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An investigation of response competition in retrieval-induced forgetting

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Abstract: It has been demonstrated that retrieval practice on a subset of studied items can cause forgetting of different related studied items. This retrieval-induced forgetting (the RIF effect) has been demonstrated in a variety of recall studies and has been attributed to an inhibitory mechanism activated during retrieval practice by competition for a shared retrieval cue. The current study generalizes the RIF effect to recognition memory and investigates this competition assumption. Experiment 1 demonstrated an effect of RIF effect in item recognition with incidental encoding of category-exemplar association during the study phase. Experiment 2 demonstrated evidence of RIF with use of an independent retrieval cue during retrieval practice. Results from this study indicate that response competition may occur outside of the retrieval-practice phase, or may not be limited to situations where there is an overt link to a shared category cue.

Subjects: Cognitive Psychology; Consciousness & Cognition; Memory

Keywords: recognition memory; retrieval-induced forgetting; response competition; independent cues; memory inhibition; transfer appropriate processing

1. Introduction

Successful memory retrieval can serve to improve subsequent memory for the previously retrieved information (Allen, Mahler, & Estes, 1969; Carrier & Pashler, 1992; Gardiner, Craik, & Bleasdale, 1973; Gotts & Jacoby, 1974). Studies of retrieval-induced forgetting (RIF; Anderson, Bjork, & Bjork, 1994), however, have demonstrated that prior retrievals can make subsequent recall of semantically related information more difficult. This phenomenon is thought to be driven by competition for two or more items in memory for a shared retrieval cue. The commonly used retrieval-practice paradigm

ABOUT THE AUTHOR

Glanc's research focuses primarily on visual word recognition and how different aspects of the visual experience inform the memory process. She is largely interested in a multidisciplinary approach to memory research, investigating how phenomena from linguistics, cognitive, and even social psychology influence information processing.

PUBLIC INTEREST STATEMENT

Have you ever forgotten where you parked your car, and then could not remember where you parked today because you kept thinking about where you parked yesterday? This is related to a memory phenomenon known as retrieval-induced forgetting. Recollecting certain items from memory causes the subject to forget other, related items. This study aims to investigate how the human memory system works to create the retrieval-induced forgetting effect, and discusses how it may behave differently within different forms of memory, specifically, recall and recognition memory. Understanding effects such as this one will allow us to better understand why the memory system, while overall very accurate and efficient, fails us from time to time.

consists of three distinct phases: an initial study phase in which participants are given a series of category-exemplar pairs (e.g. Color—Pink, Color—Brown, and Fruit—Banana) for study, a retrieval-practice phase in which retrieval of a subset of the studied items is initiated, often through the use of a task such as word-stem completion (e.g. Color—Br__), and a final test phase in which participants are asked to remember the words from the original study list via a category-cued recall task (e.g. recall the study words from the following categories: Color, Fruit). RIF is demonstrated by contrasting memory performance on the final memory test between the two different types of items (e.g. practiced: Brown, and unpracticed: Pink) from practiced categories with performance on the baseline items from the non-practiced categories (Banana). Retrieval practice of a subset of items from practiced categories (e.g. Brown) results in impaired recall of the remaining items from those same practiced categories (e.g. Pink) as compared to control items from unpracticed categories (Banana). This RIF effect is quite robust, and has been demonstrated with a variety of materials and empirical manipulations (for reviews, see Anderson, 2003; Murayama, Miyatsu, Buchli, & Storm, 2014; Raaijmakers & Jakab, 2013; Storm & Levy, 2012).

To explain the memory impairment seen in RIF, Anderson et al. (1994) proposed a suppression-based retrieval mechanism. One of the basic assumptions of this hypothesis is that multiple items from practiced categories are in competition for activation by the shared retrieval cue (the category label) during retrieval practice, based on preexisting semantic relationships. This competition elicits suppression of non-target competing items in order to increase the probability of correct retrieval of the target items. The result of this suppression, however, is impaired recall of the suppressed items on the final memory test. Although Anderson et al.'s (1994) seminal research proposed an inhibition-based accounting of RIF, it is important to note that there has been considerable debate as to the nature of the underlying retrieval mechanism [see Storm and Levy (2012) for a summary of arguments supporting inhibition theory and Raaijmakers and Jakab (2013) for a summary of arguments against].

