Interference Resolution in Retrieval-Induced Forgetting: Behavioral Evidence for a Nonmonotonic Relationship Between Interference and Forgetting

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Abstract

Retrieving memories renders related memories less accessible. This phenomenon, termed retrieval-induced forgetting (RIF), is thought to be the result of processes that resolve interference during competitive retrieval. Several studies have manipulated the level of interference to test different theoretical accounts of RIF (e.g. inhibitory vs. non-inhibitory). However, the nature of how interference and RIF are related has not been systematically investigated. Here, we introduce a design that allows for assessing interference during competitive retrieval through measuring recall RTs associated to target recall. Using such a design, we found that RIF occurred only when interference during competitive retrieval reached moderate levels, but not when it was too low or too high. This finding might indicate that low levels of interference do not trigger interference resolution, whereas interference resolution might fail when interference reaches extremely high levels.

Keywords: retrieval, forgetting, retrieval-induced forgetting, interference, inhibition

Interference Resolution in Retrieval-Induced Forgetting: Behavioral evidence for a nonmonotonic relationship between interference and forgetting

Interference as a cause of forgetting has long captured the interest of scholars of memory. One specific question that has resurfaced in scientific discussions concerns the way interference during memory retrieval is resolved (for a review of interference theories from this perspective, see for instance Anderson & Bjork, 1994). The focus in these discussions was not solely on how interference causes memory failures during retrieval. Rather, it centred around the consequences of interference resolution. What happens to memory representations when a target memory is to be retrieved in the face of competing memories? How do we achieve retrieval of the correct target memory, and what happens to competing memories?

In a seminal paper, Anderson (2003) suggested an executive process – analogous to response override – that resolves interference by weakening memory representations that interfere with target memories at the time of recall. This weakened representation would be evident in the decreased probability of recall of the interfering memory when it is tested at a later time. This model was the first to hypothesize an active executive process that can act to weaken memory representations so that these memories become less accessible for retrieval.

Early on, Anderson, Bjork, and Bjork (1994) devised a procedure, the retrieval practice paradigm, that could separate a recall phase at time *t*, when interference from competing memories has to be resolved, from a recall phase at time *t+1*, when the accessibility of these competing memory representations can be measured. In this paradigm, participants are shown several category–member word pairs (e.g. animal–tiger, furniture–couch, animal–chicken, etc.) then practice retrieval of half of the members from half of the categories with category plus stem cues (e.g. animal – ti...?). Anderson and colleagues (1994) reasoned that, during retrieval practice, non-practiced members of practiced categories (e.g. chicken) interfere with the recall of practiced members, and therefore have to be inhibited.

This should be evident from later testing, and that is exactly what they found: participants' recall of non-practised members of practised categories was worse than their recall of members of categories that had not appeared in the retrieval practice phase. Anderson and colleagues (1994) termed this effect retrieval-induced forgetting (RIF).

Inhibition, in this theoretical approach, is a process that operates when a relatively strong competing item interferes with the retrieval of a target memory. This approach involves three testable properties of RIF that are relevant for our study. First, RIF is interference-dependent, i.e., only items interfering with the retrieval of a target memory would suffer inhibition. Second, RIF is retrieval specific, i.e., manipulating target strength without retrieval of the target does not induce competition-based forgetting. Third, RIF is strength-independent, i.e., even when targets are retrieved, target strength does not influence RIF (e.g. Anderson, 2003). Together, these assumptions imply that RIF is the product of executive processes that resolve interference during competitive retrieval.

The Relationship Between Interference and Interference Resolution

Although interference dependence of RIF seems to be well established, we know little about how interference resolving processes operate in the face of increasing interference. Proponents of different inhibitory accounts of RIF conceive this relationship quite differently. Anderson (2003, p. 421) suggests that: 'The more strongly associated to the category an unpracticed competitor was, the more impairment was found'. This implies a linear function between interference and the result of inhibition: the more an item interferes with retrieval, the more inhibition it suffers.

