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What is the effect of retrieval practice on competing associates in cued-recall?

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What is the Effect of Retrieval Practice on Competing Associates in Cued-Recall?

by

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Dedication

This Masters Thesis is dedicated to my colleagues, friends, and my family, Latife, Onur, Servet Akirmak, who gave me all that I needed to succeed.

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ABSTRACT

There have been many theories on why we forget. One of the recent approaches to this phenomenon is retrieval induced forgetting (RIF). The present study investigated RIF and different kinds of disruptions and their effects by using extra-list cued recall task. Some participants studied two additional word lists after the target list and some participants studied and were tested from these interpolated lists before their final recall of target list. Relatedness of the interfering lists was also manipulated. There were two control groups that either got an immediate test or got a math task before memory test. The particular interest was on the target competitor effect. The results of the study indicated that all the disruption conditions reduced the effects of competitors. However, there was no effect of retrieval-induced forgetting and also no effect of relatedness. The importance of retention interval on forgetting was discussed.

Humans live in a constant flow of information and most of that information is forgotten during the routine of daily life. For practical and theoretical concerns, forgetting has been investigated extensively in the memory literature. One of the most commonly held views is that forgetting occurs because newly learned material interferes with the old memories, i.e. retroactive interference (Barnes & Underwood, 1959; Jenkins, & Dallenbach, 1924 as cited in McGeoch, 1932). In a typical retroactive interference experiment, one group of subjects (control) learns word list A and after an interval they are tested for recall. A second group of subjects (experimental) learns list A and then list B after which they are tested on list A. The typical finding for this experiment is that the recall performance for experimental group is worse than the control group. As an example, suppose you are trying to remember which movie you saw in the theater two months ago with a friend. If this was the only movie you went to with this friend, the friend is a useful part of the retrieval cue. But, if you have gone to the movie theater many times with this friend after seeing this movie, then all these occasions make it harder for you to remember the particular episode you want to remember.

An explanation for this phenomenon comes from response competition theory. McGeoch (1942) argues that when stimulus B is learned with the stimulus A, there is the A-B learning. Similarly, when the stimulus C is learned with A, A-C learning occurs. A-B and A-C associations are independent of each other and if these responses are learned consecutively (e.g. studying first A-B pairs and then A-C pairs), then the relative strength of a particular response determines whether B or C will be recalled given the stimulus A in test. According to the response competition explanation, interference occurs directly because of the strength of a response. The stronger responses have a higher probability of being recalled over less strong responses given that both of them were paired with the same context or test cue. Hence, the amount of interference observed depends on this strength competition (e.g. if C is stronger than B and both of them were studied with stimulus A, then at the time of test when A is given, C will be recalled more often compared to B).

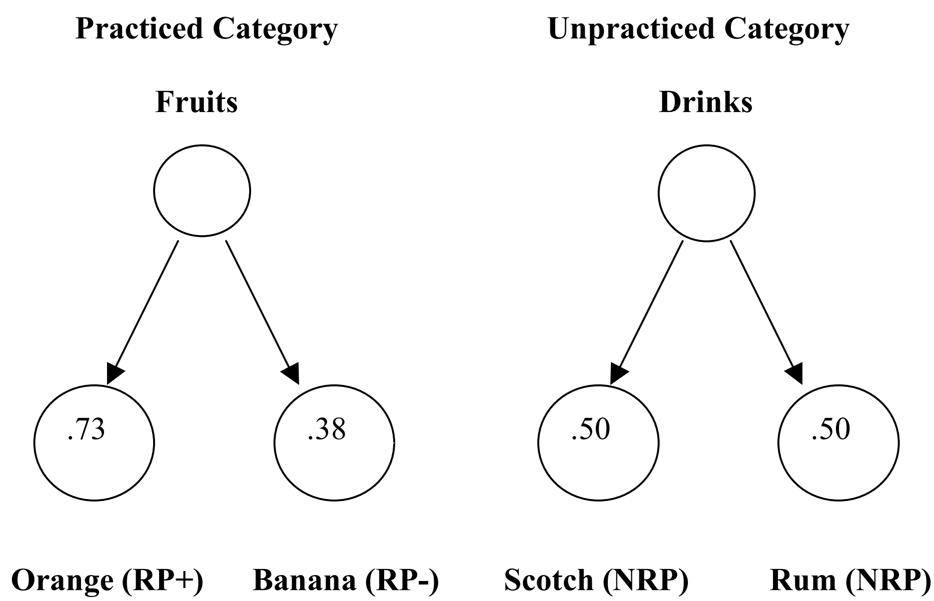
The strength dependence assumption of response competition theory for interference has been challenged by recent work on retrieval-induced forgetting (Anderson, 2003). Anderson, Bjork, & Bjork (1994) claimed that forgetting depends on the amount of retrieval practice consisting of tests on the to-be-remembered stimuli. According to this claim, interference disrupts memory and triggers a control mechanism that inhibits competing information in order to facilitate recall. A stimulus that is retrieval practiced (i.e. tested) remains accessible in memory. In contrast, a stimulus that is meaningfully related to the retrieval practiced stimulus is inhibited in order to avoid interference effects. Hence, what is central to the cause of forgetting is inhibition, not interference produced by response dominance. The focus of the paradigm is inhibition at the item level. Alternatively, some research findings suggest that disruption of context is what reduces a studied word's accessibility. Nelson, McEvoy, Janczura, & Xu (1993) claimed that forgetting can be caused by reduced accessibility to the contextual cues of the learning episode due to attention shifts to a new task or a new context. What remains a mystery in the literature is that there is no agreed upon explanation for why we forget what we learn. We may forget because of response dominance interference, inhibition of specific items, or disruption of the contextual information. The aim of the present study is to investigate and advance our knowledge of episodic forgetting. More specifically, the similarity of interpolated activity to the original study items will be manipulated in order to better understand the mechanisms of forgetting. The results of this study will affect how memory models are formulated to provide a better account of how we retrieve knowledge. This study will allow us to decide between item and context disruption interpretations for forgetting.

