Critical Review:
In adult patients with Traumatic Brain Injury, what are the characteristics of the memory impairment?

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Memory impairments are the most frequently and one of the most debilitating reported in traumatic brain injury (TBI). This critical review examines the characteristics of memory impairment in adults with TBI. A literature search of electronic databases identified four articles meeting the selection criteria. Study designs include a prospective matched control trial and three between-group designs. The results of the research suggest that there is conflicting evidence in the literature on the characteristics of memory that are impaired in individuals with TBI. Clinical implications and future research recommendations are also discussed.

Introduction

Moderate to severe traumatic brain injury (TBI) can result in an array of cognitive and physical deficits, however memory impairments are the most frequently reported and one of the most debilitating (Vanderploeg et al, 2013). Although there is widespread agreement that memory impairment occurs in this population, many questions still remain unanswered regarding the specific memory processes that are affected. These processes include encoding, consolidation, and retrieval of the information (DeLuca et al, 2000).

Encoding is the process by which new information is attended to and acquired. Deficits in encoding result in a slower rate of learning and a decreased learning curve (DeLuca et al, 2000). **Consolidation** is the process by which encoded information is retained and stored in long-term memory. Deficits in consolidation result in the impaired ability to recall information (Vanderploeg et al, 2013). **Retrieval** is the process of searching, finding and reactivating information in long-term storage that has been consolidated. Deficits in retrieval usually result in impaired recall ability but intact recognition performance (DeLuca et al, 2000). Several researchers have hypothesized that memory impairment in persons with TBI results from a deficit in acquisition/encoding of information. Research supporting this shows impaired semantic organization strategies along with a slower rate of learning (DeLuca et al, 2000). Others have hypothesized that persons with TBI have difficulty consolidating information, which is supported with a significantly greater rate of forgetting relative to healthy controls (Vanderploeg et al, 2001 & Vanderploeg at al, 2013).

It is important that Speech-Language Pathologists take into account the nature of these deficits in order to provide educated and effective assessment and treatment to persons with traumatic brain injury. Based on this foundational knowledge, the present review seeks to clarify the characteristics of the memory impairment in adults with moderate-severe traumatic brain injury.

Objectives

The primary objective of this paper is to critically examine the existing literature pertaining to the characteristics of memory impairment in adults with traumatic brain injury. Implications for clinical practice and future avenues for research will be addressed as well.

Methods

Search Strategy

Research studies were searched in the Western University Library. Electronic databases including PubMed and Scopus returned relevant articles using the following terms: (traumatic brain injury) AND (memory impairment) OR (memory encoding) OR (memory consolidation) OR (memory retrieval). Reference lists of the articles selected were also searched for further relevant articles.

Selection Criteria

The studies selected for this review addressed the specific mechanism (initial acquisition/encoding of information versus compromised consolidation or retrieval deficits) underlying memory impairment in adults with traumatic brain injury. Participants must have sustained a moderate-severe traumatic brain injury with no prior history of cognitive impairments.

Data Collection

The literature search revealed four papers that met the aforementioned selection criteria: a prospective matched control trial, and three between-group designs.

Results

Using a prospective matched control trial, DeLuca et al (2000) investigated memory characteristics of 28 individuals with moderate to severe TBI (Mean = 32 months post event; no prior rehabilitation services) and 21 matched (on age, sex, handedness, and education) normal healthy controls. To investigate whether the memory impairment in TBI was due to impaired initial acquisition/encoding, consolidation deficits or compromised retrieval from long-term storage, a modified version of a published memory test commonly employed in research was completed. The memory test provided a measure of initial learning of semantically related words across trials (number trials required to learn), as well as a consolidation and retrieval measure that involved recall and recognition at 30 and 90-minute intervals (number words recalled / recognized). TBI participants were grouped according to whether or not they met initial learning criteria. Appropriate ANOVAs revealed that individuals with TBI required significantly more trials to learn a verbal list task, however there were no significant differences in the number of words recalled and recognized after a delay.

