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The retrieval practice effect in associative recognition

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Recalling an item interferes with recall of related memories. Evidence is presented that retrieval interference occurs in associative recognition as well as recall. In Experiment 1, subjects studied pairs of category exemplars. Retrieval practice followed, during which some pairs appeared in a cued recall test. A final test of associative recognition (with remember–know judgments) found lower accuracy and hit rate for nonpracticed pairs belonging to retrieval-practiced categories. In Experiment 2, subjects studied noun pairs from overlapping sets, with study duration manipulated between subjects. Retrieval practice was manipulated by presenting some members of a set in a previous block during the recognition test. With long study duration, retrieval interference was evident in both recognition and remember judgments. With short study duration, it appeared only in remember judgments. These results support a dual-process account in which retrieval interference is specific to recollection and becomes evident in recognition performance only when recollection is sufficiently dominant.

The idea that recognition takes different forms is an old one in the memory literature. Feingold (1915) distinguished between context-free familiarity and recognition through intermediating facts like ideas, images, and associations. Lehman (1889; cited in Strong & Strong, 1916) spoke of knowing simply that something was seen before as opposed to knowing details like where and when. The distinction between a nonspecific sense of past experience, *familiarity*, and specific memory for detail or context, *recollection*, is the basis for contemporary dual-process theories of recognition (Atkinson & Juola, 1974; Mandler, 1980; Reder et al., 2000; Yonelinas, 1994). It has often been suggested that recollection in recognition is based on a retrieval process similar or identical to that found in recall (Brown, 1976; Clark, 1999; Humphreys, 1978; Mandler, 1980). If this is true, manipulations that affect recall should have similar effects on recollection-based recognition.

Familiarity is typically described as a global match between a retrieval cue and the contents of memory. It provides aggregate evidence that something was previously encountered (Gillund & Shiffrin, 1984; Hintzman, 1988). In contrast, recall of specific information is typically described as competitive search, and interference occurs when retrieval of the desired item is made more difficult by the presence of other items that also match the cue. This characteristic has been used to explain standard findings in recall such as proactive and retroactive interference, part-set cuing, output interference, and the time-course of self-paced recall (M. C. Anderson, R. A.Bjork, & E. L. Bjork, 1994; Rundus, 1973; Wixted, Ghadisha, & Vera, 1997; Wixted & Rohrer, 1994). If recollection-based recognition depends on a retrieval process similar to that found in recall, then it should also be vulnerable to competitive interference.

A phenomenon linked to competitive interference is the retrieval-induced forgetting observed in M. C. Anderson et al.'s (1994) retrieval practice paradigm. Subjects studied items belonging to a number of semantic categories. Following study, some of the items appeared again as targets in a cued recall test. This retrieval practice benefited recall of the items during a final recall test. However, other studied items from the same categories which were not given retrieval practice were less likely to be recalled than items belonging to nonpracticed categories. In other words, retrieving some members of a category interfered with the later retrieval of other members of the same category.

Phenomena such as part-set cuing and the list-strength effect have been attributed to passive forms of interference (Ratcliff, Clark, & Shiffrin, 1990; Rundus, 1973; Watkins, 1975). With retrieval practice, recalling an item might make it more available, due either to transient activation or because its association with the cue is strengthened relative to that of other items. This availability reduces the likelihood of retrieving other items associated with the cue. Anderson and colleagues have argued instead that recalling an item leads to the active inhibition

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of competitors of the target item, and these researchers point to findings that cast doubt on the viability of passive interference (M. C. Anderson, E. L. Bjork, & R. A. Bjork, 2000; M. C. Anderson & Spellman, 1995; Bauml, 1997, 1998; Koutstaal, Schacter, Johnson, & Galluccio, 1999). In either case, the explanation of retrieval-induced forgetting is ultimately tied to competition among items recruited by the same retrieval cue. The adverse effect of such competition is characteristic of the selective search in recall. If recollection in recognition is also based on competitive search, then retrieval practice should interfere with ability to recollect memories of nonpracticed, same-category items.

