



## Testing effects of free recall on organization in whole/part and part/whole transfer

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### ABSTRACT

Testing of to-be-learned material facilitates subsequent learning of new material. We investigated this forward effect of testing in two experiments using the whole/part and part/whole transfer paradigms with categorized word lists. Learning was assessed for recall of individual words, higher order categories, and category clustering. In each experiment participants learned two lists in which the number of tests on the first list was varied. The first list contained either twice as many items as the second list (whole/part paradigm) or half as many items as the second list (part/whole paradigm). In the experimental condition, the part list contained half the items of the whole list. In the control condition, the two lists were unique. In the whole/part paradigm, learning of the part list was poorer in the experimental than in the control condition. Although testing during whole list learning facilitated learning of the part list, it did not moderate the negative transfer effect. In the part/whole paradigm, learning of the whole list was better in the experimental than in the control condition, and this positive transfer effect was strengthened by repeated testing of the part list. The findings are discussed in the context of discrimination and encoding explanations of the forward effect of testing.

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### 1. Introduction

Interspersing retrieval attempts among study trials leads to better recall performance than does providing an equivalent amount of study time. This *testing effect* has been replicated with a broad range of materials in both classroom and laboratory settings (e.g., Carpenter, Pashler, & Cepeda, 2009; Gates, 1917; McDaniel, Roediger, & McDermott, 2007; Roediger & Butler, 2011). Gates (1917) attributed this testing effect to improved organization. Specifically, during study sessions compared to test trials, “the material is handled more by separate items than by groups. Less effort is used to build up a structural whole... there is less organization of the material” (Gates, 1917, p. 75). Another source of benefits from testing is that “it gives exact knowledge of the results that are being produced and serves to throw into relief the efficacy of the different aids that are being employed as a means to learning the lesson” (Gates, 1917, p. 80).

Alternative accounts of the testing effect are based on the transfer appropriate processing (TAP) framework (drawn from Morris, Bransford, & Franks, 1977; see Roediger & Karpicke, 2006), according to which the testing effect occurs because the retrieval processes engaged in initial learning are similar to those required at the final test.

Although there is some evidence supporting TAP (Duchastel & Nungester, 1982; Johnson & Mayer, 2009; McDaniel & Fisher, 1991), several studies have provided evidence inconsistent with TAP (Carpenter & Delosh, 2006; Kang, McDermott, & Roediger, 2007; Rohrer, Taylor, & Sholar, 2010; Rowland, 2014). For example, Carpenter and Delosh (2006) found that testing participants initially with free recall led to better performance on a final test, regardless of the format of the final test. This result is consistent with Gates' (1917) notion of effort as a critical factor in the testing effect. The results of a meta-analysis of the testing effect (Rowland, 2014) converged on the conclusion that effortful processing is a critical determinant of the testing effect.

Recent research has focused on the contributions of organization as a by-product of retrieval. In Zaromb and Roediger (2010, Experiment 1), participants learned three consecutive categorized lists of words under different learning conditions: study-only (SSSSSSS); two tests (STSSSTSS); and, four tests (STSTSTST). Recall 2 days later was better for the lists that had been subject to retrieval practice. In Experiment 2, a recall test during initial learning (ST) led to enhanced recall and category clustering as measured by the adjusted ratio of clustering score (ARC; Roenker, Thompson, & Brown, 1971) relative to studying alone (S or SS) on a final recall test 1 day later. In Congleton and Rajaram (2011) participants learned a categorized list of words under a repeated study (SSS) or repeated test (STT) learning procedure. ARC scores were significantly higher for participants in the repeated test condition after both a 7 min and a 1 week delay. However, the memory benefit of

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retrieval practice occurred only at the delayed test. The dissociation of study and retrieval practice effects on organization and recall at the two testing times was attributed to differences in item-specific and inter-item relational processing.

The advantages of retrieval practice over mere study in long-term recall of a single list have been labeled the *backward effect of testing* in contrast to a *forward effect of testing* (Pastötter & Bäuml, 2014) that occurs during the learning of successive lists of items. In an early demonstration of the forward effect of testing, Tulving and Watkins (1974) presented two paired-associate lists that shared stimuli across lists (A-B, A-C). Some participants were tested for recall immediately after each list; other participants were tested for recall of only the second list. Recall of the second list was poorer when the first list had not been tested. That is, there was a positive forward effect of testing.

This positive forward effect of testing has been demonstrated more recently by Szpunar, McDermott, and Roediger (2008). In Experiment 1, participants learned five successive word lists and then either completed a filler task or were given 1 min for a free recall test on the most recent list. All participants were tested for recall following the fifth list. The critical finding was that testing on the first four lists yielded higher recall of the fifth list and led to fewer intrusions from previous lists than did an absence of testing. This pattern of results occurred with both interrelated word lists, which contained different exemplars from the same categories, and unrelated word lists.

Two general explanations of the forward effect of testing have been proposed. Retrieval-based explanations emphasize the role of testing in list discrimination (Bäuml & Kliegl, 2013; Szpunar et al., 2008; Pastötter, Schicker, Niedernhuber, & Bäuml, 2011), which provides for a more focused memory search on later tests. Encoding explanations assume that testing promotes efficient encoding of successive material (Pastötter et al., 2011; Wissman, Rawson, & Pyc, 2011). In the current study, we assessed the impact of *repeated* testing of one set of materials on the forward effect of testing on recall performance and organization in whole/part and part/whole transfer paradigms. In these paradigms, two word lists are learned in succession. In the whole/part paradigm, the second list is shorter than the first; the reverse is true for the part/whole transfer paradigm. In the control conditions, the words on the two lists are unique. In the experimental conditions, the words on the two lists overlap. In the whole/part paradigm the second list in the experimental condition comprises a subset of the whole list; in the part/whole paradigm the second list includes all the items from the first list along with an equal number of new items.

