Shinshu University Journal of Educational Research and Practice, *No.12*, pp. 63-73, 2018
信州大学教育学部研究論集　第12号　pp. 63-73　2018年

<Report>

Occlusion or Unlearning:
Which Types of Interference Cause Retrieval-Induced Forgetting?

ISEKI Ryuta　Faculty of Psychology and Sociology, Taisho University
SHIMADA Hideaki　Faculty of Education, Shinshu University

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

1. Introduction

Memory retrieval can suppress the subsequent recall of related material. This phenomenon, known as retrieval-induced forgetting, involves the selective retrieval of certain items, and this process later results in impaired recall of related items (Anderson, Bjork, & Bjork, 1994; Anderson & Spellman, 1995). Retrieval-induced forgetting is typically induced and observed using a three step procedure. First, in a study phase, participants learn lists of category-exemplar pairs (e.g., fruit-orange, fruit-banana, instrument-guitar, instrument-drum). Next, in the retrieval practice phase, participants complete tests with cued-stems (e.g., fruit-or____) for half of the items from half of the studied categories. Following a distracter task, participants are asked to recall all category-exemplar pairs presented during the experiment. Typically, practiced items (e.g., orange) show the highest level of recall, whereas non-practiced items (e.g., banana) in practiced categories are remembered at a lower rate than non-practiced items in non-practiced categories (guitar or drum). This pattern has been shown in a variety of situations including eyewitness memory (Shaw, Bjork, & Handal, 1995), impression formation (MacLeod & Macrae, 2001; Macrae & MacLeod, 1999), and visuospatial materials (Ciranni & Shimamura, 1999).

Some progress has been made in elucidating the mechanisms underlying retrieval-induced forgetting. Anderson (2003) and colleagues (Anderson & Bjork, 1994; Anderson & Neely, 1996) proposed that retrieval-induced forgetting was not due to interference at the recall phase, but was instead due to inhibitory mechanisms. Theories involving memory interference would predict cue-dependent forgetting, that is, forgetting would depend on associative links through retrieval cues to competitors. In support of Anderson's proposal that retrieval-induced forgetting is due to inhibitory mechanisms, the phenomenon has been found to be cue-independent (Anderson & Bjork; Anderson & Neely). Indeed, the effect has been observed when different cues are used for study phases than for test phases (e.g., fruit for studying orange, but round for testing the same item), and numerous studies have replicated the cue-independent nature of forgetting (Anderson & Bell, 2001; Anderson, Green, & McCulloch, 2000; Anderson & Spellman, 1995; Johnson & Anderson, 2004; but see also, Williams & Zacks, 2001). Given the strong empirical

support for the cue-independent nature of retrieval-induced forgetting, it appears this phenomenon is not due to interference at the recall phase.

A second rationale in support of the inhibitory explanation for retrieval-induced forgetting comes from the dependence of the phenomenon on selective retrieval during the retrieval practice phase (Anderson, Bjork, & Bjork, 2000; Bäuml, 2002). As demonstrated in various studies, the process of selective retrieval is thought to cause retrieval-competition (see Anderson & Bjork, 1994; Anderson & Neely, 1996 for reviews), which subsequently generates inhibition of responses. For example, when retrieval practice was replaced by a presentation of the original studied items (Bäuml, 2000), or practice of each category name (Anderson, Bjork et al., 2000), no inhibition effect was found. Moreover, Anderson et al. (1994) demonstrated that retrieval-induced forgetting was dependent on the taxonomic frequency of the words, with the effect present only when to-be-inhibited items were high frequency words, but not when they were low frequency words. This difference was thought to result because the high frequency words caused more competition during the practice phase, and thus required more inhibition to suppress their responses. Taken together, these findings support the idea that retrieval-competition is necessary for the inhibition effect to occur.

