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Memory Restoration Using Computerized Cognitive Training After Pediatric Traumatic Brain Injury: A Review of the Evidence

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Structured Abstract

Clinical Question: For children and adolescents with memory impairments after traumatic brain injury (TBI), do computerized cognitive training (CCT) programs used in conjunction with traditional therapy vs. traditional therapy alone lead to memory gains in daily activities?

Method: Literature Review

Study Sources: Google Scholar, CINAHL via EBSCOhost, MEDLINE via PubMed, PsycBITE, and ASHAWire

Search Terms: TBI OR brain injury AND child/children OR pediatric AND memory AND computer(s)/computerized OR cognitive training OR therapy

Number of Included Studies: 2

Primary Results: There are a limited number of studies examining the use of CCT programs for memory training following pediatric TBI. A larger number of studies have examined CCT for memory training with adults following TBI and in children with other diagnoses (e.g., ADHD).

Conclusions: There is limited and low-quality evidence to support the use of CCT for memory training following pediatric TBI, over and above traditional therapy. Further research is needed examining the use of CCT for memory training in this population. Future studies should evaluate and report on how any potential gains found following CCT might transfer to daily activities (e.g., academic performance).

Memory Restoration Using Computerized Cognitive Training After Pediatric Traumatic Brain Injury: A Review of the Evidence

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Clinical Scenario

Natalie, a speech-language pathologist, has worked at a pediatric hospital for many years with children and adolescents who have sustained a traumatic brain injury (TBI). Following their TBI, these individuals frequently have long-term challenges that impact their cognitive-communication skills. Natalie works with her clients to improve these skills so that they can participate successfully in family, community, and school activities.

Natalie works with Owen, a 16-year-old who sustained a severe TBI one year ago in a car accident. Owen sees Natalie for outpatient therapy; his primary deficit is in learning and recalling new information, significantly impacting his ability to be successful at school. Owen's mother expressed frustration recently because she feels that Natalie is only teaching Owen how to compensate for his memory problems and she would like Natalie to focus on improving his memory. In a recent therapy session, Owen's mom talked to Natalie about a computerized program that she has seen discussed in some of the social media forums for TBI survivors to which she belongs. This "brain training" program is supposed to help build and strengthen a person's memory. Owen's mom is willing to pay the fee for such a program if it would help him and is interested in Natalie's thoughts on such a program.

Natalie has heard of these types of computerized cognitive training (CCT) programs, but she does not know much about the evidence base behind them. Specifically, she wonders if Owen participated in a CCT program, in addition to continuing his current outpatient therapy program, would he show improvements in memory for functional, everyday tasks? Natalie tells Owen's mom that they can discuss CCT during Owen's next session, once Natalie has a chance to review the current literature on this topic.

Background Information

Traumatic Brain Injury

TBI is the leading cause of acquired disability for children in the United States (Centers for Disease Control and Prevention, 2015). Following a TBI, a young person's normal developmental trajectory may be disrupted. Rapid recovery may occur immediately after the injury, but then the student may hit a plateau where continued development does not keep pace with that of peers (Chapman, 2006). Challenges with new learning may be one explanation for this "neurocognitive stall" (Chapman, 2006), as memory problems are one of the most frequent difficulties observed or reported following a TBI (Babikian, Merkley, Savage, Giza, & Levin, 2015). Students with TBI who also have trouble learning new facts and skills may experience low academic achievement (Fulton, Yeates, Taylor, Walz, & Wade, 2012).

If students with TBI who have memory impairments are properly identified, there are several evidence-based treatment strategies that can be introduced. An international group of researchers and clinicians (known as INCOG) recently published several papers with recommendations for management of cognition following TBI (Bayley et al., 2014). In the INCOG review for the management of memory deficits following TBI (Velikonja et al., 2014), the authors found good evidence to support using specific rehabilitation-focused instructional practices to teach internal and external compensatory memory strategies. They reported that evidence to promote restorative strategies remains weak.

