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Incorrect Answer in Pretest and Memory Fixation

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In schools, tests are given mainly to evaluate learning achievements. Receiving a test is also known to promote learning and long-term retention of memory. Recently, even incorrect test answers have been revealed to improve scores in later evaluation tests（pre-test effect）. To develop an effective teaching method by using the pre-test effect, it is necessary to understand how the effect differs between individual students depending on their characteristics. However, it has not been investigated whether the pre-test effect in promoting long-term retention of memory differs by the characteristics of students or not. In this study, the authors examined whether the pre-test effect appeared or not in a paired-associate learning task of new words, which has been widely used in studies on learning, by using Japanese stimulus words（Experiment 1）. Then, the working memory capacity of each student was measured as an index for personal characteristics, and the effects of the personal difference on pre-test effect was investigated（Experiment 2）. The experiments showed that the group that experienced pretest scored better in a subsequent evaluation test than the group that did not receive a pretest, confirming the pre-test effect as in preceding studies. However, no relationship was found between the pre-test effect and working memory capacity. Therefore, the pre-test effect is possibly a phenomenon independent of working memory capacity.
Key Words: memory, pre-test effect, paired-associate learning, incorrect answer, working memory

Topic and objectives

In schools, tests are given to evaluate the acquisition of knowledge and/or skills. In studies on memory, recall and recognition tests have been used as indices to evaluate performances. Besides being a tool for assessing performances, testing is also known to be as effective as repetitive learning for students to memorize information. This phenomenon is called the "testing effect", and has been widely investigated (Endo, 2007; Richland & Karpicke, 2006; Tajika, 2008).

Effects of succeeding and failing a test on memory fixation

The first question is whether answering a correct or incorrect answer in a test is more effective. In terms of behaviorist learning theories, incorrect test answers were believed to compete with correct answers (stimulus words to be answered in an evaluation test) and inhibit retention of memory. Thus, only correct pre-test answers were believed to promote memory retention. However, incorrect answers, or recalling wrong information, have recently been found to promote learning of correct information. Kornell, Hays, & Bjork (2009) and Richland, Kornell, & Kao (2009) conducted experiments consisting of paired-associate learning tasks of two words (cue word and target word to recall at an evaluation test, e.g. "tide" and "beach") that were not mutually deeply related and reported that the "pre-test effect", which involved recalling incorrect information, was observed. They divided the participants into Pretest and No-Pretest groups, assigned them paired-associate learning tasks, and conducted an evaluation test of recalling the target words based on cue words. For each cue word, the pretest group received a pretest to find an associated word (e.g. wave). The evaluation test score of the pretest group was significantly better than that of the no-pretest group. In the study by Kornell et al. (2009), word pairs were used as stimulus words. Similar results have also been reported by a study in which the subjects read a prose and later tested for the contents (Richland et al., 2009) and a study that compared evaluation test scores between groups subjected and not subjected to pretest on university lecture (Butler & Roediger, 2007).

No consistent knowledge has been acquired on the generation mechanism of the pre-test effect; but two theories have been proposed: 1) an associated word acts as a mediator between the cue word and target word, and 2) an associated word stimulates elaboration. According to the mediator theory, pretesting assists recalling an associated word from the cue word, from which the person recalls the target word, and thus enhances memory (Pyc & Rawson, 2010). On the other hand, the elaboration theory hypothesizes that retrieval from the cue word activates a search set of candidates of the meaning covering an associated word and the target word and the activation promotes recalling of the target word (Grimaldi & Karpicke, 2012; Hays, Kornell & Bjork, 2013).

Personal difference factors affecting the pre-test effect

Another question is whether there is pre-test effect for all persons or not regardless of their personal characteristics. There has been no study that directly investigated the effects of individual difference on memory promotion of correct information by retrieval of incorrect information, i.e. the pre-test effect. Related studies include the following ones.

Monitoring ability. If memory is promoted only by retrieval of correct information from a set (network) of candidates containing various information as mentioned by Grimaldi & Karpicke (2012) and Hays et al. (2013), the pre-test effect should vary depending on the ability of an individual to judge whether the information is correct (the one demanded) or not. Source monitoring ability is one of the abilities involved in making such judgment and is believed to be supported by working memory. Working memory is a cognitive system indispensable for complicated cognitive activity and is in charge of simultaneous processing and remembering of information. The capacity of working memory is limited and is commonly measured by a span test. Because the results of a span test is related to those of higher cognitive activities such as language processing, reasoning and problem solving, working memory is believed to be a mechanism that supports such cognitive functions (e.g. Osaka, 2006; Tsuchida, 2009).

False memory has been investigated by using various paradigms. It has been shown that persons who have larger working memory have better source monitoring ability and are less prone to false recalling and false recognition. According to Leding (2012), this is because a person having a large working memory can monitor the information source in his or her memory more correctly than a person who has a small working memory and thus is capable of judging correct learning during a retrieval process that is liable to cause false memory.

Based on this theory, the pre-test effect observed during a task that requires judging whether information included in a retrieval network is correct (one demanded) or not is expected to be similar to the results of the studies on false memory. The effect of memory promotion by pretest is likely to be larger in persons who have larger working memory and higher source monitoring ability than in their counterpart.