Bäuml, Pastötter, and Hanslmayr (2010, p. 1049) suggest that 'very low levels of interference may not trigger inhibitory processes when competing material is retrieval practiced', but otherwise the strength of interference a competing item causes during retrieval has only a minor role in defining the level of forgetting. In their interpretation, inhibition would be a process that kicks in only when interference reaches a certain threshold. They also theorise that, over this threshold level, the effect of inhibition does not change significantly with increasing interference.

Norman and colleagues (2007) programmed a neural network model of RIF in which increasing competitor strength increases the effect of inhibition, but, over a certain point, can lead to a decrease in its success, (i.e., a decrease in RIF). Similarly, Anderson and Levy (2010) suggested that there is a positive linear relationship between the level of interference and inhibition demand, and a negative linear relationship between the level of interference and inhibition success. Together, these opposing relationships lead to a demand-success trade-off where very low levels of interference do not lead to RIF because the level of inhibition demand remains low, whereas interference can reach a level over which inhibition cannot be effective, resulting in above baseline facilitation of competitors. The carryover assumption put forward by these authors states that RIF would be seen only for items that induce moderate levels of interference.

The lack of knowledge about the function relating interference to forgetting makes it hard to design tests that try to tap properties of RIF. Take a study that tries to provide evidence for interference dependence by including a group of items with strong taxonomic frequency (supposedly inducing large interference) and another with low taxonomic frequency (supposedly inducing small interference) (e.g. Anderson et al., 1994; Williams & Zacks, 2001). This study would reliably provide significant RIF differences between these two groups if the relationship between interference and forgetting was a simple linear one, as suggested by Anderson (2003). In the case of a threshold-like interference resolution process, suggested by Bäuml et al. (2010), differences will only be found if the low taxonomic frequency words do not achieve a certain threshold where inhibition kicks in. Moreover, if inhibition causes forgetting to decrease over a certain level of interference, as predicted by

Norman et al. (2007) and Anderson and Levy (2010), one might see no differences between the two groups because one of them does not cause interference at all, while the other one causes too much interference. Studies using factorial designs might obtain contradictory results (see, for instance, Anderson et al. (1994) vs. Williams & Zacks (2001)) simply because the groups of words chosen to be causing large or small interference are chosen on an arbitrary basis and without any knowledge of the underlying relationship between interference and the effect of interference resolution.

Another advantage of understanding how the effect of interference resolution changes as interference increases would be to design tests that are more sensitive to detect RIF. Such tests could focus only on memories that truly caused interference during memory retrieval, and thus are expected to suffer the results of interference resolution. Such sensitive tests would be very useful in settling some hot debates about the nature of interference resolving processes in memory, e.g. to clarify whether RIF generalises to novel, independent cues (for positive evidence see e.g. Aslan, Bäuml, & Pastötter, 2007, Levy, McVeigh, Marful, & Anderson, 2007; Saunders & MacLeod, 2006, for negative evidence see e.g. Camp et al., 2007; Perfect et al., 2004)..

Item-by-Item RIF

Our goal in this study was to develop a test that can give an indication of how RIF changes as a function of competition during retrieval. Therefore, we needed a design that could provide data on how retrieval of each memory item is affected by interference during the retrieval practice phase. We set two objectives to achieve this goal. First, the design should be such that each item has an individual competitor which interferes with it. Second, we needed to collect data that at least indirectly informs us about the amount of interference a memory item suffers during its retrieval in the retrieval practice phase. For this second purpose we chose reaction times (RTs) of target memory retrieval during the retrieval practice phase.

Reaction times have been used to measure the level of interference caused by competing representations or processes, among others, in negative priming (Tipper, 1985), repetition priming (Rajaram, Srinivas, & Travers, 2001), and the stop signal reaction time task (Logan & Cowan, 1984). Blaxton and Neely (1983) showed that RTs to generate the target exemplar were faster if the participant first read other exemplars from the same category compared with reading exemplars from a different category. However, the RTs were slower if the participants had first generated other exemplars from the same category.

Reaction time data has rarely been collected in RIF studies. Anderson (2003, p. 439) has suggested that 'when the measure of interference is reaction time, the presence of multiple competitors or a single strong competitor should slow the recall of a target'. Indeed, RTs have been used in RIF studies to measure the magnitude of the RIF effect (e.g. Racsmány & Conway, 2006; Veling & Knippenberg, 2004; Verde & Perfect, 2011).