Interference theory attributes the magnitude of forgetting to the similarity of the interpolated activity to the initial study (McGeoch, 1932). McGeoch, & McDonald (1931 as cited in McGeoch, 1942) showed how the similarity of interpolated activities to the original learning task affected remembering. For this purpose, they formed target lists with two-syllable adjectives and manipulated the similarity of the interpolated lists to the target adjectives. Subjects learned the adjectives to a perfect criterion after which they either did nothing for 10 minutes, learned 3 digit numbers, learned nonsense syllables, learned unrelated adjectives, learned antonyms or learned synonyms. The results of the experiment showed that as the similarity of the interpolated items increased (similarity was judged by independent raters), the recall of target items decreased. Particularly, recall was highest in the rest condition and declined systematically in the other conditions, with lowest recall for participants studying synonyms as the interpolated list. Hence, the results of the study demonstrated that interference effects were moderated by the degree of similarity between the interpolated list and the target list. Highest impairments in recall were observed with highly similar tasks to the target list and less interference was observed as this similarity decreased.

Although interference theory explains decreased recall when the interpolated items are similar to target items, recent work on retrieval processes provides evidence against interference accounts of forgetting. Specifically, Anderson et al. (1994) argued that the act of retrieval can inhibit related memories in order to make it easier to recall the episode. Related memories are inhibited to avoid confusion with items that need to be remembered. This explanation is based on the retrieval processes engaged in between study and final recall, rather than task similarities. Both interference and retrieval induced forgetting explanations assume that competition between the pairs of words is a necessary condition for interference to occur. They diverge in the theoretical position of the strength of competing items. In other terms, the amount of interference is strength dependent according to interference theory. Stronger responses dominate weaker responses and can cause forgetting of the weaker responses. Any procedure or method that affects the strength of interfering material (e.g. presenting the interfering items 3 times instead of 1 time produces more competition) will also have an effect on the magnitude of interference (Hall, 1989; Reisberg, 2001). In contrast, according to the retrieval induced forgetting point of view, the interference observed is independent of the strength of interfering responses, but dependent on the inhibitory control processes that are used to resolve the interference. Particularly, retrieval practice is a necessary condition for forgetting to occur, regardless of the strength (Bauml, 1996).

The idea of retrieval-induced forgetting is tested in a paradigm that has four stages (Anderson et al. 1994). The experimental stimuli consist of categories and category exemplars. In the study phase, participants memorize category-exemplar pairs. After study, participants were given a stem completion test on half of the categories with half of the exemplars, i.e., retrieval practice. For example, if animal, planet, fruit, and furniture are the categories and tiger-walrus, Pluto-Mars, cherry-banana, chair-table are the exemplars of those categories, participants retrieval-practice (i.e. get tested) on animal-tiger and fruit-banana. With this procedure, three different types of items are created. Retrieval practiced items are the exemplars from the practiced categories (RP+), e.g., tiger-banana. Non-retrieval practiced items are the exemplars that belong to a practiced category but are not practiced in the retrieval-practice phase (RP-), e.g. walrus-cherry. Finally, there are the items that are unpracticed exemplars from the unpracticed categories (NRP), e.g. Pluto-chair. After the retrieval-practice phase, participants receive a distractor task for 20-30 minutes, which is usually a reasoning task. In the final phase, they are given the cues and asked to remember all the words they have seen throughout the experiment. As shown in Figure 1, RP+ items are generally better remembered than NRP items and RP- items are remembered less well than NRP items. Engaging in retrieval-practice improves memory for the practiced items. However, the results also showed that unpracticed items from the practiced category are inhibited, i.e. their recall rate was lower compared to unpracticed category items (Anderson, 2003; Anderson et al., 1994). The inhibition, in this context, is the reduction of the level of activation compared to baseline (Anderson et al, 1994; Veling & Knippenberg, 2004). Hence, inhibited items have a higher chance of being forgotten.

Figure 1. The results of Anderson et al.'s (1994) retrieval induced forgetting study. Probability of correct recall for the selected categories



The results of these experiments are interesting because they show the importance of retrieval practice on the interpolated list. Anderson, Bjork, & Bjork (1994, 2000) demonstrated the importance of retrieval practice more clearly by making a slight change to the task. Instead of giving a retrieval test for the interpolated list, they asked the participants to study some of the category exemplars in the absence of the retrieval practice component. This experiment and others using repeated study sessions instead of test trials failed to find inhibition, i.e. failed to find interference from the interpolated activity. Anderson (2003; Anderson et al., 2000) concluded that retrieval practice is necessary in order to obtain inhibition effects. Moreover, the ineffectiveness of extra study trials alone suggests that inhibition is strength independent (Anderson, 2003). Although the strength of the pairs is assumed to increase during extra study trials, these extra trials failed to produce inhibition effects.

Bauml (1996) also found support for the inadequacy of extra study exposures alone. He manipulated the degree of original learning and examined retroactive interference while controlling for output interference. In his experiment, the participants studied a list of words after which some of them only studied two interpolated lists and some studied and were tested on two interpolated lists. Also, some participants studied the interpolated lists for 3 seconds and some studied them for 5 seconds. The results of his experiments showed that the amount of retroactive forgetting was independent of the degree of interpolated study. However, it did vary with the amount of retrieval practice on the interpolated material as indicated by presence of interference only when participants were tested on the interpolated lists (Bauml, 1996). Merely studying the interpolated lists failed to produce interference. This difference indicates a privileged role for the act of recalling over studying and gives support to the idea that retrieval itself may cause forgetting of related material. In order to obtain interference effects, it appears to be necessary to test participants on the interpolated list (Anderson, 2003; Bauml, 1996). Hence, it has been argued that studying an interpolated list is neither sufficient nor necessary to observe interference. The proposed underlying mechanism is an inhibitory process that is responsible for reducing the activation levels of related episodes relative to the retrieved episode (see Anderson (2003) for a detailed discussion of retrieval induced forgetting).