Though Anderson (2003) has rejected interference as an operator of suppression at the recall phase, this does not rule out interference during the retrieval practice phase. Indeed, if there were no interference during retrieval practice, there would be no need for inhibition of the interfering items. Anderson characterized this property of forgetting as "interference dependence". However, it remains unclear as to what type of interference yields this inhibition effect. In the present study, we examined the specific types of interference involved in retrieval-induced forgetting: Occlusion and unlearning.

Previous research has suggested that the type of interference present is important in terms of encouraging the inhibition effect. Anderson and colleagues (e.g., Anderson, 2003; Anderson et al., 1994; Anderson, Bjork et al., 2000) proposed that retrieval-induced forgetting results from inhibitory processes that arise to resolve retrieval interference. The inhibition effect is thought to depend on the degree to which the to-be-inhibited items interfered with retrieving the practiced items (Anderson et al., 1994). This type of interference is akin to occlusion; the intrusion of items that have strong associations with the retrieval cue (see Anderson & Bjork, 1994; Anderson & Neely, 1996). Figure 1 illustrates how the process of the occlusion-type interference would occur during the retrieval practice phase. Retrieving only a subset of items creates competition with the remaining items, and reciprocal inhibition is required to resolve the competition. Thus, occlusion-type interference would be stronger in situations where there is more intrusion during the practice phase, and depends on the effect of non-practiced items. The taxonomic frequency of to-be-inhibited items has been found to increase retrieval competition (Anderson et al., 1994),

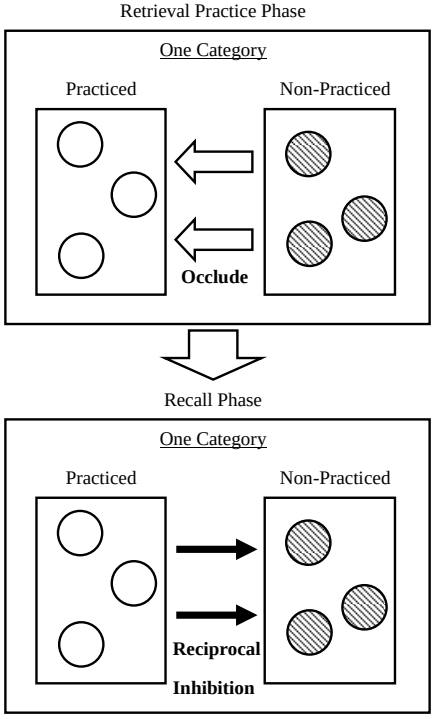

Figure 1. A schematic of the processes underlying occlusion-type interference in a practiced category, and the resulting retrieval inhibition. Retrieving the practiced items (white circles) competes with repeated intrusions of the non-practiced items (shaded circles). Blocked arrows indicate occlusion in action. To resolve the retrieval-competition, inhibition (black arrows) of the non-practiced items is required. Thus, the amount of inhibition of the non-practiced items with this type of interference depends on the action of the non-practiced items themselves.

though other researchers have failed to replicate these results (Williams & Zacks, 2001).

In addition to occlusion, some literature has indicated that increasing the amount of retrieval practice leads to increased inhibition (Johnson & Anderson, 2004; Macrae & MacLeod, 1999). This type of interference is similar to unlearning. As practiced items are strengthened, the recall of competing items (i.e., to-be-inhibited items) is decreased. In the present study, this mechanism was assumed to eventually inhibit target representations per se rather than decrease associations to their retrieval cue, as has been previously assumed (Anderson & Bjork, 1994; Anderson & Neely, 1996). Figure 2 illustrates how retrieving some items would cause rejection of the remaining items, resulting in unilateral inhibition. Unlearning-type interference would increase as the number of retrievals of the practiced items increased. Thus, more retrieval practice would cause more unlearning and eventually more inhibition for competing representations. Unlike occlusion interference, this unlearning type of interference would depend on the action of the practiced items. Of note, previous findings concerning the amount of practice necessary for this unlearning interference have not been particularly robust, showing inconsistent results across differing material or non-significant trends (e.g., Johnson & Anderson, 2004; Macrae & MacLeod, 1999).