One of the critical properties in Anderson et al.'s (1994), theoretical account of RIF is its dependence on associative response competition. In additional studies, Anderson et al. (1994) found that unpracticed items from practiced categories are more likely to be suppressed when they are high-frequency exemplars of the category rather than low-frequency exemplars. This would indicate that items which compete most strongly with retrieval are more likely to be inhibited. Other researchers have provided additional evidence that RIF is a product of response competition. For example, Shivde and Anderson (2001) designed a RIF paradigm using homographs as categories. Exemplars of both their dominant and subordinate meanings were used. Words relating to the homograph's dominant meeting were inhibited more than words related to its subordinate meaning. Also, Storm, Bjork, and Bjork (2007) demonstrated that items on lists that participants are instructed to remember are more susceptible to the effects of RIF than items on lists that participants are instructed to forget (see also Bäuml & Samenieh, 2010, 2012).

Based on the above findings, the response competition assumption predicts that suppression elicited during retrieval practice is cue independent, and can be generalized to any item in memory that may compete with the target item, based on preexisting semantic relationships, for activation from the common retrieval cue (Anderson & Spellman, 1995). Evidence in support of this prediction has been found using an independent cue technique. This is a modified version of the retrieval-practice paradigm which has been expanded to include exemplars that could be related to more than one category label (e.g. Red—Blood, Red—Tomato and Food—Strawberry, Food—Crackers; Anderson & Spellman, 1995). It is important to note here that the exemplars Tomato and Strawberry, although studied with different category label cues, can actually each be considered members of both categories based on preexisting semantic relationships. Performance results from the final recall test typically show evidence of cross-category impairment. That is, when practiced items (Red—Blood) are related to exemplars from non-practiced categories (Food—Strawberry) impairment of the non-practiced items (Food—Strawberry) is seen on the final recall test. Based on these studies, it would appear that suppression does, in fact, generalize to any item in memory that might be activated by a practiced category label and therefore compete with the target item for retrieval.

Subsequent studies have also demonstrated cue-independent impairment when using independent (novel) cues during the final memory test (Anderson, 2003; Anderson & Bell, 2001; Anderson et al., 1994; Anderson, Bjork, & Bjork, 2000; Levy & Anderson, 2002; Saunders & MacLeod, 2006; Shivde & Anderson, 2001). To date, however, studies investigating the response competition and cue independence assumptions of RIF theory have resulted in a somewhat inconsistent body of literature in which some researchers have found additional evidence supporting cue-independent forgetting (Anderson, Green, & McCulloch, 2000; Anderson & Spellman, 1995; Hulbert, Shivde, & Anderson, 2011; Johnson & Anderson, 2004; MacLeod & Saunders, 2005; Saunders & MacLeod, 2006), while others have not (Camp, Pecher, & Schmidt, 2007; Perfect, Stark, Tree, Moulin, Ahmed, & Hutter, 2004; Williams & Zacks, 2001). Still other researchers have demonstrated that preexisting category-exemplar associations are not solely necessary in order for RIF to occur. For example, Jakab and Raaijmakers (2009) manipulated both study position and number of learning trials and found that, while both increased general recall performance, neither moderated the amount of RIF. Additionally, Tempel and Frings (2014) demonstrated that episodic categorization will also suffice to elicit the RIF effect by using non-word letter strings organized into arbitrary categories.

