The longer the ambiguous region is, the longer the reader is led down the garden path and will thus have more difficulty reanalyzing the sentence. They concluded that the reason for the misinterpretation that the man is hunting the deer is, "a combination of misanalyzing the syntax as well as the plausibility of the implication which seems to override the grammar" (Christianson et al. 2001, 387).

Experiment 2 focused on manipulating the comprehension question. Instead of asking the question, "Did the man hunt the deer?" experiment 2 asks "Did the deer run into the woods?" and "Did the man hunt the deer?" This showed that the deer is not being interpreted exclusively as the direct object and theme of the subordinate verb and that the difficulty with the longer ambiguous region is not merely a result of a longer sentence being more difficult to comprehend.

In 2006, Christianson, Williams, Zacks, & Ferreira compared the comprehension of these garden path sentences between older and younger adults. The authors were able to draw the conclusion that the difficulties that the older adults had compared to the younger adults resulted from a combination of factors. When the garden path sentences were to read "While the man

hunted the deer paced in the zoo", the semantics of the sentence now make the misinterpretation more implausible because it is considered implausible to hunt zoo animals. The results from this experiment were that older and younger adults were affected similarly by all manipulations, including plausibility.

Christianson et al. concluded that working memory plays a significant role in answering the comprehension questions. When the comprehension question is manipulated, those who did not fully reanalyze the sentence during the first read need to reinstantiate the syntactic structure of the sentence (Christianson et al. 2006). The results from the experiment found a strong correlation between reading spans and accuracy. According to Christianson's theory, this correlation supports the idea that, "memory differences are the reason that older adults are much less accurate in the garden path condition, and thus more often rely on good-enough processing" (Christianson et al. 2006).

1.2.2 Different Types of Garden Path Sentences

This experiment examines the comprehension of four different types of garden-path sentences. The different sentences manipulate the syntax and plausibility of the sentences and add another variable to the experiment in terms of level of difficulty based on the predicted amount of temptation that a listener would have towards the incorrect interpretation of the sentence. There was an additional four sentences that were examined, which are considered non-garden-path because they reverse the clause order of the original sentence. I will explain the various sentences in the order of my predicted level of difficulty ranging from the type of

sentence that will be the most likely to lead to an incorrect interpretation and ending with the type of sentence that will be the least likely to lead to an incorrect interpretation.

The first type of sentence is the traditional garden-path structure, "While the man hunted the deer ran into the woods." This sentence begins with an initial clause including a subordinating conjunction (while), followed by the subject of the subordinate clause (the man) and the subordinate clause verb (hunted). The sentence then contains the temporarily ambiguous noun phrase (the deer), the matrix verb (ran), and finally the prepositional phrase (into the woods). This type of sentence is maximally tempting because it is not until the listener hears the disambiguating verb that he considers the idea that the man is not hunting the deer. The listener is very far into the sentence before he needs to reanalyze. The longer the ambiguous region is, the longer the reader is led down the garden path and will thus have more difficulty reanalyzing the sentence (Christianson et. al., 2001).

The second type of sentence manipulates the semantics of the sentence by changing the plausibility. An example of this sentence is, "While the man hunted the deer paced in the zoo." This sort of sentence reduces the plausibility of the incorrect interpretation because it is not very likely that a man would be hunting a deer in a zoo. This should make it a little bit easier to arrive at the correct interpretation, but it is still relatively tempting because the initial clause still leads the listener down the garden path. It is not until the final word of the sentence that it becomes implausible. Results from Christianson et al. reveal that participants were significantly more likely to answer the comprehension question correctly and accuracy was comparable to the non-garden path control sentences (Christianson et al. 2001).

The third type of sentence manipulates the plausibility of the temporarily ambiguous noun. An example of the third type of sentence is, "While the man hunted the plane flew over

the woods." The garden path interpretation of this sentence is very implausible because a man would never hunt a plane. It is predicted that as soon as a listener would hear the object of the sentence (the plane) s/he would reconsider the sentence and thus does not hold onto his/her initial interpretation as long. Additionally, the strong implausibility of hunting a plane may block the listener from being led down the garden path at all. The listener might not even briefly adopt the incorrect interpretation making this sentence not very tempting. This sentence was not used in any of Christianson's experiments and is novel to this study.

The fourth type of sentence gives an object to the action of the subject. An example of the fourth type of sentence is, "While the man hunted the pheasant the deer ran into the woods." This last sentence is the least tempting of the four. The additional object (the pheasant) gives the hunter an object to hunt. It seems the deer running into the woods would be much easier to separate out as its own clause. More specifically, the presence of the word 'pheasant' should block the misanalysis entirely, making it syntactically impossible. If the subjects have trouble with this sentence, they are possibly having syntactic difficulties because this sentence relies on an ability to parse the sentence.

Each of the four sentences is also altered by reversing the clause order, which takes away the garden-path structure. This creates the additional four types of sentences that are used. An example of this type of sentence is, "The deer ran into the woods while the man hunted." It should be less tempting to arrive at the incorrect interpretation of these types of sentences because the initial part of the sentence is no longer leading the listener to believe that the deer is the object of the man hunting. Also, there is no longer a difference in the degree of difficulty between the four sentences which have the clause order reversed. This is because by eliminating

the garden path structure, the listener should not be tempted to misinterpret any of the sentences, thus giving all sentences an equal level of difficulty.

Table 1. Sample sentence for eight conditions in Garden Path Task

	Sample Sentence	Sentence Characteristics	Level of Predicted Difficulty
1.	While the man hunted the deer ran into the woods.	Traditional Garden Path Sentence	Most temping ↓ Least Tempting
2.	While the man hunted the deer paced in the zoo.	Pragmatically Implausible (global)	
3.	While the man hunted the plane flew over the woods.	Semantically Implausible (local)	
4.	While the man hunted the pheasant the deer ran into the woods.	Non-Garden path, control sentence	
5.	The deer ran into the woods while the man hunted.	Reverse Clause Order of sentence #1 (non-garden path structure)	Reversing the clause order of the sentences should eliminate any differences in difficulty between the four sentences. This is because without the garden path structure, the listener should not need to reanalyze the sentence, and none of the sentences should be difficult.
6.	The deer paced in the zoo while the man hunted	Reverse Clause Order of sentence #2 (non-garden path structure)	
7.	The plane flew over the woods while the man hunted.	Reverse Clause Order of sentence #3 (non-garden path structure)	
8.	The deer ran into the woods while the man hunted the pheasant.	Reverse Clause Order of sentence #4 (non-garden path structure)	

Table 1 summarizes the various sentences that will be used in this experiment. The portion of the table that contains the level of predicted difficulty is the prediction for the normal controls based on previous research studies. However, it is unknown how the subjects with mTBI will perform in language based tasks. Because we do not know the normalcy of sentence processing for TBI subjects, it should be noted that these predictions are tentative.

1.2.3 Garden Path Sentences and Cognitive Performance

Working-memory has been shown to predict success in inhibiting the incorrect interpretation of garden-path sentences among older adults using reflexive absolute transitive (RAT) verbs (Christianson et al., 2006). RAT verbs, (e.g. wash, shave, and dress) retain transitive argument structures even when there is no object present; meaning that the action of the verb is done reflexive to the subject of the sentence. In our experiment, we will use optionally transitive (OPT) verbs which, contrary to RAT verbs, allow for inferences to be made regarding the ultimately correct interpretation. Since we are not using the RAT verbs and working memory might not affect the comprehension of these sentences, we need to look at other functions that will be used in understanding garden path sentences.

The sentences that are used in the current study using OPT verbs were examined in a population of adults with ADHD, which compared sentence comprehension to working memory using the Stroop working memory task (Engelhardt, P., Nigg, J., Carr, L., Ferreira, F., 2008). Participants saw a series of Stroop trials in which they were required to name the color of ink in which a color word was presented, and at the end of a series of words, participants had to recall the named colors in serial order. This task consists of a processing component (i.e., naming the color of ink as the words appears) and a storage component because the already named colors must be held in memory. The results of the Stroop task were compared to the results of the garden path sentence task. Both the ADHD and control groups had more difficulty correctly interpreting the garden path sentence as compared with the non-garden path structure. These results compare to what Christianson and colleagues found in their experiments and gives validation for this follow-up experiment. More interesting results were that ADHD participants performed more poorly on non-garden path sentences than the controls. An explanation of this

finding could be that those with ADHD rely more heavily on the plausibility of events in the real world rather than the syntactic indications of the sentence. The experiment showed some evidence of working memory impacting performance of garden path sentences. However we also know that inhibition was necessary to complete the Stroop Working Memory task (Engelhardt et. al., 2008). This is because the nature of the task in which subjects must name aloud the color of ink in which a color word is presented requires an individual to inhibit the word that they see on the page and instead be able to give the examiner alternate information - the color in which it is printed (Stroop, 1970). This task not only requires subjects to perform this task, but to also rely on working memory to later recall the colors that the words were printed in after two to seven trials. While Engelhardt's research is related to a different disordered group than the one we will be examining, other research has shown that many patients with TBI have working memory deficits and this impairment has been identified as a predictor of successful return to work in some studies of mTBI patients (Drake, et al., 2000). If Engelhardt's results were actually showing a correlation between the inhibition aspect of the Stroop Working Memory task, it is important to look at the inhibitory function in relation to the garden path sentences. Cognitive control and inhibition positively correlate with sentence comprehension because the same area of the brain becomes active during both the Stroop test, which looks at inhibition, and the comprehension of other complex sentences (January et. al., 2008). These other sentences also involve inhibiting an ultimately incorrect response and a reanalysis so it would be interesting to apply this to the garden path sentence structure.

This information is supplemented by the fact that reanalysis of such sentences was impacted by damaged left inferior frontal gyrus (LIFG) functioning in stroke patients (Novick et. al., 2005). The area of the brain that was damaged in the stroke victims is the same area that is

activated for both the Stroop test and the comprehension of complex language. When the stroke patients had damage to the LIFG, they had difficulty inhibiting the incorrect interpretation of the garden path sentences. This connection leaves open questions as to what areas are affected by traumatic brain injury and what information we can gather from performance on the garden path test. A language comprehension test using garden path sentences will encompass many of the functions that the current neuropsychological tests examine; but this task should prove to be more challenging and should detect the need for rehabilitation in the mTBI veteran population.

1.3 SPECIFIC AIMS

The current study was motivated by the increasing number of soldiers returning from Iraq and Afghanistan with diagnoses of mild traumatic brain injury (mTBI), and the disorder affecting their personal and professional lives. There is a great possibility that there are even more soldiers who are affected by TBI than are receiving the diagnosis. This indicates a gap in the current neuropsychological tests and a need for a test that is more challenging which will target more mild cases of TBI. Accuracy in the comprehension of garden path sentences, as well as reaction time, are the quantified measures used in this experiment.

The current investigation used garden-path sentences to test those with and without mTBI diagnoses to determine whether the comprehension of garden path sentences can successfully distinguish those with and without mTBI. The current evidence indicating the relationship between garden path sentences and executive functions affected by TBI is documented by Christianson et al. 2001, 2006, as well as Novick et al. 2005. It was predicted that the veterans with diagnosed mild traumatic brain injury will have poorer accuracy on correctly interpreting the garden-path sentences than the unimpaired population. It was also predicted that the veterans with mTBI will have slower reaction times for the garden path task than the unimpaired population based on evidence from Tombaugh and colleagues (2007).

The current investigation also used non-garden-path sentences to test those with and without TBI diagnoses to determine whether the garden-path structure is more difficult to comprehend than a non-garden path sentence. It is predicted that the garden path sentences will be more difficult and take longer to answer than the sentences that do not have a garden path structure. This has already been proven through previous experiments with the garden path sentence (Christianson et. al., 2001, Christianson et. al., 2006) which show that the complexity of the sentence makes it more difficult, and takes longer to process, than a non-garden path sentence. This result would maintain consistency with previous literature to give this test validity and reliability.