The predicted effect of retrieval practice on the familiarity process is less clear. The additional exposure to items as a result of retrieval practice might in theory be expected to increase the familiarity of related items as well (Arndt & Hirshman, 1998; Dyne, Humphreys, Bain, & Pike, 1990; Shiffrin, Ratcliff, & Clark, 1990). In practice, however, repeating items is typically shown to have little effect on the recognition of other items, and some recent models of familiarity predict this alternate pattern of results (Shiffrin, Huber, & Marinelli, 1995; Shiffrin & Steyvers, 1997).

Retrieval Practice and Recognition

Although Hicks and Starns (2004) observed an adverse affect of retrieval practice on recognition, Koutstaal et al. (1999) observed no effect. From a dual-process perspective, such inconsistent findings are not surprising if a manipulation differentially affects the component processes. Retrieval practice is expected to decrease recollection of nonpracticed, same-category items, but it may have little effect on, or actually increase, the familiarity of these items. If recollection plays only a minor role relative to familiarity, the decrease in recollection caused by interference might have little impact on overall recognition performance. If interference decreases recollection but increases familiarity, the tendencies may cancel each other, again leaving little apparent effect on recognition. Thus, according to dual-process logic, the observed effect of retrieval practice on recognition depends critically on the relative contributions of recollection and familiarity.

One way to increase the likelihood of observing interference is to use a memory task that relies primarily on recollection: associative recognition, which requires discriminating intact from rearranged studied pairs. Accurate performance depends on knowledge of specific episodic associations rather than the familiarity of individual words. In fact, performance in associative recognition has been shown to resemble cued recall in a number of ways (Clark, 1992; Nobel & Shiffrin, 2001; Yonelinas, 1997). However, because people sometimes make use of familiarity even in associative recognition (Cleary, Curran, & Greene, 2001; Kelley & Wixted, 2001), recollection might need to be isolated in other ways.

A decrease in recognition accuracy (d') can be taken as evidence of retrieval interference. In the present study, recognition judgments were supplemented by subjective remember–know judgments as a further way to isolate the contribution of recollection. Remember judgments have been shown to converge with other behavioral and physiological measures of recollection (for a review, see Yonelinas, 2002). If retrieval practice interferes with the recollection of existing memories, this should decrease the number of old items that are said to be "remembered" (remember hit rate). This should be true even if the manipulation has no apparent effect on the overall recognition hit rate (which depends on a combination of recollection and familiarity). It should be noted that because remember judgments may be subject to response bias (Hirshman & Henzler, 1998; Postma, 1999; Rotello, Macmillan, & Reeder, 2004), they do not represent an absolute threshold of recollection. Rather, they are assumed here to represent the relative amount of recollection between conditions when response bias is constant. People are typically resistant to changing criteria for different classes of items within the same test list (Morrell, Gaitan, & Wixted, 2002; Stretch & Wixted, 1998), so retrieval practice was always manipulated within-list in the present study.

The idea that remember–know judgments tap qualitatively different retrieval processes is not without controversy. An alternative interpretation, the signal detection model, suggests that when subjects claim an "old" item is also "remembered," they are merely indicating a more conservative response criterion (Donaldson, 1996; Hirshman, 1998; Hirshman & Master, 1997). Because response bias should not affect accuracy, the signal detection model predicts that accuracy will remain constant, whether it is calculated from overall recognition hit and false alarm rates or from remember hit and false alarm rates. In the experiments to follow, d' was calculated from both sets of hit and false alarm rates, so that the data could be evaluated in terms of both the (single-process) signal detection and dual-process interpretations of remember–know judgments.