In light of the inconsistent results found in the literature regarding the response competition assumption and evidence found using independent retrieval cues, it is important to address effects of response competition in the retrieval-practice paradigm. As mentioned previously, it is commonly accepted that suppression occurs as a result of response competition for a shared retrieval cue which arises during the retrieval-practice phase. Therefore, the impairment seen for those competing items on a later memory test is a residual effect of the suppression elicited by earlier retrieval during the practice session, and not a direct result of competition occurring during retrieval of items during the memory test. Typically, the effects of retrieval-induced suppression have been found only in conditions where there is competition for a semantically shared retrieval cue; that is, in conditions which do not use individual item-specific information as a cue for item retrieval (Bäuml, 2008; Butler, Williams, Zacks, & Maki, 2001; Camp et al., 2007; Verde, 2009). Traditionally, in the standard retrieval practice paradigm, items are presented during the study phase in category—exemplar pairs, practiced as category—stem completion pairs, and then tested using category labels as retrieval cues. Thus, in this paradigm, the category label is a common retrieval cue used in all three phases of the paradigm. It may be predicted, therefore, that as long as category labels are used as both study and retrieval cues, competition will ensue, resulting in suppression of non-target items. If this competition is alleviated, then RIF should be attenuated and, if this competition is eliminated, then RIF should not occur at all. Some studies have investigated the response competition assumption of RIF by designing conditions in which competition is alleviated during the practice phase (Anderson, Green, et al., 2000; Anderson & McCulloch, 1999; Migueles & García-Bajos, 2007). In these studies, reducing competition resulted in less RIF seen on a final recall test.

The current study attempted to investigate the role of response competition by modifying the retrieval-practice paradigm in two novel ways: first, by presenting the study items without the presence of category labels and second, by utilizing an independent cue during the retrieval-practice phase. This manipulation was designed to eliminate response competition by de-emphasizing the semantic relationships between studied items. This should eliminate the need for suppression, thereby eliminating the RIF effect. In addition, a recognition test will be used for the final memory test to assess RIF. Most of the studies investigating RIF, including the ones mentioned above, have used final cued recall tests to assess RIF; however, some researchers have argued that recognition tests may provide an additional way of assessing both the assumptions of response competition and cue independence in RIF (Gómez-Ariza, Lechuga, Pelegrina, & Bajo, 2005; Hicks & Starns, 2004; Spitzer & Bäuml, 2007). Due to their item-specific nature, and the use of studied items themselves as cues, recognition tests should circumvent any episodic interference due to category-exemplar associations. Therefore, the argument has been made that observation of RIF seen using final recognition tests supports both the assumptions of response competition and cue independence (Román, Soriano, Gómez-Ariza, & Bajo, 2009; Spitzer & Bäuml, 2007, 2009; Starns & Hicks, 2004;

Veling & van Knippenberg, 2004; Verde, 2004). That is, response competition occurring during the retrieval-practice phase is caused by the preexisting semantic relationships between items competing for a shared cue (the category label). This competition causes the inhibition of competing items, and this inhibition is reflected in memory impairment for competing items on the final recognition test.

2. Experiment 1

The first experiment was an attempt to replicate RIF effects found in recall studies by other researchers, as well as to serve as an experimental baseline for Experiment 2. A retrieval-practice paradigm similar to the original one used by Anderson et al. (1994), was used in Experiment 1, with the exceptions that the study list included individual exemplars (e.g. Pink, Banana, Tulip, and Elbow), as is typically used in studies of item recognition, rather than category-exemplar pairs (e.g. Color—Pink, Fruit—Banana, Flower—Tulip, and Body Part—Elbow) and the final test was one of item recognition instead of cued recall. Based on the active suppression hypothesis, it was predicted that recognition hit rates would reflect the same empirical pattern as recall rates seen in previous studies. That is, it was expected that hit rates for practiced items would be significantly higher than hit rates for control items (unpracticed items from categories that were not practiced during the retrieval-practice phase), while at the same time it was expected that hit rates for unpracticed items from practiced categories would be significantly lower than hit rates for control items from unpracticed categories.

2.1. Method

2.1.1. Participants

Sixty-two students from introductory psychology classes participated to fulfill a class requirement.