A different view of the causes of forgetting can be found in recent work about the relationship between attention and memory (Nelson & McEvoy, 2005). This type of research has focused on how automatically activated information is maintained in an accessible state in memory, e.g. the word DOG automatically activates ANIMAL, CAT, BARK, and so forth. One memory model that focuses on the influence of implicitly activated memories is Nelson et al.'s (1993) Processing Implicit and Explicit Representations (PIER). According to this model, remembering something is a function of both explicit and implicit representations. The influence of these two representations is investigated in an extralist cued recall task. In this task, participants study a list of words and then in the test phase, they are given cues that are associatively related to the studied words in order to aid the recall of the studied words, called targets. The cues presented in the test are not shown in the study phase and are related to the targets via preexisting connections (e.g. if "dog" is a studied word, "cat" might be used as a cue to test memory for "dog"). This type of research focuses on the influence of implicitly activated information on episodic recall by examining effects that the associative structure of the words has on recall.

The explicit representation of the target word includes the contextual information that is present during encoding as well as the quantity and quality of the study (i.e. whether it is rehearsing words, counting vowels or rating concreteness, etc.) (Nelson & Goodmon, 2002; 2003). Studying a word produces an explicit representation that is linked to the context of study. In a sense, the context[1] of the learning experience can act as a retrieval cue because contextual cues are encoded into the explicit representation. Moreover, context cues influence the effects of implicitly activated memories because those memories are bound to the target. Thus, any disruption of context affects both explicit and implicit representations of the target (Nelson & Goodmon, 2003).

Research has shown that recall in extralist cuing task varies as a function of the associative structure of the words (For a detailed discussion, see Nelson & McEvoy, 2005). It is assumed that studying a word implicitly activates all of its associatively related words in parallel. Of particular interest, words are found to have different number of associates related to them, a variable named set size. It has been shown that words that have a small set size are easier to recall compared to words that have large set size, all other things being equal (Nelson et al., 1994; Nelson, McKinney & McEvoy, 2003). The explanation for set size effects rests on the probability of sampling a target among its associates given the cue. When words are studied or when they serve as test cues, they implicitly activate their associates. Hence, the associates of the cue and the target are activated during testing and the intersection between the target's and the cue's associative sets determine the probability of recall (Nelson et al. 1993). Some associates of the target aid recall whereas some of them disrupt recall. Specifically, associates of the target that are not in the cue's associative set hinder recall because they compete with the target for

[1] More evidence for the importance of contextual cues in forgetting is also found in animal learning studies. Capaldi & Neath (1995) argues that memory performance depends on how well a test cue discriminates between to-be-remembered memory and other memories.

recall. Target set size effects are derived directly from the number of competitors, and having more and stronger competitors for the target makes sampling it less probable (Nelson, McKinney, Gee & Janczura, 1998). Targets with many competitors have lesser probability of being remembered in extralist cued recall compared to targets with few competitors. This is called the competitor effect, which signifies the recall advantage of targets that have few competitors. Besides number of target competitors, other measured variables also influence the probability of correct recall. In PIER, the connections that link cue and target act as a measure of the net strength of the cue-target relationship[2]. Net strength is decreased by dividing by net strength plus the strength of the competing associates of the cue and of the target (Nelson & McEvoy, 2005). In general, targets that have smaller set sizes (fewer competitors), and more linking connections with the cue yield higher cued-recall performance (Nelson & McEvoy, 2005). Set size and other linking connections operate implicitly and affect episodic memory when tested with a cued recall task.

The positive effects of such implicitly activated memories are susceptible to switching the focus of attention (Nelson et al., 1998). More specifically, variables that are found to affect cued recall lose their advantage when there is a change in the focus of attention. Target set size effects diminish when participants solve math problems after studying a list of words. Although words with small set size have a recall advantage due to having fewer competitors, this advantage is eliminated when participants switch

[2] The strength of the link between cue and the target was determined by free association. The links may be forward (cue activates target) or backward (target activates cue). Also the links maybe indirect such as shared associates (both cue and target activates a common associate) or mediators (cue activates an associate which activates target).

attention to a different task before the final recall test. In an attempt to investigate the effects of different interpolated activities on forgetting, Nelson et al. (1993) manipulated the types of activities engaged in between study and recall. They used extralist cued-recall and manipulated target competitors in order to examine the effects of interpolated activity on implicit memories. In their experiments, participants first studied a list of words (targets). Some of the participants studied two additional word lists of either related or unrelated words, some of the participants worked on math problems during the retention interval, and some controls were tested immediately. The results revealed a recall advantage of small set size words over the large set size words, i.e. competitor effect on the immediate test. Importantly, set size effects disappeared when participants solved math problems, but not when they studied related or unrelated lists of words, as shown in Table 1. The obtained results were attributed to the attention shift from the context of studying words to that of solving math problems (Nelson et al., 1993). Doing multiplication problems after the word learning episode reduced access to context cues acquired during the word learning task. In the case of the math test, attention was switched from a word context to a math context that made it harder to gain access to the previous word context because it was not in the focus of attention (Nelson et al., 1993). In other words, when attention is switched to a new task, access to memory for the previous task is reduced. It may be reduced because the memory of the words is actively inhibited or because performance on the math task reduces access to the context of word learning experience.

Table 1. Findings adopted from Nelson et al. (1993) study. Probability of correct recall as a function of Interpolated conditions and target set size

	Target Set Size		
Conditions	Small	Large	Mean
Control	.67	.52	.60
Related	.52	.38	.45
Unrelated	.51	.35	.43
Math	.50	.50	.50

However, there was only a small specific interference effect in Nelson et al.'s (1993) study. In this particular experiment, recall on the related list was not different from recall on the unrelated list. This finding is interesting, because it goes against the predictions of interference theory. Interference theory predicts that the similarity of the two tasks will have a negative impact on recall (McGeoch, 1942). It would be expected that studying interpolated word lists that are associates of the targets would cause more interference compared to studying interpolated unrelated lists of words, i.e. specific interference. Nelson et al.'s (1993) results indicated that recall of the original list did not drop as much as what might be expected from the interference theory when subjects studied associatively related words rather than associatively unrelated words. General interference effects were present because recall after studying additional lists was lower than in the control condition, but there were only small specific interference effects caused by word relatedness (see Table 1). Furthermore, studying interpolated lists of either type had no influence on the magnitude of the competitor effects. In Nelson et al.'s (1993) study, set size effects were reduced only when attention was diverted to a conceptually different task. Participants supposedly maintained their attention on words when studying interpolated lists, whether they were related or unrelated to the original targets. However, when participants solved math problems, it required a shift from the context of words to the context of numbers, which are two different domains. Therefore, eliminating set size effects seems to be more controlled by attention shifts rather than by the similarity of the task.