Computerized Cognitive Training (CCT) Programs

In the past decade, several new computerized cognitive training (CCT) programs have advertised their ability to improve learning and memory, offering many advantages over traditional face-to-face therapy. For example, individuals with a TBI might struggle to find a cognitive rehabilitation provider close to their home and may also

have a limited number of visits reimbursed by an insurance provider. Younger individuals may be more motivated to participate in therapy activities that are a closer match to the games they play on their smartphones, tablets, or gaming systems. Additionally, many CCT programs meet the general principles of experience-dependent neuroplasticity (Kleim & Jones, 2008), such that training is intense, repetitive, and adaptive (increases and decreases the degree of difficulty based on performance). These qualities support the idea that CCT may, in fact, be a motivating alternative to traditional therapy and may also help to restore function that has been impaired as a result of a TBI.

Natalie was aware of some reviews that examined the evidence for CCT to improve global cognitive-communication skills in persons with TBI (Politis & Norman, 2016) and memory, attention, and academic performance in children with ADHD (Cortese et al., 2015), but she needed additional information to guide her discussion with Owen's mother regarding whether or not CCT seemed like a valuable investment of their time and money. Therefore, she decided to complete a review of the available evidence to answer Owen's mom's question.

Clinical Question

Natalie used the PICO (population, intervention, comparison, outcome) framework (Akobeng, 2005) recommended by the American Speech-Language-Hearing Association (ASHA) to develop the question that would guide her review of the literature. Natalie identified the following parameters:

P: children and adolescents with memory impairments after TBI

I: computerized cognitive training programs + traditional therapy

C: traditional therapy alone

O: improvements in memory for daily activities

Based on this model, Natalie's question was: For children and adolescents with memory impairments after TBI, do computerized cognitive training (CCT) programs used in conjunction with traditional therapy vs. traditional therapy alone lead to memory gains in daily activities?

Search for the Evidence

Natalie searched Google Scholar, CINAHL via EBSCOhost, MEDLINE via PubMed, PsycBITE, and ASHAWire databases to locate appropriate research articles using the following search terms: TBI OR brain injury AND child/children OR pediatric AND memory AND computer(s)/computerized OR cognitive training OR therapy. Additionally, Natalie focused only on citations published in English after 2000. Initially, Natalie found 405 articles, but after removing duplicates, there were only 189 references to review (see Figure 1). She eliminated 181 of the remaining references by reading through titles and abstracts and excluded citations that were not journal articles (i.e., textbook chapters) and those that were not (human) treatment studies (e.g., descriptive, expert opinion, animal studies). She also rejected papers that focused only on adults and those that included individuals with non-TBI diagnoses. Because Natalie wanted to be able to make an evidence-based recommendation to Owen's mom, she excluded papers that did not involve CCT as a treatment strategy (e.g., treatment strategies were compensatory only). For references that did include CCT, she only chose studies that looked at memory training specifically, not other cognitive processes (e.g., attention, problem-solving). Natalie understood that it was somewhat artificial to separate memory from other aspects of cognition that are needed to encode and retrieve information successfully (e.g., attention, organization); however, for the purposes of this search, she wanted to focus on studies that evaluated the effects of CCT on memory processes specifically. Using these criteria, Natalie was left with eight articles that she downloaded and skimmed in order to assess them more closely for eligibility.

Of the eight articles Natalie reviewed, she was able to exclude an additional six papers. Three papers were excluded because they focused on memory training and/or CCT, but mainly in adults. Three additional papers were excluded because they dealt with CCT and memory training, but in children who did not have TBIs. Though these six references were excluded, they did give Natalie a better overview of findings from CCT studies (including systematic reviews) in other groups. Following all of these exclusions, Natalie was left with two papers that addressed her PICO question (see Figure 1).