To investigate whether occlusion-type, unlearning-type, or both types of interference play

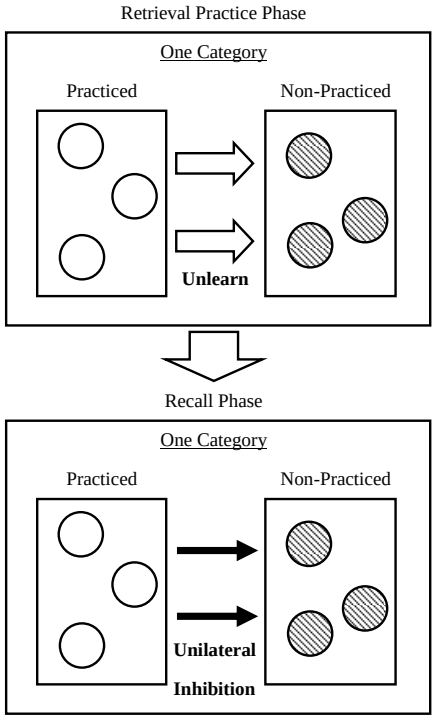

Figure 2. A schematic of the processes underlying unlearning-type interference in a practiced category, and the resulting retrieval inhibition. Retrieving the practiced items (white circles) unlearns or deactivates the non-practiced items (shaded circles). Blocked arrows indicate unlearning, and this action results in subsequent inhibition at recall phase (black arrows). Thus, the amount of inhibition of the non-practiced items here depends on the action of the practiced items.

a role in the inhibition effect, two types of practiced categories were compared in the present study: those with 4-practiced items and 2-non-practiced items, and those with 2-practiced and 4-non-practiced items. By manipulating the number of practiced items in the category, the effect of the practiced and non-practiced items on the inhibition effect could be determined. Figure 3 illustrates the possible results. If occlusion-type interference is the primary determinant of forgetting, the categories with 2 practiced items (2-practiced categories) should cause more suppression than the categories with 4-practiced items (4-practiced categories) because the former condition has more possible intrusion items (i.e., non-practiced items) than the latter. Alternatively, if unlearning-type interference influences inhibition, the 2-practiced categories should produce less recall impairment than the 4-practiced categories because the former condition has fewer chances to inhibit the non-practiced items relative to the latter condition.

The difference in the total amount of practice in each condition should be noted. Although the 4-practiced categories have less non-practiced items than 2-practiced categories, simultaneously, the former condition has double the practice times of the latter category. Thus, there should be no difference in 4- and 2-practiced categories if both types of interference affect performance equally.

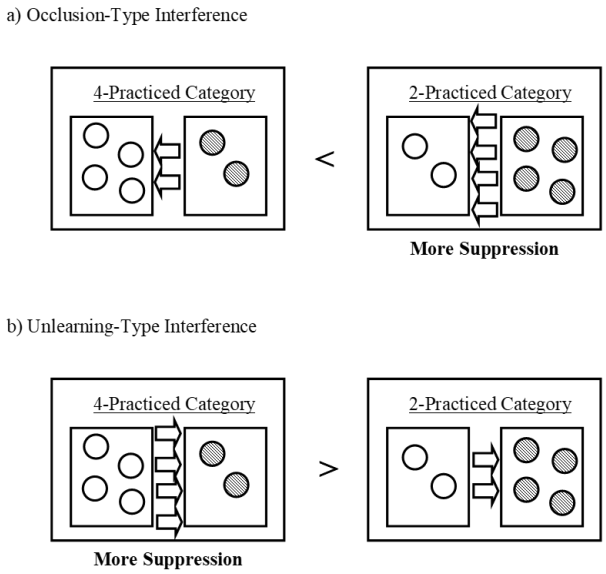

Figure 3. Illustration of the difference in action of inhibition effects at the retrieval practice phase for the 4- and 2-practiced item categories depending on the type of interference involved (occlusion- vs. unlearning-type interference).