In a similar vein, RTs have been used to measure interference during retrieval practice. One study (Levy et al., 2007, experiment 2) split subjects into two groups according to the interference a memory suffered during retrieval practice. In this study, participants had to name pictures in their second language, and were tested later on using the same pictures in their first language. Levy and colleagues median-split their participants along the overall RT differences between their performance in first and second language. They suggested that slower naming performance in the second language compared with the first language indicates poorer knowledge of the second language. Based on this, they hypothesised that participants with larger RT differences will need to resolve a larger interference from the first language when having to name pictures in their second language than participants who have a better knowledge of their second language. This would lead to larger RIF among poorer speakers than in the other group. This is exactly what they found.

Kuhl, Dudukovic, Kahn, & Wagner (2007), measured RTs and activation in prefrontal areas during retrieval practice, and correlated the amount of RIF with the decrease of these measures from first to third practice cycle. They found that the decrease of prefrontal activations, but not RTs, correlated positively with forgetting of interfering memories. It is important to note that such a reduction is more a measure of successful interference resolution than a measure of interference per se.

Here, we used a variation of the retrieval practice paradigm introduced by Anderson et al. (1994) with only two items sharing the same category cue (and competing for retrieval) in every category. We did not manipulate interference in a factorial design, rather we used retrieval practice RTs as an independent variable to assess the magnitude of interference. Of course, we do not assume that retrieval RTs only reflect interference. They are influenced by several other factors such as target strength, number of competitors, etc. In the methods section, we discuss how we tried to control variability of these potential factors.

Using such an item-by-item RIF we intended to reproduce the findings supporting interference-dependence of RIF and to better understand how interference and the forgetting effect caused by interference resolution are related.

Method

Participants. Sixty-four students (age M = 21.81 years, SD = 2.12, 32 women) participated in the experiment for credit in partial fulfilment of introductory psychology courses at the Budapest University of Technology and Economics. Participants were tested individually in a quiet room in sessions that lasted for a maximum of 30 minutes. Due to a computer error one participant could not complete the test phase. This participant's data were excluded from the analyses.

Materials. We used 22 categories with two members in each category, making up a list of 44 wordpairs. To induce the competitive retrieval supposed to be necessary to produce RIF, and to avoid moderation of the RIF effect (see Anderson, 2003), we followed strict selection criteria. To produce any RIF effect, it was essential to have items in a category that would interfere with each other. Integration has been shown to counteract the RIF effect robustly (Anderson & McCulloch, 1999) and reducing the number of elements in a category increases the chances of integration (e.g. Camp et al., 2007). Since we used only two members per category we had to take care to reduce the chances of integration.

Frequency and association data were drawn from the open-source Frequency Dictionary of the Hungarian Webcorpus, developed by BME Média és Szociológia Tanszék - Média Oktatási és Kutató Központ (Media Research Centre at the Department of Sociology and Communications of Budapest University of Technology and Economics) (BME-MOKK, 2003). For a full description of the database, see Halácsy et al. (2004) and Kornai et al. (2006). We included categories that were not associated to each other (either semantically or phonetically), and that were themselves of moderate frequency. Category labels and targets were neutral words. Category members were moderate frequency words, and within their category they had a moderate to high relative frequency. Too typical category members and rare ones were both excluded. No member from a given category was associated to another member in another category nor were they members of another category. We made an effort to choose the two members of one category from different subcategories. To avoid cues that would uniquely refer to one target in semantic memory during the test phase, the first letter of each target could also be completed to at least one other low or moderate frequency category member that did not appear in the experiment. In contrast, to avoid extraexperimental interference during retrieval practice, we excluded words of which the first two letters could be completed to another category member not seen in the experiment. The first two letters had a moderate versatility, i.e., a moderate number of words could be generated from the same two letters from semantic memory. We made an effort to reduce the number of words of which the first two letters made up or included a syllable of the word.