Evaluating the Evidence

Natalie selected two papers (Linden et al., 2016; Phillips et al., 2016) that were appropriate to include in her review and rated them using the Oxford Center for Evidence-Based Medicine's 2011 Levels of Evidence (OCEBM Levels of Evidence Working Group, 2011) focusing specifically on treatment benefits (see Table 1). One reference (Linden et al., 2016) was a systematic review published in the Cochrane Database of Systematic Reviews. The second applicable article (Phillips et al., 2016) detailed results from a randomized control trial involving 27 children with TBI.

Linden et al. (2016) completed a systematic review to assess the effects of CCT compared to placebo intervention, no treatment, or other types of treatment in remediating executive function or memory impairments in children and adolescents with acquired brain injury. Three studies were identified that met their inclusion criteria, but focused on executive function impairments. One study (Thomas-Stonell, Johnson, Schuller, & Jutai, 1994) targeted memory impairments and closely approximated the PICO question for this review; however, this study was completed over two decades before the current review, and Natalie was aware that technology has changed dramatically in the last 20 years. In this older study, 12 adolescents (mean age = 16.75 years) were randomly assigned to either a CCT intervention or a usual-care condition. The broad CCT intervention used in this study was intended to remediate cognitive-communication, memory, attention, and problem-solving skills. The authors reported finding statistically significant differences between intervention and control groups in regards to memory. These results were based on scores from a recalling sentences subtest, and not a more appropriately validated test of memory skills. Additionally, this study did not address secondary outcomes such as academic achievement. Due to a small sample size, no intention-to-treat (e.g., offering a computerized program to the control group as a placebo), and incomplete reporting of findings, the authors of the systematic review determined that this study provided limited evidence that CCT supported the rehabilitation of memory impairments in adolescents following brain injury.

In the second included reference, Phillips et al. (2016) completed a double-blind, randomized, placebo-controlled trial examining the benefits of CCT for memory training following pediatric TBI. They enrolled 13 children (median age = 11.8 years) to the CCT group and 14 children (median age = 12.8 years) to the nonadaptive placebo training group. Three children withdrew from the treatment group and one from the control group prior to completing the study. For placebo training (i.e., intention-to-treat), participants were involved in a computerized training program where the memory demands remained low and did not change as a result of the child's performance. The authors examined participants' performance on working memory tests (near transfer) and generalization of any gains that might be seen to attention, inhibition, and academic achievement (far transfer). Testing was completed before CCT, immediately after CCT, and three months following the completion of training. The paper did not discuss whether or not participants were enrolled in any other therapy services during the five-week intervention period. Families received "standardized weekly phone calls" from a trained CCT coach. At both time points following CCT, participants in the treatment group showed significantly greater gains on working memory tasks (near transfer) than participants in the control group. These individuals also showed significantly greater gains on a test of reading achievement, but not mathematics (far transfer). No significant differences were found on other outcome measures. While the authors did analyze results using completed cases (treatment group: n = 10; placebo group: n = 13), it is noteworthy that 23% of participants withdrew from the treatment group, compared to only 7% from the placebo group.

In order to determine the levels of evidence from these two references, Natalie consulted the OCEBM Levels of Evidence (OCEBM Levels of Evidence Working Group, 2011; see Table 1). While Linden et al. (2016) is a systematic review of CCT programs for children and adolescents following TBI, only one of the four included studies in this review focuses on memory training. However, the study (Thomas-Stonell et al., 1994) that approximates the PICO question for Natalie's review has several methodological issues that led her to downgrade the level of evidence from a 1 to a 2. The second study (Phillips et al., 2016) reports results from a recent randomized controlled trial that more closely aligned with Natalie's PICO question. Natalie determined that the study by Phillips et al. (2016) met the requirements for level 2 evidence.