The current investigation examines four different types of garden path sentences. The various types are potentially more or less difficult to interpret based on the amount of temptation to maintain an incorrect interpretation. We expect that the more tempting sentences will be less accurate, and have a slower reaction time, than the least tempting

sentences. Based on the reasoning for the ranking of the various sentences, it is expected that both accuracy and reaction times should correspond to the respective levels of how tempting the sentence itself is predicted to be. If the data does not show this clearly, our scale could be inaccurate and certain sentences may be easier or more difficult than initially thought. This also brings up the issue of semantics and pragmatics versus syntactic processing. For example, if the subjects incorrectly answer the comprehension question about the sentences where the "hunter is hunting a plane," which is pragmatically implausible, it will be evident that the listener is relying on the syntactic structure of the sentence, and not thinking about the real world applicability. We can use the scale of temptation to determine whether the subjects are having more difficulty deciphering the sentence based on the syntax or the semantics.

The current investigation also examines the affect of fatigue on patients with mTBI due to the length and difficulty of the task. We expect the mTBI subjects will slow down and from block 1 to block 4 of the task, due to fatigue. The test is designed to be long and difficult. Since it has been shown that fatigue is a common problem associated with mTBI (DVBIC 2009), it is expected that towards the end of the test, the soldiers would require a longer break between the presentations of the stimuli. If this is not the result and the subjects are actually pacing themselves more quickly towards the end of the test, this could be a result of a carryover effect of learning throughout the task. Alternatively, this could be simply because they want to be finished with the task because it is long.

There is also evidence that TBI can affect learning. In order to determine if there is a short-term learning effect, we will measure the average accuracy throughout the test.

Since the test is broken down into four blocks, we will examine the pattern of accuracy from block 1 to block 4 to see if it improves or declines. It is hypothesized that subjects with mTBI will not improve in accuracy from the beginning of the task to the end of the task, indicating they are not learning throughout the test.

2.0 METHODS

2.1 PARTICIPANTS

Data for the control subjects (n=31), in this study, were observed and recorded at McMaster University in Ontario, Canada. These participants served as a convenience sample, roughly demographically matched in age and formal education completed to the veteran participants with TBI. To be included in the study, all participants are between 18 and 29 years of age (mean=20.97), have no prior history of a neuropsychological or language disorder, and are able to pass hearing screens. The sample consisted of 23 women and 8 men. According to self-report, all participants in this study met the prerequisites of being right-handed and speaking/writing English as their primary language.

During the initial testing session with each control subject, a hearing screening was conducted to ensure that participants could complete the auditory experimental tasks. Participants were tested in the right, then left, ears with a warble tone at 500, 1000, 2000, and 4000 Hz. To pass the screening, they needed to be able to identify the 30 dB HL tone at 500, 1000, 2000 and 4000 Hz.

All participants with mTBI (n=2) had a diagnosis of mTBI made by members of the VAPHS Neuropsychology service, based on published WHO criteria for mTBI diagnosis (Holm, et al., 2005) and DVBIC operational definitions for mTBI in a military setting (DVBIC, 2006):

1. Exposure to external biomechanical force (such as blast and/or acceleration/deceleration forces) which may result in brain injury
2. Patient or medical report of one or more of the following:
    a. Confusion or disorientation
    b. Brief alteration or loss of consciousness (lasting 30 minutes or less)
    c. Some post-traumatic amnesia (lasting 24 hours or less)
    d. Other brief evidence of neurological abnormality, such as seizure
3. Glasgow Coma Scale (GCS) score of 13-15, when available
4. Symptoms are not due to substance abuse, other injuries (such as facial injuries), other causes (such as psychological trauma or other co-morbidity), or penetrating head trauma.

Under DSM-IV criteria (APA, 2000), followed at VAPHS, these individuals also had one or more below normal-range neuropsychological scores for tests of attention and/or memory function. In addition, consistent with DVBIC criteria (DVBIC, 2006), these veterans also reported one or more neurobehavioral symptoms consistent with mTBI on the 22-item Neurobehavioral Symptom Checklist. The onset of these symptoms must be close in time to the event which caused the mTBI. The event causing the mTBI will have taken place no more than 5 years before study enrollment: that is, the maximum time between injury and study enrollment will be 5 years. Both subjects were male, right handed, and ages 24 and 40.

OEF/OIF participation/deployment was not required of unimpaired control participants. Since the stated goal of this study is to evaluate the effects of TBI on OEF/OIF veteran populations, OEF/OIF deployment was required of TBI participants.

2.2 STIMULI

The stimuli for this experiment consists of garden-path sentences, non garden-path sentences, as well as filler sentences, which were audio recorded by a female speaker. A male speaker audio recorded the comprehension questions which immediately followed every stimulus. The sentences were pre-recorded and every sentence maintained "base-line" prosody. This means that each sentence was read without any prosodic cues and in a flat, monotone voice. This is because both cooperating and conflicting prosody significantly ease or dampen (respectively) the accuracy and reaction times for the task (Titone et. al., 2006).

2.2.1 Stimuli Organization

The stimuli that were used for this experiment included 48 experimental stimuli, as well as 112 filler sentences, which were all counterbalanced using a traditional latin-square design across eight conditions. There were six sentences per condition. This created eight different lists (A-H) to be evenly distributed amongst both control and experimental participants. For a list of all stimuli used, see Appendix A.

2.3 EXPERIMENTAL APPARATUS AND PROCEDURES

Data for control subjects were compiled at McMaster University in Ontario, Canada. There were 31 participants in the study, all between the ages eighteen to twenty-nine, which aimed to evaluate younger adults' ability to comprehend garden path sentences. All subjects reported no history of a speech or language disorder, no history of traumatic brain injury or head injury, and were right handed.

Testing for the experimental participants occurred in one 120-minute session. All study procedures were conducted in a quiet room in the Audiology and Speech Pathology Section at the VAPHS Highland Drive Division. Participants first completed screening procedures, followed by either auditory processing testing or language processing testing. The two tasks were counterbalanced. The auditory processing testing is an additional experimental task that was performed along with the garden-path sentence task but will not be included in this paper.

2.3.1 Experimental Task

Prior to the experimental sessions, the laptop was equipped with the E-Prime software, as well as "yes" and "no" response buttons located where the "z" and "c" key are located, respectively. Participants were seated in front of the computer and told that they would hear a variety of sentences, each immediately followed by a comprehension questions about each sentence. They were instructed to use their left hand only to respond to these questions, in order to keep the task consistent across participants. Each subject was then instructed to use the "space bar" in order to hear the next question.

Before the experimental task began, each participant was given the same practice set of ten sample sentences and questions in order to get used to the speed of presentation, make sure the sound level was comfortable, and feel comfortable with the task. This practice set is identical to the experimental task but uses different sentences/questions than the ones used in the actual test. After the practice set, the subjects were allowed to ask any questions before proceeding with the experimental task.

Subjects would hear either a garden-path sentence or a filler sentence. The image on the screen during the sentence was a black background and a red asterisk. Immediately following the sentence, a question was then asked about the sentence that was just presented. At this time, the screen was a black background with a white plus sign. The purpose of these images was to give a minor visual cue to the listener to create a consistent pattern of the presentation of a sentence followed by a comprehension question. Questions for garden-path sentences consistently ask about the briefly tempting, but ultimately incorrect interpretation (that the hunter hunted the deer), providing a measure of how well participants are able to inhibit this interpretation.

Manual responses and reaction times were recorded by the E-Prime 1.0 software.

3.0 RESULTS

This study assessed the hypothesis that OEF/OIF veterans with mild traumatic brain injury would have less accurate performance and slower reaction times for the garden path sentence task than the unimpaired control subjects. Both groups were expected to follow the predicted scale of temptation which determined the level of assumed difficulty for the four different types of sentences (traditional, pragmatically implausible, semantically implausible, and non-GP control). Both groups were also expected to perform equally on the sentences where the clause order is reversed because the listener should no longer be tempted towards the incorrect interpretation without the garden path structure. It was also predicted that throughout the course of the test, the veterans with mTBI would increase their reaction times from the beginning of the test to the end of the test, indicating fatigue.

Both accuracy and RT data were collected and analyzed.

3.1 PRIMARY ANALYSIS

3.1.1 Analytic Approach

Due to the small sample size for the TBI group, both subjects will be looked at on an individual basis. All data for the control group will be an average of all subjects' performance across the conditions. Nonparametric, single-subject statistics were performed (Crawford & Garthwaite 2007). A significance criterion of $p \leq .05$ was adopted for all analyses.

3.1.2 Accuracy Data

Accuracy data were totaled across the four block sessions and averaged for each sentence type. For every experimental sentence, responses to the comprehension questions required a correct answer of 'no'. Descriptive data for TBI subject 1, TBI subject 2, and the control group are provided in Table 2.

Table 2. Accuracy Means across conditions for each TBI subject and Control subjects (averaged)

	A	B	C	D	E	F	G	H	Z
TBI 1	0.125	0	0.25	0.375	0.375	0.375	0.625	1	0.6975
TBI 2	0	0.125	0.25	0.75	0.75	0.875	0.5	0.25	0.8025
Control	0.41	0.47	0.6	0.68	0.72	0.77	0.64	0.78	0.6337

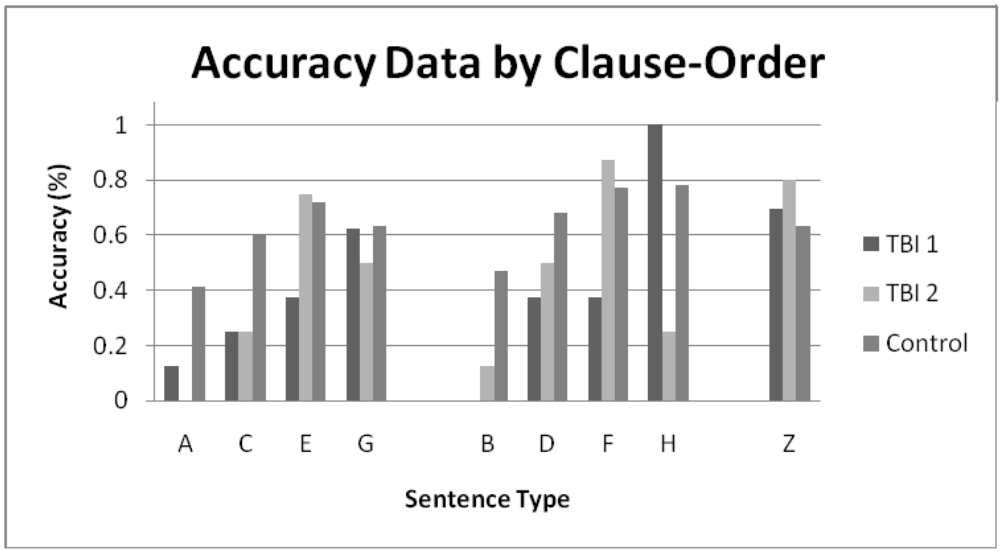
A = While the man hunted the deer ran into the woods.
B = The deer ran into the woods while the man hunted
C = While the man hunted the deer paced in the zoo.
D = The deer paced in the zoo while the man hunted.
E = While the man hunted the plane flew over the woods.
F = The plane flew over the woods while the man hunted.
G = While the man hunted the pheasant the deer ran into the woods.
H = The deer ran into the woods while the man hunted the pheasant.
Z = Filler

It was hypothesized that, regardless of group, accuracy would improve in the order of the predicted "scale of temptation" or predicted level of difficulty of the sentence, from the traditional garden path sentences through the non-garden path control sentences. TBI subject 1 had an accuracy of 0.12 for the traditional garden path sentence (A), predicted to be the hardest sentence in the scale of temptation. The sentence which has a predicted level of difficulty just above the garden path sentence (C), has an improved accuracy of 0.25. Continuing down the scale of temptation, sentences E and G, the semantically implausible manipulation and the non-garden path control, continue to follow this pattern of improved accuracy – with the percent correct 0.375 and 0.625, respectively. TBI subject 2 also improved in accuracy from sentence A (0.0) to sentence C (0.25) to sentence E (0.75). However, TBI subject 2 decreases in accuracy for the non-garden path control sentence (0.5) which was predicted to be the easiest sentence because it eliminates any temptation towards the incorrect interpretation. The control subjects follow a similar pattern to TBI subject two. Control subjects on average improve from sentence A (0.41) to sentence C (0.6) to sentence E (0.72), but then decline in accuracy for sentence G (0.64).

