Retrieval Practice as an Effective Memory Strategy in Children and Adolescents With Traumatic Brain Injury

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Abstract

Objective: To investigate whether retrieval practice (RP) is a more effective memory strategy than restudy in children and adolescents with traumatic brain injury (TBI).

Design: Three × two within-subjects experiment: 3 (learning condition: massed restudy [MR], spaced restudy [SR], retrieval practice [RP]) × 2 (stimulus type: verbal paired associates [VPAs] and face-name pairs [FNPs]). The dependent measure was delayed recall of VPAs and FNPs.

Setting: Subacute pediatric neurorehabilitation center.

Participants: Pediatric survivors of TBI (N = 15) aged 8 to 16 years with below-average memory.

Intervention: During RP, participants were quizzed on to-be-learned information (VPAs and FNPs) shortly after it was presented, such that they practiced retrieval during the learning phase. MR consisted of repeated restudy (tantamount to cramming). SR consisted of restudy trials separated in time (ie, distributed learning).

Main Outcome Measures: Delayed recall of 24 VPAs and 24 FNPs after a 25-minute delay. VPAs and FNPs were equally divided across 3 learning conditions (16 per condition).

Results: There was a large main effect of learning condition on delayed recall (P < .001; η² = .84), with better mean recall of VPAs and FNPs studied through RP (6.23 ± 1.39) relative to MR (3.60 ± 1.53; P < .001) and SR (4.77 ± 1.39; P < .001). Moreover, RP was the single best learning strategy for every participant.

Conclusions: Memory problems and related academic learning difficulties are common after pediatric TBI. Herein, we identify RP as a promising and simple strategy to support learning and improve memory in children and adolescents with TBI. Our experimental findings were quite robust and set the stage for subsequent randomized controlled trials of RP in pediatric TBI.

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Each year, almost half a million (473,947) children and adolescents are hospitalized for traumatic brain injury (TBI) within the United States and experience negative consequences for cognition and academic achievement, as well as later employment and functional independence. Not surprisingly, memory dysfunction is a strong predictor of academic and vocational outcomes. There are currently no validated memory treatments for children and adolescents after pediatric TBI, thereby underscoring the critical importance of research to develop effective interventions.

Children and adolescents are accustomed to being tested in school because quizzes and examinations are standard tools for evaluating skill/knowledge acquisition. Importantly, however, the act of retrieving information during a test also has a mnemonic function, strengthening memories such that information is easier to recall in the future. Several studies in healthy undergraduates show that “retrieval practice” (RP) during a test leads to much better memory for information than does re-reading/restudying the information multiple times, whether through massed restudy (MR) (cramming) or through spaced restudy (SR) (distributed learning). These findings have been extended to memory-impaired adult survivors of TBI. Herein we investigate whether RP improves learning of information in children and...
adolescents after pediatric TBI, as compared with the ubiquitous learning strategy of repeated restudy (MR and SR). Findings will have important implications for memory rehabilitation interventions after pediatric TBI, including academic learning.

**Methods**

**Subject enrollment**

The sample included 15 children and adolescents (7 girls) with a history of TBI recruited from a subacute pediatric neuro-rehabilitation center. The mean age of subjects was 12.0 ± 2.6 years (8–16y), and mean time since injury was 3.3 ± 2.0 years (1–7y). Subjects were fluent in English and had no premorbid history of academic learning disability, attention-deficit/hyperactivity disorder, or any other psychiatric or neurologic condition. TBI severities were categorized as mild (n = 5), moderate (n = 4), and severe (n = 6). Capacity for learning and memory was below average overall (mean norm-referenced z score = −0.80 ± 0.89) as estimated with Digit Span of the Wechsler Intelligence Scale for Children, Fourth Edition, and the Children’s Auditory Verbal Learning Test. This study was approved by the Kessler Foundation Institutional Review Board, written informed consent was obtained from all subjects’ parents or guardians, and signed informed assent was obtained from all subjects.

**Procedures**

In a within-subject experiment, subjects learned 24 verbal paired associates (VPAs) and 24 face-name pairs (FNPs) equally divided across 3 learning conditions: MR, SR, and RP. As such, 8 VPAs and 8 FNPs were processed with each type of learning (MR, SR, or RP). As shown in figure 1, MR consisted of an initial study trial in which the complete VPA (or FNP) was presented (eg, ART – GIRL) followed by 2 consecutive restudy trials. MR is tantamount to “cramming.” The SR condition consisted of an initial study trial followed by restudy trials separated in time (not consecutive). SR is also known as “distributed learning,” which typically leads to better learning than does cramming (MR). RP consisted of an initial study trial followed by 2 spaced cued-recall trials in which the first word of the VPA (or face without name) was presented (eg, ART − ____ ) and the subject was to retrieve the paired word (or paired name). RP trials were presented on the same schedule as SR to ascertain whether RP improves memory over and above SR. As shown in figure 1, the 3 learning conditions were interspersed throughout the learning phase so that any interference was evenly distributed across conditions. Also, specific VPAs and FNPs were counterbalanced across the 3 different conditions across subjects. The schedule for FNPs was exactly the same as the schedule for VPAs.