2.1.2. Design

A standard retrieval-practice paradigm was utilized, consisting of three main phases: a study phase, a retrieval-practice phase, and a final test phase, with a distractor task separating the practice phase from the test phase. This design created three particular types of test items: practiced items from practiced categories (Rp+), non-practiced items from practiced categories (Rp−), and non-practiced items from non-practiced categories (Nrp). This results in a 2 × 3 repeated measures design, with factors including word status (old versus new) and practice condition (Rp+, Rp−, and Nrp). The dependent variable measured was the number of positive ("yes") responses in a standard yes/no test of item recognition.

2.1.3. Materials

Target stimuli consisted of 12 exemplars from eight common semantic categories (*Animal*, *Color*, *Fruit*, *Furniture*, *Weapon*, *Body Parts*, *Occupation*, and *Musical Instruments*), plus four exemplars from three additional categories (*Flower*, *Clothing*, and *Fabric*) which were used as buffer/filler items and not tested. Category labels were chosen to be as unrelated to each other as possible. For example, both *Vegetable* and *Fruit* were not used as categories, because exemplars from both could be considered belonging to an additional, related category *Food*. The words chosen for each category consisted of the 12 items with the largest response proportions for that category according to free association norms published by Van Overschelde, Rawson, and Dunlosky (2004). Items that contained the same first two letters as a previous list item in the same category were substituted with the next most qualified item in that category. Exemplars that could possibly fit into more than one category (e.g. *Orange*, which could be considered an exemplar for both the *Fruit* and *Color* categories) were omitted and replaced in the same fashion.

Experiment 1 presented the study items without the presence of a category label. The study list consisted of 54 exemplars, divided into six exemplars from each of the eight target categories, plus two primacy/recency buffers from the three buffer categories that were not tested. Practice booklets were designed for use during the retrieval-practice phase. Four of the eight categories were used for

subsequent retrieval practice (designated Rp), while items from the remaining four categories did not receive additional retrieval practice (designated Nrp). The Rp categories were further divided into exemplars that were practiced (Rp+) and not practiced (Rp−). Recognition status (presented/new) and item status (Rp+, Rp−, Nrp) for each category and exemplar were counterbalanced, resulting in eight different study list/retrieval practice combinations, so that each item appeared equally as often as a presented or new item and equally as often in each item status (Rp+, Rp−, Nrp). Practice booklets contained 12 designated target items and three filler items (one item from each of the three buffer categories). A category name and the first two letters of a target exemplar (e.g. Fruit—Ap___) were printed in the center of each page and participants were instructed to complete the stem with a word that had been previously presented on the study list.

The final memory test consisted of a standard 96-item yes–no recognition test in which half of the items were old and half new. The initial order of test items for each group was randomly determined, and the test items were given in the same presentation order on the recognition test for all members of each group. Because each individual received a different retrieval practice booklet, the order of presentation of Rp+, Rp−, Nrp, and new items on the recognition test was counterbalanced so that each type of item appeared before the other types of items equally as often. This was done in an effort to balance effects of output interference.

2.1.4. Procedure

The study list consisted of 54 exemplars, divided into six exemplars from each of the eight target categories, plus two primacy/recency buffers from the three buffer categories that were not tested. The eight counterbalanced study list/retrieval practice combinations were presented to separate groups of participants. Each testing session consisted of a group of 15–20 students. Participants were seated in classroom style, and all study and test items were projected onto a large screen in the front of the room. The study list was presented one word at a time and each word remained on the screen for 2 s. Participants were instructed to pay equal attention to each word as it appeared on the screen, and were informed that a memory test for the study list would be given at the end of the session.

Following the initial study phase, participants completed a retrieval-practice phase consisting of a word stem completion task. Practice booklets contained 12 designated target items and three filler items (one item from each of the three buffer categories). A category name and the first two letters of a target exemplar (e.g. Fruit—Ap___) were printed in the center of each page and participants were instructed to complete the stem with a word that had been previously presented on the study list. The last three pages of the test booklet consisted of a distractor phase in which subjects completed a series of simple math problems. This task was designed to keep subjects occupied for a period of approximately 5 min.