3.1.2.1 Accuracy and clause-order

Figure 1 displays the same accuracy data as in table 2, but organizes the sentences by clause order.

Figure 1. Accuracy data presented by clause order for TBI 1, TBI 2, and control subjects



A = While the man hunted the deer ran into the woods.
C = While the man hunted the deer paced in the zoo.
E = While the man hunted the plane flew over the woods.
G = While the man hunted the pheasant the deer ran into the woods.

B = The deer ran into the woods while the man hunted
D = The deer paced in the zoo while the man hunted.
F = The plane flew over the woods while the man hunted.
H = The deer ran into the woods while the man hunted the pheasant.

Z = Filler

It was hypothesized that the sentences which were manipulated to have a reverse clause order from the garden path structure would be overall easier to comprehend. It was also predicted that these reverse-clause order sentences would not have any scale of temptation and will all be equally difficult because of the lack of an object following the ambiguous verb (no misleading). Figure 1 displays the accuracy data for TBI subject 1, TBI subject 2, and the control subjects, organized by clause-order. When comparing the garden path sentences to the reversed clause order sentences, there is no significant effect. For TBI subject 1, performance on the traditional garden path sentence A (0.12) was nearly as bad as performance on the reverse clause order, sentence B (0.0). Similarly, accuracy for TBI subject 1 on the other pairs of

sentences showed little to no differences in performance: sentence C (0.25) and sentence D (0.37); sentence E (0.37) and sentence F (0.37). Since sentence G is a non-garden path control sentence, the reversal of the clause order does not matter because the original sentence is not misleading. These results do not agree with the proposed hypothesis. TBI subject 2 shows similar results except for the pragmatically manipulated sentences (deer paced in the zoo). In this case, there was a difference in accuracy between the garden path sentence C (0.25) and the reverse clause order sentence D (0.75).

T-tests were performed on the control data in order to determine whether there was a significant difference between the garden path sentences and the non-garden path versions. Table 3 displays the p-values for this analysis.

Table 3. T-test analysis for control data accuracy between sentence type based on clause order

T-Test comparison	P-Value
A vs. B.	0.09036
C vs. D.	0.333354
E vs. F.	0.372476
G vs. H.	**0.023434**

The data indicates that for the control subjects, there was only one sentence in which the clause order made a significant difference in accuracy. For the sentence "while the man hunted the pheasant the deer ran into the woods," there was a significant difference in accuracy for the garden path sentence and non-garden path clause order.

3.1.2.2 Single subject statistics – Accuracy: TBI vs. Control

Single subject statistics were performed using the Bayes Single Case program based on Crawford and Garthwaite (2007). Bayesian point and interval estimate of the abnormality of a patient's test score was performed in order to compare the individual accuracy data for each TBI subject to the average performance of the control group. Results demonstrate marginally

significant differences (p-value between .05 and .1) and nearly or fully-significant differences (p-value of .05 or below) for some of the conditions. For condition A, the traditional garden path sentence, TBI subject 2 performed marginally significantly lower than the controls (one-tailed probability=0.0868). For condition D, the non-GP control sentence, TBI subject 2 performed marginally significantly lower than the controls (one-tailed probability=0.078). For condition B – the deer ran into the woods while the man hunted – TBI subject 1 performed marginally significantly lower than the controls (one-tailed probability=0.054).

While there were no apparent differences between the garden path sentences and the reverse clause order sentences, additional single-subject statistics were done in order to collapse the data for the conditions which were supposed to be the hardest (sentences A and C) as well as their complimentary non-garden path versions (sentences B and D). Each TBI subject was compared to the average of the control group. For conditions A+C, TBI subject 1 performed significantly less accurately than the control subjects (one-tailed probability = 0.047). For conditions A+C, TBI subject 2 performed significantly less accurately than the control subjects (one-tailed probability = 0.026). For conditions B+D (reverse clause order of A+C), TBI subject 1 performed significantly less accurately than the control subjects (one-tailed probability = 0.038). For conditions B+D, TBI subject 2 performed significantly less accurately than the control subjects (one-tailed probability = 0.038). Results show that both TBI subjects performed worse than the controls on both the garden-path versions (A+C) and the non-garden-path versions (B+D).

3.1.2.3 Accuracy across blocks

It was predicted that the veterans with mTBI would not demonstrate any short term learning throughout the 30-minute garden path sentence task. This would be measured by examining the accuracy throughout the course of the task to see if the subjects begin to learn the pattern of the garden path sentence, and improve in accuracy throughout the task. The garden path sentence task was broken up into four sections (blocks) and each individual was allowed to take a break in between each block if they choose. The hypothesis states that if the subjects improve, on average, in performance from the first one-fourth of the test to the last one-fourth, it would indicate a short-term learning affect. It is predicted that the subjects with mTBI will not improve accuracy throughout the task. The accuracy (% correct) for each sentence was averaged across each block of time. Results of the average accuracy across the four blocks for TBI subject 1 and TBI subject 2 are presented below in table 4.

Table 4. Average accuracy across time for the garden path sentence task.

	TBI 1	**TBI 2**
Block 1	0.1875	0.5
Block 2	0.4375	0.25
Block 3	0.5625	0.4375
Block 4	0.375	0.4375

The results for this data do not indicate any pattern of an increase or decrease in accuracy for TBI subject 2. This is consistent with the hypothesis showing that the lack of pattern indicates that there is no learning throughout the task. TBI subject 1 does improve in accuracy from block 1 (19%), to block 2 (44%); and again from block 2 (44%) to block 3 (56%). However, TBI subject 1 declines in accuracy for the final section of the test. This pattern in particular is inconsistent with the hypothesis because it does show that subject 1 was potentially

learning and improving in accuracy throughout the task. It was predicted that subjects with TBI would not improve in accuracy throughout the task indicating a decline in short-term learning skills. These results are only partially inconsistent with the hypothesis in that they do not indicate a strong pattern of learning.

3.1.3 Reaction time data

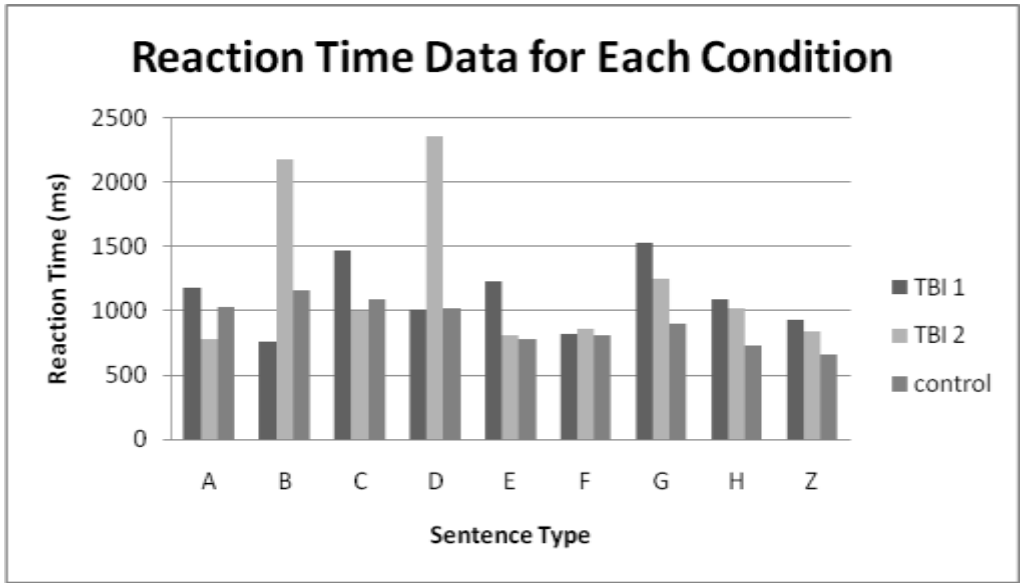
Reaction time data were summed across the four block sessions and averaged for each sentence type. Reaction time data, measured in milliseconds, are based on the time it took for the participant to press 'yes' or 'no' on the computer keyboard after hearing the comprehension question. RT data is collected and presented regardless of accuracy. Descriptive data for TBI subject 1, TBI subject 2, and the control group are provided in Table 5. The data is displayed graphically in figure 2.

Table 5. Reaction time (ms) means across conditions for each TBI subject and control subjects (averaged)

	A	B	C	D	E	F	G	H	Z
TBI 1	1177.125	762.5	1470.875	1005.5	1228.125	824.375	1528.25	1094.375	934.3425
TBI 2	783.375	2173.75	998.5	2357.125	814.625	858.25	1253.875	1022.25	839.285
Control	1027.58	1162.766	1085.516	1016.678	784.0156	807.0215	899.1531	731.2453	658.4921

A = While the man hunted the deer ran into the woods.
B = The deer ran into the woods while the man hunted
C = While the man hunted the deer paced in the zoo.
D = The deer paced in the zoo while the man hunted.
E = While the man hunted the plane flew over the woods.
F = The plane flew over the woods while the man hunted.
G = While the man hunted the pheasant the deer ran into the woods.
H = The deer ran into the woods while the man hunted the pheasant.
Z = Filler

Figure 2. Reaction time (ms) results for TBI 1, TBI 2, and the mean for the control group



A = While the man hunted the deer ran into the woods.
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E = While the man hunted the plane flew over the woods.
F = The plane flew over the woods while the man hunted.
G = While the man hunted the pheasant the deer ran into the woods.
H = The deer ran into the woods while the man hunted the pheasant.
Z = Filler

It was predicted that the traditional garden path sentence would have the slowest reaction time because it would be the most difficult to parse. Similar to the accuracy hypothesis, it was also predicted that the more difficult the sentence is, the longer the reaction time. For TBI subject 1, the sentence that had the slowest reaction time is sentence G (1528.25ms), the non-garden path control sentence. For sentence B, the reverse clause order of the traditional GPS, TBI subject one had the fastest reaction time (762.5 ms). For TBI subject 2, sentence D – the reverse clause order of the pragmatically manipulated GPS – had the slowest reaction time (2357.125 ms). TBI subject 2 had the fastest reaction time for sentence A (783.375ms).

It was predicted that the veterans with mTBI would be much slower than the control subjects. In general, it appears that in most conditions, TBI subject 1 was slower than the mean controls. TBI subject 2 demonstrates a similar pattern but it is inconsistent. Results indicate that a slowed reaction time is not evident for this population. Further statistics will be performed in order to determine if any of the slowed reaction times for the two veterans were statistically significant given the larger control sample.

