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BRIEF REPORT

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 ($P<.001$; $\eta_p^2=.84$), 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[1] and experience negative consequences for cognition[1,2] and academic achievement,[3] as well as later employment and functional independence.[4] Not surprisingly, memory dysfunction is a strong predictor of academic[5] and vocational[4] outcomes. There are currently no validated memory treatments for children and adolescents after pediatric TBI,[6] 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.[7] 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).[7] These findings have been extended to memory-impaired adult survivors of TBI.[8,9] Herein we investigate whether RP improves learning of information in children and

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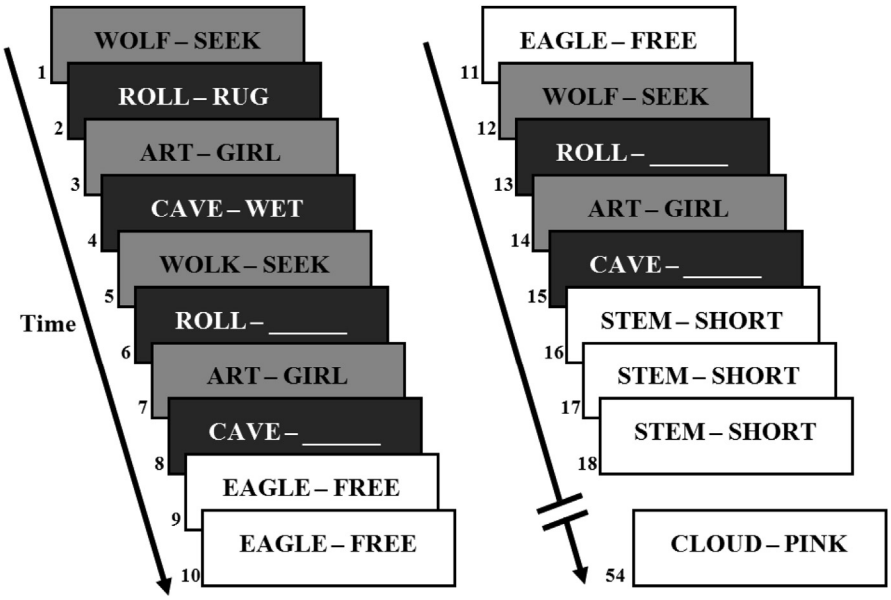

Fig 1 Sample presentation schedule for VPAs in each learning cognition: MR (*white*), SR (*light gray*), RP (*dark gray*). Each VPA within the MR condition was presented for 3 consecutive trials (no intervening trials of other VPAs). Each VPA within the SR or RP condition was presented in a spaced fashion, with 3 intervening trials (of other VPAs) between the first presentation and the first restudy (or test) trial and 6 intervening trials (of other VPAs) between the first and second restudy (or test) trials. This basic presentation schedule was used for all 24 VPAs, totaling 72 eight-second trials evenly divided across two 4-minute 48-second learning phases. Note that the 8-second RP trials consisted of a cued-recall screen for 7 seconds (eg, *ROLL - _____*) followed by a 1-second feedback screen (eg, *ROLL — RUG*). Given that VPAs in each condition were evenly distributed throughout the learning phase, any retroactive or proactive interference or practice effects were also equally distributed across conditions. Also, VPAs were counterbalanced across the 3 different conditions across subjects. The schedule for FNPs was exactly the same as the schedule for VPAs.

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 neurorehabilitation 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.

List of abbreviations:

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

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).[10] 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 conditions across subjects. The dependent measure was cued-recall of all VPAs and FNPs after a delay of 25 minutes.

Statistical analysis

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;