After filtering possible material through these selection criteria we had a list of 88 words, four words belonging to each of the 22 categories. In order to reduce item-based confounds in the RT data, we wanted to create a final list that produces the least variation in baseline retrieval RT. To this end, we ran a pilot study in which participants learned all 88 category–member pairs, then performed retrieval practice on all items once. To obtain the final list to be used in our experiment we excluded two items per category based on the results of retrieval practice in this study. Based on recall RTs, we excluded words that produced RTs that were either more than one SD away from the group mean, or differed substantially (more than 1000 ms) from the group mean RT of their category. Based on recall accuracy, we excluded words that were recalled by every participant in the pilot, and words that were recalled by less than 33 percent of participants (ca. the lower and upper deciles of the 88 words) (see the Appendix for the list of wordpairs used.)

We used Presentation (Version 14.1 Build 09.21.09) for presentation of stimuli and preanalysis of the data.

Design. Out of the 22 categories, two were used to provide filler items, 10 were categories from which no members were retrieval practised (Nrp categories, and Nrp targets). From the other 10 categories (Rp categories) one member (Rp+) was practised during retrieval practice, leaving the other member non-practised (Rp-). Members of the Nrp categories were divided into Nrp+ and Nrp- items. These served as baselines for the Rp+ and Rp- items respectively. For each participant, categories (except filler categories) were randomly assigned to category types (Nrp vs. Rp) and members of each category (except filler items) were then randomly assigned to item types (+ vs. -). Fillers were the same categories in each experiment.

Procedure. Participants went through four phases of the experiment; a study, a retrieval practice, a delay, and a test phase. In the study phase, participants were shown all 44 category-member pairs once on a computer screen, and were asked to remember the members with the help of the category cues. In each trial a category word appeared to the left of the middle of the screen together with one of the words from that category to the right of the middle of the screen. The wordpair was shown for 3000 ms followed by a 500 ms intertrial interval (blank screen). We opted for such a short presentation of wordpairs in order to further decrease the possibility of integration of items from the same category. The study list was pseudorandomly shuffled for each participant with the constraint that the same category could not appear within five consecutive trials. Presentation of the study list started and ended with two filler category–member pairs. When the study phase was finished participants immediately received the instructions for the retrieval practice phase. This phase consisted of three cycles. In every cycle all Rp+ items were retrieval practised once in a random order. In each trial participants saw a category cue to the left of the middle of the screen and the two-letter stem of the Rp+ member of the category. Their instruction was to try to recall and report the correct answer. They were asked to press the response button (the Enter key on the keyboard) as soon as they had the answer in mind. In order to have a valid measure of how fast an item comes to mind (and not just a measure of category familiarity or feeling of knowing), we told participants that we were curious about how fast they could recall memories, and instructed them to act as if in a TV quiz show, where they can loose points if they press the response button but cannot come up with an answer immediately. After pressing the button they were asked to type in the answer. They had 8 seconds for this. If they pressed the response button or exceeded the time limit they were shown the subsequent trial.

Participants had six seconds in the first cycle to report that they knew the answer, and four seconds in the following two cycles. If they did not press the response button, the next trial was introduced. The retrieval phase also started and ended with two filler trials.

After retrieval practice, participants engaged in a five-minute two-back task. This served as a delay before test.

The test phase consisted of 44 trials that tested memory for all category members. This phase also started and ended with two filler items. Trials were the same as in the first retrieval practice cycle except that the category-plus-word-stem cue contained only a first-letter stem of the category member. In order to avoid output interference effects (Anderson, 2003), the test phase involved two blocks. Rp- items and their controls were tested in the first block followed by Rp+ items and their controls in the second block. Items were randomly intermixed within both blocks. The use of different control items for Rp+ and Rp- items was necessary to circumvent baseline deflation (Anderson, 2003).

Results

During analysis we used an alpha set to .05. We corrected for multiple comparisons using Bonferroni correction. Retrieval practice success rate was 85%, 86%, and 89% in the three practice cycles, respectively. Final recall performance can be seen in Table 1.