3.1.3.1 Single subject statistics – Reaction time

Single subject statistics were performed using the Bayes Single Case program based on Crawford and Garthwaite (2007). Bayesian point and interval estimate of the abnormality of a patient's test score was performed in order to compare the individual reaction time data for each TBI subject to the average reaction time of the control group. Results demonstrate marginally significant differences (p-value between .05 and .1) and nearly or fully-significant differences (p-value of .05 or below) for some of the conditions. For condition B, clause order reversal of traditional GPS, TBI subject 2 had a reaction time that was marginally significantly slower than the control subjects (one-tailed probability=0.0915). For condition H, clause order reversal of non-GP control sentence, TBI subject 2 had a reaction time that was fully significantly slower than the control subjects (one-tailed probability=0.0461).

3.1.3.2 Reaction time across blocks

It was predicted that veterans with mTBI would show signs of fatigue throughout the 30-minute garden path sentence task. This would be measured by examining the reaction times throughout the course of the task to see if the veteran slows down or speeds up throughout the

task. The garden path sentence task was broken up into four sections (blocks) and each individual was allowed to take a break in between each block if they choose. The hypothesis states that if the participant with mTBI has a faster RT during the first one-fourth of the test than the last one-fourth, it would indicate fatigue. The reaction times for each sentence were averaged across each block of time. Results of the reaction times across the four blocks for TBI subject 1 and TBI subject 2 are presented below in table 6.

Table 6. Average reaction times (ms) of TBI 1 and TBI 2 across the four sections of the GPS task

	TBI 1	**TBI 2**
Block 1	969.56	1500.746
Block 2	1175.548	887.1189
Block 3	1247.643	1629.214
Block 4	1063.012	916.7144

TBI subject 1 showed a slowing of reaction time – on average – from block 1 (969.56 ms) to block 2 (1175.5 ms) to block 3 (1247.64 ms). However, TBI subject 1 had faster average reaction times for the final block of the test (1063 ms). This pattern indicates an overall slowing from block 1 to block 3 for TBI subject 1, but the overall difference from the fastest block (1) to the slowest block (3) is only 278 milliseconds. TBI subject 2 has a wider range of reaction times for the task, with a difference of 742.1 milliseconds from the slowest block (2) to the fastest block (3). And yet, there is no indication of any pattern of slowing or speeding up from block 1 to block four. These results do not clearly demonstrate any strong sign of fatigue for either subject.

4.0 DISCUSSION

This experiment tested the predicted hypothesis that veterans with mTBI would have poorer accuracy and slower reaction times for the garden path sentence task as compared with the control subjects. The results demonstrate that, contrary to the hypothesis, the veterans with mTBI were not significantly slower than the controls. They did have poorer accuracy than the controls on sentences where there were no strong cues; and results indicated that this population does have problems with complex, multi-clausal language. It was also predicted that the traditional garden path sentence would be more difficult and have slower reaction times than the non-garden path sentences. Contrary to the hypothesis, the results indicate no significant difference between the garden path sentences and the non garden path sentences. There is no pattern indicating a slowing down (fatigue) from the first trial to the fourth, nor is there any pattern showing an increase or decrease in accuracy (learning effect) across trials.

4.1 WITHIN-GROUPS ACCURACY VS. SENTENCE TYPE

It was predicted that the veterans with mTBI would have the least accurate performance on the traditional garden path sentence and would improve in accuracy according to the scale of

temptation. TBI subject 1 had very poor accuracy for the traditional garden path sentence and continued to improve in accuracy for each sentence on the scale of temptation. TBI subject 2 also improved in accuracy from the traditional garden path sentence, through the semantic manipulation. However, TBI 2 actually did worse on the non-GP control sentence (while the man hunted the pheasant…) than on the semantically manipulated sentence (plane flew over the woods). In general, there was a trend with both subjects which showed improvement in accuracy as the sentences were less tempting. This finding justifies the order that the sentences were ranked in terms of predicted level of difficulty based on how tempting they are towards the incorrect interpretation.

Another hypothesis that was examined was that there would be overall improved performance for the sentences where the clause order is reversed and there is no longer a garden path structure. This prediction is based on evidence from previous research using these sentences (Christianson et al., 2001, Christianson et al., 2006). T-tests were performed in order to determine if the control group's performance on the garden path sentences were significantly different from performance on the non-garden path sentences. While the data showed that only one sentence type showed a significant difference, this contradicts many prior research experiments and may indicate a problem with the control data.

A second hypothesis relating to this is that accuracy between the four types of sentences with the clause order reversed would all have similar performance because without the garden path structure, there should not be any temptation towards the incorrect interpretation. Single subject statistics compared each veteran with mTBI to the average control group to see if there was a difference in performance between the hardest sentences (traditional GPS + pragmatic manipulation) and their complimentary non-GP structure. Interestingly, there was no evidence

that the TBI participants did worse in the garden-path order in these cases. Performance on sentence B is actually just as bad as sentence A.

Contrary to our hypothesis, there is no difference in performance for the subjects with mTBI on garden path and non-garden path sentences. This means that the garden path structure, which is supposed to be tempting (towards the incorrect interpretation) and misleading, is not any harder to comprehend than the non garden path sentences. However, even without the garden path structure, these sentences with the reverse order are still challenging and multi-clausal, as compared with the filler sentences. Overall performance on all sentences, regardless of clause order, was much poorer than accuracy on the simple filler sentences. This result provides clear evidence that the TBI participants have a hard time coming to the correct interpretation of these challenging sentences in the absence of strong cues. When the going gets tough, as it does in these multi-clause, often ambiguous sentences, they seem to give up and adopt any plausible interpretation, regardless of whether it is compatible with the sentence's structure (B, the non-garden-path order) or not (A, the garden-path order). They even misinterpret (perform worse than controls on) a complex but completely unambiguous sentence, as in sentence D, the non-garden path control sentence. This still contradicts the original hypothesis, that garden-path sentences would be especially hard as compared with other sentences, but it is evidence that these individuals perform very poorly in challenging language-based tasks, as in the Tombaugh et al. (2008) semantic choice RT task.

It was also predicted that the veterans with mTBI would not improve in accuracy throughout the task, indicating an absence of short-term learning skills. TBI subject 1 did improve from the first block of the task to the second and third blocks. However, his improvement declined for the fourth block. TBI subject 2 did not have any pattern indicating

improvement across the task. The hypothesis that veterans with mTBI would not improve in accuracy throughout the task is incorrect because there is no clear pattern indicating a decline in performance.

4.2 BETWEEN-GROUPS ACCURACY

Due to the small sample size of the veterans with TBI group, single subject statistics were run in order to compare the individual veterans with the control group to minimize a group effect.

There is no significant difference in accuracy between the two TBI subjects and the control groups for the filler sentences. This finding is very important because it shows that any difference in performance between the two groups with the experimental sentences is not a result of a misunderstanding of the task.

It was hypothesized that the veterans with mTBI would have significantly worse accuracy than the control subjects for all garden path sentences. While this was not the case for all sentences, as predicted, there were some sentences which showed a language deficit for the TBI subjects. The results show that both of the TBI participants were measurably worse than controls in the garden-path and non-garden-path versions of 'while the man hunted the deer ran into the woods'. In both of these sentences, there are no particularly strong cues blocking the unlicensed inference that the man was in fact hunting the deer. Unlike other sentences, where a plane or a

zoo serve as cues to the listener that the man may not be hunting the deer, this traditional garden path sentence does not provide the listener with any cues to indicate that the man is not hunting the deer. In this case, in order to correctly comprehend the sentence, the listener must rely fully on syntax and a correct parsing of the sentence. Without strong cues, the veterans with mTBI thought that the man was indeed hunting the deer.

In addition, the veterans with mTBI were measurably worse than controls in sentence G, 'The deer ran into the woods while the man hunted the pheasant.' While this sentence was intended to be a control sentence and performance was expected to be comparable to the control subjects, this finding indicates that the veterans were relying on strong cues in order to comprehend the sentence. Although this sentence is not ambiguous, it does involve more referents (more creatures potentially being hunted) and a slightly more complex scenario as a result. If the TBI subjects are relying heavily on cues, they will hear 'deer' and 'pheasant' and have to rely on their working memory to remember which animal was being hunted by the man. It should be noted that while these veterans have performed a battery of neuropsychological tests, access to this data in detail concerning specific results is not available.

As described in section 4.1, both TBI participants performed worse than the controls on the garden-path versions (A+C) and on the non-garden-path versions (B+D). Again, this finding suggests that the TBI participants were likely to draw the wrong conclusion/arrive at the wrong interpretation for sentences where there were no cues (A, B) or only weak, pragmatic/world-knowledge cues (G,H) to the intended meaning. Again, when the sentences are particularly challenging, the TBI subjects arrive at the wrong interpretation. They do so regardless of whether that interpretation is compatible with the structure of the sentence (as in the non-garden-path conditions, B+D) or incompatible with it (as in the garden-path versions, A+C).

4.3 WITHIN-GROUPS REACTION TIME VS. SENTENCE TYPE

It was predicted that the traditional garden path sentence would have the slowest reaction time because it would be the most difficult to parse. Similar to the accuracy hypothesis, it was also predicted that the more difficult the sentence is, the longer the reaction time. TBI subject 2 completely contradicts this hypothesis because the traditional garden path sentence was actually the fastest reaction time. Because TBI 2 had such poor accuracy with this sentence, it can be inferred that TBI 2 heard 'man,' 'hunting,' and 'deer' and quickly answered 'yes,' that the man was hunting the deer, without any reanalysis of the sentence. TBI subject 2 had the slowest reaction time for sentence D, 'the deer paced in the zoo while the man hunted.' This sentence was also significantly more difficult and less accurate for the mTBI subjects, so the longer RT finding indicates that they struggled with this sentence. TBI subject 1 had the slowest reaction time for sentence G, 'While the man hunted the pheasant the deer ran into the woods.' With the additional information of more than one animal that could potentially be hunted by the man, TBI subject 1 might have taken more time to remember which object was being hunted. TBI subject 1 had the fastest reaction time for sentence B, 'the deer ran into the woods while the man hunted.' As stated in section 4.1, there was no accuracy difference between the traditional garden path sentence and the reverse clause order.

The results show that that both TBI subjects were very fast for sentences A and B and were very inaccurate. This indicates that the TBI participants often went with a plausible interpretation which was not strongly affected by the particular structure of the sentence. For these challenging sentences, they went with a plausible interpretation (that the man was hunting the deer) regardless of whether that interpretation was consistent with the structure or not. This

is very consistent with Christianson et al., 2001 where they found that often reanalysis of garden path sentences are 'good enough' and not fully reanalyzed.

The TBI participants have a hard time in conditions where there are not strong cues (like the presence of an extra object, 'the pheasant,' or a strongly implausible object, 'the plane') which would prevent them from getting the unintended interpretation. Again, this difficulty doesn't show up in the garden-path condition, unlike the hypothesis.

That suggests that maybe the TBI participants were not remembering the structural details of the sentences when they were answering the question, or even that much about the fine detail of their content. (They didn't seem to care that the deer was in the zoo in the G/H conditions, for instance.) This finding would be consistent with their having a problem with working memory, much like the older adults in Christianson et. al., (2006) study and the ADHD participants in the Engelhardt, et. al., (2006). It is also consistent with the Drake, et al (2000) findings suggesting that working memory is impaired in an mTBI population, and is predictive of poor post-discharge outcomes.

It was also predicted that veterans with mTBI would become slower throughout the duration of the test due to fatigue. TBI subject 1 did slow down from the first part of the test, to the second and third blocks. However, TBI 1 was faster for the final section of the test. TBI subject 2 did not indicate any pattern or slowing down or speeding up and was very inconsistent in reaction times across the blocks. Neither subject indicates any strong evidence for fatigue.