Experiment 1 was designed to be as similar as possible to previous studies of retrieval-induced forgetting in recall, with the goal of providing a necessary replication of the phenomenon in recognition. After studying pairs belonging to a number of semantic categories, some of the pairs appeared in a cued recall test (retrieval practice). Retrieval interference was examined by comparing associative recognition for nonpracticed, same-category pairs with that of nonpracticed pairs from categories that never appeared during the cued recall test. Experiment 2 examined predictions specific to dual-process theory. First, if recognition makes use of a recall-like process, then recognition should also be capable of producing retrieval interference. In Experiment 2, cued recall was replaced with associative recognition during the retrieval practice phase. Second, if retrieval practice affects recollection and familiarity in different ways, then manipulating the relative contributions of the two processes should change the observed effect of retrieval practice on overall recognition performance. If this happens, interference should still be evident in the rate of remembering old items, which is specifically tied to recollection.

EXPERIMENT 1

In the retrieval practice paradigm, the study list consists of items drawn from a number of categories (usually common semantic categories, although more arbitrary groupings have been used; Ciranni & Shimamura, 1999; Koutstaal et al., 1999; Shaw, Bjork, & Handal, 1995). A retrieval practice phase, in which some of the items from half of the categories are presented as targets in a cued recall test, follows the study phase. During a final cued recall test, these retrieval-practiced (RP+) items are intermixed with nonretrieval-practiced (RP−) items from the same categories as well as other (NP) items from nonpracticed categories. Studies of retrieval practice using this standard design have consistently found cued recall rates for the three conditions to fall in the order RP+ > NP > RP−. In other words, retrieving items from a given category (RP+) reduced the ability to subsequently recall the remaining items from the same category (RP−) relative to baseline (NP).

Experiment 1 modified the standard retrieval practice design in two ways: Study items were pairs of category exemplars, and for the final test, recall was replaced with an associative recognition test. If recall and associative recognition are affected in similar ways by retrieval practice, then with respect to recognition accuracy and remember hit rates, the three conditions should be ordered: RP+ > NP > RP−.

Table 1
Experiment 1: Design and Sample Items

Recognition Probe	Appeared in Phase: Study	Appeared in Phase: Cued Recall	Condition
salmon tomato	yes	yes	old RP+
shark spinach	yes	yes	old RP+
herring broccoli	yes	no	old RP−
trout corn	yes	no	old RP−
crow diamond	yes	no	old NP
parrot topaz	yes	no	old NP
shark tomato	no	yes	new RP+
herring corn	no	no	new RP−
crow topaz	no	no	new NP

Note—In the case of new RP+ pairs, the individual words appeared in different pairs during the cued recall test.

Method

Subjects. Fifty undergraduates from the University of Illinois, Urbana-Champaign, participated in the study for course credit.

Materials and Design. Subjects were individually assigned to computers that controlled list generation, presentation, and response recording. The assignment of categories and exemplars to experimental conditions, the order of items within lists, and the mapping of response keys were uniquely randomized for each subject.

Stimuli were common exemplars from 14 semantic categories (mean rank = 5.35; Battig & Montague, 1969). Each exemplar was 4–9 letters long, and no two exemplars from the same category shared the same first 2 letters. Categories were arbitrarily divided into pairs. For each pair of categories, an *interference set* of 8 word pairs was created by taking an exemplar from each category to form each pair. This process yielded seven interference sets, for a total of 56 word pairs. Individual exemplars were never repeated within an interference set. Examples of the pairs for each condition and phase of the experiment are shown in Table 1.

Three lists were created, one for each phase of the experiment: the study list, the cued recall test list, and the recognition test list. All items from the seven interference sets appeared in the study list. One set was used only for filler items. Of the six nonfiller sets, half were assigned to the retrieval practice condition. Four items from each of these three sets (RP+ condition) appeared in both the cued recall list and the recognition list. The remaining four items from these sets (RP− condition), as well as the eight items from each of the nonpracticed sets (NP condition), appeared only in the recognition list.