2. Method

Participants and Design

Fifty-five Japanese undergraduate students (24 male and 31 female) participated to fulfill a psychology course requirement. This experiment had a single-factor (number of practiced items per category: 0, 2, or 4) within-participants design.

Materials

Ten taxonomic categories were used from Japanese category norms (Ogawa, 1972). For each category, six exemplars were selected with moderate to high taxonomic frequency. Every exemplar within a category began with a unique two-letter combination. Eight categories served as experimental sets, and the remaining two served as filler sets, which were included to control for primacy and recency effects.

All of the above described category-exemplar pairs (i.e., 48 experimental and 12 filler items) were printed in a learning booklet, with one category-exemplar pair was printed on each page (e.g., fruit apple). The pairs were ordered by block randomization (see Anderson et al., 1994 for details). Only one exemplar from each category appeared in each block. Therefore, 10 items from different categories formed a block. The order of items within a block was randomized with the restriction that the first and last items were always filler items.

Selected items for practice were printed in a retrieval practice booklet. The eight experimental categories were divided into two non-practiced and six practiced categories. Eight items in the two non-practiced categories served as baseline items (non-practiced items in

non-practiced category) and the remaining four items served as filler. The six practiced categories were further separated into two conditions: Four categories had 4-practiced items and two categories had 2-practiced items. This format was selected for two reasons. First, some categories would have more potential members than other categories. As a result, recall performance for the items from the larger categories could potentially be worse than those from the smaller categories simply due to differences in the number of possible items to recall from each category (Murdock, 1960). Manipulating the ratio of practiced and non-practiced items in the categories would facilitate comparisons to baseline items easier. Second, having twice as many categories with 4-practiced items equated the number of non-practiced items in 4- and 2-practiced categories, resulting in equivalent statistical power. Consequently, there were eight non-practiced items in both 4- and 2-practiced categories. For a parallel comparison, only eight items from the non-practiced baseline categories were used in data analyses. Changing the assignment of items from practiced or non-practiced in practiced categories, or to non-practiced categories created eight sets of retrieval practice booklets which were assigned in order to every eight participants.

A category name plus two-letters-stem cue (e.g., fruit ap___) was printed on each page in the 60 page retrieval practice booklets. Every practiced item was tested three times. The order of the items was randomized in blocked fashion analogous to the study booklets. No two items from the same category were presented successively. Items in filler categories were used to meet this constraint and to control for primacy and recency effects. Mazes were presented during the distracter phase.

Test booklets contained one category name on each page. The filler categories were presented on the first and last page, and the remaining eight experimental categories made up the rest of the pages. One of two test booklets was randomly assigned to each participant, with the order of the eight experimental categories differentially randomized across the two booklets.

Procedure

The procedure generally followed that of Anderson et al. (1994) and consisted of four phases: study, retrieval practice, a distracter period, and the final recall test. In the study phase, participants turned over each page and learned each category-exemplar pair for 5 s by relating each exemplar to their category name.

In the retrieval practice phase, the participants were asked to recall and write down the studied item indicated by the two-letters-cue paired with a category name. They were allowed 10 s to complete the one item presented on each page, and were told that items would be tested several times, and that they should try to recall the correct item each time. After completing all retrieval practice trials, the participants performed a paper-and-pencil maze task for 5 min.