(Table 1 about here)

To test whether our retrieval practice manipulation was successful we performed a one-way repeated measures ANOVA on final recall data with four levels of item type: Rp+, Nrp+, Rp-, Nrp-. Item type had a significant effect on final recall, $F(3,186) = 88.11$, $p < .001$. To test for the beneficial effect of practice on practised items, and the detrimental effect of practice on recall of competitors, we performed two post-hoc tests. Recall of Rp+ items was significantly better than recall of their Nrp+ baseline, $t(62) = 15.31$, $p < .001$, $r = .89$. Recall of Rp- items was significantly lower than recall of their Nrp- baseline, $t(62) = 2.46$, $p = .034$

(Bonferroni-corrected), $r = .30$. This shows that our item type manipulation was successful, and that it provided a strong practice effect and a medium size RIF effect.

The primary target of our investigation was the relationship between recall RTs of Rp+ items during practice and later recall of their Rp- competitors. We analysed first cycle RTs only because we assumed that variance in interference, and thus in the RT data is the largest in the first practice cycle, and is smoothed out during further practice.

In order to rule out cheating (i.e., pressing the button when the participant does not know yet the answer), we analysed typing time (the time that elapsed between two Enter presses: the first indicating that the participant knew the response, and the second indicating they finished typing) for each participant. This analysis showed that no participant had individual outliers in typing times, therefore all successfully recalled Rp+ items were included in the analysis.

Within each participant we ranked Rp+ items by their RTs measured in the first practice cycle. Then, based on their rank, we split Rp+ items into tertiles with fast, moderate, and slow RTs. For each tertile we calculated the recall rate of the corresponding Rp- items at the final test (see Figure 1).

To test which of the Rp- tertiles contributed to the RIF we ran an ANOVA on final recall data with four levels of item type ($Rp\text{-}_{1.tertile}$, $Rp\text{-}_{2.tertile,}$ $Rp\text{-}_{3.tertile,}$ Nrp-). In this analysis, Mauchly's test of sphericity was significant, *Mauchly's W* = .81, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Item type had a significant effect on final recall, $F(3,186) = 2.85$, $p = .042$. Planned contrasts (Bonferroni-corrected) showed that RIF was significant only for items corresponding to second tertile Rp- items (corresponding to Rp+ items with moderate RT), $F(1,62) = 9.73$, $p = .006$. Rp- items corresponding to Rp+ items with fast and slow RTs also showed a lower recall compared to baseline, but these differences were not significant, $F(1,62) = 0.57$, $p = .99$, for Rp- items corresponding to Rp+ items with fast, and $F(1,62) = 2.28$, $p = .41$, for Rp- items corresponding to Rp+ items with slow RTs.[1]

To assess the nature of the relationship between interference and the result of interference resolution we conducted a repeated measures ANOVA on Rp- recall with first cycle Rp+ recall RT (Fast vs. Moderate vs. Slow) as a within-subject factor. There was a trend toward an effect of Rp+ RT on recall of Rp- items, $F(2,124) = 2.17$, $p = .118$, which was due to a tendency toward a quadratic trend in final recall data, $F(1,62) = 3.78$, $p = .057$, indicating that there is one change in the direction of the relationship between Rp+ RTs during retrieval practice and recall rate of the corresponding Rp- items at final test.

(Figure 1 about here).

Discussion

We found practice and RIF effect with a variant of the retrieval practice paradigm that involved only two members per category. This was a novel finding that showed that the materials and the design adopted here did not allow for integration of the two category members, an effect that might mask RIF (e.g. Anderson, 2003).

Retrieval of target memories induced forgetting of competing items only when targets were recalled with moderate retrieval RTs. RIF did not occur for competitors of memories that were either recalled too fast or too slow. This suggests that processes resolving

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[1] Originally, we had run the experiment with 32 participants. In this original experiment final recall percentages (SEs in parentheses) for $Rp-_{1.tertile}$, $Rp-_{2.tertile}$, $Rp-_{3.tertile}$, and Nrp- items were .46 (.05), .38 (.06), .44(.05), .51(.04), respectively. Rp- recall was significantly below baseline only for second tertile items with moderate practice RTs, $t(31) = 2.35$, $p = .038$, one-tailed (Bonferroni corrected). Because this experiment was, in essence, exploratory, in order to see that this result was not a Type I error, we extended the experiment with the inclusion of another 32 participants. Logically, this was an extension rather than a replication of the original experiment (same material, same university population, same lab, same assistant). The pattern of results obtained from this extension replicated the results of the original experiment, and the extended experiment provided greater power in detecting the same effect: only second tertile Rp- items were recalled below baseline, $t(62) = 3.16$, $p = .006$ (Bonferroni corrected). Data presented here is pooled from all 63 participants (as described above, one participant's data were excluded from the analyses).

interference during recall lead to forgetting when retrieval attempts produce moderate levels of interference.

