Why Testing Improves Memory: Mediator Effectiveness Hypothesis

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An intuitive but incorrect assumption is that learning only occurs during study and that testing is useful only for evaluating the state of memory (*1*). However, testing improves memory, as demonstrated with a wide variety of materials and learners (*2*). Given the wealth of research establishing the empirical benefits of testing, it is surprising that the mechanisms underlying testing effects are not well understood.

We propose the mediator effectiveness hypothesis, stating that testing improves memory by supporting the use of more-effective mediators during encoding (a mediator is a word, phrase, or concept that links a cue to a target). What makes a mediator effective? Two key factors are mediator retrieval (i.e., mediator is recallable when prompted with the cue) and mediator decoding (i.e., mediator elicits the target from memory) (*3*). The mediator effectiveness hypothesis assumes that mediators generated during testing (versus restudy only) are more likely to be subsequently retrieved and decoded, increasing recall of target responses.

To test this hypothesis, we presented 118 participants with 48 Swahili-English translation pairs (e.g., wingu-cloud) for an initial study trial and then three blocks of practice trials. In the test-restudy group, each practice trial for an item involved a cued recall test followed immediately by restudy. In the restudy group, each trial involved only restudy. On the initial study trial and each restudy trial, all participants generated and reported keyword mediators (keywords are mediators that look or sound similar to the foreign language cue and are semantically related to the English target) (*4*). On the final test 1 week later, participants received only the cue (cue only, C group, as in prior research), the cue with their own mediator from practice (cue plus mediator, CM group), or the cue with a prompt to recall their own mediator before recalling the target (cue plus mediator recall, CMR group).

The mediator effectiveness hypothesis makes two key predictions. Concerning mediator retrieval, retrieval of mediators at the final test in the CMR group will be greater after test-restudy versus restudy practice. Concerning mediator decoding, retrieval of targets at final test in the CM group will be greater after test-restudy versus restudy practice.

Replicating the robust testing effects from prior research, test-restudy practice produced almost a threefold increase in final test performance in the C group (Fig. 1A). According to the mediator effectiveness hypothesis, this benefit is due to differential effectiveness of mediators, with testing improving mediator retrieval and decoding.

Confirming the prediction of increased mediator retrieval, recall of mediators at final test in the CMR group was greater after test-restudy versus restudy practice (51% versus 34%). For converging evidence, consider final test performance in the C and CM groups. Providing mediators at final test significantly improved recall after restudy practice but not after test-restudy practice, suggesting that explicitly providing mediators was largely redundant with participants' spontaneous retrieval of mediators in the test-restudy group.

Confirming the prediction of increased mediator decoding, final test performance in the CM group was significantly greater after test-restudy versus restudy practice. Even when differences in mediator retrieval were circumvented by providing participants with their mediators, mediators were more likely to elicit recall of targets after test-restudy versus restudy practice. As converging evidence, the same pattern is apparent when examining recall as a function of mediator retrieval in the CMR group (Fig. 1B). Although mediator retrieval benefited recall in both groups, the benefit was greater after test-restudy versus restudy practice. Furthermore, in trials in which mediators were retrieved, recall was greater after test-restudy versus restudy practice.

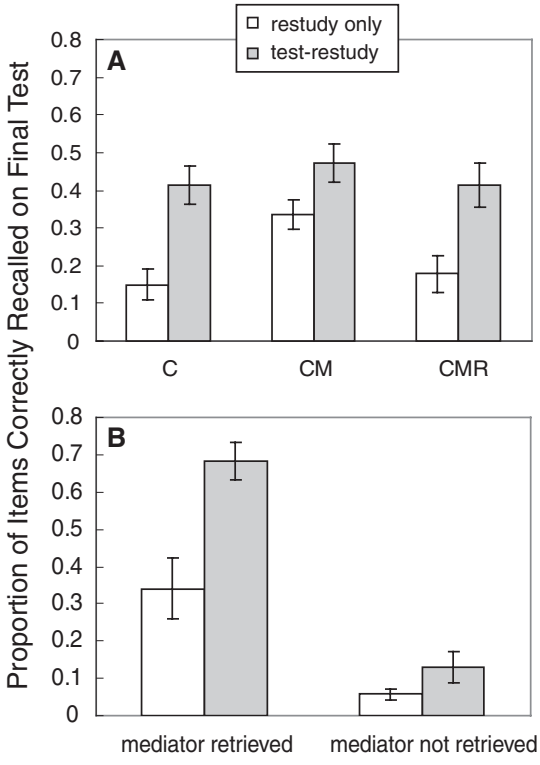

Fig. 1. (**A**) Final recall by group. (**B**) Final recall in CMR group as a function of whether mediators were retrieved before attempting target recall. Error bars represent standard errors.

Results support the mediator effectiveness hypothesis and offer one theoretical explanation for why testing is beneficial for memory: Mediators generated during encoding are more effective (i.e., more likely to be retrieved and decoded) with test-restudy versus restudy practice. We are not claiming that mediator effectiveness is the only mechanism underlying testing effects. However, mediator effectiveness may be an important contributor.

Why did testing yield more-effective mediators? Successfully retrieving mediators during practice may enhance their memory strength. Additionally, retrieval failures during encoding may promote shifting from less- to more-effective mediators (*5*), and retrieval failure occurs during testing but not restudy. Consistent with this idea, shifting to new keywords was more likely during test-restudy versus restudy practice (25% versus 19% of trials). Importantly, the mediator effectiveness hypothesis defines two components of mediator effectiveness (i.e., mediator retrieval and decoding), and results provide evidence for a contribution of each of these factors to the testing effect.

References and Notes

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4. Materials, methods, and keyword example are available as supporting material on *Science* Online.
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Supporting Online Material

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Materials and Methods
References

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