Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2014;95:397-400

BRIEF REPORT

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 [a]Neuropsychology and Neuroscience, Kessler Foundation, West Orange, NJ; [b]Department of Physical Medicine and Rehabilitation, Rutgers, New Jersey Medical School, Newark, NJ; and [c]Children'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 ($P<.001$, $\eta^2=.72$), 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 ($P=.001$, $\eta^2=.56$), 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.

Archives of Physical Medicine and Rehabilitation 2014;95:397-400

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 sclerosis[5] 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.

Supported by the Kessler Foundation and Children's Specialized Hospital.

No commercial party having a direct financial interest in the results of the research supporting this article has conferred or will confer a benefit on the authors or on any organization with which the authors are associated.

0003-9993/14/$36 - see front matter © 2014 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2013.10.021

Table 1 Sample characteristics and memory performance

Sub	Age (y)	Sex	Education (y)	Age at Injury (y)	Cause of Injury	HVLT-R DR Raw	HVLT-R DR T-sc	SDMR	SDSR	SDRP	LDMR	LDSR	LDRP
1	41	F	13	25	MVA	3	19	2	0	7	0	0	1
2	31	M	12	22	Hit by train	3	19	2	2	4	0	0	0
3	53	M	14	44	MVA	2	19	0	1	3	0	0	1
4	51	M	12	35	MVA	4	19	0	0	1	0	0	0
5	24	M	14	16	Skiing	5	19	0	2	3	0	0	1
6	55	M	16	52	MVA	5	23	1	1	2	0	0	0
7	46	M	18	43	MVA	5	25	0	0	3	0	0	2
8	21	F	14	18	MVA	4	19	1	2	5	0	1	1
9	57	F	16	49	Fall	7	33	3	3	5	0	0	1
10	55	F	12	46	Fall	5	24	1	1	4	0	0	2

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.

Methods

Subject enrollment

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 cognitions [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 SR; 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.[5,6] Dependent measures included delayed recall 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). Subjects were presented with the first word of each VPA and were asked to recall the second word.

List of abbreviations:

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

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.

Results

There was a large main effect of learning condition after the short delay ($F_{2,18}$=23.41, P=.00001, η^2 =.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 ($F_{2,18}$=11.53, P=.001, η^2=.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 persons[4] and persons with TBI[6] 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.