In the study list, four filler pairs appeared at the beginning and four at the end of the list. The remaining 48 pairs were randomly ordered, with the constraint that a particular category never appeared in consecutive pairs. In the cued recall list, the 12 RP+ items were randomly ordered and appeared in fragmentary form. For each pair, the left-hand word was shown intact, but the right-hand word was missing all but the first two letters. In the recognition list, old pairs from the study list were mixed with an equal number of new pairs. For each interference set, a set of new pairs was created by rearranging the left and right exemplars into pairs that had never appeared during study. The exemplars in a new pair were always drawn from the same retrieval practice condition. Twelve practice pairs, created from filler items, were placed at the beginning of the recognition list. The order of the 96 critical test pairs was randomized, with the constraint that a particular category never appeared in consecutive pairs.

Procedure. The 50-min session was divided into four phases: study, cued recall test, delay interval, and recognition test. At the beginning of the study phase, subjects were instructed to learn the list of word pairs for a memory test to follow. Study pairs were presented on the computer screen, each pair displayed for 4,000 msec followed by a 500-msec blank interval. The study phase was followed by a cued recall test. During each trial of the test, a pair fragment appeared on the computer screen, and subjects were given 15 sec to recall the missing word and write the complete pair on a response sheet. A 15-min delay period followed the cued recall phase, during which subjects worked on picture-based logic puzzles. For the final associative recognition test, subjects used the "z" and "/" keys to indicate respectively whether pairs were old (intact pairs from the study list) or new (rearranged pairs). If subjects responded "old," they also indicated whether the recognition was based on remembering or knowing using the "1" and "2" keys. At the beginning of the test, subjects were given both written and verbal instructions. Remember–know instructions were adapted from standard ones used by Gardiner, Ramponi, and Richardson-Klavehn (1998). In brief, subjects were told that remembering is the conscious recollection of details of the study episode, such as where in the study list an item had appeared or what images it had invoked at the time; knowing, on the other hand, is a sense of familiarity in the absence of such detail.

Results

Because retrieval practice was the critical manipulation, 5 subjects who failed to recall at least one item from each category during the retrieval practice phase were

Table 2
Experiment 1: Accuracy, Hit (H) Rate, and False Alarm (FA) Rate

	Accuracy		H		FA	
Condition	*d′*	*SE*	Rate	*SE*	Rate	*SE*
			Recognition			
RP+	1.00	0.08	.69	.02	.34	.02
RP−	0.56	0.11	.50	.03	.31	.03
NP	0.72	0.07	.53	.02	.27	.02
			Remember			
RP+	1.06	0.07	.40	.02	.09	.01
RP−	0.63	0.10	.25	.02	.09	.02
NP	0.89	0.09	.32	.02	.10	.01

Note—Remember hit rate is the proportion of old items that were judged both "old" and "remembered." Remember FA rate is the proportion of new items that were judged "old" and "remembered."

excluded from further analysis. Mean correct recall for the remaining subjects was 66%.

Data from the recognition and remember–know judgments are shown in Table 2. Recognition accuracy was calculated using d', which takes into account both hit and false alarm rates. Accuracy was calculated for both the initial recognition judgments and the remember judgments (the latter, which occurred when subjects responded that a word was both "old" and "remembered," yielded a separate hit and false alarm rate that the signal detection model treats as representing a more conservative decision criterion). The critical comparisons, RP+ vs. NP (facilitation of practiced items) and RP− vs. NP (inhibition of nonpracticed, same-category items), were examined separately for recognition and remember accuracy. In order to examine the dual-process predictions for recollection, hit rates were also analyzed in this way.

For accuracy (d') based on recognition judgments, the ordering of conditions was RP+ (1.00) > NP (0.72) > RP− (0.56). Accuracy in the RP+ condition was reliably greater than in the NP condition, [$t(44) = 2.95, p < .01$], although the difference between the NP and RP− conditions was not reliable [$t(44) = 1.13$, n.s.]. For accuracy based on remember judgments, the ordering of conditions was RP+ (1.06) > NP (0.89) > RP− (0.63). Accuracy in the RP+ condition was not reliably greater than in the NP condition [$t(44) = 1.62$, n.s.], but the difference between the NP and RP− conditions was reliable [$t(44) = 2.37, p < .05$].