When all participants had completed their test booklets, a memory test was presented on the screen one item at a time. The test items appeared one at a time, accompanied by the question “Did this item appear on the study list?” and remained on the screen for a duration of 6 s. Participants were given answer sheets and instructed to mark YES on the answer sheet if the test word had appeared previously on the study list and to mark NO if it had not appeared on the list. Following presentation of the last test item, all booklets and answer sheets were collected and the testing session ended.

2.2. Results

Hit and false-alarm rates are shown in Table 1. An α level of 0.05 was used as the standard of significance for all tests unless otherwise stated. A RIF effect was reflected in the pattern of recognition hit rates, which followed the order Rp+ > Nrp > Rp−. Retrieving items from a given category (Rp+) reduced the ability to recognize unpracticed words (Rp−) from the same practiced category during a later recognition test relative to baseline items (Nrp) from unpracticed categories.

Table 1. Mean proportion of positive recognition responses as a function of retrieval practice condition in Experiment 1

	Item status			
	Old (hit rate)		New (false-alarm rate)	
Retrieval practice condition		S.D.		S.D.
Rp+	0.92	0.09	0.15	0.11
Nrp	0.70	0.13	0.14	0.11
Rp−	0.65	0.16	0.15	0.11

Notes: Values are mean proportions of positive recognition responses made to presented (hit) and new (false-alarm) items. The false-alarm rates to new Rp+ and new Rp− items represent a common proportion ("yes" responses to new items from practiced categories).

2.2.1. Retrieval practice

In the retrieval practice phase, 87% of the items were correctly completed, indicating successful retrieval of target items.

2.2.2. Analysis of variance

An analysis of variance (ANOVA) on numbers of positive responses found significant main effects of both item status (old versus new), $F(1, 61) = 502.89$, MSe = 5.29, and practice condition, $F(2, 122) = 28.60$, MSe = 0.19, as well as a significant interaction between these two factors, $F(2, 122) = 624.71$, MSe = 18.57.

2.2.3. Hit rates

Mean performance in the test phase reflected a typical RIF effect for hit rates. That is, Rp+ items were recognized at higher proportion (92%) than Nrp (70%) items and Rp− items (65%), while Rp− items were recognized at a lower proportion than Nrp items and Rp+ items. The effect of practice condition was significant for hits, $F(2, 122) = 46.55$, MSe = 0.49. Pairwise comparisons of hit rates confirmed the differences: the hit rate for Rp+ items was significantly different from the hit rates for both Nrp items [$t(61) = 8.60$] and Rp− items [$t(61) = 7.91$], and the hit rate for Rp− items was significantly different from the hit rate for Nrp items, $t(61) = 2.01$.

2.2.4. Accuracy

In order to take false alarms into account, d' was compared to reflect overall recognition accuracy. The pattern of recognition accuracy was the same as the pattern for hit rates: Rp+ > Nrp > Rp−. The comparison of d' between Nrp and Rp+ items was found to be significant, $t(61) = 5.39$. The comparison of d' between Nrp and Rp− items was also found to be significant, $t(61) = 3.31$. This indicates that RIF was reflected in overall recognition accuracy as well as in recognition hit rates.

2.3. Discussion

The results seen here reflect both a benefit of retrieval practice for practiced (Rp+) items and an impairment of related, non-practiced (Rp−) items in later recognition as compared to baseline (Nrp) words from non-practiced categories. Recognition hit rates showed the same empirical pattern as performance rates seen in recall studies. Experiment 1 presented the study items without the presence of a category label. Participants, therefore, were expecting to see a list of individual words, not words that belong to specific categories, thereby de-emphasizing the importance of the category—exemplar association.

