Retrieval Practice Improves Memory in Survivors of Severe Traumatic Brain Injury

James F. Sumowski, PhD, a,b Julia Coyne, PhD, a,c Amanda Cohen, BA, a
John DeLuca, PhD a,b

From the aNeuropsychology and Neuroscience, Kessler Foundation, West Orange, NJ; bDepartment of Physical Medicine and Rehabilitation, Rutgers, New Jersey Medical School, Newark, NJ; and cChildren’s Specialized Hospital, Mountainside, NJ.

Abstract

Objective: To investigate whether retrieval practice (RP) improves delayed recall after short and long delays in survivors of severe traumatic brain injury (TBI) relative to massed restudy (MR) and spaced restudy (SR).

Design: 3(learning condition: MR, SR, RP) × 2(delayed recall: 30min, 1wk) within-subject experiment.

Setting: Nonprofit medical rehabilitation research center.

Participants: Memory-impaired (<5th percentile) survivors of severe TBI (N = 10).

Intervention: During RP, patients are quizzed on to-be-learned information shortly after it is presented, such that patients practice retrieval. MR consists of repeated restudy (ie, cramming). SR consists of restudy trials separated in time (ie, distributed learning).

Main Outcome Measures: Forty-eight verbal paired associates (VPAs) were equally divided across 3 learning conditions (16 per condition). Delayed recall for one half of the VPAs was assessed after 30 minutes (8 per condition) and for the other half after 1 week (8 per condition).

Results: There was a large effect of learning condition after the short delay (P < .001, η² = .72), with much better recall of VPAs studied through RP (46.3%) relative to MR (12.5%) and SR (15.0%). This large effect of learning condition remained after the long delay (P = .001, η² = .56), as patients recalled 11.3% of the VPAs studied through RP, but nothing through MR (0.0%) and only 1.3% through SR. That is, RP was essentially the only learning condition to result in successful recall after 1 week, with most patients recalling at least 1 VPA.

Conclusions: The robust effect of RP among TBI survivors with severe memory impairment engenders confidence that this strategy would work outside the laboratory to improve memory in real-life settings. Future randomized controlled trials of RP training are needed.

More than 200,000 survivors of moderate and severe traumatic brain injury (TBI) are discharged from American hospitals annually.1 Many of these survivors suffer chronic memory impairment,2 leading to diminished quality of life. Unfortunately, current memory rehabilitation interventions for persons with brain injury lack efficacy,3 thereby highlighting the urgent need for new and effective treatments. Extensive research within the cognitive psychology literature supports retrieval practice (RP) (also known as the testing effect) as an effective mnemonic strategy among healthy college undergraduates.4 Testing in educational and clinical settings is considered a tool for evaluation, but RP research demonstrates that the act of retrieving information also strengthens one’s memory trace.4 That is, when persons are quizzed on information during learning (RP), they are better able to subsequently recall the information than if they restudied the information multiple times without testing. Translating this mnemonic effect to clinical samples, RP has improved recall after a short delay (45min) in cross-sectional experiments with memory-impaired patients with multiple sclerosis5 and survivors of severe TBI,6 and these memory benefits of RP are maintained after a long delay (1wk) in memory-impaired patients with multiple sclerosis.7 Here, we investigate whether RP leads to better memory after short (30min) and long (1wk) delays among memory-impaired survivors of severe TBI.
and were asked to recall the second word. Subjects were presented with the first word of each VPA for one half of the VPAs (8 in each condition: MR, SR, RP) after a short delay (30min) and for the other half after a long delay (1wk). Our sample included 10 survivors of severe TBI with memory impairment (≤5th percentile on delayed recall of the Hopkins Verbal Learning Test, Revised). See table 1 for sample characterization. This study was approved by the Kessler Foundation Institutional Review Board, and written informed consent was obtained from all subjects.

### Experimental procedure

In a within-subject design, subjects studied 48 verbal paired associates (VPAs) (eg, Ground-Cold) equally divided across 3 learning conditions: massed restudy (MR), spaced restudy (SR), and RP. (To ensure against any possible systematic error associated with differential VPA difficulty, we [1] used only those VPAs that were previously classified as weakly associated, [2] randomly assigned the 48 VPAs to 1 of 3 lists [A, B, C], and then [3] counterbalanced lists [A, B, C] across learning conditions [MR, SR, RP] across subjects.) As illustrated in figure 1, MR is tantamount to “cramming,” a ubiquitous memory strategy among college students and neurologic patients alike. SR represents distributed learning, recognized as superior to MR for over a century.8 For RP, VPAs were presented on the same schedule as MR; however, after the VPA was presented in its complete form initially (eg, Ground—Cold), the 2 subsequent reexposure trials were framed as cued recall tests (eg, Ground—_____). A more detailed description of learning trials is available in figure 1 and elsewhere.15 Dependent measures included delayed recall across pairs of learning conditions (eg, MR vs SR). These analyses were repeated for long delay recall.