Bauml's (1996) study is relevant, because the results of his experiment suggest that it is necessary to test memory for the interpolated list to obtain interference. Particularly, Nelson et al (1993) may not have found specific interference effects because they did not test memory for the interpolated list items. Competition produced by only studying interpolated lists may have been too weak to produce large specific interference effects in the extralist cuing task. Testing participants on the interpolated lists may be required in order to produce high enough competition to produce specific interference. Hence, switching attention to a different study list may be insufficient for observing specific interference compared to shifting attention to this list and also being tested on the items acquired. Moreover, with larger specific interference effects, the effects of competing associates may have been eliminated by specific interference as well as by task switching. Following Anderson's (2003) retrieval-induced forgetting paradigm, it might be that specific interference effects will be larger when interpolated list items are both studied and tested. According to Anderson et al. (2000), retrieval practice inhibits items that are related to the tested items. More specifically, when participants are tested on interpolated lists, they are not only getting extra study exposures to interpolated list items and increasing probability of correct recall for these items, but they are also inhibiting related words, including targets from the original list that are related to the retrieval-practiced words.

It is extremely important to distinguish two sources of interference generated during a study episode. One source concerns the influence of implicitly activated associates (competitors) on episodic recall. Having more competitors leads to greater interference and thus lower recall. Cued recall performance is higher for small set size targets due to fewer associates that are in competition for recall and thus resulting in low interference arising from its associative structure. Thus, interference can be produced by implicitly activated associates. The other source of interference is produced by the episodic study itself. Recall that the similarity of the interpolated task can have an effect on recall. When participants first study a list of words and then study additional word lists that are associatively or semantically related with the initial learning, recall performance declines more than engaging in unrelated interpolated tasks. Thus, this source of interference concerns the similarity of the interpolated activity. In the context of studying word lists, recall performance is lower when the interpolated lists are associatively related to the to-be-remembered list, i.e. specific interference compared to interpolated lists that are associatively unrelated to the target list, i.e. general interference. In a given study episode, both of these sources of interference are present. It is unknown whether manipulations of explicit sources of interference have an effect on implicit source of interference and vice versa. One of the aims of the present study is to examine the effects of interference generated by competitors on episodic recall and another aim is to examine the interference generated by the nature of the interpolated study and its influence on such competitor effects.

In order to understand what causes specific interference in episodic tasks, it is important to vary the type of interpolated activity in an experimental setting to see what disrupts performance. From a theoretical perspective, attention shifts and retrieval-induced inhibition accounts are two different approaches to explaining forgetting. The former makes predictions about recall performance on the basis of task similarity and task differences between the original learning and interpolated learning. The latter attributes memory performance to retrieval processes engaged in between original learning and final recall. In order to understand why the effects of competing associates disappear as in Nelson et al.'s (1993) study, there is a need to design an experiment that crosses retrieval practice with the relatedness of interpolated word lists. While pursuing this aim, this proposed study will help us understand the two sources of interference (explicit and implicit) and their effects on memory.

The goal of the present study was to investigate whether retrieval-practice would produce larger interference effects compared to study-only conditions and whether it would influence the effects of competing associates. Also, two sources of interference (implicit and explicit) will be examined. The stimuli consisted of words (targets) that were taken from Nelson, McEvoy & Schreiber's (1999) free association norms. Half of the study words in each target list had low competitor strength and the other half had high competitor strength. Word relatedness (related and unrelated) in the interpolated relatedness conditions and the nature of the interpolated activity (study only, study-test) were manipulated between subjects and the target competitors was manipulated within subjects. Also, there were two control groups, one of which received an immediate cued recall test and the other received 10 minutes of multiplication. This interval was equal to the retention interval for subjects who were tested on interpolated lists in between study and test. The former control determines the baseline performance for words that have few and many competitors. The latter control provides information on the effects of the math task on the competing associates. These control conditions aimed to replicate previous findings on competitor effects as a manipulation check on new lists. In experimental conditions, participants first studied the target word list, which was followed by some subjects studying two additional word lists and the other subjects studying and getting tested subsequently on two additional word lists. The study-only condition refers to the former one in which participants studied 3 lists of words and were tested on the first list. The study-test condition refers to the latter group in which participants studied the first list, then studied second list and got tested on second list, studied third list and got tested on third list and finally got tested on the original list. Interpolated word lists was a between subjects variable composed of related and unrelated words to examine the effects of relatedness on specific interference. In the test phase, subjects were given other words as cues that are associatively related with the targets according to Nelson et al.'s (1999) norms. The task of the participant was to recall the word that he/she saw in the study episode with the help of the cue provided.

It is hypothesized that if testing is crucial in elevating response competition, then there will be more forgetting observed in study-test condition compared to study only condition at the final recall. Moreover, the influence of relatedness was investigated. Broadly, the present study investigates whether the combination of testing and relatedness will increase response competition and thus result in larger specific interference effects. The status of competing associates was examined by comparing the magnitude of competitor effects in all conditions to determine which experimental manipulation disrupts their effects most. Previous research has found that the effects of competing associates are reduced only when multiplication problems were employed as a distractor task. The present study aimed at replicating this finding, and at determining whether the combination of studying and being tested on items in interpolated lists would produce similar results to math disruption. Larger specific interference effects induced by testing may be sufficient to eliminate competition generated by competing associates. Eliminating implicitly generated interference may be determined by both loss of context and by specific inhibition.