Crucially, we showed that it is only a subsample of memories that contribute to the RIF effect. Choosing the right sample of items to be included in the analysis might be critical in detecting the RIF effect. This can guide further investigations of the boundary conditions of RIF, for instance, when designing studies that test the cue-independence of RIF.

As for the exact nature of the relationship between target recall RTs and later recall of competing memories our study is not conclusive. Our data suggest that the direction of the relationship between interference and the recall of interfering memories changes at one point from negative to positive. This would then support the suggestion that RIF is an inverted U-shaped function of interference (Norman et al., 2007; Anderson & Levy, 2010). However, since this was supported by only a statistical tendency, strong conclusions are not warranted.

One weakness of our study is that it is hard to find three data points that would lead to rejection of a U-shaped function. A better test of this type of relationship would be to analyze final recall data binned into quartiles instead of tertiles. However, the number of items in our study was too low to provide enough power to detect such an effect if data was split to more than three bins.[2]

Future studies could clarify several further issues raised by our results. For instance, retrieval RTs are not only affected by the magnitude of interference retrieval processes have to resolve during retrieval, but are influenced by a range of factors, such as target strength and the strength of the association between category cues and targets, or the relative strength

[2] Binning our data into quartiles did reveal a U-shaped pattern of final recall (SEs in parentheses): .50 (.04), .41 (.04), .44(.04), .48 (.04) for $Rp\text{-}_{1.quartile}$, $Rp\text{-}_{2.quartile}$, $Rp\text{-}_{3.quartile}$, $Rp\text{-}_{4.quartile}$, respectively. Only second and third quartile Rp- items differed significantly from Nrp- recall ($p = .013$, for $Rp\text{-}_{2.quartile}$, and $p = .042$, for $Rp\text{-}_{3.quartile}$). However, these comparisons do not survive Bonferroni correction. Also, this analysis did not have enough power to detect a quadratic trend in the data ($F(1,62) = 1.98$, $p = .164$). We thank one anonymous reviewer for drawing our attention to this problem.

of targets and competitors. To assess the differential contribution of these factors to interference during retrieval would require new methodologies.

Another interesting issue is that the use of RT data made it impossible to analyse the effect of interference during unsuccessful retrieval attempts. Storm, Bjork, Bjork and Nestojko (2006) showed that even unsuccessful Rp+ retrieval contributes to Rp- forgetting. Therefore, an experiment that uses a measure of interference that can be collected for both retrieved and non-retrieved Rp+ items might be a significant addendum to the pattern of results presented here.

We provided converging evidence for the interference dependence of RIF, and suggest that interference resolving processes are causing forgetting of interfering memories at moderate levels of interference. This might provide evidence for both the theoretical model based on the carry-over assumption of Anderson and Levy (2010) and the computational model of Norman et al. (2007) that state that the supposed nonmonotonic function relating interference to forgetting is the sum of two linear monotonic functions. One positive, relating interference and inhibition demand, and one negative relating interference and success of inhibition. Although our results seem to be in line with these theories, there are two caveats to be mentioned here. First, as noted earlier, converging evidence is necessary to refute either of the models describing the relationship between interference and forgetting. Second, nothing in our data suggest that the process resolving interference involves inhibition at all. Replicating our findings with independent cues would be a strong indication of the role inhibition plays in resolving interference.