3. Experiment 2

Experiment 2 utilized an independent retrieval cue during the retrieval-practice phase in an attempt to circumvent the response competition proposed to give rise to retrieval-induced impairment of unpracticed competing items. For example, if retrieval practice occurs in the form of *Fruit—Banana* (or *Animal—Bear*, *Color—Blue*), then any unpracticed target items that would strongly compete with the

target word (*Banana*, *Bear*, *Blue)* for the category label cue (*Fruit*, *Animal*, *Color)* would be suppressed during retrieval practice of the target word (*Banana*, *Bear*, *Blue)* and the result of this suppression would be evident in retrieval impairment of these competing items (e.g. *Apple*, *Dog*, *Red*) on the final memory test. However, it was predicted that recall elicited by an independent practice cue would not cause response competition during the retrieval-practice phase. That is, if the retrieval cue *Monkey* (or *Grizzly*, *Sky*) was used during the retrieval-practice phase to elicit retrieval of the target item *Banana (Bear*, *Blue)*, then it would not be expected to cause suppression of the other exemplars from the *Fruit* (*Animal*, *Color*) category, as the cue *Monkey* (*Grizzly*, *Sky*) was not a commonly shared cue, making suppression unnecessary. Therefore, no evidence of RIF would be predicted if an independent cue was used during the practice phase.

3.1. Method

3.1.1. Participants

Eighty-two participants consisted of students from introductory psychology classes, who participated to fulfill a class requirement.

3.1.2. Design

The same 2 × 3 repeated measures design was used as in Experiment 1, with factors including word status (old versus new) and practice condition (Rp+, Rp−, and Nrp). The dependent variable measured was the number of positive ("yes") responses in a standard yes/no test of item recognition.

3.1.3. Materials

The target stimuli used during the presentation and testing phases were identical to those used in Experiment 1. The retrieval-practice phase used independent cues instead of category labels to elicit retrieval of the target items. Independent cues were defined as cues that were unrelated to the shared category cue, but sufficiently related to the practice target item to elicit retrieval. For example, the study list contained exemplars from the *Fruit* category, including *Banana*, *Apple* and *Cranberry*. For retrieval practice of the target item *Banana*, an independent cue, *Monkey*, was used instead of the shared category label *Fruit* (used in Experiment 1). Independent cues were chosen according to normative data from Nelson, McEvoy, and Schreiber (1998; Appendix B). Cues were chosen according to strength of the forward association connection between the cue and the target (the probability that the cue will elicit retrieval of the target item). The item with the strongest forward connection was chosen unless that item could be confused as a member of another category, in which case the next strongest item was chosen. For the small number of target items that did not have normative data listed, an independent cue was arbitrarily assigned by the experimenter.

3.1.4. Procedure

The current experiment used the same experimental procedure as used in Experiment 1 except that an independent cue was used instead of the category label during the retrieval-practice phase in order to directly assess the effect of response competition in the practice phase.

3.2. Results

Hit and false-alarm rates are shown in Table 2. A RIF effect was reflected in the pattern of recognition hit rates, which followed the order Rp+ > Nrp > Rp−. Retrieving items from a given category (Rp+) reduced the ability to recognize unpracticed words (Rp−) from the same practiced category during a later recognition test relative to baseline items (Nrp) from unpracticed categories.

3.2.1. Retrieval practice

In the retrieval practice phase, 78% of the items were correctly completed, indicating successful retrieval of target items.

Table 2. Mean proportion of positive recognition responses as a function of retrieval practice condition in Experiment 2

	Item status			
	Old (hit rate)		New (false-alarm rate)	
Retrieval practice condition		S.D.		S.D.
Rp+	0.94	0.09	0.16	0.17
Nrp	0.83	0.12	0.18	0.15
Rp−	0.76	0.15	0.16	0.17

Notes: Values are mean proportions of positive recognition responses made to presented (hit) and new (false-alarm) items. The false-alarm rates to new Rp+ and new Rp− items represent a common proportion ("yes" responses to new items from practiced categories).

3.2.2. Analysis of variance

An ANOVA on numbers of positive responses found significant main effects of both item status (old vs. new), $F(1, 81) = 460.86$, MSe = 24.62, and practice condition, $F(2, 162) = 18.30$, MSe = 0.15, as well as a significant interaction between these two factors, $F(2, 162) = 23.71$, MSe = 0.15.