4.4 BETWEEN GROUPS REACTION TIME

It was predicted that the veterans with mTBI would be much slower than the control group due to the general slowing of information processing from traumatic brain injury. Single subject statistics show that there is a general lack of differences in reaction time between the TBI participants and the controls. These results show that overall, the TBI subjects weren't slower, and does not provide any evidence for the argument that TBI causes a generalized slowed-processing. However, according to Vasterling et. al (2006) deployment alone can have the effect of speeding up reaction times. If this is the case, the veterans with TBI may have slowed processing due to the disorder, but will not perform as slow as someone with TBI who has not been deployed. This makes RT likely less reliable/useful as a measure for this population. At the very least, the current findings do not provide any support for the slowed-processing account of mild TBI, at least for this particular population.

5.0 LIMITATIONS OF THE CURRENT STUDY

One limitation of this study is the small sample size for the experimental TBI group. This flaw was addressed through the single subject statistics which compared each individual subject to the mean of the control groups. However, for future research studies, a larger sample size for the TBI group would enhance the validity of the findings. This affects the external validity of this study and the results/conclusions based on the two individuals can not be generalized to the entire veteran mTBI population.

Another limitation for this study was the ability to match control subjects to the experimental subjects. While the age range was similar, gender was not. Also, the control subjects have never been deployed. Vasterling et al (2006) demonstrated the effect that deployment alone can have on an individual. Future studies should try to use deployed, unimpaired veterans as a control group.

The reaction time data that were presented in the results section represent reaction time for both correct and incorrect responses. This was necessary because there were only six trials for every condition and if the subject only got one correct per condition (which was common for the TBI subjects) the reaction time data would be based on only one

sentence. It is important for future experiments to include more experimental sentences per condition to allow for a more valid representation of reaction time data.

There is also the potential for overlap between the two competing hypotheses of a domain general slowing, represented by a slowing in reaction time, and domain specific problems, assessed by the accuracy data. It must be noted that all conclusions attempted to separate the two conclusions, however there is the possibility that they are interrelated. A generalized slowing of all processes may affect accuracy performance as well as all of the executive functions. Because of this, some of the conclusions in the discussion are not necessarily as clearly defined as initially hoped.

6.0 CONCLUSION

This experiment sought to determine whether complex garden path sentences would be particularly difficult for a sample (n=2) of U.S. veteran soldiers with mild traumatic brain injury. Many of the findings did not support the original hypotheses but still implied that complex language is impaired for this population. It also indicated that working memory may be critically impaired for this population and that a generalized slowing of all mental processes might not be an accurate description of the symptoms of mTBI. In the future, a larger sample size would indicate the validity of these findings. Other experiments should aim to address the major finding that complex language is difficult for this population and should be developed to be used as a future diagnostic tool.

7.0 APPENDIX A

List of All Stimuli and Comprehension Questions

Item	Type	Stimuli	Questions
1	a	While the man hunted the deer ran into the woods.	Did the man hunt the deer?
1	b	The deer ran into the woods while the man hunted.	Did the man hunt the deer?
1	c	While the man hunted the pheasant the deer ran into the woods.	Did the man hunt the deer?
1	d	The deer ran into the woods while the man hunted the pheasant.	Did the man hunt the deer?
1	e	While the man hunted the plane flew over the woods.	Did the man hunt the plane?
1	f	The plane flew over the woods while the man hunted.	Did the man hunt the plane?
1	g	While the man hunted the deer paced in the zoo.	Did the man hunt the deer?
1	h	The deer paced in the zoo while the man hunted.	Did the man hunt the deer?
2	a	As the athlete wrestled the opponent shouted insults.	Did the athlete wrestle the opponent?
2	b	The opponent shouted insults while the athlete wrestled.	Did the athlete wrestle the opponent?
2	c	As the athlete wrestled the teammate the opponent shouted insults.	Did the athlete wrestle the opponent?
2	d	The opponent shouted insults while the athlete wrestled the teammate.	Did the athlete wrestle the opponent?
2	e	As the athlete wrestled the crowd shouted insults.	Did the athlete wrestle the crowd?
2	f	The crowd shouted insults as the opponent wrestled.	Did the athlete wrestle the crowd?
2	g	As the athlete wrestled the opponent arrived at the gym.	Did the athlete wrestle the opponent?
2	h	The opponent arrived at the gym while the athlete wrestled.	Did the athlete wrestle the opponent?
3	a	While the warrior fought the enemy retreated.	Did the warrior fight the enemy?
3	b	The enemy retreated while the warrior fought.	Did the warrior fight the enemy?
3	c	While the warrior fought the bear the enemy retreated	Did the warrior fight the enemy?
3	d	The enemy retreated while the warrior fought the bear.	Did the warrior fight the enemy?
3	e	While the warrior fought the children played baseball.	Did the warrior fight the children?
3	f	The children played baseball while the warrior fought.	Did the warrior fight the children?
3	g	While the warror fought the enemy slept soundly.	Did the warrior fight the enemy?
3	h	The enemy slept soundly while the warrior fought.	Did the warrior fight the enemy?
4	a	As the detective investigated the robbery caused panic.	Did the detective investigate the robbery?
4	b	The robbery caused panic as the detective investigated.	Did the detective investigate the robbery?
4	c	As the detective investigated the murder the robbery caused panic	Did the detective investigate the robbery?
4	d	The robbery caused panic as the detective investigated the murder.	Did the detective investigate the robbery?
4	e	As the detective investigated the tiger caused panic	Did the detective investigate the tiger?
4	f	The tiger caused panic as the detective investigated.	Did the detective investigate the tiger?
4	g	As the detectice investigated the robbery occurred.	Did the detective investigate the robbery?
4	h	The robbery occurred as the detective investigated.	Did the detective investigate the robbery?

5	a	As the lion attacked the baboon screamed in terror.	Did the lion attack the baboon?
5	b	The baboon screamed in terror as the lion attacked.	Did the lion attack the baboon?
5	c	As the lion attacked the gazelle the baboon screamed in terror	Did the lion attack the baboon?
5	d	The baboon screamed in terror as the lion attacked the gazelle.	Did the lion attack the baboon?
5	e	As the lion attacked the ship left the harbor.	Did the lion attack the ship?
5	f	The ship left the harbor as the lion attacked.	Did the lion attack the ship?
5	g	As the lion attacked the baboon watched from its cage.	Did the lion attack the baboon?
5	h	The baboon watched from its cage as the lion attacked.	Did the lion attack the baboon?
6	a	While the woman drank the water spilled on the floor.	Did the woman drink the water?
6	b	The water spilled on the floor while the woman drank.	Did the woman drink the water?
6	c	While the woman drank the beer the water spilled on the floor	Did the woman drink the water?
6	d	The water spilled on the floor while the woman drank the beer.	Did the woman drink the water?
6	e	While the woman drank the river dried up.	Did the woman drink the river?
6	f	The river dried up while the woman drank.	Did the woman drink the river?
6	g	While the woman drank the water overflowed from the toilet.	Did the woman drink the water?
6	h	The water overflowed from the toilet while the woman drank.	Did the woman drink the water?
7	a	As Bill ate the turkey sat on the table.	Did Bill eat the turkey?
7	b	The turkey sat on the table as Bill ate.	Did Bill eat the turkey?
7	c	As Bill ate the ham the turkey sat on the table	Did Bill eat the turkey?
7	d	The turkey sat on the table as Bill ate the ham.	Did Bill eat the turkey?
7	e	As Bill ate the letter was on the table	Did Bill eat the letter?
7	f	The letter was on the table as Bill ate.	Did Bill eat the letter?
7	g	As Bill ate the turkey pecked at the corn.	Did Bill eat the turkey?
7	h	The turkey pecked at the corn as Bill ate.	Did Bill eat the turkey?
8	a	As Harry chewed the steak fell to the floor.	Did Harry chew the steak?
8	b	The steak fell to the floor as Harry chewed.	Did Harry chew the steak?
8	c	As Harry chewed the apple the steak fell to the floor	Did Harry chew the steak?
8	d	The steak fell to the floor as Harry chewed the apple.	Did Harry chew the steak?
8	e	As Harry chewed the statue fell to the floor.	Did Harry chew the statue?
8	f	The statue fell to the floor as Harry chewed.	Did Harry chew the statue?
8	g	As Harry chewed the steak thawed on the counter.	Did Harry chew the steak?
8	h	The steak thawed on the counter as Harry chewed.	Did Harry chew the steak?
9	a	As the mare fed the colt stamped its hoof.	Did the mare feed the colt?
9	b	The colt stamped its hoof as the mare fed.	Did the mare feed the colt?
9	c	As the mare fed the yearling the colt stamped its hoof	Did the mare feed the colt?
9	d	The colt stamped its hoof as the mare fed the yearling.	Did the mare feed the colt?
9	e	As the mare fed the politician stamped his feet	Did the mare feed the politician?
9	f	The politician stamped his feet as the mare fed	Did the mare feed the politician?
9	g	As the mare fed the colt raced in the field	Did the mare feed the colt?
9	h	The colt raced in the field as the mare fed.	Did the mare feed the colt?
10	a	While the snake swallowed the frog kicked vigorously.	Did the snake swallow the frog?
10	b	The frog kicked vigorously while the snake swallowed.	Did the snake swallow the frog?
10	c	While the snake swallowed the mouse the frog kicked vigorously	Did the snake swallow the frog?

10	d	The frog kicked vigorously while the snake swallowed the mouse.	Did the snake swallow the frog?
10	e	While the snake swallowed the player kicked the ball	Did the snake swallow the player?
10	f	The player kicked the ball while the snake swallowed.	Did the snake swallow the player?
10	g	While the snake swallowed the frog jumped into the pond	Did the snake swallow the frog?
10	h	The frog jumped into the pond while the snake swallowed	Did the snake swallow the frog?
11	a	While the sailor smoked the pipe glowed brightly.	Did the sailor smoke the pipe?
11	b	The pipe glowed brightly while the sailor smoked.	Did the sailor smoke the pipe?
11	c	While the sailor smoked the cigar the pipe glowed brightly	Did the sailor smoke the pipe?
11	d	The pipe glowed brightly while the sailor smoked the cigar.	Did the sailor smoke the pipe?
11	e	While the sailor smoked the candle glowed brightly	Did the sailor smoke the candle?
11	f	The candle glowed brightly while the sailor smoked.	Did the sailor smoke the candle?
11	g	While the sailor smoked the pipe remained unlit.	Did the sailor smoke the pipe?
11	h	The pipe remained unlit while the sailor smoked.	Did the sailor smoke the pipe?
12	a	While Janet baked the bread rose in the oven.	Did Janet bake the bread?
12	b	The bread rose in the oven while Janet baked.	Did Janet bake the bread?
12	c	While Janet baked the pie the bread rose in the oven	Did Janet bake the bread?
12	d	The bread rose in the oven while Janet baked the pie.	Did Janet bake the bread?
12	e	While Janet baked the dog ran up the stairs	Did Janet bake the dog?
12	f	The dog ran up the stairs while Janet baked	Did Janet bake the dog?
12	g	While Janet baked the bread grew moldy.	Did Janet bake the bread?
12	h	The bread grew moldy while Janet baked.	Did Janet bake the bread?
13	a	While Tom grilled the hot dog began to burn.	Did Tom grill the hot dog?
13	b	The hot dog began to burn while Tom grilled.	Did Tom grill the hot dog?
13	c	While Tom grilled the hamburger the hot dog began to burn	Did Tom grill the hot dog?
13	d	The hot dog began to burn while Tom grilled the hamburger.	Did Tom grill the hot dog?
13	e	While Tom grilled the couch began to burn	Did Tom grill the couch?
13	f	The couch began to burn while Tom grilled	Did Tom grill the couch?
13	g	While Tom grilled the hot dog cooled in the fridge	Did Tom grill the hot dog?
13	h	The hot dog cooled in the fridge while Tom grilled	Did Tom grill the hot dog?
14	a	While the chef stirred the soup boiled over.	Did the chef stir the soup?
14	b	The soup boiled over while the chef stirred.	Did the chef stir the soup?
14	c	While the chef stirred the sauce the soup boiled over	Did the chef stir the soup?
14	d	The soup boiled over while the chef stirred the sauce.	Did the chef stir the soup?
14	e	While the chef stirred the cats meowed	Did the chef stir the cats?
14	f	The cats meowed while the chef stirred.	Did the chef stir the cats?
14	g	While the chef stirred the soup thawed on the counter.	Did the chef stir the soup?
14	h	The soup thawed on the counter while the chef stirred.	Did the chef stir the soup?
15	a	As the man walked the poodle barked loudly.	Did the man walk the poodle?
15	b	The poodle barked loudly as the man walked.	Did the man walk the poodle?
15	c	As the man walked the collie the poodle barked loudly	Did the man walk the poodle?
15	d	The poodle barked loudly as the man walked the collie.	Did the man walk the poodle?
15	e	As the man walked the girl shouted loudly	Did the man walk the girl?
15	f	The girl shouted loudly as the man walked	Did the man walk the girl?