Method

Design and Participants

The design of the experiment was a 2x2x2 mixed-subjects factorial, with word relatedness (interfering lists were either related or unrelated to the targets) and test conditions (study-only and study-test groups) manipulated between subjects. Target competitors (many or few) were manipulated within subjects. Also, there were two control conditions (immediate test and test after 10 minutes of math problems) to determine whether the manipulation of target competitors works as expected. One hundred and twenty participants were recruited from University of South Florida's participant pool of undergraduate psychology students and they were given extra credit for their participation in the study. Ten participants were assigned randomly to each list of words in the experiment with a total of 20 participants per condition.

Materials

All of the words were chosen from Nelson et al.'s (1999) pool of word norms that are collected by using free association and are presented in Appendix A. Targets were the words that were studied by the participants and the cues were the words that were used to test memory for the targets. There were two main target lists (List1 and List 2) and one other target list (List 3) to serve as a third unrelated word list that was used in the experiment. Each list of words consisted of 24 targets, 12 of them having many competitors and 12 of them having fewer competitors. A target competitor is an associate of the target that is not connected to the test cue. Targets having fewer competitors had a mean of 4.25 competitors (SD=1.29) and targets having many competitors had a mean of 10.83 competitors (SD=3.98). The number of cue competitors (M=7.67, SD=6.05 and M=9.17, SD=4.73 respectively for few and many target competitors) was equated at each level of target competitors. The strengths of individual competitors were added in order to find the total competitor strength and then the average of this value was used to determine the competitor strength of a given list. Target competitor strength averaged .78 for the words that have many competitors and .32 for the words that have few competitors.

The words that comprise the target lists are associatively unrelated to each other. There is a unique word associatively related to each target and it serves as a cue to test the memory for that target. For example, if EXPERT is the target that is studied in the list, then NOVICE serves as the test cue to prompt memory for the target The forward strength (cue to target connection), backward strength (target to cue connection) and mediator strengths (connections between the cue and the target that are indirect via other words that link them) affect extra-list cued recall so in this experiment they were controlled at each level of target competitors. The strength values were pooled over the two lists of words. The pooled mean forward strength is .07 (SD=.02), mean backward strength is .02 (SD=.03), and mean mediator strength is .05 (SD=.08). These two lists are the ones that will be analyzed for specific interference and competitor effects. The test cues used in the present study were weaker than Nelson et al. (1993) study which had an average forward strength of .15 and backward strength of.10. Also another list of targets (List 3) is constructed to fill the need for a third unrelated word list in the experiment. List 3's forward strength is .07 (SD=.01), backward strength is .02 (SD=.03), and mediator strength is .02 (SD=.04). These three lists are associatively unrelated with each other and thus they will serve as unrelated lists in the experiment.

Two related interpolated lists were constructed for the two target lists (for List 1 and for List 2). These lists were made by choosing two associates of the target. For example, for the word EXPERT, BEGINNER and AMATEUR were selected respectively for the first and second interpolated list. If there is a test for the given interpolated list, then same cue will be used (e.g. NOVICE) to test memory for interpolated lists as used for the initial list so that changes in recall may not be attributed to different cues. These associates of the targets are also equated on both forward and backward strength at each level of competitor strength. For the targets with lower levels of competitor strength, forward strength averaged .14 (SD=.16), and .13 (SD=.19), respectively for the first and second interpolated list; for targets with higher levels of competition, these values are .15 (SD=.17), and .14 (SD=.19). Backward strength is also controlled at each level of target competitors (M=.02, SD=.04).

A four page booklet that has the multiplication problems was prepared. The numbers were written vertically to allow enough space for participants to work on multiplication. The numbers were generated randomly. The numbers in the booklet have two or three digits (e.g. 24x123=?). This booklet will be given to the participants that are in the 10 minutes of math disruption condition.

Procedure

Each participant was tested in individual sessions. Each word that is studied appeared individually for 3 seconds on a computer screen. The words were written in uppercase bold letters and were positioned in the middle of the screen.

Extra-list cued recall was used to test memory for words. In this task, participants study a list of words and then are tested on this list by presenting associatively related words at test. Study instructions for the word lists required the participants to read aloud a list of words on the computer screen and to remember as many of them as possible for later questions from the list. The form of the memory test was not mentioned. Before presenting the actual word list, there was a practice session in which names of people were presented so that participants could adjust to the presentation rate of the word lists. Immediately after the practice words, the actual experiment started and the participant followed the instructions of a given experimental condition. Presentation order of lists was counterbalanced. Interpolated lists were either related or unrelated to the list of targets and subjects were randomly assigned to one of these conditions. In order to control for the possible confound of time, i.e. to equate the retention interval equal for all the conditions, participants in the study-only condition studied the interpolated word lists twice (see Table 2).

Table 2. Layout for the study and the experimental conditions showing the time sequence for each of them

		Time					
Experimental conditions		t_1	t_2	t_3	t_4	t_5	t_6
Study-only	(Related)	$S^a{}_1$	S_2	S_2	S_3	S_3	$T^b{}_1$
	(Unrelated)	S_1	S_2	S_2	S_3	S_3	T_1
Study-test	(Related)	S_1	S_2	T_2	S_3	T_3	T_1
	(Unrelated)	S_1	S_2	T_2	S_3	T_3	T_1
Immediate Test		S_1	T_1				
Disruption		S_1 ---10 minutes of math problems-- T_1					

Note. Related indicates that the interpolated list is composed of words that are associates of the targets and unrelated indicates that the interpolated list is composed of words that are not associates of the target. Also, note that time (retention interval) was carefully controlled in this study.
[a]*Study of the numbered list*
[b]*Test of the numbered list*

In the study-only condition the participants first studied one of the target lists. At the end of the presentation of the targets, participants were told that either they would study another unrelated list of words or they would study a list of words related to the target words depending on whether they were assigned to unrelated or related word list conditions. They were told to concentrate on the second list they see and to try to remember them. They were not told that there is a memory test after the interpolated list of words. After the first interpolated list of words, they were told that they would see the same list again. Then, there was a second interpolated list and participants were given same instructions as with the first interpolated list of words except to concentrate on the third list of words. Similarly, the last interpolated list was also presented second time. After the presentation of the final word, instructions for the memory test were read to them. They were told that they would see words (i.e. cues) that are associatively related to the words that they saw in the first list (i.e. target list). Their task was to read the cue first and produce the word that comes from the first list and was semantically related with the cue. The test was paced at a 6 second rate.