The Evidence-Based Decision

Natalie reviewed both of the papers that met the inclusion criteria for her specific PICO question and

determined the level of evidence and major findings for each (see Table 2). Natalie knew that in order to make a recommendation for Owen's treatment, she needed to consider the strengths and weaknesses of the evidence she found, her clinical experience, and the values and preferences of Owen's family (American Speech-Language-Hearing Association, 2005).

Following her next session with Owen, Natalie sat down with Owen and his mom to discuss CCT and whether or not Natalie thought it might be beneficial for Owen. After completing a careful, thorough review of the literature, Natalie determined that there was limited and low-quality evidence to support the use of CCT for memory training over and above traditional therapy following pediatric TBI. Similar to findings in studies examining CCT with adults (e.g., Zickefoose, Hux, Brown, & Wulf, 2013), gains may only be observed when memory tasks closely approximated the games practiced during training. Phillips et al. (2016) found that participants in the CCT group showed significant gains to reading achievement scores, while the placebo group did not. Natalie explained that it was important to consider that the tasks assessed (word reading and reading comprehension) were not necessarily at the level required for competent classroom performance (e.g., the ability to integrate newly learned information with prior knowledge); therefore, it was difficult to determine if the changes in reading abilities observed following CCT would result in real differences in performance using the classroom curriculum or other everyday tasks.

However, Natalie noted that there was also no evidence to suggest that CCT would be harmful or that it would counteract the benefits of continued therapy focusing on compensatory memory strategies. Natalie expressed that based on her own clinical experience, she believed that the best thing to support Owen's memory was to continue to focus on using compensatory strategies in real-life academic and home situations. Natalie understood Owen's mom desire to consider a CCT trial if Owen was motivated to do additional training at home and Owen's mom appreciated the open conversation and the work Natalie did to review the current literature. Natalie understood Owen's mom's frustrations and recognized that CCT offers some potential benefits to individuals who struggle with the long-term results of a TBI. Natalie committed to watching for new research related to this topic using automatic PubMed e-mail alerts (https://www.ncbi.nlm.nih.gov/guide/howto/receive-search-results/). In the meantime, she will keep working with Owen and his mother to support his progress by continuing to focus therapy activities on improving Owen's independence using external memory strategies to help him complete everyday tasks at school and home. If Owen begins working on a CCT program, Natalie will continue to be a great resource for him and his family.