15	g	As the man walked the poodle whimpered in the city pond	Did the man walk the poodle?
15	h	As the poodle whimpered in the city pond the man walked	Did the man walk the poodle?
16	a	As the champion raced the challenger stumbled and fell.	Did the champion race the challenger?
16	b	The challenger stumbled and fell as the champion raced.	Did the champion race the challenger?
16	c	As the champion raced the coach the challenger stumbled and fell	Did the champion race the challenger?
16	d	The challenger stumbled and fell as the champion raced the coach.	Did the champion race the challenger?
16	e	As the champion raced the satellite went into orbit	Did the champion race the satellite?
16	f	The satellite went into orbit as the champion raced	Did the champion race the satellite?
16	g	As the champion raced the challenger watched from the sidelines	Did the champion race the challenger?
16	h	The challenger watched from the sidelines as the champion raced.	Did the champion race the challenger?
17	a	While Rick drove the car veered into a ditch.	Did Rick drive the car?
17	b	The car veered into a ditch while Rick drove.	Did Rick drive the car?
17	c	While Rick drove the truck the car veered into a ditch	Did Rick drive the car?
17	d	The car veered into a ditch while Rick drove the truck.	Did Rick drive the car?
17	e	While Rick drove the geese flew out of a ditch	Did Rick drive the geese?
17	f	The geese flew out of a ditch while Rick drove	Did Rick drive the geese?
17	g	While Rick drove the car warmed up in the garage	Did Rick drive the car?
17	h	The car warmed up in the garage while Rick drove	Did Rick drive the car?
18	a	As the farmer steered the tractor pulled the plough.	Did the farmer steer the tractor?
18	b	The tractor pulled the plough as the farmer steered.	Did the farmer steer the tractor?
18	c	As the farmer steered the golf cart the tractor pulled the plough	Did the farmer steer the tractor?
18	d	The tractor pulled the plough as the farmer steered the golf cart.	Did the farmer steer the tractor?
18	e	As the farmer steered the children played in the haystack	Did the farmer steer the children?
18	f	The children played in the haystack the farmer steered.	Did the farmer steer the children?
18	g	As the farmer steered the tractor lay in a ditch	Did the farmer steer the tractor?
18	h	The tractor lay in a ditch as the farmer steered.	Did the farmer steer the tractor?
19	a	While Kendra parked the van bumped the curb.	Did Kendra park the van?
19	b	The van bumped the curb while Kendra parked.	Did Kendra park the van?
19	c	While Kendra parked the bus the van bumped the curb	Did Kendra park the van?
19	d	The van bumped the curb while Kendra parked the bus.	Did Kendra park the van?
19	e	While Kendra parked the elephant ate the grass	Did Kendra park the elephant?
19	f	The elephant ate the grass while Kendra parked	Did Kendra park the elephant?
19	g	While Kendra parked the van rusted in the junkyard	Did Kendra park the van?
19	h	The van rusted in the junkyard while Kendra parked	Did Kendra park the van?
20	a	As the cowboy rode the horse sweated profusely.	Did the cowboy ride the horse?
20	b	The horse sweated profusely as the cowboy rode.	Did the cowboy ride the horse?
20	c	As the cowboy rode the bull the horse sweated profusely	Did the cowboy ride the horse?
20	d	The horse sweated profusely as the cowboy rode the bull.	Did the cowboy ride the horse?
20	e	As the cowboy rode the trees blew in the wind	Did the cowboy ride the trees?
20	f	As the trees blew in the wind the cowboy rode	Did the cowboy ride the trees?
20	g	As the cowboy rode the horse slept peacefully	Did the cowboy ride the horse?
20	h	The horse slept peacefully as the cowboy rode	Did the cowboy ride the horse?

21	a	While the skipper sailed the boat veered off course.	Did the skipper sail the boat?
21	b	The boat veered off course while the skipper sailed.	Did the skipper sail the boat?
21	c	While the skipper sailed the ship the boat veered off course	Did the skipper sail the boat?
21	d	The boat veered off course while the skipper sailed the ship.	Did the skipper sail the boat?
21	e	While the skipper sailed the truck ran off the road	Did the skipper sail the truck?
21	f	The truck ran off the road while the skipper sailed	Did the skipper sail the truck?
21	g	While the skipper sailed the boat remained at the dock	Did the skipper sail the boat?
21	h	The boat remained at the dock while the skipper sailed	Did the skipper sail the boat?
22	a	As the explorer paddled the canoe headed toward a waterfall.	Did the explorer paddle the canoe?
22	b	The canoe headed toward a waterfall as the explorer paddled.	Did the explorer paddle the canoe?
22	c	As the explorer paddled the raft the canoe headed toward a waterfall	Did the explorer paddle the canoe?
22	d	The canoe headed toward a waterfall as the explorer paddled the raft.	Did the explorer paddle the canoe?
22	e	As the explorer paddled the chopper headed home	Did the explorer paddle the chopper?
22	f	The chopper headed home as the explorer paddled	Did the explorer paddle the chopper?
22	g	As the explorer paddled the canoe rotted on the river bank	Did the explorer paddle the canoe?
22	h	The canoe rotted on the river bank as the explorer paddled	Did the explorer paddle the canoe?
23	a	While the student read the notes blew off the desk.	Did the student read the notes?
23	b	The notes blew off the desk while the student read.	Did the student read the notes?
23	c	While the student read the magazine the notes blew off the desk	Did the student read the notes?
23	d	The notes blew off the desk while the student read the magazine.	Did the student read the notes?
23	e	While the student read the dust blew off the desk	Did the student read the dust?
23	f	The dust blew off the desk while the student read	Did the student read the dust?
23	g	While the student read the notes burned in the fireplace	Did the student read the notes?
23	h	The notes burned in the fireplace while the student read	Did the student read the notes?
24	a	While the lawyer studied the contract lay on the roll-top desk.	Did the lawyer study the contract?
24	b	The contract lay on the roll-top desk while the lawyer studied.	Did the lawyer study the contract?
24	c	While the lawyer studied the will the contract lay on the roll-top desk	Did the lawyer study the contract?
24	d	The contract lay on the roll-top desk while the lawyer studied the will.	Did the lawyer study the contract?
24	e	While the lawyer studied the flowers bloomed outside	Did the lawyer study the flowers?
24	f	The flowers bloomed outside while the lawyer studied	Did the lawyer study the flowers?
24	g	While the lawyer studied the contract remained in the safety deposit box	Did the lawyer study the contract?
24	h	The contract remained in the safety deposit box while the lawyer studied	Did the lawyer study the contract?
25	a	As Susan wrote the letter fell off the table.	Did Susan write the letter?
25	b	The letter fell off the table as Susan wrote.	Did Susan write the letter?
25	c	As Susan wrote the note the letter fell off the table	Did Susan write the letter?
25	d	The letter fell off the table as Susan wrote the note.	Did Susan write the letter?
25	e	As Susan wrote the baby napped in the crib.	Did Susan write the baby?
25	f	The baby napped in the crib as Susan wrote	Did Susan write the baby?
25	g	As Susan wrote the letter arrived from Paris	Did Susan write the letter?
25	h	The letter arrived from Paris as Susan wrote	Did Susan write the letter?
26	a	While the secretary typed the memo neared completion.	Did the secretary type the memo?
26	b	The memo neared completion while the secretary typed.	Did the secretary type the memo?

26	c	While the secretary typed the letter the memo neared completion	Did the secretary type the memo?
26	d	The memo neared completion while the secretary typed the letter.	Did the secretary type the memo?
26	e	While the secretary typed the picture fell off the wall.	Did the secretary type the picture?
26	f	The picture fell off the wall while the secretary typed	Did the secretary type the picture?
26	g	While the secretary typed the memo arrived in the mail	Did the secretary type the memo?
26	h	The memo arrived in the mail while the secretary typed	Did the secretary type the memo?
27	a	As the artist painted the model sat in the chair.	Did the artist paint the model?
27	b	The model sat in the chair as the artist painted.	Did the artist paint the model?
27	c	As the artist painted the landscape the model sat in the chair	Did the artist paint the model?
27	d	The model sat in the chair as the artist painted the landscape.	Did the artist paint the model?
27	e	As the artist painted the calculation was completed	Did the artist paint the calculation?
27	f	The calculation was completed as the artist painted	Did the artist paint the calculation?
27	g	As the artist painted the model went out for lunch	Did the artist paint the model?
27	h	The model went out for lunch as the artist painted	Did the artist paint the model?
28	a	While the reporter photographed the rocket sat on the launch pad.	Did the reporter photograph the rocket?
28	b	The rocket sat on the launch pad while the reporter photographed.	Did the reporter photograph the rocket?
28	c	While the reporter photographed the astronaut the rocket sat on the launch pad	Did the reporter photograph the rocket?
28	d	The rocket sat on the launch pad while the reporter photographed the astronaut.	Did the reporter photograph the rocket?
28	e	While the reporter photographed the song was on the radio	Did the reporter photograph the song?
28	f	The song was on the radio while the reporter photographed	Did the reporter photograph the song?
28	g	While the reporter photographed the rocket landed on Mars	Did the reporter photograph the rocket?
28	h	The rocket landed on Mars while the reporter photographed	Did the reporter photograph the rocket?
29	a	While the caricaturist drew the child stood on the sidewalk.	Did the caricaturist draw the child?
29	b	The child stood on the sidewalk while the caricaturist drew.	Did the caricaturist draw the child?
29	c	While the caricaturist drew the dog the child stood on the sidewalk	Did the caricaturist draw the child?
29	d	The child stood on the sidewalk while the caricaturist drew the dog.	Did the caricaturist draw the child?
29	e	While the caricaturist drew the weather turned bad	Did the caricaturist draw the weather?
29	f	The weather turned bad while the caricaturist drew	Did the caricaturist draw the weather?
29	g	While the caricaturist drew the child watched a movie	Did the caricaturist draw the child?
29	h	The child watched a movie while the caricaturist drew	Did the caricaturist draw the child?
30	a	While the director filmed the actor recited the lines.	Did the director film the actor?
30	b	The actor recited the lines while the director filmed.	Did the director film the actor?
30	c	While the director filmed the extras the actor recited the lines	Did the director film the actor?
30	d	The actor recited the lines while the director filmed the extras.	Did the director film the actor?
30	e	While the director filmed the coffee spilled in his lap	Did the director film the coffee?
30	f	The coffee spilled in his lap while the director filmed	Did the director film the coffee?
30	g	While the director filmed the actor took a break	Did the director film the actor?
30	h	The actor took a break while the director filmed	Did the director film the actor?
31	a	As Henry whittled the stick broke in half.	Did Henry whittle the stick?
31	b	The stick broke in half as Henry whittled.	Did Henry whittle the stick?
31	c	As Henry whittled the log the stick broke in half	Did Henry whittle the stick?
31	d	The stick broke in half as Henry whittled the log.	Did Henry whittle the stick?