The strengths of this study include very thorough methodology that incorporated multiple demographic and neuropsychological controls between groups to ensure the TBI group and the control group had little to no unattended variables that could have influenced the results. Another strength is that the researcher's controlled for differences in initial acquisition between TBI and control groups before making a conclusion about performance on recall and recognition tasks, as this is a major limitation with much of existing TBI memory literature. However, a limitation of this study is that the authors suggest that a delayed recall ceiling effect was present in the TBI and the control group. Another limitation of this study is that 8 participants in the TBI group did not meet the learning criteria, which resulted in comparisons between a subset of the TBI group with the controls. The authors did not report whether the groups remained matched on inclusion criteria once only the subset was considered.

Given the strengths and limited weaknesses of DeLuca et al's (2000) study, the evidence presented is suggestive that memory impairment after TBI is characterized by impairments in initial acquisition of information rather than in compromised retrieval of information. However, the ceiling effect that is present raises the need for caution in the interpretation.

Using a between-groups design, Vanderploeg, Crowell and Curtis (2001) investigated the type of verbal memory deficits (encoding, consolidation and retrieval) in verbal learning and memory in 55 individuals with moderate to severe TBI and healthy control groups matched either on (1) age and initial learning performance or (2) age, education, and race. Using a standardized memory test, participants completed a learning task with outcome measures related to rate of learning / encoding, rate of forgetting, proactive interference / consolidation, and free versus cued recall and recognition / retrieval tasks. Appropriate statistical analyses using ANOVAs revealed impaired consolidation relative to encoding and retrieval for the TBI group.

A major strength in this study was the matching of the TBI group and one control group on initial acquisition. Other strengths included the reasonable sample size and 2 matched control groups. A limitation of the study was that subjects in both control groups were males, even though there were females in the TBI group, which raises concern about possible sex differences in memory performance.

Given the multiple strength's and limited weaknesses of Vanderploeg et al.'s (2001) study, the evidence presented is compelling. The findings suggest that impaired consolidation is the primary memory deficit in persons with TBI.

Using a between-groups design, Vanderploeg, Donnell, Belanger and Curtiss (2013) completed a follow up study to Vanderploeg et al (2001) to investigate the type (encoding, consolidation and retrieval) of deficit underlying verbal memory in 105 individuals with moderate to severe TBI and a healthy control group (matched on education and race). Using a standardized memory test, participants completed a learning task with outcome measures related to encoding / acquisition, consolidation / storing, and retrieval / recall. The test was repeated again a year later. Appropriate statistical analyses using ANOVAs revealed initial baseline deficits in encoding, consolidation and retrieval. However, after one year, resolution of the encoding and retrieval

deficits occurred with consolidation remaining impaired.

A major strength in this study was the increased sample size from the previous 2001 study strengthening the power of the results. The participants and procedures were described in detail. A limitation of the study was the age differences between the TBI group and the control group, however the two age ranges had the same normative data in the standardized scores of the assessment, which lessons concern about age differences in memory performance.

Given the strengths of Vanderploeg et al's (2013) study, the evidence presented is compelling. The findings suggest that although all three processes (encoding, consolidation, retrieval) are impaired initially, consolidation remains impaired over time.

Using a between-groups design, Hillary et al (2003) investigated the difference in learning and memory in 20 individuals with moderate to severe TBI (>1 year post-injury) when information is presented over time (spaced) as opposed to consecutively (massed). This well-known psychology phenomenon is called the Spacing Effect, in which different groups of participants (n=5, randomly allocated in this study) learned words according to a particular schedule: once-presented, massed, and spaced conditions. Outcome measures included number of words within each condition recalled (immediately and after 30 min), and number of words recognized from a longer list. Statistical analyses were done using repeated-measures ANOVA and paired sample t-tests, which may not be appropriate given the small sample size and 4 group design. The researcher's found participants had better recall when the information is presented spaced rather than massed, only once, or not at all.