In the final recall test, the participants were required to recall and write down all of the items that they had studied in this experiment. The participants recalled the studied items in

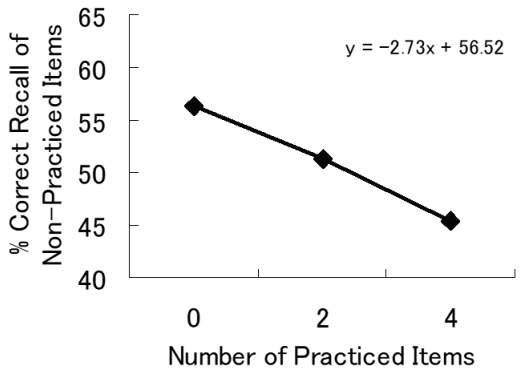

Figure 4. Percentage of non-practiced items correctly recalled in a final recall test as a function of the number of retrieval practiced items in each category.

response to the category name printed on each page. They were given 30 s to complete each category.

3. Results

Retrieval-practice success rates for the 4- and 2-practiced categories were 98.8 and 97.4%, respectively. To examine the presence of inhibition effects in the 4- and 2-practiced categories, a single factor (number of practiced items: 0, 2, or 4) within-participants ANOVA was conducted on the final recall test performance of the non-practiced items. The number of practiced items in the category significantly affected recall performance, $F(2,108) = 5.77$, $MSe = 284.06$, $p < .004$. Post hoc analyses using a Newman-Keuls test indicated that the non-practiced items in the 4-practiced categories were remembered at a lower rate (M = 45.5%) than those in the non-practiced baseline categories (M = 56.4%), $p < .003$. This inhibitory effect was in the same direction, but was not significant for the comparison between the average recall for 2-practiced categories (M = 51.4%) and baseline categories (M = 56.4%). The difference between the 4- and 2-practiced categories showed a trend toward significance (Ms = 45.5% vs. 51.4%, $p < .07$). These patterns appeared to be consistent with the hypothesis that only unlearning-type interference operates in retrieval-induced forgetting.

Although the pattern of recall rates suggested that unlearning-type interference contributed to the performance, it would be possible that occlusion-type interference also affect performance. To examine this possibility, we conducted a regression analysis on the recall rates of the non-practiced items as a function of the number of practiced items in each category (see Figure 4). If occlusion-type interference contributed to recall performance, recall rates would not have a linear relationship with the number of practiced items. This is because occlusion-type interference increase with the number of the non-practiced items. We used a regression procedure for repeated

design (Lorch & Myers, 1990). The analysis revealed that the regression coefficient was significant, $t(54) = -3.33$, $p < .002$. Increasing the number of items practiced in a category monotonically increased the inhibition effect for the remaining non-practiced items. Therefore, the effect of unlearning-type interference alone satisfactorily accounted for the pattern differences observed in recall accuracy.

Retrieval practice also produced a facilitation effect for the practiced items, $F(2,108) = 55.94$, $p < .001$. Post hoc analyses (Newman-Keuls) showed that practiced items in both the 4- and the 2-practiced categories (*M*s = 75.9% and 80.0% respectively) were remembered better than the non-practiced items in baseline categories ($M = 45.0\%$, *p*s < .001 for both comparisons). The facilitation effect did not differ significantly across the 4- and 2-practiced categories ($M = 75.9\%$ vs. 80.0%, ns). Thus, the degree of strengthening with practice did not differ between these two conditions.

Of note, an alternative explanation for retrieval-induced forgetting has been proposed in several previous studies (e.g., Anderson, 2003; Anderson et al., 1994; Anderson & Spellman, 1995). The explanation holds that the observed inhibition effect might be due not to forgetting, but instead to output interference. According to this view, retrieval practice strengthens the accessibility of the practiced items, so that these items are produced earlier than the non-strengthened, non-practiced, items during the final test phase. In this case, the earlier production of the practiced items might interfere with the recall of the remaining non-practiced items in the same category.