For recognition judgment hit rates, the ordering of conditions was RP+ (.69) > NP (.53) > RP− (.50). Hit rate in the RP+ condition was reliably higher than in the NP condition [$t(44) = 6.60, p < .001$], but the difference between the NP and RP− conditions was not reliable [$t(44) = 0.93$, n.s.]. For remember judgment hit rates, the ordering of conditions was RP+ (.40) > NP (.32) > RP− (.25). Hit rate in the RP+ condition was reliably higher than in the NP condition [$t(44) = 3.69, p < .01$], and the hit rate in the RP− condition was reliably lower than in the NP condition [$t(44) = 3.36, p < .01$].

Discussion

In the retrieval practice paradigm, the standard finding with free and cued recall is that the prior retrieval of RP+ items facilitates the subsequent retrieval of those RP+ items but interferes with the retrieval of RP− items relative to the NP baseline. This pattern was observed for both recognition accuracy and hit rates. For both measures, the conditions were ordered RP+ > NP > RP−, and this was true for recognition as well as for remember judgments.

Evidence for retrieval interference rests on the comparison of the NP and RP− conditions. Hit rate and d' for the RP− condition were reliably lower only for remember judgments. For recognition judgments, the trends were in the same direction, but the differences were not statistically reliable. The latter result may simply be an issue of insufficient power. However, it is consistent with the dual-process perspective: Remember judgments, which are more directly tied to the recollection process, are expected to show clearly patterns like that observed in recall (i.e., retrieval interference). Overall recognition judgments, on the other hand, because they are based on familiarity as well as recollection, are not expected to show such patterns as clearly if familiarity is affected differently by the manipulation.

EXPERIMENT 2

In Experiment 1, the remembering of old items was shown to be vulnerable to retrieval-induced forgetting in a manner typically found in free and cued recall. Experiment 2 departed from the standard procedure and materials of the retrieval practice paradigm. The purpose here was to replicate and generalize the findings, but also to investigate two issues specifically associated with the dual-process view of recognition. First, retrieval-induced forgetting has until now been demonstrated with recall practice. If a recall-like process is normally present in recognition, then recognition judgments should themselves produce retrieval-induced forgetting. Second, evidence for retrieval practice effects in recognition has been inconsistent (Hicks & Starns, 2004; Koutstaal et al., 1999). If recollection and familiarity are affected differently by retrieval practice, interference in overall recognition should be more evident when recollection plays a greater role.

As they did in Experiment 1, subjects studied pairs of words that could be grouped into several sets of related items. The pairs this time were random nouns, and a related (interference) set was composed of a number of pairs that overlapped (e.g., *beard–grain*, *beard–plate*, *shirt–plate*, etc.). The study list was followed by an associative recognition test. The test list was blocked so that items from only four interference sets appeared within a given block (see Table 3). Two of these sets comprised the interference condition: Half of the set members appeared in the block, and half appeared in the

Table 3
Experiment 2: Test Design and Sample Items

Recognition Probe	Tested in:	Type	Condition
beard grain	Block 2	old	baseline
beard plate	Block 3	old	interference
truck cloud	Block 3	old	baseline
beard cloud	Block 3	new	
truck artist	Block 4	old	interference

preceding block. The remaining two sets comprised the baseline condition: Members of the set appeared for the first time in the test list. Having members of a set appear in the preceding test block is analogous to retrieval practice. Prior recollection of set members should lead to retrieval interference for other members of the set—but unlike in previous studies, recollection comes from associative recognition rather than cued recall. As before, accuracy and hit rate (especially for remember judgments) for the interference condition should be lower than for the baseline condition.