Author Note

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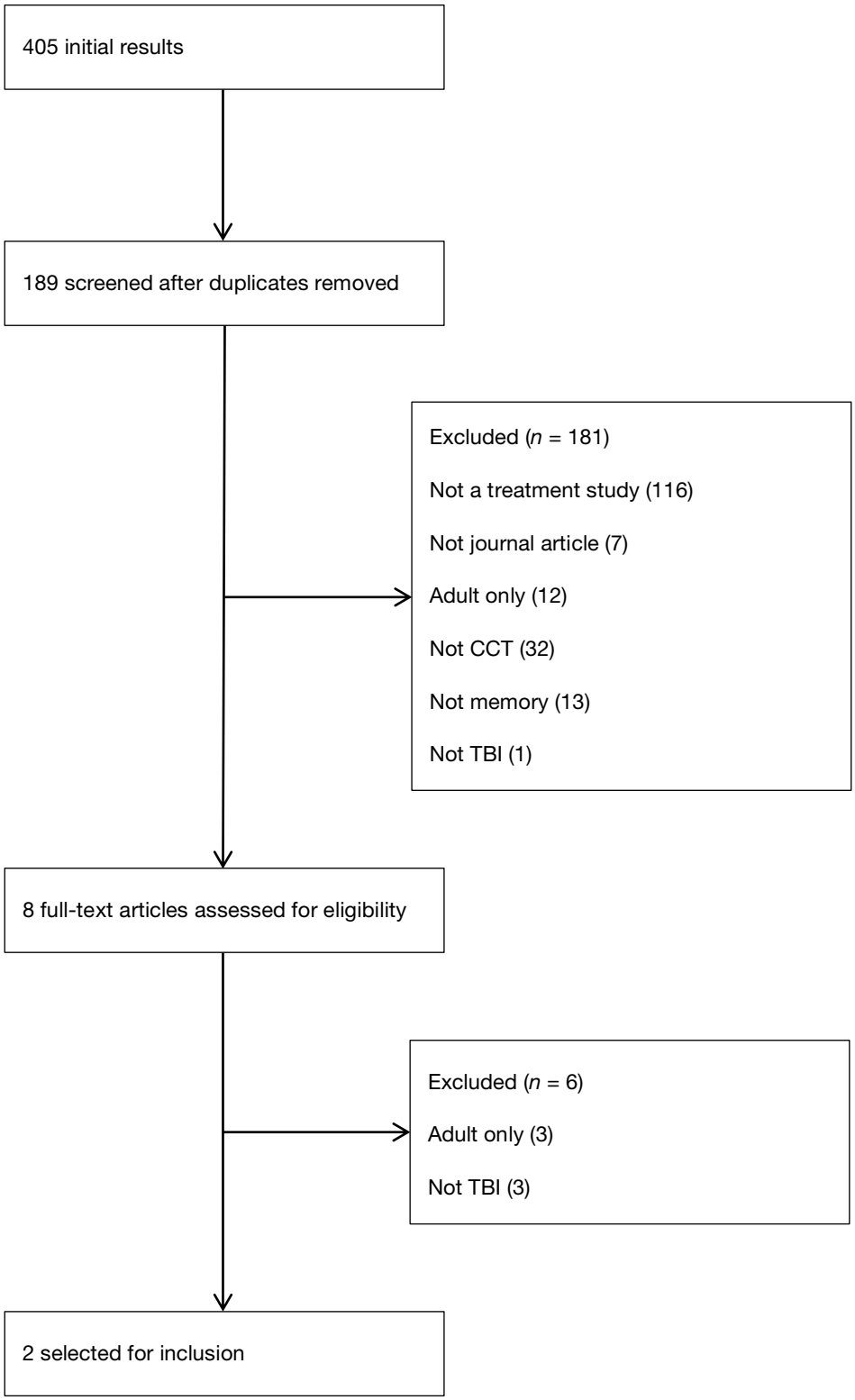

Figure 1. The study search and selection process.

Table 1. Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence[1] to Assess Treatment Benefits (Does this intervention help?)

Level	
1	Systematic review of randomized trials or *n*-of-1 trials
2	Randomized trial or observational study with dramatic effect
3	Nonrandomized controlled cohort/follow-up study
4	Case-series, case-control studies, or studies using a historic control
5	Mechanism-based reasoning

[1] OCEBM Levels of Evidence Working Group. (2011). *The Oxford 2011 levels of evidence.* Retrieved from http://www.cebm.net/wp-content/uploads/2014/06/CEBM-Levels-of-Evidence-2.1.pdf

Table 2. Summaries and Ratings of Studies Included in This Review

Reference	OCEBM level	Included studies/participants	Major findings
Linden et al., 2016	2[a]	1 of 3 studies included in the review approximated the PICO question from this review	Limited evidence to support the use of CCT for the rehabilitation of memory in children and adolescents with brain injury.
Phillips et al., 2016	2	27 adolescents with moderate-to-severe TBI; 13 enrolled in an adaptive CCT program (10 completed) and 14 enrolled in a nonadaptive/placebo CCT program (13 completed)	When compared to participants in the placebo group, those in the adaptive CCT group demonstrated significantly greater gains on memory tasks that were similar to training tasks and on tests of reading achievement. No between-group differences were found on tests of more complex memory, attention, or math achievement.

[a] This study was graded down, per OCEBM recommendations, because only 1 of 3 studies in this systematic review approximated the specific PICO question addressed in this review and due to the overall quality of that study (no intention-to-treat program for control participants, poor reporting of blinding, and selective reporting of outcome data).