To confirm that the present results were not due to output interference, the participants were classified by the order in which they had produced the practiced items, as per the methodology of previous studies (see MacLeod & Macrae, 2001; Macrae & MacLeod, 1999; Macrae & Roseveare, 2002). Recall sequences for the final test were specified for each participant and the recall positions of each item were numbered in order. Then, difference scores were calculated by subtracting the average recall-position-number of the practiced items from those of the non-practiced items in the practiced categories. The higher the difference score, the greater the number of practiced items that were produced earlier in the sequence. Separating the participants based on the median of the scores, the inhibition effect for the two groups was compared. The inhibition effect was computed by subtracting the proportional recall of the baseline items (i.e., the items in the non-practiced categories) from the non-practiced items in the practiced categories. This analysis demonstrated that the group with the earlier practiced items did not produce more inhibition relative to the group with the later practiced items in both the 4- and the 2-practiced conditions. For the 4-practiced condition, $M = -1.14$ early and $M = -0.61$ late, $t(53) = 1.03$, ns. For the 2-practiced condition, $M = -0.23$ early and $M = -0.55$ late, $t(53) < 1$, ns. In addition, the difference scores, which were assumed to reflect the degree of output interference, were not dissimilar between the 4- and 2-practiced conditions, *M*s = 0.55 and 0.69 respectively, $t(54) < 1$, ns.

Thus, if any output interference were to exist, it did not affect the critical comparison in the present study.

4. Discussion

The regression analysis for the recall rates of the non-practiced items showed a linear relationship with the number of practiced items. This suggests that retrieval-induced forgetting depends on the number of practiced items, rather than the number of non-practiced items in a category.

The present results supported the hypothesis that an unlearning-type mechanism underlies retrieval-induced forgetting. According to the two process explanation of retrieval-induced forgetting, interference during retrieval practice would cause unlearning of competing items. However, unlike the original unlearning explanations offered (Anderson, 2003; Anderson & Bjork, 1994; Anderson & Neely, 1996), this unlearning-type process would extinguish or decrease the accessibility of competing representation directly, rather than affecting their associative links to the retrieval cues. This finding requires previous inhibitory explanations to be modified in one point: Retrieval-induced forgetting occurs by interference that is like unlearning, as inhibitory action by the practiced items during retrieval practice can account for the effect. Occlusion-like interference, which depends on non-practiced items, does not appear to play a role.

The current study was able to obtain different degrees of inhibition by changing the retrieval practice states of just two items across experimental categories. In contrast, previous studies in which practice times were manipulated from one to six or eight times have not shown decisive results (Johnson & Anderson, 2004; Macrae & MacLeod, 1999). Although all studies have manipulation of practice time in common, the present study differs from previous studies in terms of whether or not the same items were retrieved repeatedly. It is possible that retrieving the same items repeatedly would not provoke more interference with each repetition because the items remain highly accessible as a result of earlier practice. Thus, there might be less need for retrieval and less resultant interference as items repeat. Or, if retrieval competition suppresses some aspects of the competing representations that interfere with the practiced items, repeated practice of the same items would inhibit limited features of the competing representations, provided that items were represented in a distributed fashion in memory (Anderson, 2003; Anderson, Green, et al., 2000). Practicing various items, as was done in the present study, would eliminate these two possibilities.

Given the findings in the present study that only unlearning-type interference operates in retrieval-induced forgetting, the question of why taxonomic frequency of to-be-inhibited items produced an effect in previous research (Anderson et al., 1994) remains. One possibility is that low frequency words may elicit baseline deflation (Anderson, 2003). That is, the low frequency words

might be less strongly related to their category label than high frequency words. Thus, at the final recall test, they would be cued less by their category name, thereby decreasing the recall rates in the non-practiced baseline categories. On the contrary, the to-be-inhibited items might be primed by presentations of the category labels during the retrieval practice phase. This would increase their accessibility. Consequently, it might become difficult to detect the inhibitory effect with low frequency words. If this were the case, the failure to replicate the cue-independent nature of the effect might be partly attributable to the same reason (Williams & Zacks, 2001).