According to dual-process logic, when a manipulation affects recollection and familiarity in different (perhaps opposite) ways, the pattern observed in recollection-based judgments may be reflected in overall recognition judgments only when the contribution of recollection is sufficiently high. The finding in Experiment 1 that evidence for retrieval interference was most clear in the remember judgments hinted at this possibility. Experiment 2 explicitly manipulated the contribution of recollection by varying study duration, which has been shown to affect remembering more than knowing (Gregg & Gardiner, 1994; Jacoby, 1998). Subjects studied each pair for either 4,000 msec (long presentation) or 2,000 msec (short presentation). If short presentation reduces the contribution of recollection relative to familiarity, interference may not be clearly observed in overall recognition but should still be apparent in remember judgments.

Method

Subjects. Sixty undergraduates from the University of Illinois, Urbana-Champaign, participated in the study for course credit.

Design. Subjects were individually assigned to computers that controlled list generation, presentation, and response recording. The composition of word pairs and interference sets, the order of presentation of pairs and sets during study and test, and the mapping of response keys, were uniquely randomized for each subject.

Stimuli were drawn from a pool of 400 nouns equated on length (5–7 letters) and frequency (<100/million; Kučera & Francis, 1967). Twelve interference sets were created, each with 9 word pairs. For each set, three unique words were assigned to the left position and three other words were assigned to the right position of pairs. The 9 pairs in a set were created from all possible combinations of the left- and right-position words (A–D, A–E, A–F, B–D, B–E, B–F, C–D, C–E, C–F; letters *A* to *F* stand for individual words). A particular word never appeared in more than one set. The 108 pairs were randomly ordered within the study list. An additional 5 filler pairs were placed at both the beginning and end of the study list.

The test list was divided into six blocks of 32 pairs. Within each block, half of the pairs were from the study list, and half were novel pairs created from words that had appeared during study. Retrieval interference was manipulated by presenting 4 studied pairs from an interference set (e.g., A–D, A–F, B–F, C–E) in one block and 4 of the remaining studied pairs from the set (e.g., A–E, B–D, C–D, C–F) in the following block. The presentation of interference sets was staggered so that in each of the test blocks (excluding the first and last), half of the old pairs were drawn from two sets that had appeared in the immediately preceding block (interference condition), and half of the old pairs were drawn from two sets appearing for the first time in the test list (baseline condition). Novel pairs were created by re-pairing individual words from the old pairs present in a block. Every new pair contained one word from an interference condition set and one word from a baseline condition set, so that in contrast to the old items, there was only one class of new items.

Procedure. Subjects were assigned randomly to either the long or the short presentation group. The procedure for these groups differed only in the speed of presentation of the study items. The 40-min session was divided into a study phase followed by a test phase. Subjects were instructed to study the list of word pairs for a memory test to follow. During the study phase, 118 pairs were presented on the computer screen. Each pair appeared for either 4,000 msec (long presentation) or 2,000 msec (short presentation), followed by a 500-msec blank interval.

At the beginning of the test, subjects were given both written and verbal instructions for the associative recognition and remember–know judgments. They were then given a 20-trial practice test (with targets and lures drawn from the filler pairs), followed by the 192-trial test. Instructions and trial procedure were identical to those of Experiment 1.

Results

Data from the recognition and remember–know judgments are shown in Table 4. As before, accuracy (d') was calculated based on the hit and false alarm rates from the initial recognition judgments as well as from the remember judgments. The critical contrasts between the interference and baseline conditions were examined separately for recognition and remember accuracy. In order to examine the dual-process predictions for recollection, hit rates were also analyzed in this way.

Table 4
Experiment 2: Accuracy, Hit (H) Rate, and False Alarm (FA) Rate

	Accuracy		H		FA	
Group	d'	*SE*	Rate	*SE*	Rate	*SE*
			Recognition			
Long						
Baseline	1.17	0.11	.64	.03	.25	.03
Interference	0.98	0.09	.58	.04	.25	.03
Short						
Baseline	0.38	0.12	.55	.02	.42	03
Interference	0.44	0.10	.57	.03	.42	.03
			Remember			
Long						
Baseline	1.53	0.09	.41	.04	.04	.01
Interference	1.15	0.07	.28	.03	.04	.01
Short						
Baseline	0.88	0.09	.29	.02	.09	.02
Interference	0.54	0.08	.20	.02	.09	.02

Note—Remember hit rate is the proportion of old items that were judged both "old" and "remembered." Remember FA rate is the proportion of new items that were judged "old" and "remembered." New pairs contained one word from the baseline condition and one word from the interference condition. Thus, there were two classes of old items but only one class of new items.