The typical finding in these transfer paradigms with both categorized and uncategorized word lists is that memory for the second list is impaired when the two lists share items (Novinski, 1969; Sternberg & Bower, 1974; Tulving, 1967; Tulving & Osler, 1967; Wood, 1970, 1971). This negative transfer effect has been replicated with varying list lengths and amounts of practice in the part-whole (Elmes, Roediger, Wilkinson, & Greener, 1972; Tulving, 1967; Novinski, 1969; Sternberg & Bower, 1974; Slamecka, Moore, & Carey, 1972; Wood & Clark, 1969), and whole-part transfer paradigms (although less work has examined the whole-part transfer paradigm; Novinski, 1969; Wood, 1971).

There are two competing theories of the mechanisms responsible for the transfer effects in the whole/part and part/whole paradigms. One explanation is that negative transfer occurs when the organization of items differs across the first and second lists and participants have difficulty changing their organizational strategy in order to incorporate the structure of the new list (Ornstein, 1970; Rundus, 1978; Tulving, 1967; Tulving & Osler, 1967). This notion is supported by studies which found that *positive* transfer may occur when organization of the part and whole list are consistent in the part-whole transfer paradigm and thus there is no requirement for participants to change their organizational strategy when learning the whole list (Ornstein, 1970; Rundus, 1978). No work to our knowledge has investigated the possibility of positive transfer in the whole/part transfer paradigm.

Positive transfer may also occur in the part-whole transfer paradigm as a result of other factors, such as when critical learning strategies are employed (Elmes et al., 1972; Slamecka et al., 1972; Wood & Clark, 1969). For example, Slamecka et al. (1972) found that encouraging participants to guess during recall of the whole list led to positive transfer, whereas an absence of such instructions led to negative transfer. That result was attributed to difficulty in list discrimination, resulting in a cautionary style which was eliminated when participants were encouraged to guess. Thus, an alternate explanation of negative transfer is that it occurs due to participants' failure to discriminate items as belonging to one or both lists (Anderson & Bower, 1972; Slamecka et al., 1972; Sternberg & Bower, 1974).

The goal of the present studies was to test the effects of repeated testing of the first list in both the whole/part (Experiment 1) and part/whole (Experiment 2) paradigms. In Experiment 1, participants learned a 50-word list of categorized words under repeated study (SSSST) or repeated test (STSTST) conditions, followed by four alternating study-test trials on a second 25-word list of categorized words. In Experiment 2, participants learned a 25-word list of categorized words in either the study (SSST) or test (STST) condition, followed by six alternating study-test trials on the categorized 50-word list. In the overlapping condition the two lists shared words and in the novel condition the two lists had no items in common.

We believe this is the first study to assess the impact of *repeated* testing on the forward testing effect. That is, previous studies have investigated the effect of having a single test relative to no tests on a set of materials on subsequently learned material (e.g. Szpunar et al., 2008). Given that studies of the backward effect of testing have found that multiple recall tests on a set of materials results in better recall of that material relative to having a single test (e.g. Roediger & Karpicke, 2006), it would be of interest to see if this pattern extends to the forward effect of testing as well.

The whole/part and part/whole transfer paradigms may provide a comparison of alternative accounts of the forward testing effect. The forward effect of testing is positive due to enhanced retrieval (through enhanced list discrimination or enhanced retrieval effort/strategy) or more efficient encoding of later material, or perhaps due to a combination of both enhanced retrieval and encoding. Thus, it might be expected that testing would mitigate a negative transfer effect and promote a positive transfer effect. In whole/part transfer, participants must learn to discriminate the old items that continue to be relevant from those that are no longer relevant. If the forward effect of testing reflects improved retrieval through an enhanced discrimination process, then the negative transfer that results from discrimination in the whole/part paradigm should be abated. In contrast, the part/whole transfer paradigm demands that all prior items remain relevant during whole list learning. Thus, the discrimination process need not be engaged. As such, if the forward testing effect is greater in the experimental condition of the whole/part transfer paradigm than in the part/whole paradigm or control conditions, this would support the enhanced list discrimination account of the forward testing effect. To the extent that the forward effect of testing is due to enhanced encoding of new items, then repeated testing of the part list should enhance learning in the overlapping condition where there is an accretion of additional information into an existing organizational framework. That is, if repeated testing during List 1 learning enhanced learning of List 2 to a similar extent across both the part/whole and whole/part transfer paradigms, this would suggest that list discrimination was not the mechanism of the forward testing effect in the present study. Instead, such a finding would support the notion that repeated testing either enhanced encoding of items following testing, or enhanced participants' retrieval through means other than list discrimination. (e.g. enhanced effort/strategy during recall tests).

An anonymous reviewer directed us to a recent paper (Cho, Neely, Crocco, & Vitrano, 2016) in which a form of part/whole list learning was used to test encoding and retrieval as mediators of the forward testing effect. In those studies, participants learned two lists of Swahili

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