The study and test instructions were the same in the study-test condition. The testing of interpolated-lists was timed (6 seconds for each word) so that the time between the study of the first list and the test of the first list was controlled (approximately 5 minutes for the two interpolated tests and a total of approximately 10 minutes of retention interval with study times and time to read instructions added all together). Participants first studied the list of targets. At the end of the target list, they were instructed to study the first interpolated list of words after which their memory for the interpolated list would be tested. Next, they studied the second interpolated list and were tested on that list. At the end, there wad a final cued-recall test from the first list that they studied. The cues used in the related condition were the same in all the tests whereas the cues used in the unrelated condition were different for each given interpolated list.

There were two control groups of participants one of which studied the target words and got an immediate extra-list recall test with the same study and test instructions. In the other control condition, participants studied the target list and at the end of the study phase, they were told that they would do a second very important task, which was related to speed of processing. They were handed a booklet that contained multiplication problems. The duration of the math test was 10 minutes to match the retention interval in the study-test condition. After 10 minutes of math problems, participants were given extra-list cued recall test instructions and were tested for memory for the targets. This test was self-paced to be comparable with the Nelson et al. (1993) study.

Results

The results are presented in Table 3 in which the probabilities of first list recall are shown for each condition. The overall recall was better in the immediate condition next best in the math condition and worse in the interference conditions that involve the use of words. Also, words that have few competitors were recalled best when there was no interference. This competitor effect was reduced with the induction of either math or word interference. Data were analyzed in a series of two factor ANOVAs in which the factors of interest were study conditions and competitors.

The immediate and the math conditions were control conditions to replicate the previous findings on competitor effects by using different materials. A 2x2 analysis of variance test restricted to the control conditions showed that main effects of competitors, $F(1,38) = 14.04$, $MS_e = .02$, and conditions $F(1,38) = 7.52$, $MS_e = .05$. Targets with few competitors were recalled better than targets with many competitors, and recall was better in the immediate condition than the math condition. The Conditions x Competitors interaction is also significant $F(1,38) = 5.68$, $MS_e = .02$. A Fisher's LSD of .09 indicated that competitor effects were present when participants' memory was tested immediately, however this advantage of having few competitors were eliminated with the math condition. This finding replicates the past results (Nelson et al, 1993) by showing that competitor effects were greater in the immediate condition than in the math condition.

Table 3

Probability of correct recall as a function of number of competitors, relatedness and distractor tasks

	Controls		Study-only		Study-test	
Number of competitors	Immediate	Math	Related	Unrelated	Related	Unrelated
Few	.60	.40	.27	.28	.31	.28
Many	.42	.36	.20	.22	.24	.20
MEAN	.51	.38	.24	.25	.28	.24

A 2 x 2 ANOVA restricted to the immediate and study-only conditions indicated the main effects of study conditions, $F(2,57) = 35.06$, $MS_e = .03$ and competitors, $F(1,57) = 18.08$, $MS_e = .02$. The interaction between study conditions and competitors was reliable $F(2,57) = 3.07$, $MS_e = .02$. As can be seen from Table 3, participants' overall recall was better when there was no disruption compared to related or unrelated study-only conditions which did not differ from each other(LSD = .08). Targets with few competitors were recalled better regardless of the study condition. However, there was a significant reduction in the competitor effect in study-only conditions compared to the immediate test control. The strength of competitor effects dropped from .18 (immediate condition) to .07 (study-only related) and .06 (study-only unrelated) (LSD = .08).

Another 2 x 2 ANOVA restricted to the immediate and study-test conditions indicated similar results as with study-only conditions. There was a main effect of study conditions, $F(2,57) = 25.27$, $MS_e = 0.03$ indicating that participants in the immediate condition recalled better than participants in the study-test condition (LSD = .08). There was a main effect of competitors, $F(1,57) = 22.47$, $MS_e = .02$ indicating that targets that had few competitors were recalled better than targets with many competitors. The study Conditions x Competitors interaction failed to reach significance, $F(2,57) = 2.50$, $p=.09$. However, same trend towards reduction of competitor effects can also be observed when the means are examined in Table 3. The magnitude of competitor effect dropped from .18 (immediate) to .07 (study-test related) and .08 (study-test unrelated) (LSD = .07).

A separate 2x2x2 analysis of variance was conducted between study-only and study-test conditions to investigate the effects of testing and relatedness. There was a main effect of competitors, $F(1,76) = 12.33$, $MS_e = .03$. Recall on targets with few competitors was better than recall on targets with many competitors. However, there was no effect of condition (study-only vs. study-test), no effect of relatedness, and no reliable interaction between them. Also, set size did not interact with any of the variables.

Finally a 5x2 ANOVA conducted on the interference conditions (math and word interference conditions) indicated that there was a main effect of study conditions $F(4,95) = 4.57$, $MS_e = .03$. An LSD of .08 indicated that highest recall was in the math condition whereas the word study or word study and test conditions did not differ from each other.

There was a main effect of competitors, $F(1,95) = 28.13$, $MS_e = .02$, however there was no reliable interaction $F = .13$, $p>.05$.

Discussion

Target competitors are the associates of the target that are not associatively linked to the cue. Targets that have fewer competitors and weaker competitor strength were found to have a recall advantage over those with many competitors, named the competitor effect (Nelson et al., 1993). The present study investigated the effects of testing on the competitor effects in extra-list cued recall. Specifically, the question of interest was whether the competitor effects would be eliminated as a function of different distraction tasks after the initial study. The findings replicated previous results on competitor effects (Nelson et al., 1993). Participants recalled words with few competitors better than words with many competitors. Overall recall was higher in the immediate condition and next highest in the math condition, and it was worse in study-only (mere study of interpolated lists) and study-test (study and test of interpolated lists) conditions. Competitor effects were present when participants' memory was tested immediately as well as when the participants either studied or studied and were tested on the interpolated lists, but not present when they did a math task. Neither testing nor the relatedness of the interpolated word lists changed the presence of the competitor effects as indicated by the unreliable interactions. However, there was a reduction in the magnitude of the competitor effects in all study conditions. These results indicated that both math and studying interference lists reduced the effects of competitor strength.