Long presentation group. For recognition judgments, d' in the interference condition (0.98) was reliably worse than in the baseline condition (1.17) [$t(29) = 2.66, p < .05$]. For remember judgments, accuracy in the interference condition (1.15) was again reliably worse than in the baseline condition (1.53) [$t(29) = 6.24, p < .001$]. The hit rates followed a similar pattern. Recognition hit rate was reliably lower in the interference condition (.58) relative to baseline (.64) [$t(29) = 2.75, p < .05$]. Remember hit rate was also reliably lower in the interference condition (.28) relative to baseline (.41) [$t(29) = 2.75, p < .001$].

Short presentation group. For recognition judgments, d' in the interference condition (0.44) did not differ reliably from the baseline condition (0.38) [$t(29) = 0.79$, n.s.]. For remember judgments, however, accuracy in the interference condition (0.54) was reliably worse than in the baseline condition (0.88) [$t(29) = 5.71, p < .001$]. The hit rates followed a similar pattern. Recognition hit rate in the interference condition (.57) did not differ reliably from the baseline condition (.55) [$t(29) = 0.70$, n.s.]. Remember hit rate, on the other hand, was reliably lower in the interference condition (.20) relative to baseline (.29) [$t(29) = 2.75, p < .001$].

Discussion

Length of study presentation determined the pattern of overall recognition performance. When study duration was fairly long, retrieval practice led to a decline in recognition d' and hit rate. When study duration was much shorter, however, there was no effect of retrieval practice on recognition accuracy and hit rate—in fact, the trends were in the opposite direction. A dual-process interpretation is that retrieval practice increased familiarity while decreasing recollection. The net effect of these opposing tendencies was that recognition performance most resembled the pattern expected of a recollection process when recollection played a larger role in recognition (long presentation).

With remember judgments, the negative effect of retrieval practice was observed regardless of study duration. Remember d' and hit rate decreased in the interference condition for both long and short presentation groups. This is evidence that, like recall, recollection-based recognition can produce retrieval interference. It might be suggested that the mere presentation of related pairs in a previous block, rather than the retrieval processes associated with testing the memory for those pairs, is responsible for the decline of remembering in the interference condition. Studies using recall have examined this possibility, and they have shown consistently that mere presentation does not produce the retrieval practice effect (M. C. Anderson & Bell, 2001; M. C. Anderson et al., 2000; M. C. Anderson & Spellman, 1995; Ciranni & Shimamura, 1999). Moreover, in studies of recognition, merely repeating related items is not typically found to have an adverse effect on other items (Ratcliff et al., 1990; Shiffrin et al., 1995; but see Norman, 2002). Thus, a good deal of prior evidence points to retrieval practice as the cause of the interference effects observed in the present experiment, although future work might examine this question more closely.

GENERAL DISCUSSION

Recalling an item from memory interferes with the later recall of other, related items. Evidence that recall can have a similar adverse effect on the later recognition of related items has so far been mixed: Hicks and Starns (2004) observed a retrieval practice effect in recognition of category exemplars, but Koutstaal et al. (1999) failed to find an effect in recognition of photographs. In the present study, a retrieval practice effect was observed in associative recognition of both category exemplars and random noun pairs. Not only does this result establish the generality of the effect in recognition, but the pattern of data suggests a reason for why retrieval practice effects in recognition may be elusive.

