



## Effects of criterion level on associative memory: Evidence for associative asymmetry<sup>☆</sup>



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### ABSTRACT

A wealth of research has established that retrieval practice promotes subsequent memory, particularly when the retrieval attempt is successful. Furthermore, the number of successful retrievals during practice (i.e., *criterion level*) dramatically influences final test performance. For example, Vaughn and Rawson (2011) had participants learn Lithuanian–English word pairs via test–restudy practice until they were correctly recalled. Despite retrieval practice always occurring in the forward direction during practice (A – ?), performance increased as a function of criterion level both on final forward (A – ?) and backward (? – B) cued recall tests. Importantly, the performance gain across criterion levels appeared asymmetric, as the gains were much larger in the forward versus backward cued recall direction. However, one potential explanation for the observed asymmetry in criterion level effects is that the materials strongly favored forward cued recall, as retrieving Lithuanian versus English is inherently more difficult for native English speakers. The present experiments utilized English–English pairs to more appropriately investigate whether the effects of criterion level on associative memory are symmetric or asymmetric. Across experiments, results from recall and recognition tests indicated that criterion level effects on associative memory are asymmetric. Advantages in forward versus backward cued recall could not be attributed to differences in cue memory or target memory, indicating differences in forward and backward associative memory.

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### Introduction

A wealth of research has demonstrated that testing enhances memory, often more than an equivalent amount of studying (e.g., for recent reviews, see Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger & Butler, 2011). However, the effectiveness of testing depends on many factors, including the type of test format used and

the retention interval between practice and final test (see Roediger & Karpicke, 2006 for a review). Another key factor influencing the effectiveness of testing is retrieval success. Testing enhances memory to a greater degree when the retrieval attempt is successful versus unsuccessful (e.g., Carrier & Pashler, 1992). Additionally, the effectiveness of successful retrieval practice is influenced by the number of successful retrievals during practice (i.e., *criterion level*). Recently, studies have investigated the effects of criterion level on subsequent memory (e.g., Pyc & Rawson, 2009; Rawson & Dunlosky, 2011; Vaughn & Rawson, 2011). Across these studies, the general finding is that memory is substantially enhanced with higher versus lower criterion levels (i.e., final test performance increases as the number of correct recalls during practice increases). In

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the current research, we explored the nature of criterion level effects on subsequent memory, with particular focus on the gains in associative memory. To what extent is the effect of criterion level on associative memory symmetric (i.e., increasing criterion level produces similar gains in the forward and backward associations for cue–target word pairs) or asymmetric (i.e., increasing criterion level produces stronger gains in either the forward or backward association for cue–target word pairs)?

Although previous research has established that memory performance increases as criterion level increases, only one recent study has explored the nature of criterion level effects. Vaughn and Rawson (2011) had participants learn Lithuanian–English word pairs. After the word pairs had been presented for an initial study trial, participants completed practice cued recall tests until they correctly retrieved the word pairs a pre-assigned number of times (from one to five). Importantly, the practice cued-recall tests always occurred in the forward direction (i.e., participants were shown the Lithuanian word and retrieved the English translation). The final test phase assessed forward cued recall (the same test format used during practice) and backward cued recall (i.e., participants were shown the English word and retrieved the Lithuanian translation). Despite practicing only forward cued recall, performance increased as criterion level increased for both forward and backward cued recall. Although performance increased in both cued recall directions, performance gains were much greater in the forward versus backward direction (gains of 35% versus 12%, respectively). The discrepancy in performance gains between forward and backward cued recall raises an interesting theoretical question: Are the effects of criterion level on associative memory symmetric or asymmetric?

#### *Basis for predicting asymmetric effects of criterion level on associative memory*

Several theoretical accounts support the prediction that the effects of criterion level on associative memory are asymmetric (i.e., forward and backward links are encoded and strengthened independently and thus need not be equivalent). For example, according to the *transfer appropriate processing* framework (TAP; Morris, Bransford, & Franks, 1977), performance on a final test will be maximized when the initial tests and final tests require similar cognitive operations. If individuals practice in the forward direction, TAP would predict that performance on the final test will be maximized when individuals are again tested in the forward direction.

Although theories proposed to explain the benefits of retrieval practice in particular are silent on associative symmetry, reasonable extensions follow given the mechanisms proposed by these theories. For example, according to the *elaborative retrieval hypothesis* (ERH; e.g., Carpenter, 2009), attempting retrieval from a cue word activates related semantic information that can be encoded along with the retrieved target, which in turn can later serve as additional pathways to retrieve the target information. For instance, testing on the word pair *morning* – *light*

(*morning* – ?) may activate associates of the cue word (e.g., breakfast, shower, commute, tired), all of which can be used later in the service of retrieving the target information (e.g., light). Presumably, the information activated during testing may be more strongly associated with the word serving as the cue (e.g., *morning*) versus the target (e.g., *light*), suggesting that the effects of criterion level on associative memory will be asymmetric (favoring forward versus backward associative memory).

Similarly, the *mediator effectiveness hypothesis* (MEH; e.g., Pyc & Rawson, 2010) states that retrieval practice benefits memory by promoting the use of more effective mediators (i.e., information linking cues to targets). For example, keyword mediators commonly involve words that share phonetic similarities to a particular cue in a cue–target word pair (e.g., *wing* for the Swahili–English word pair *wingu* – *cloud*). The mediator *wing* can then be used to link the mediator to the target word (e.g., birds have wings and fly in the clouds; *wingu* – *wing* – *cloud*). Importantly, these verbal mediators are likely to function asymmetrically (e.g., *wingu* elicits *wing*, but *cloud* does not elicit *wing* due to lack of phonetic similarity). If the benefits of testing occur due to more effective mediator use and these mediators tend to link cue–target information asymmetrically, the implication is that the effects of criterion level on associative memory will be asymmetric (again favoring forward versus backward associative memory).

For clarification purposes, although both ERH and MEH support the prediction that the effects of criterion level on associative memory will be asymmetric, the underlying mechanisms driving this prediction differ somewhat between the two accounts. Both accounts would attribute the difference in forward versus backward associative memory across criterion level to differences in the directionality of semantic information added to the nominal cue–target stimulus. However, the accounts differ regarding how and when this semantic information is added to the nominal cue–target stimulus. According to ERH, the additional semantic information is activated during a retrieval attempt, and reflects a more automatic and implicit process. In contrast, MEH assumes a more strategic process in which participants are consciously selecting keywords as part of a metacognitive control strategy to learn the words (which would likely occur during restudy that takes place after a retrieval attempt; for evidence, see Pyc & Rawson, 2012). Nonetheless, these accounts are not mutually exclusive, and either or both mechanisms could contribute to asymmetric associations.

Another relevant account comes from basic research on associative memory. According to the *independent association hypothesis* (IAH; Wolford, 1971), two elements in episodic memory are associated with two unidirectional links: one linking the two elements in a forward direction, and the other linking the two elements in a backward direction. Importantly, these separate unidirectional links can be enhanced independently of each other, such that learning in one direction can occur independently of learning in the other direction (e.g., greater learning in the forward versus backward direction).

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