3.2.3. Hit rates

Mean performance in the test phase reflected a typical RIF effect for hit rates. That is, Rp+ items were recognized at higher proportion (94%) than Nrp (83%) items and Rp− items (76%), while Rp− items were recognized at a lower proportion than Nrp items and Rp+ items. The effect of practice condition was significant for hits, $F(2, 162) = 30.67$, MSe = 0.30. Pairwise comparisons of hit rates confirmed the differences: the hit rate for Rp+ items was significantly different from hit rates for both Nrp items [$t(81) = 5.12$] and Rp− items [$t(81) = 7.17$], and the hit rate for Rp− items was significantly different from the hit rate for Nrp items, $t(81) = 3.14$.

3.2.4. Accuracy

As in Experiment 1, d' was compared to reflect overall recognition accuracy. The pattern of recognition accuracy was the same as the pattern for hit rates: Rp+ > Nrp > Rp−. The comparison of d' between Nrp and Rp+ items was found to be significant, $t(81) = 8.08$, $p < 0.01$. The comparison of d' between Nrp and Rp− items was also found to be significant, $t(81) = 2.87$, $p < 0.01$. This indicates that RIF was reflected in overall recognition accuracy as well as in recognition hit rates.

3.3. Discussion

Clear evidence of RIF was seen when independent cues were used for the retrieval-practice phase. This result, combined with the results from Experiment 1, draw into question the assumption that the impairment seen in RIF is caused by semantic competition for a shared retrieval cue that arises during the retrieval-practice phase.

It may be tempting, however, to assume that the evidence of RIF seen in the current experiment is the result of covert cueing by the participants, which could result in covert retrieval practice other than the type intended by the independent cue manipulation. For example, during the retrieval-practice phase it is possible that participants see the independent cue *Monkey*, which elicits retrieval of the studied item *Banana*. Along with this retrieval, participants may also remember that *Banana* was one of the "fruits" that they had seen on the study list. This would serve the same purpose as using the category cue itself as a retrieval cue and result in unintended retrieval competition. Although the effect of covert retrieval practice in RIF has not yet been directly addressed, there is some evidence from studies of part-list cueing and the list-strength effect that appear to indicate that most individuals do not engage in covert retrieval practice unless they are specifically encouraged to do so (Bäuml & Aslan, 2004; Verde, 2009). In the current study, the category labels were not used during presentation of the study list, so there was no direct encouragement for participants to use them for covert retrieval cues in the retrieval-practice phase. If covert retrieval practice is not a

common occurrence, then it is not entirely persuasive as an explanation of the results seen in this study. In addition, Anderson (2003) hypothesized that covert cueing, because it provides the subject with multiple retrieval cues, should not inherently produce forgetting and may actually reduce, rather than enhance, the RIF effect in studies utilizing independent cues.

If covert cueing is occurring, it may be impossible to completely eliminate response competition among all of the items, as subjects' previous knowledge may interfere with the experimental manipulation when the study items have a strong semantic relationship. If response competition is not completely eliminated, then it could be expected that the independent cue manipulation would, at least, serve to de-emphasize (and thus weaken) the semantic connection between practiced items and result in an attenuation of the RIF effect. An examination of the means from the two experiments in Tables 1 and 2 shows the difference in performance between the two groups was minimal, and a direct statistical comparison confirms the difference in performance between the two groups was not significant.

4. General discussion

Evidence from the experiments presented here suggests that the RIF seen on a final recognition memory test may not be solely influenced by semantic response competition that occurs during the retrieval-practice phase. Evidence of RIF was seen in two experiments using an item recognition test in the final phase of the retrieval-practice paradigm. Both recognition hit rates and overall recognition accuracy were higher for practiced items from practiced categories (Rp+ items) than for items from unpracticed categories, but this increase in performance for practiced items was accompanied by a decrement in performance for unpracticed items from these same practiced categories (Rp− items). Recognition performance for the unpracticed items (Rp− items) showed hit rates that were significantly lower than both practiced items and control items from unpracticed categories (Nrp items). This RIF was seen even with the use of independent cues during the retrieval-practice phase. Rp− items continued to show evidence of impairment as opposed to Nrp items even though response competition that would normally take place during the retrieval-practice phase was circumvented by the use of non-shared retrieval cues.