According to the dual-process view, people base their recognition judgments on both recollection of specific details or associations and a nonspecific sense of familiarity. Theoretical descriptions of recollection and familiarity predict that the two processes will be affected differently by retrieval practice. Recollection can be likened to recall, which is typically modeled as a competitive search in which different memories associated with the retrieval cue can compete and interfere with one another during retrieval. Retrieving an item suppresses its competitors, making them less available for subsequent retrieval. Models of familiarity, on the other hand, suggest that repeating items during retrieval practice may increase, or simply have no effect on, the familiarity of related items. If recollection and familiarity are affected in different ways by retrieval practice, then observing an adverse effect of retrieval practice on recognition will depend on the extent to which recollection contributes to recognition performance.

Looking only at recognition judgments, evidence for retrieval interference was weak (an unreliable trend) in Experiment 1, strong in the long presentation group of Experiment 2, and absent in the short presentation group of Experiment 2. In contrast to these mixed results, remember judgments (both d' and hit rates) showed consistent, reliable patterns of retrieval interference in all experiments. In other words, retrieval practice does have an adverse effect on recognition, but this effect is specific to recollection. Two issues should be considered before accepting this conclusion: the role of the associative recognition task in producing the results, and the alternative interpretation of remember–know judgments provided by the signal detection model.

Associative recognition sometimes resembles recall more than it does item recognition. This has been observed with the manipulation of word frequency (Clark, 1992; Clark & Burchett, 1994) and in the shapes of response time distributions (Nobel & Shiffrin, 2001) and receiver operating characteristic curves (Rotello & Heit, 2000; Yonelinas, 1997). Moreover, some manipulations thought to selectively target familiarity affect item recognition but not associative recognition (Cameron & Hockley, 2000; Westerman, 2000, 2001). If associative and item recognition rely on different retrieval processes, do the present findings necessarily generalize to item recognition? First, Hicks and Starns (2004) have shown empirically that a retrieval practice effect can appear in item recognition. In addition, despite the predominant role of recollection in associative recognition, it is clear that people sometimes do use familiarity in this task (Cleary et al., 2001; Kelley & Wixted, 2001; Yonelinas, Kroll, Dobbins, & Soltani, 1999). These factors, when taken together, are consistent with the idea that associative and item recognition are related, both falling on a continuum that represents the relative contribution of recollection and familiarity.

An alternative to the dual-process interpretation of remembering and knowing is the signal detection model outlined by Donaldson (1996) and Hirshman and Master (1997; see also Hirshman, 1998). Drawing on a tradition of single-process, familiarity-based accounts of recognition, the model assumes that old–new recognition and remember–know judgments are based on the same underlying information but represent different response criteria. In other words, saying that an item is "old and remembered" reflects a more conservative criterion than simply saying that an item is "old." Adopting this model does not change the conclusions of the study: Finding an accuracy difference at either the recognition or the remember criterion point constitutes evidence of a retrieval practice effect. What the signal detection model does not readily explain, however, are the data in the short presentation condition of Experiment 2, in which remember accuracy differed between conditions, but recognition accuracy did not. If the two types of judgment rely on the same information, any manipulation should affect both in the same way. The finding that recognition and remember d's are differently affected by a manipulation suggests that the two may be based on different types of information.

The idea that a recall-like retrieval process plays a role in recognition comes not only from the study of certain forms of recognition (e.g., associative recognition) but, more generally, from a variety of phenomena that do not seem readily accommodated by a familiarity process alone (e.g., Clark, Hori, & Callan, 1993; Hintzman, Curran, & Oppy, 1992; Hockley, Hemsworth, & Consoli, 1999; Jacoby, Jones, & Dolan, 1998; Joordens & Hockley, 2000). The finding that recollection-based recognition and recall are affected in similar fashions by retrieval practice is certainly consistent with this idea. Of course, it has been known for some time that recognition and recall often behave in different ways (J. R. Anderson & Bower, 1972). For this reason, a common view has been that the two memory tasks rely on qualitatively different retrieval processes. The dual-process view of recognition provides an alternative framework for investigating the differences and similarities between memory tasks.

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