**List of abbreviations:**

- FNP: face-name pair
- MR: massed restudy
- RP: retrieval practice
- SR: spaced restudy
- TBI: traumatic brain injury
- VPA: verbal paired associate

We performed a 3 (learning condition: MR, SR, RP) × 2 (stimulus type: VPA, FNP) repeated measures analysis of variance to investigate (1) the effect of learning condition on delayed recall;
(2) the effect of stimulus type on delayed recall; and (3) whether the effect of learning condition differed across type of stimulus. Our principal a priori hypothesis was a main effect of learning condition whereby SR would lead to better memory than would MR, but that RP would lead to better memory than would both MR and SR (RP > SR > MR).

As a supplemental follow-up analysis, we repeated the previous analysis as an analysis of covariance, with norm-referenced memory function entered as a covariate to investigate whether the effect of learning condition differed depending on the memory function of the subject.

Results

Tests for skewness and kurtosis indicated that the results for MR, SR, and RP were normally distributed, thereby permitting parametric statistical analyses. There was a very large main effect of learning condition on delayed recall ($F_{2,28} = 72.40; \ p < .001; \ \eta^2_p = .84$), whereby subjects recalled more information restudied through SR (mean ± SD, 4.77±1.39) than through MR (3.60±1.53; $\ p < .001$); however, RP (6.23±1.39) led to better memory than did both MR and SR ($P_s < .001$). In fact, RP was the best learning condition for every subject in this study (fig 2A), thereby underscoring the robust mnemonic benefits of RP. There was also a large main effect of stimulus type ($F_{1,28} = 14.62; \ p = .002; \ \eta^2_p = .31$), with better memory for VPAs (mean ± SD, 5.73±1.66) than for FNPs (4.00±1.56). Finally, there was an interaction between learning condition and stimulus type ($F_{2,28} = 4.13; \ p = .027; \ \eta^2_p = .23$), whereby the mnemonic benefits of RP were even larger for FNPs than for VPAs (fig 2B).

In a supplemental analysis, there was no interaction between subject memory function and learning condition ($P = .506$), indicating that our pattern of results (RP > SR > MR) was similar across levels of subject memory function.

Discussion

Memory problems are a prevalent consequence of pediatric TBI, with deleterious effects for academic achievement and subsequent vocational outcomes. Consistent with previous work in adult survivors of TBI, we demonstrate herein that RP leads to better memory than do restudy strategies (MR and SR) in child and adolescent survivors of TBI. In fact, RP was the most effective learning strategy for each and every child and adolescent within our sample (see fig 2), thereby supporting the robust efficacy of RP as a compensatory approach to memory rehabilitation.

Previous work on RP in TBI (and other memory-impaired populations) has investigated the learning of verbal information alone (VPAs), but the present study extends these findings to include the learning of visual-verbal (FNPs) information. This is important because academic achievement requires visual-verbal learning in addition to verbal learning alone (eg, geography). Note that the mnemonic effect of RP was stronger for FNPs than for VPAs (see fig 2B), likely because FNPs were more challenging than VPAs to remember. That is, our results suggest that the mnemonic effect of RP (relative to restudy) may be even stronger when learning demands are greater.

Study limitations

The sample size was relatively small, although the within-subject design afforded adequate power for the large observed effects. Importantly, the robust mnemonic effect of RP is indicated by the findings that RP was the more effective learning strategy for each and every subject. Although norm-referenced memory was below average for our sample on average, not all subjects had objective memory deficits. Although this may be a limitation, it permitted us to evaluate whether the effect of RP differed across levels of memory function, which it did not. Note that previous work showed that RP was far superior to restudy in adult patients with TBI with more severe memory impairment (<5th percentile), but this needs to be replicated in children and adolescents with severe impairment. Finally, our use of paired associates may not adequately reflect the types of information children and adolescents need to learn in school (eg, prose passages), and so future research should investigate the impact of RP across a broader range of to-be-learned stimuli (eg, science textbooks).

Conclusions

RP presents a promising learning strategy for children and adolescents with memory problems after a TBI. The strategy appears simple to use because children and adolescents can be taught to quiz themselves on academic material (eg, reading comprehension and history notes) or be quizzed by their parents. Future randomized controlled trials are necessary to investigate whether
students can learn and apply RP and whether the use of RP improves academic achievement.

Keyword

Memory; Rehabilitation; Testing effect; Traumatic brain injury

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References