4.1. Interference versus inhibition

These results seem to question the response competition assumption made by Anderson (2003) and Anderson et al. (1994) in his original explanation of RIF. According to this assumption, suppression occurs as a result of items in memory competing, based on pre-existing semantic relationships, for a shared retrieval cue (the category label) during the retrieval-practice phase. It follows from this hypothesis that if the retrieval cue used during the practice phase is an independent, rather than shared, cue, then competition would not ensue and suppression would not be necessary.

A discussion of an alternate explanation of RIF, based on non-inhibitory accounts, may be useful here. According to these accounts, successful memory retrieval is based on the relative strengths of associations between competing memory items and their retrieval cues. Retrieval practice of cue-target item increases the strength of the association between that particular cue-target combination, therefore producing associative interference on a subsequent memory test. This interference blocks retrieval of the unstudied items, resulting in impaired memory performance (Gillund & Shiffrin, 1984; Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981; Rundus, 1973). This is a result of strengthening of some of the studied items during retrieval practice. This strengthening of individual items would be predicted to occur regardless of the retrieval cue used. However, previous studies have shown that simply strengthening individual studied items (i.e. through repeated presentations) does not elicit RIF (Anderson, Bjork, et al., 2000; Bauml, 2002; Hulbert et al., 2011; Saunders, Fernandes, & Kosnes, 2009).

In their investigation into the RIF effect, Perfect et al. (2004) found evidence of memory impairment only when memory for the studied items was tested with their original study cues. These findings were interpreted as evidence of transfer-appropriate forgetting, and it was concluded that RIF is both context-, and cue-dependent. Subsequent recall studies have supported this hypothesis

(Camp et al., 2007; Camp, Pecher, Schmidt, & Zeelenberg, 2009). Results from the current study would appear to support a hypothesis of transfer-appropriate forgetting, as the criteria for transfer-appropriate forgetting were met in both Experiment 1 and Experiment 2: that is, the study conditions and final testing conditions did match, and significant RIF was found. It should be noted that these results are similar to those found in several recent recall studies questioning the inhibition account of RIF (Hanczakowski & Mazzoni, 2013; Jonker, Seli, & MacLeod, 2013; Raaijmakers & Jakab, 2012; Storm & Nestojko, 2010; but also see Grundgelger, 2014).

4.2. Recall versus recognition

As mentioned previously, results from Experiment 1 confirm evidence already seen in recall studies. Results from Experiment 2, however, do not show such agreement with similar manipulations done in recall studies. It was predicted that recall elicited by an independent practice cue would not cause response competition during the retrieval practice phase, thus eliminating (or reducing) memory impairment on the final recognition test. This hypothesis was not supported; however, as a significant RIF effect was still found even with the use of an independent cue. This finding, although contrary to prediction, may be seen as evidence of another property of RIF known as retrieval specificity (see Anderson, 2003; Hulbert et al., 2011, for a review).

According to retrieval specificity, RIF is dependent upon active retrieval of studied items. The cued recall tests typically used in RIF studies decidedly emphasize active recollection of studied items. Recognition decisions however, may not be based on conscious recollection to the same extent as recall performance (Verde & Perfect, 2011). That is, recognition decisions may also be influenced by relative familiarity of the test items. Single- and dual-process theorists have argued extensively over the differential contributions made by recollective and familiarity-based retrieval processes in recall and recognition decisions (see Ratcliff & McKoon, 2000, for a review). Other variables, such as normative word frequency, have been shown to affect recognition and recall processes differently (Gregg, 1976). Perhaps, the impairment seen in RIF is another example of this type of dissociation. Future research should focus on the differences seen in RIF between recall and recognition tasks in order to learn how and why it happens. This may provide a better picture of the actual mechanism underlying the effect.

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