The leap of thought introduced in the seminal paper of Anderson and Bjork (1994) was the shift of attention from interference as a cause of forgetting to the consequences of interference resolution (Anderson, 2003). Our results support the view that the amount of interference plays a role in how retrieval probabilities of related memories are shaped for later retrieval. Our study also highlights the fact that using factorial designs alone might not be sufficient to fully understand the mechanisms of interference resolution. In recent years we have gained considerable knowledge about how the brain implements interference resolution at the systems level (e.g. Kuhl et al., 2007; Wimber, Rutschmann, Greenlee, & Bäuml, 2009). The approach and results presented here might contribute to a better understanding of interference resolution at the level of cognitive processes.

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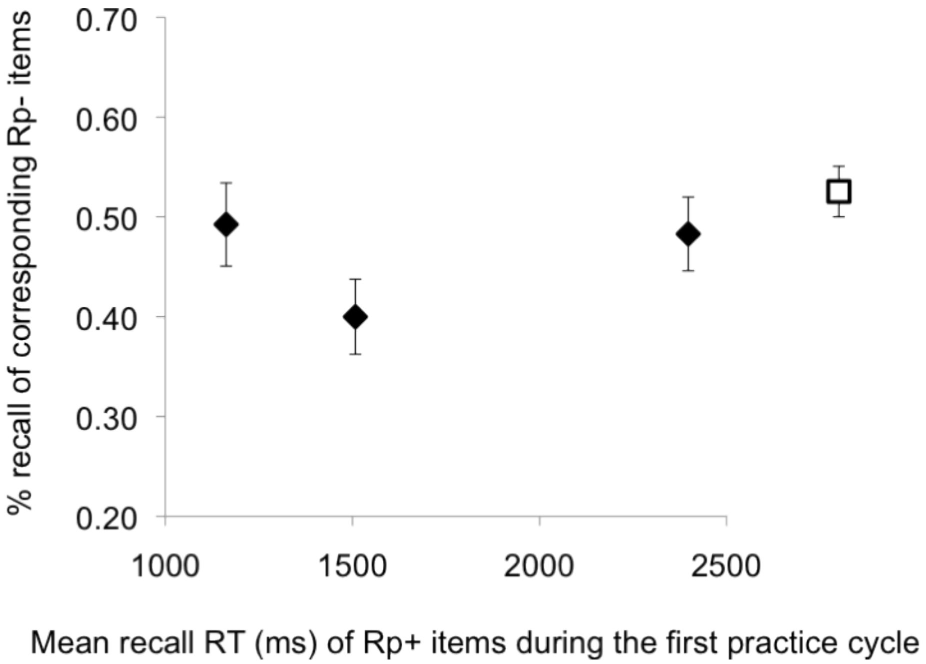
Table 1

Mean Recall Percentages at Test for the Four Item Types

	Item Type			
	Rp+	Nrp+	Rp-	Nrp-
M	.82	.45	.46	.53
SD	.17	.19	.19	.20

Figure 1. Recall of Rp- Items at Test as a Function of Rp+ Recall RTs during the First Cycle of the Retrieval Practice Phase



Note. The empty rectangle on the right represents average Nrp- (the baseline for Rp- items) recall. Data is grouped into three tertiles according to Rp+ RT during the first practice cycle. Rp- recall was significantly below baseline only for Second tertile items with moderate practice RTs. Error bars represent standard error of the mean.

Appendix

English translation of the categories and target words used in the experiment (The original experimental material was Hungarian).

category cue	**target member**
bird	gull
bird	pelican
body part	elbow
body part	front
cloth	gloves
cloth	pajamas
drink	hot chocolate
drink	lemonade
fish	herring
fish	trout
flower	geranium
flower	lily
fruit	ananas
fruit	prune
game	dominoes
game	hide-and-seek
illness	allergy
illness	cold
insect	butterfly
insect	tick
job	model
job	soldier
kitchen utensils	microwave
kitchen utensils	whisk
mammal	bear
mammal	elephant
material	aluminium
material	concrete
musical instrument	harp
musical instrument	synthesizer
nature	cliff
nature	swamp
office utensil	calculator
office utensil	xerox
spice	marjoram
spice	parsley
sports	horse riding
sports	triathlon
weapon	rifle
weapon	spear
country*	Argentina*
country*	Bulgaria*
tools*	pliers*
tools*	screwdriver*

Note. * indicates filler categories, and filler items.