31	e	As Henry whittled the tree bent in the wind.	Did Henry whittle the tree?
31	f	The tree bent in the wind as Henry whittled	Did Henry whittle the tree?
31	g	As Henry whittled the stick burned in the campfire	Did Henry whittle the stick?
31	h	The stick burned in the campfire as Henry whittled	Did Henry whittle the stick?
32	a	As Jerry played the violin went out of tune.	Did Jerry play the violin?
32	b	The violin went out of tune as Jerry played.	Did Jerry play the violin?
32	c	As Jerry played the piano the violin went out of tune	Did Jerry play the violin?
32	d	The violin went out of tune as Jerry played the piano.	Did Jerry play the violin?
32	e	As Jerry played the car gained speed	Did Jerry play the car?
32	f	The car gained speed as Jerry played	Did Jerry play the car?
32	g	As Jerry played the violin gathered dust in the attic	Did Jerry play the violin?
32	h	The violin gathered dust in the attic as Jerry played	Did Jerry play the violin?
33	a	While the clown juggled the balls fell on the ground.	Did the clown juggle the balls?
33	b	The balls fell on the ground while the clown juggled.	Did the clown juggle the balls?
33	c	While the clown juggled the apples the balls sat on the table	Did the clown juggle the balls?
33	d	The balls fell on the ground while the clown juggled the apples.	Did the clown juggle the balls?
33	e	While the clown juggled the raindrops fell on the ground	Did the clown juggle the raindrops?
33	f	The raindrops fell on the ground while the clown juggled	Did the clown juggle the raindrops?
33	g	While the clown juggled the balls sat on the table	Did the clown juggle the balls?
33	h	The balls sat on the table while the clown juggled	Did the clown juggle the balls?
34	a	As the maid dusted the picture tipped over.	Did the maid dust the picture?
34	b	The picture tipped over as the maid dusted.	Did the maid dust the picture?
34	c	As the maid dusted the coffee table the picture tipped over	Did the maid dust the picture?
34	d	The picture tipped over as the maid dusted the coffee table.	Did the maid dust the picture?
34	e	As the maid dusted the horse jumped over the fence	Did the maid dust the horse?
34	f	The horse jumped over the fence as the maid dusted	Did the maid dust the horse?
34	g	As the maid dusted the picture developed in the dark room	Did the maid dust the picture?
34	h	The picture developed in the dark room as the maid dusted	Did the maid dust the picture?
35	a	As Mark vacuumed the drapes hung in the window.	Did Mark vacuum the drapes?
35	b	The drapes hung in the window as Mark vacuumed.	Did Mark vacuum the drapes?
35	c	As Mark vacuumed the carpet the drapes hung in the window	Did Mark vacuum the drapes?
35	d	The drapes hung in the window as Mark vacuumed the carpet.	Did Mark vacuum the drapes?
35	e	As Mark vacuumed the teacups broke in the dishwasher	Did Mark vacuum the teacups?
35	f	The teacups broke in the dishwasher as Mark vacuumed	Did Mark vacuum the teacups?
35	g	As Mark vacuumed the drapes spun in the dryer	Did Mark vacuum the drapes?
35	h	The drapes spun in the dryer as Mark vacuumed	Did Mark vacuum the drapes?
36	a	As Angela cleaned the dog stood in the yard.	Did Angela clean the dog?
36	b	The dog stood in the yard as Angela cleaned.	Did Angela clean the dog?
36	c	As Angela cleaned the oven the dog stood in the yard	Did Angela clean the dog?
36	d	The dog stood in the yard as Angela cleaned the oven.	Did Angela clean the dog?
36	e	As Angela cleaned the speech was broadcast	Did Angela clean the speech?
36	f	The speech was broadcast as Angela cleaned	Did Angela clean the speech?
36	g	As Angela cleaned the dog ran down the street	Did Angela clean the dog?

36	h	The dog ran down the street as Angela cleaned	Did Angela clean the dog?
37	a	While the puppy sniffed the kitten sat on the sofa.	Did the puppy sniff the kitten?
37	b	The kitten sat on the sofa while the puppy sniffed.	Did the puppy sniff the kitten?
37	c	While the puppy sniffed the baby the kitten sat on the sofa	Did the puppy sniff the kitten?
37	d	The kitten sat on the sofa while the puppy sniffed the baby.	Did the puppy sniff the kitten?
37	e	While the puppy sniffed the speedboat won the race	Did the puppy sniff the speedboat?
37	f	The speedboat won the race while the puppy sniffed	Did the puppy sniff the speedboat?
37	g	While the puppy sniffed the kitten remained lost	Did the puppy sniff the kitten?
37	h	The kitten remained lost while the puppy sniffed	Did the puppy sniff the kitten?
38	a	While Sam counted the children boarded the bus.	Did Sam count the children?
38	b	The children boarded the bus while Sam counted.	Did Sam count the children?
38	c	While Sam counted the tickets the children boarded the bus	Did Sam count the children?
38	d	The children boarded the bus while Sam counted the tickets.	Did Sam count the children?
38	e	While Sam counted the ice melted in the drinks.	Did Sam count the ice?
38	f	The ice melted in the drinks while Sam counted	Did Sam count the ice?
38	g	While Sam counted the children failed to arrive	Did Sam count the children?
38	h	The children failed to arrive while Sam counted	Did Sam count the children?
39	a	As the professor lectured the students took notes.	Did the professor lecture the students?
39	b	The students took notes as the professor lectured.	Did the professor lecture the students?
39	c	As the professor lectured the parents the students took notes	Did the professor lecture the students?
39	d	The students took notes as the professor lectured the parents.	Did the professor lecture the students?
39	e	As the professor lectured the groceries fell off the shelf	Did the professor lecture the groceries?
39	f	The groceries fell off the shelf as the professor lectured	Did the professor lecture the groceries?
39	g	As the professor lectured the students drove home	Did the professor lecture the students?
39	h	The students drove home as the professor lectured	Did the professor lecture the students?
40	a	While the scientists explored the cave grew cold .	Did the scientists explore the cave?
40	b	The cave grew cold while the scientists explored.	Did the scientists explore the cave?
40	c	While the scientists explored the island the cave grew cold	Did the scientists explore the cave?
40	d	The cave grew cold while the scientists explored the island.	Did the scientists explore the cave?
40	e	While the scientists explored the fries grew cold	Did the scientists explore the fries?
40	f	The fries grew cold while the scientists explored	Did the scientists explore the fries?
40	g	While the scientists explored the island remained undiscovered	Did the scientists explore the cave?
40	h	The island remained undiscovered while the scientists explored	Did the scientists explore the cave?
41	a	As Jack ordered the fish cooked in a pot.	Did Jack order the fish?
41	b	The fish cooked in the pot as Jack ordered.	Did Jack order the fish?
41	c	As Jack ordered the pizza the fish cooked in a pot	Did Jack order the fish?
41	d	The fish cooked in the pot as Jack ordered the pizza.	Did Jack order the fish?
41	e	As Jack ordered the giraffe came around the corner	Did Jack order the giraffe?
41	f	The giraffe came around the corner as Jack ordered	Did Jack order the giraffe?
41	g	As Jack ordered the fish swam upstream	Did Jack order the fish?
41	h	The fish swam upstream as Jack ordered	Did Jack order the fish?
42	a	While the orchestra performed the symphony played on the radio.	Did the orchestra perform the symphony?

42	b	The symphony played on the radio while the orchestra performed.	Did the orchestra perform the symphony?
42	c	While the orchestra performed the concerto the symphony played on the radio	Did the orchestra perform the symphony?
42	d	The symphony played on the radio while the orchestra performed the concerto.	Did the orchestra perform the symphony?
42	e	While the orchestra performed the debate became heated	Did the orchestra perform the debate?
42	f	The debate became heated while the orchestra performed	Did the orchestra perform the debate?
42	g	While the orchestra performed the symphony played on the phonograph	Did the orchestra perform the symphony?
42	h	The symphony played on the phonograph while the orchestra performed	Did the orchestra perform the symphony?
43	a	As the bully tripped the girl tumbled down the stairs.	Did the bully trip the girl?
43	b	The girl tumbled down the stairs as the bully tripped.	Did the bully trip the girl?
43	c	As the bully tripped the teacher the girl tumbled down the stairs.	Did the bully trip the girl?
43	d	The girl tumbled down the stairs as the bully tripped the teacher.	Did the bully trip the girl?
43	e	As the bully tripped the wasp stung the girl	Did the bully trip the wasp?
43	f	The wasp stung the girl as the bully tripped	Did the bully trip the wasp?
43	g	As the bully tripped the girl giggled with delight.	Did the bully trip the girl?
43	h	The girl giggled with delight as the bully tripped.	Did the bully trip the girl?
44	a	While the crowd applauded the policeman saved the little girl.	Did the crowd applaude the policeman?
44	b	The policeman saved the little girl while the crowd applauded.	Did the crowd applaude the policeman?
44	c	While the crowd applauded the fireman the policeman saved the little girl.	Did the crowd applaude the policeman?
44	d	The policeman saved the little girl while the crowd applauded.	Did the crowd applaude the policeman?
44	e	While the crowd applauded the bookshelf collapsed	Did the crowd applaude the bookshelf?
44	f	The bookshelf collapsed while the crowd applauded	Did the crowd applaude the bookshelf?
44	g	While the crowd applauded the policeman secretly observed the suspect.	Did the crowd applaude the policeman?
44	h	The policeman secretly observed the suspect while the crowd applauded.	Did the crowd applaude the policeman?
45	a	As the child splashed the lifeguard blew the whistle.	Did the child splash the lifeguard?
45	b	The lifeguard blew the whistle as the child splashed.	Did the child splash the lifeguard?
45	c	As the child splashed the sunbather the lifeguard blew the whistle.	Did the child splash the lifeguard?
45	d	The lifeguard blew the whistle as the child splashed the sunbather.	Did the child splash the lifeguard?
45	e	As the child splashed the sun burned fiercely	Did the child splash the sun?
45	f	The sun burned fiercely as the child splashed	Did the child splash the sun?
45	g	As the child spashed the lifeguard took a break in the shade.	Did the child splash the lifeguard?
45	h	The lifeguad took a break in the shade as the child splashed.	Did the child splash the lifeguard?
46	a	While the customer paid the clerk entered the amount.	Did the customer pay the clerk?
46	b	The clerk entered the amount while the customer paid.	Did the customer pay the clerk?
46	c	While the customer paid the manager the clerk entered the amount.	Did the customer pay the clerk?
46	d	The clerk entered the amount while the customer paid the manager.	Did the customer pay the clerk?
46	e	While the customer paid the dog entered the shop	Did the customer pay the dog?
46	f	The dog entered the shop while the customer paid	Did the customer pay the dog?
46	g	While the customer paid the clerk stocked the shelves.	Did the customer pay the clerk?
46	h	The clerk stocked the shelves while the customer paid.	Did the customer pay the clerk?
47	a	As the artist sketched the worker sat in the chair.	Did the artist sketch the worker?