It was hypothesized that testing participants' memory for the interpolated lists might increase the amount of interference and thus reduce the recall advantage of words that have few competitors. Words that are the associates of the first list were used in the related interpolated lists and the participants either studied or studied and were tested on them. Words that have few competitors were recalled better than words that have many competitors regardless testing on the interpolated study lists. Thus, the results of the present study found no support for the proposed hypothesis. Testing the interpolated lists did not produce more interference compared to merely studying the interpolated lists. The size of the competitor effect was about the same for study-only and study-test conditions.

The results of the present study showed that there was no difference in the overall recall between the conditions which participants studied the interpolated words or participants studied and got tested on them. Testing interpolated items seems to be not different than merely studying them. This finding is interesting because, retrieval-induced forgetting paradigm predicts that when participants get retrieval practice on related items to the targets, targets get inhibited and thus they are recalled poorly. However, there was no support for a retrieval-induced forgetting mechanism in the present study.

The present study failed to find retrieval induced forgetting effects in the extra-list cuing task. The amount of forgetting was independent of the retrieval practice, which is contrary to the findings by recent studies on retrieval induced forgetting (Anderson, 2003). One reason for this result is that the nature of extra-list cued recall task is different than the standard retrieval-induced forgetting paradigm. An obvious difference between the two paradigms is that in the interpolated tests, RIF paradigm uses stem completion which enables participants to recall the desired target word (e.g., Fruit – Or____). However, in cued recall test, participants receive the meaning cue but not the initial letters of the target and thus they do not always recall the specific word given the cue. Hence, one may argue that the memory for first list words were not inhibited strongly in the interpolated study-test phase, because participants did not recall the word they studied in the interpolated lists at a high recall rate (M=.35). In contrast, the stem completion task used in RIF paradigm yield a higher recall rate. This difference is a limitation of the present study although strongly related cue-target pairs were used in the interpolated lists so that the memory for the words in those lists would be better.

Another difference between the RIF paradigm and the present study is the type of words used. The standard RIF paradigm uses category exemplar pairs. It is quite possible that the use of category exemplar pairs may be a special case. Categories and their exemplars may be related in a special way. In addition, the words used in a given list of the present study were unrelated to each other and when related words were studied, they were studied in a different list. In contrast, a single word list in a RIF paradigm is composed of related word lists (e.g., participants study the category members of “Fruit”: “apple”, “orange”, “banana”, etc.). This difference in the way relatedness was manipulated may be contributing to the obtained results. Manipulating the relatedness intra-list or inter-list may produce different outcomes in terms of the amount of inhibition or interference produced. This possibility remains to be determined. Moreover, the presentation of the study items was different among two tasks. Category exemplar pairs were shown on the screen in RIF paradigm whereas only the target word was studied in the extra-list cuing task and the cue word was shown at the test phase. The RIF procedure is more similar to intra-list cuing task where target and the cue pairs are studied together. Nevertheless, the focus of the present study was to investigate the possibility that the results of Nelson et al. (1993) study might be due to the absence of test trials, thus extra-list cuing task was more appropriate in order to answer this question.

In terms of the theoretical model of PIER, the results of the present study are important. PIER assumes that explicit and implicit representations are independent. The results of the present study indicated that the explicit representation seemed to be affected by the similarity of the task. Overall recall was better in the math condition compared to word study/test conditions. Hence, as the similarity between the original task and the interpolated task increased the amount of general interference increased and thus yielded lower recall. This difference may partly rest on the list length effect. At least in the free recall task recall on longer lists is worse compared to shorter lists (Yonelinas, 1994). Participants studied 24 words in math condition however they studied 72 words in the other distraction conditions. This difference in the number of words studied might have caused general interference effects and thus might have made the overall recall worse compared to word learning tasks. In addition, multiplication of numbers uses different types of processing than working with words. From an interference theory perspective more interference would be expected when the original and interpolated tasks are similar (i.e., studying words and studying other words as a distractor task). However, the results of the current study failed to show any specific interference effects. Related words did not produce more interference than unrelated words. The related versus unrelated manipulation was used in an attempt to produce response competition by using associatively related words as competitors to the target in interfering lists. These results also replicate Nelson et al. (1993) study, which also failed to find specific interference effects. From these results it seems that response competition is an inadequate explanation for forgetting observed in these experiments. The response competition account predicts more forgetting should be observed when the interpolated lists were related compared to unrelated lists because competition is higher when the words are related to each other. However, no differences between related or unrelated interpolated words were found.

The implicit representation seemed to be affected more by the delay between the study and the test, because there was a reduction of the competitor effects in all disruption conditions. Nelson et al. (1993) claimed that task related attention shifts were the main causes of the reduction in competitor effects because the math task eliminated such effects but studying additional word lists did not. Contrary to this claim, the present study found that word study reduced competitor effects. The benefits of the implicitly activated information may depend more on the interval between study and test than on attention shifts per se. In order to see the effects of retention interval on competitor effects, there is a need to conduct a study by varying different retention intervals. The expectation would be that with longer retention intervals competitor effects would be further reduced. One reason why the present results may differ from earlier findings is that time was controlled carefully in the present study. In the Nelson et al (1993) study the retention interval in the math condition was longer than the retention intervals used in the list study conditions.