Anderson (e.g., Anderson, 2003; Anderson et al., 1994) proposed that retrieval-induced forgetting was regulated by characteristics of the to-be-inhibited items, not that of the practiced items. The present findings suggest that this conclusion is not always accurate. However, it remains to be seen whether the characteristics of the practiced items themselves affect the inhibition effect. It may be the relationship between the practiced and non-practiced items rather than the characteristics of each item that govern the retrieval dynamics. If unlearning-type interference is critical for inhibition, and if inhibition is independent of the characteristics of either practiced or non-practiced items, the more chances for inhibition there are, the more inhibition should emerge. The idea that forgetting is independent of characteristics of practiced and non-practiced items is consistent with the view that assumes interference and inhibition are two separate processes.

References

Anderson, M C. (2003). Rethinking interference theory: Executive control and the mechanisms of forgetting. *Journal of Memory and Language, 49,* 415-445.

Anderson, M. C., & Bell, T. (2001). Forgetting our facts: The role of inhibitory processes in the loss of propositional knowledge. *Journal of Experimental Psychology: General, 130,* 544-570.

Anderson, M. C., & Bjork, R. A. (1994). Mechanisms of inhibition in long-term memory: A new taxonomy. In D. Dagenbach, & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 265-325). San Diego: Academic Press.

Anderson, M. C., Bjork, R. A., & Bjork, E. L. (1994). Remembering can cause forgetting: Retrieval dynamics in long-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1063-1087.

Anderson, M. C., Bjork, E. L., & Bjork, R. A. (2000). Retrieval-induced forgetting: Evidence for a recall-specific mechanism. *Psychonomic Bulletin & Review, 7,* 522-530.

Anderson, M. C., Green, C., & McCulloch, K. C. (2000). Similarity and inhibition in long-term memory: Evidence for a two-factor model. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26,* 1141-1159.

Anderson, M. C., & Neely, J. H. (1996). Interference and inhibition in memory retrieval. In E. L. Bjork, & R. A. Bjork (Eds.), *Memory: Handbook of perception and cognition* (pp. 237-313).

San Diego: Academic Press.

Anderson, M. C., & Spellman, B. A. (1995). On the status of inhibitory mechanisms in cognition: Memory retrieval as a model case. *Psychological Review, 102,* 68-100.

Bäuml, K.-H. (2002). Semantic generation can cause episodic forgetting. *Psychological Science, 13,* 356-360.

Ciranni, W. A., & Shimamura, A. P. (1999). Retrieval-induced forgetting in episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 1403-1414.

Johnson, S. K., & Anderson, M. C. (2004). The role of inhibitory control in forgetting semantic knowledge. *Psychological Science, 15,* 448-453.

Lorch, R. F., & Myers, J. L. (1990). Regression analyses of repeated measures data in cognitive research. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 149-157.

MacLeod, M. D., & Macrae, C. N. (2001). Gone but not forgotten: The transient nature of retrieval-induced forgetting. *Psychological Science, 12,* 148-152.

Macrae, C. N., & MacLeod, M. D. (1999). On recollections lost: When practice makes imperfect. *Journal of Personality and Social Psychology, 77,* 463-473.

Macrae, C. N., & Roseveare, T. A. (2002). I was always on my mind: The self and temporary forgetting. *Psychonomic Bulletin & Review, 9,* 611-614.

Murdock, B. B. Jr. (1960). The immediate retention of unrelated words. *Journal of Experimental Psychology, 60,* 222-234.

Ogawa, T. (1972). 52 kategori ni zokusuru go no shutsugen-hindo-hyo [Normative data for verbal items in 52 categories]. *The Journal of the Literary Association of Kwansei Gakuin University, 22,* 1-60.

Shaw, J. S., III, Bjork, R. A., & Handal, A. (1995). Retrieval-induced forgetting in an eyewitness-memory paradigm. *Psychonomic Bulletin & Review, 2,* 249-253.

Williams, C. C., & Zacks, R. T. (2001). Is retrieval-induced forgetting an inhibitory process? *American Journal of Psychology, 114,* 329-354.

（2017年11月 1日　受付）
（2018年 1月18日　受理）