Strengths of this study included well-described inclusion criteria for participants and detailed procedures. The main limitation is the small sample size.

Given the clear demonstration of a Spacing Effect in persons with TBI, the evidence presented by Hillary et al (2003) is suggestive.

Discussion

This critical review examined four articles related to the characteristic of the impairment underlying memory deficits in individuals with TBI. Overall, the literature presented conflicting findings regarding the characteristic of the memory impairment in individuals with TBI that leaves it unclear as to the specific impairment. There is suggestive evidence that encoding is the impaired process and compelling evidence that consolidation is the impaired process.

The three between-groups studies (DeLuca et al, 2000, Vanderploeg at al, 2001 & Vanderploeg et al, 2013) controlled for differences in initial learning between the TBI group and the control group before analyzing their data. As much of the documented research on memory impairment does not account for this, it was a strength across all three studies. DeLuca et al (2000) presented suggestive evidence that encoding was the specific characteristic of memory impaired in TBI patients, however due to the ceiling effect (both their TBI group and control group were able to learn the initial 10 words), their recall and recognition data may not have been accurate.

The two studies by Vanderploeg et al (2001, 2013) had similar methods however the later study (2013) accounted for limitations of the earlier study (2001) by increasing the sample size and tracking the recovery course of the different memory processes up to one year post-injury. They provided compelling evidence that consolidation was the specific impairment in individuals with TBI in both the original and follow-up study. As they initially found all three processes impaired, the one-year post-injury re-assessment showed resolution of the encoding and retrieval deficits but continued impairment in the consolidation process. DeLuca et al (2000) did not follow up with their TBI subjects one year post-injury, therefore there is uncertainty as to whether the encoding difficulties found would have resolved.

The study by Hillary et al (2003) provides suggestive evidence about optimal learning conditions for individuals with TBI, however the implications for impaired memory characteristics in TBI are less clear and this paper was not a major contributor to this review. Although it provides little information beyond the presentation style of the information, this evidence could be used in clinical practice as a strategy to aid memory retention in these individuals. As there is disagreement in regards to the characteristic of memory that is impaired, presenting the information in a spaced versus massed manner may help all individuals with TBI.

As two of the four articles included the same author, any methodological biases that presented in the first study may have presented in the second study. This was realized when the control group in both studies included males only, however females were included

in TBI group. Nevertheless, a strength of having the same author for two of the articles is the ability of that author to address and improve some of the weaknesses mentioned in the first study. A general limitation of the research is the case-specific differences that are present in every individual with TBI. As these individuals cannot be generalized into one encompassing group, there may be many different subgroups of persons with TBI that present with different symptoms. This makes it difficult to determine which specific process is impaired as it may differ within different subgroups, which may suggest that the search for a specific memory impairment is futile as the heterogeneous population might mean some individuals have an impairment predominantly in one process or another.

Further research needs to be completed in the area of traumatic brain injury in order to alleviate the confusion regarding the characteristics of the memory impairment in these subgroups of individuals. Clinical practice can therefore be tailored towards the process that is impaired. Future studies should include the use of sex-matched controls and larger sample sizes. Follow up testing should also be included as the brain is dynamic and may change and heal over time.

Conclusion

There is conflicting evidence in the literature on the characteristics of memory that is impaired in individuals with TBI. Due to the inconsistent findings, further studies confirming the characteristics would substantiate the pre-existing evidence.

Clinical Implications

The results from the four studies included in this critical review offer conflicting evidence as to which specific memory processes are impaired in individuals with TBI. Therefore, no firm clinical conclusions can be drawn. However, there was some evidence in the literature to suggest that encoding and consolidation are the main deficits relative to retrieval. This is important when speech-language pathologists are determining how to best intervene with patients with TBI and how to best treat their memory impairment. Nevertheless, all persons should be assessed and treated individually based on the impairment they present with. While no firm clinical conclusions can be drawn, it may be of use to incorporate the strategy of spaced information presentation in therapy sessions in order to facilitate memory.

References

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