### Results

There was a large main effect of learning condition after the short delay (F2,18 = 23.41, P <.0001, η2 = .72). Subjects recalled 46.3% of the VPAs studied through RP compared with only 12.5% through MR (P <.0001) and 15% through SR (P = .002). SR did not result in better memory than MR (P = .555). The beneficial effect of RP was enduring, as the large effect of learning condition remained after the long delay (F2,18 = 11.53, P <.001, η2 = .56). Patients recalled 11.3% of the VPAs studied through RP compared with 0.0% through MR (P = .004) and 1.3% through SR (P = .011). MR and SR did not reliably differ from each other (P = .343).

The magnitude of the RP effect is perhaps better captured by examining the raw data on a case-by-case basis (see table 1). RP was the best memory strategy for each and every patient after a short delay. After 1 week, subjects could not recall a single VPA learned through MR and only 1 subject recalled 1 VPA learned through SR. In contrast, most subjects were able to recall at least 1 VPA learned through RP.

### Discussion

RP resulted in much better recall than restudy strategies in memory-impaired survivors of severe TBI even after a weeklong delay. Moreover, RP was the most effective memory strategy for every patient after a short delay, and RP was essentially the only strategy that supported recall after a long delay (1wk). These findings highlight the strength of the RP strategy and engender confidence that RP might result in improved real-life memory functioning for survivors of TBI. Importantly, however, healthy persons1 and persons with TBI1 identify MR (ie, cramming) as a more effective memory strategy. As such, education, training, and practice will be required for persons with TBI to replace MR with the more effective RP technique.

### Table 1 Sample characteristics and memory performance

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<th>Sub</th>
<th>Age (y)</th>
<th>Sex</th>
<th>Education (y)</th>
<th>Age at Injury (y)</th>
<th>Cause of Injury</th>
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<th>HVLT-R DR T-sc</th>
<th>SDMR</th>
<th>SDR</th>
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Abbreviations: F, female; HVLT-R DR, Hopkins Verbal Learning Test, Revised Delayed Recall; LD, long delay of 1wk; M, male; MVA, motor vehicle accident; SD, short delay of 30min; Sub, subject; T-sc, T score.

### Statistical analysis

Repeated-measures analysis of variance assessed differences in short delay recall across the 3 learning conditions: MR, SR, RP. Next, pairwise comparisons investigated differences in recall across pairs of learning conditions (eg, MR vs SR). These analyses were repeated for long delay recall.

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**List of abbreviations:**
- MR: massed restudy
- RCT: randomized controlled trial
- RP: retrieval practice
- SR: spaced restudy
- TBI: traumatic brain injury
- VPA: verbal paired associate

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As discussed elsewhere, RP is an example of a compensatory (vs restorative) approach to memory rehabilitation (for further distinction, see Cicerone et al). Similar to the use of a cane for walking, RP supports memory without repairing/restoring the neurophysiologic basis of memory. Although restoration of function may seem optimal or preferable, restoration is often impossible after normal neurophysiologic function is damaged. For this reason, compensatory approaches to rehabilitation are often more effective than attempts at restoration (rehabilitation of hemianopic dyslexia represents a fine example). Therefore, RP will be effective only if persons with TBI learn to incorporate RP into their routines and apply the strategy in new learning situations. For example, persons wishing to learn information from a newspaper or textbook may engage in intermittent self-quizzing throughout their reading (ie, after each paragraph or page). This act of RP will result in greater subsequent memory than rereading the information multiple times.

A randomized controlled trial (RCT) of RP training will be an important next step in this line of research because such a study will evaluate whether persons with TBI can learn and apply the RP strategy. Importantly, given that RP represents a compensatory (not a restorative) strategy, the primary outcome of an RP RCT (or an RCT of any other compensatory memory intervention) should not include standardized neuropsychological memory tests that prevent subjects from using the very compensatory strategy one wishes to evaluate. RCTs of compensatory memory strategies should instead train subjects in the use of the strategy and then investigate the strategy’s efficacy with less-standardized tasks on which subjects are free to learn/study new information using whichever strategy they choose. There are some drawbacks of using less-standardized tasks (ie, unestablished reliability). Also, there may be great variability in how different persons with TBI apply the RP strategy. Alternate/secondary outcomes could include self-report and observer-report of memory change in daily activities after receiving RP training (relative to controls). Regarding variability in RP execution across subjects, single-subject designs may be helpful in investigating the ways in which different persons with TBI apply RP strategies to learn new information.

Study limitations
Our sample size was small, although this is somewhat mitigated by the within-subject design and robust results.

Conclusions
RP represents a promising memory strategy for survivors of TBI with memory impairment. In addition to the apparent effectiveness of RP, this strategy appears simple/straightforward to apply (quizzing oneself or someone else), cost-effective, safe, and noninvasive. RCTs of RP training are needed.

Keywords
Brain trauma; Memory; Rehabilitation; Traumatic brain injuries
Corresponding author

James F. Sumowski, PhD, Neuropsychology and Neuroscience, Kessler Foundation Research Center, 300 Executive Dr, Ste 70, West Orange, NJ 07052. E-mail address: jsumowski@kesserfoundation.org.

References