47	b	The worker sat in the chair as the artist sketched.	Did the artist sketch the worker?
47	c	As the artist sketched the fruit basket the worker sat in the chair.	Did the artist sketch the worker?
47	d	The worker sat in the chair as the artist sketched the fruit basket.	Did the artist sketch the worker?
47	e	As the artist sketched the sounds grew louder	Did the artist sketch the sounds?
47	f	The sounds grew louder as the artist sketched	Did the artist sketch the sounds?
47	g	As the artist sketched the worker went out for lunch.	Did the artist sketch the worker?
47	h	The worker went out for lunch as the artist sketched.	Did the artist sketch the worker?
48	a	While Karen brushed the cat purred loudly.	Did Karen brush the cat?
48	b	The cat purred loudly while Karen brushed.	Did Karen brush the cat?
48	c	While Karen brushed the dog the cat purred loudly.	Did Karen brush the cat?
48	d	The cat purred loudly while Karen brushed the dog.	Did Karen brush the cat?
48	e	While Karen brushed the sky grew dark.	Did Karen brush the sky?
48	f	The sky grew dark while Karen brushed.	Did Karen brush the sky?
48	g	While Karen brushed the cat chased a mouse in the yard.	Did Karen brush the cat?
48	h	The cat chased a mouse in the yard while Karen brushed.	Did Karen brush the cat?

Filler Sentences

Filler Sentence	**Comprehension Question**	**Answer**
Mabel fixed the socks while she watched the TV.	Did Mabel watch the fire?	no
The mother served the broccoli while the kids banged the table.	Did the kids bang the gong?	no
Joseph freed the bird as the zookeeper watched in horror.	Did Joseph free the lion?	no
The bird flew over the house while it searched for a nesting place.	Did the bird fly over the nest?	no
The astronomer watched the moon while he charted the stars.	Did the astronomer watch the ball game?	no
The tornado destroyed the city hall as it visited the city.	Did the tornado destroy the auditorium?	no
The professor scolded the student when they collided in the hallway.	Did the professor scold the senator?	no
The cowboy branded the cow after he warmed the instrument over the fire.	Did the cowboy brand the goat?	no
The camper stirred the beans while the fire warmed the pot.	Did the fire warm the house?	no
Mickey watched the parade while the drummer dropped his instrument.	Did the drummer drop his pants?	no
The exterminator entered the school while the cockroaches scurried.	Did the exterminator enter the restaurant?	no
The archaeologist dug the pit as the supervisor broke the artifact.	Did the supervisor break the computer?	no
Yasmeen memorized the formula while the instructor erased the board.	Did the instructor erase the hard drive?	no
The wife washed the dishes as the husband did the laundry.	Did the wife wash the windows?	no
The class left the building as it formed a line.	Did the class leave the restaurant?	no
The bat bit James as he screamed.	Did the bat bite Kelly?	no
The truck driver wiped his brow while he removed his shirt.	Did the truck driver remove his watch?	no
The pitcher threw the pitch while the batter held the bat.	Did the batter hold the pipe?	no

Desmond held the football while Kevin took a fall.	Did Desmond hold the kitten?	no
Diana requested the painkiller as she began childbirth.	Did Diana request a hamburger?	no
The shopkeeper earned a commission when Kate bought the vase.	Did Kate buy the picture frame?	no
The judge addressed the jury as the witness gave the testimony.	Did the judge address the class?	no
The construction worker eyed Karen as he poured the cement.	Did Karen pour the cement?	no
The carpenter sanded the wood as Marcia built the bench.	Did Marcia build the wagon?	no
The golden retriever buried the bone as he refilled the hole.	Did the golden retriever bury the toy?	no
The zookeeper held the snake as the children touched it.	Did the children touch the lizard?	no
The customer contracted salmonella when she ate the hamburger.	Did the consumer eat the lemon?	no
As Mark packed the suitcase Neil called the travel agent.	Did Mark call the travel agent?	no
While the ambassador toured the country the bomb exploded in the capital.	Did the ambassador tour the city?	no
As the police chased the prisoner they crashed their car.	Did the prisoner crash the car?	no
While the cashier bagged the groceries the customer dropped the coupons.	Did the cashier drop the coupons?	no
While the lawyer argued the case the jury slept in the courtroom.	Did the lawyer sleep in the courtroom?	no
While Janis watched the fish she cleaned the tank.	Did Janis watch the snake?	no
As the repairman patched the roof he fell on the tiles.	Did the repairman fall on the steps?	no
As the grandma recited the story the son read in bed.	Did the son recite the story?	no
While Alexander tasted the wine the butler answered the door.	Did the butler taste the wine?	no
As Michael stirred the filling the crust baked in the oven.	Did the filling bake in the oven?	no
As the researcher compiled the data she created graphs.	Did the researcher compile the graphs?	no
While the father prepared the burgers he covered them with pepper.	Did the mother cover the burgers with pepper?	no
As Christy recited the monologue the janitor left the room.	Did Christy leave the room?	no
As the realtor sold the house she celebrated with her colleagues.	Did the colleagues sell the house?	no
As the grandpa picked the raspberries he saved them for the granddaughter.	Did the grandpa pick the blueberries?	no
While Jennifer held the cigar she told bad jokes.	Did Jennifer hold the cigarette?	no
As the cat chased the mouse it slid on the linoleum.	Did the dog chase the mouse?	no
As the artist demonstrated the technique the painting fell off the easel.	Did the artist fall?	no
As the waiter lit the candle he took the couple's order.	Did the waiter light the cigar?	no
As the mother woke the son she realized he was late for work.	Did the mother wake the son?	yes
While the man reversed the car he listened to the radio.	Did the man reverse the car?	yes
After Richard dried the fruit he bagged it for trail mix.	Did Richard dry the fruit?	yes
As the golfer swung the club the caddy pulled the cart.	Did the caddy pull the cart?	yes
While the kids teased the friend they watched the movie.	Did the kids watch the movie?	yes
While the woman jumped rope she sprained her ankle.	Did the woman jump rope?	yes
While the archer aimed the bow the bird hid in the tree.	Did the archer aim the bow?	yes
While the goalie smoothed the ice he fell on the center line.	Did the goalie fall on the center line?	yes
As NASA launched the shuttle they taunted the Russians.	Did NASA launch the shuttle?	yes

As the chef sampled the sauce she boiled the noodles.	Did the chef sample the sauce?	yes
As the skier removed the skis he collapsed in the snow.	Did the skier collapse in the snow?	yes
As the maid tidied the house she made the bed.	Did the maid make the bed?	yes
As the contestant spun the wheel she clapped her hands.	Did the contestant clap her hands?	yes
When the secretary made the copies she broke the photocopier.	Did the secretary make the copies?	yes
As the campers built the fire they gathered more wood.	Did the campers gather more wood?	yes
As the biologist observed the specimen the patient screamed in pain.	Did the biologist observe the specimen?	yes
While the actor memorized the lines he walked his dog.	Did the actor memorize the lines?	yes
While the ghost rattled the chains it woke the tired child.	Did the ghost wake the tired child?	yes
As the salesman laced the shoe he slid it on the customer's foot.	Did the salesman slide the shoe on the customer's foot?	yes
While the doctor injected the medicine he held the patient.	Did the doctor hold the patient?	yes
While the student played the clarinet the brother covered his ears.	Did the brother cover his ears?	yes
While the choir sang the hymn the child squirmed in the pew.	Did the choir sing the hymn?	yes
While the minister married the couple he wore the robe.	Did the minister wear the robe?	yes
The poodle sniffed the food as he scratched his ear.	Did the poodle sniff the food?	yes
Fido gnawed the bone as Dave fed the cat.	Did Dave feed the cat?	yes
The woman applied lipstick as she rode her bike.	Did the mistress ride the bike?	yes
The butterfly fluttered its wings while it laid the eggs.	Did the butterfly flutter her wings?	yes
Andrew observed the house as his mother baked cookies.	Did the mother bake the cookies?	yes
Gary lost the data when he reformatted his hard drive.	Did Gary reformat his hard drive?	yes
The fireman rescued the kitten as the house burned to the ground.	Did the fireman rescue the kitten?	yes
The gymnast hurt her ankle when she performed the vault.	Did the gymnast complete the vault?	yes
The hostess folded the bedspread as the guest entered the bedroom.	Did the hostess fold the bedspread?	yes
The grandma braided the pigtails while she groomed the girl.	Did the grandma braid the pigtails?	yes
The patient threatened suicide as the psychiatrist administered drugs.	Did the psychiatrist administer drugs?	yes
The toddler wore pajamas when he went to bed.	Did the toddler go to bed?	yes
The woman cashed the check when she stopped at the bank.	Did the woman cash the check?	yes
The mother comforted the toddler while the clown handed him a balloon.	Did the mother comfort the toddler?	yes
The referee blew the whistle when he noticed the foul.	Did the referee notice the foul?	yes
Tim kneaded the dough after the kids mixed the ingredients.	Did Tim knead the dough?	yes
The guitarist plucked the guitar while the lovers entered the room.	Did the guitarist pluck the guitar?	yes
The blonde wore a bikini while she washed the car.	Did the blonde wear the bikini?	yes
The soldier went to war while the wife worried at home.	Did the wife worry at home?	yes
The postman delivered the package while the neighbor watered the plants.	Did the neighbor water the plants?	yes
The designer earned money when the miniskirt became popular.	Did the designer earn money?	yes
The bowler whispered a prayer as he rolled the ball.	Did the bowler throw the ball?	yes
The boys forgot the books as they left for school.	Did the boys leave for school?	yes
As Kevin stirred the fleas they jumped out of the bowl.	Did Kevin stir the flees?	yes

As the student compiled the eggs the chickens panicked.	Did the student compile the eggs?	yes
While uncle Frank prepared the cat the children looked forward to the explosion.	Did uncle Frank prepare the cat?	yes
As the athlete hurt the president the crowd backed away	Did the athlete hurt his president?	yes
As the broker sold the tires the car came to a halt.	Did the broker sell the tires?	yes
As the witch picked the numbers, her cat watched the lottery.	Did the witch pick the numbers?	yes
As the policeman rescued the cigar the doctors looked after the victims.	Did the policeman rescue the cigar?	yes
As the tiger chased the cloud he fell from the tree.	Did the tiger chase the cloud?	yes
As the photographer demonstrated the cleaner the other models were jealous.	Did the photographer demonstrate the cleaner?	yes
As the minister lit the contract the couple held hands.	Did the minister light the contract?	yes
After the innkeeper woke the computer he longed for his typewriter	Did the innkeeper wake the computer?	yes
While the driver reversed the song the children kept singing.	Did the driver reverse the song?	yes
While the nanny dried the books the baby went back to sleep.	Did the nanny dry the books?	yes
As the teacher comforted the frog the pupils played with their toys.	Did the teacher comfort the frog?	yes
While the baby teased the politician the journalists wrote enthusiastically.	Did the baby tease the politician?	yes
While the dancer wore the teapots the audience applauded	Did the dancer wear the teapots?	yes
While the soldier aimed the pen his friends started reciting.	Did the soldier aim the pen?	yes
While the workmen buried the ship the wind tore up the sails	Did the workmen bury the ship?	yes
As the scientists launched the pineapple the monkeys cheered.	Did the scientists launch the pineapple?	yes
As the cook sampled the paintings he was disappointed.	Did the cook sample the paintings?	yes

8.0 APPENDIX B

DVBIC Operational Definitions for mTBI in a Military Setting:

1. Exposure to external biomechanical force (such as blast and/or acceleration/deceleration forces) which may result in brain injury
2. Patient or medical report of:
    a. Confusion or disorientation
    b. Brief alteration or loss of consciousness (lasting 30 minutes or less)
    c. Some post-traumatic amnesia (lasting 24 hours or less)
    d. Other brief evidence of neurological abnormality, such as seizure
3. Glasgow Coma Scale (GCS) score of 13-15
4. Symptoms are not due to substance abuse, other injuries (such as facial injuries), other causes (such as psychological trauma or other co-morbidity), or penetrating head trauma.

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