It is crucial to point out the role of context in implicit memory. It is well known that shifts in context disrupt explicit recall of events (Godden, & Baddley, 1975).The present study provided support for these findings. Words that have few competitors still kept their recall advantage when participants switch to a conceptually different task such as multiplying numbers. However, the magnitude of this advantage was smaller compared to the tasks that maintain the focus of attention such as studying other words. According to PIER, an explicit representation (episodic study of the word) and the implicit representation (activated associative information) are both encoded in a certain context and thus it is important to recover context information for successful recall. When there is a need to allocate attentional resources to a conceptually different task, a shift in the mental and environmental context occurs and accessibility to the original study episode is reduced because of this change (Nelson, & McEvoy, 2005). Such a reduction in access occurs because the demands of an earlier task may be irrelevant to the demands of a new task and thus earlier context becomes less accesible. Hence, what is activated during the study episode (i.e., associative structure of a word) may be harder to re-access. For example, suppose that a person studies a list of words and then is given multiplication exercises immediately after the study. He/she needs to put the study context on hold while doing the multiplication task, because study of the words has no relevance with multiplying numbers. Hence, accessibility to the study context is weakened when that person switches to a conceptually different task. It is assumed that such a process occurs automatically and out of the awareness. If, however, participant studies other word lists after the initial study, there is a relationship between them. Specifically, studying different word lists are not irrelevant to each other although they constitute slightly different contexts. Thus, PIER predicts that study or study and test of additional word lists should not affect the benefits of implicitly activated information, because they involve using similar conceptual resources and thus do not produce a strong change of context. The results of the present study gave weak support to these predictions of PIER. Disruptions that involved words reduced the magnitude of competitor effects, a finding that is contrary to PIER's predictions. Forgetting might have caused some by loss of access to previous or to-be-remembered context and also more by the delay between study and test. The amount of time passes seemed to be the most important factor in determining the magnitude of loss in implicitly activated information such as competitors. However it is not the only factor because the overall recall performance in math task was better compared to study interference conditions. Also, the results of the present study found that forgetting in cued recall did not depend on an inhibition process as RIF suggests.

Future studies can look at the effects of testing on implicit memory by using intra-list cuing task. In this task, target and the cue pairs are shown together in the study phase. This procedure is more alike to the way participants study category – exemplar pairs in retrieval induced forgetting (RIF). Also, the list statistics for the experiments done in RIF paradigm should be investigated in terms of the strength of the relationship between category and exemplar pairs. Previous studies controlled only printed frequency. Target competitors, cue competitors or the strength indexes may increase or decrease the amount of interference. Finally, the present study used words not categories as stimuli. It is possible that when category and exemplars are used, standard RIF effects may be evident.

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Appendices

Appendix A. Word lists used in the experiments

Appendix A

Materials for List 1

TARGETS[3]	Interpolated Lists: FIRST	Interpolated Lists: SECOND	TEST CUES
LAST	FINISH	END	FINAL
INSECT	BITE	FLY	MOSQUITO
DECAY	ROT	DETERIORATE	DECOMPOSE
YOUTH	CHILD	KID	ADOLESCENT
MINUTE	SECOND	TIME	MOMENT
SIGHT	SEE	BLIND	VIEW
GLUE	STICK	STICKY	STICKER
INTELLGENT	SMART	DUMB	WISDOM
SAND	OCEAN	BEACH	ISLAND
CORRECT	WRONG	MISTAKE	ERROR
PEPPER	SALT	SEASONING	SPICE
JOG	RUNL	WALK	EXERCISE
AWAY	FAR	NEAR	DISTANT
APARTMENT	HOUSE	ROOM	BALCONY
BRAIN	CELL	TUMOR	NERVE
ORIGINAL	NEW	COPY	UNIQUE
COAT	JACKET	SWEATER	VEST
WIRE	CORD	TELEVISION	CABLE
MONSTER	BUG	UGLY	BEAST
STRING	ROPE	THREAD	KNOT
STEAK	MEAT	FOOD	GRILL
INNOCENT	CRIME	COURT	VICTIM
DUCK	HUNT	BIRD	QUAIL
AWKWARD	FUNNY	STRANGE	CLUMSY

[3] The first 12 targets have few and the last 12 have many competitors

Appendix A (continued)

Materials for List 2

Interpolated Lists

TARGETS[4]	FIRST	SECOND	TEST CUES
HAMMER	TOOL	SCREWDRIVER	WRENCH
LAUNDRY	SOAP	WASH	DETERGENT
CANOE	SWIM	BOAT	RIVER
DICTIONARY	WORDS	ENCYCLOPEDIA	ALMANAC
GEM	JEWEL	STONE	RUBY
ISOLATED	ALONE	LONELY	SECLUDED
ORCHESTRA	VIOLIN	INSTRUMENT	CELLO
AFFECTION	KISS	LUST	HUG
STOP	START	BEGIN	HESITATE
AIRPORT	PLANE	TRIP	BAGGAGE
MOM	DAD	MOTHER	PARENTS
RICH	POOR	WEALTH	FORTUNE
DECORATION	HOLIDAY	CHRISTMAS	ORNAMENT
COLD	FLU	HOT	FEVER
ARCHITECT	BUILDING	PLAN	BLUEPRINT
GLASS	WINDOW	MIRROR	PANE
INSURANCE	COMPANY	GOVERNMENT	AGENCY
METER	YARD	MEASURE	MEASUREMENT
HALL	CORRIDOR	ENTRANCE	LOBBY
WRITE	PEN	PENCIL	NOTEBOOK
CASTLE	PALACE	KNIGHT	DUNGEON
METAL	IRON	GOLD	SCRAP
SCULPTURE	MOLD	ART	CLAY
EXPERT	BEGINNER	AMATEUR	NOVICE

[4] The first 12 targets have few and the last 12 have many competitors

Appendix A (continued)

Materials for List 3

TARGETS[5]	**TEST CUES**
CANDLE	WICKER
WHITE	BROWN
CIRCLE	CYLINDER
MIDGET	GIANT
DESERT	SAFARI
PRECISE	SPECIFIC
AUTHOR	TITLE
LUST	PASSION
MOIST	DEW
ROBIN	SPARROW
INTERSTATE	FREEWAY
THIN	WIDE
ADVICE	SUGGESTION
ANXIETY	STRESS
DENY	ADMIT
DRIVER	TAXI
FLOWER	WEED
JOINT	KNEE
MICROSCOPE	TELESCOPE
POLITICIAN	GOVERNOR
PANTS	POCKET
STORE	CUSTOMER
TRAIN	WAGON
WOLF	FANGS

[5] The first 12 targets have few and the last 12 have many competitors