Use of strategy. Personal differences in strategies used for performing a task are known to affect the scores of span test for measuring working memory (Endo & Osaka, 2012; Saito & Miyake, 2000). Endo & Osaka (2012) compared the strategies used by participants while they performed a reading span test between low- and high-working memory span groups. The high-working memory span group used efficient strategies more frequently than the low-working memory span group. This suggests that a person who is scored to have small working memory is just not capable of selecting an effective strategy for remembering. Actually, the score of span test has been reported to have increased by training use of effective strategy (McNamara & Scott, 2001).

Based on the results, for people having small working memory, the Pretest condition, in which they are provided with a strategy of generating incorrect information, is likely to better promote memory retention than the No-Pretest condition, in which they have to devise a strategy for remembering. On the other hand, people having large working memory use their own effective strategies and are thus expected to score high also in the No-Pretest condition. Therefore, the differences in score between the No-Pretest and Pretest conditions would be larger in the low-working memory span group.

Objectives of this study

With such a background, this study was conducted aiming to investigate the effects of personal working memory difference on pretest effect. If the memory promotion effect by pretesting is larger in the high-working memory span group than in the low-working memory span group, the mechanism of pre-test effect may involve source monitoring for discriminating correct information from incorrect one. It will also suggest that pretesting is not an effective method for enhancing memory retention for people having small working memory, who are believed to have low source monitoring ability. On the other hand, if the difference in score between the No-Pretest and Pretest conditions is larger in the low-working memory span group than in the high-working memory span group, the pretest may have presented a strategy for remembering and can be concluded to be effective for people having small working memory. If pretesting enhances memory retention in all persons regardless of their working memory capacity, pretesting can be concluded to be a memory retention strategy for which individual difference does not need to be considered. In all cases, it is important to investigate personal difference factors that affect the pretest effect in order to develop new teaching methods.

Experiment 1 was first conducted by preparing stimulus words in Japanese and performing a test similar to that of Kornell et al.（2009）as a preliminary test to decide a list of stimulus words that are appropriate to investigate the pretest effect in subsequent experiments. In Experiment 2, the working memory of the participants was measured to classify them into the low- and high-working memory span groups. The participants were then subjected to paired-associate learning tasks each consisting of two words, and the differences in pretest effect by working memory capacity was investigated.

Investigating the pretest effect using Japanese stimulus words （Experiment 1）

Experiment 1 was conducted to select Japanese stimulus words to be used for investigating the pre-test effect.

Methods

Participants. 24 undergraduate and graduate university students（consisting of 9 males and 15 females）paticipated in this experiment. Their age was 19 to 25 years old（mean: 20.13 years, SD=1.51）. The participants were randomly divided into Pretest group（11 persons including 4 males）and No-Pretest group（13 persons including 5 males）. The contents of the experiment was explained orally, and their written consents were obtained.

Stimulus words. Kornell et al.（2009）selected cue and target words based on their association strength（the percentage of people who recall the target word upon being presented the cue word）. In this Experiment, 60 word pairs of cue and target words（120 words in total）of association strength of 0.045 to 0.054 were selected by referring to a similar study by Mizuno （2011）. Cue words consisted of 3 morae, and the target words consisted of 2 to 4 morae. The words were expressed in kanji, hiragana and/or katakana.

Assignment. The experiment consisted of the study phase, a distractor task, and evaluation test as in the study by Kornell et al.（2009）. In preceding studies, the participants were to type their answers during evaluation tests. In Japanese, typing requires additional time for kanji or katakana conversion; so the participants were asked to say their answers aloud while looking at the display. No visual feedback by the associated word was presented.

During the study phase, the Pretest group took a pretest and learned pairs of cue and target words (paired-associates learning task). The No-Pretest group was only assigned with paired-associates learning task. During the study phase for the Pretest group, a cue word and an empty box were displayed on the computer screen for 7 seconds. The participant was asked to think of a word (hereinafter referred to as the "generated word") that can be a target word for the cue word and answer the word orally (pretest). The empty box disappeared in 7 seconds. Five-hundred milliseconds later, the picture changed, and the correct target word was presented together with the cue word for 5 seconds. The participant was asked to remember not the generated word but the correct word as a set with the cue word in 5 seconds (paired-associates learning). Five-hundred milliseconds later, the participant was to answer the pretest on the next cue word and learn a new pair of words. The study phase for the No-Pretest group consisted of only paired-associates learning task of word pairs. The order of presenting word pairs was determined randomly on a participant-by-participant basis.

The distractor task involved 5 minutes of mental arithmetic (four rules of arithmetic of integers of 2 to 3 digits). A numerical formula and an empty box were displayed on the computer screen. The participant inputted the answer in the box by typing the ten keys. In the evaluation test, both groups performed the same cue-recall test. A cue word and an empty box were displayed on the computer screen for 7 seconds. Within the period, the participant was to recall and answer the paired target word orally. Seven seconds later, the cue for the next word was displayed. The order of word presentation was determined randomly on a participant-by-participant basis.

Procedure. All participants were first explained that they were to learn word pairs and later be tested for how much they remembered the word pairs. Before studying word pairs, the participants practiced 10 problems. The scores in the practice were not used in the analysis. Then the Pretest group proceeded to the study phase consisting of pretest and paired-associate learning task. The No-Pretest group worked only on paired-associate learning task during the study phase. After learning all 60 word pairs, the participants were assigned to perform the distractor task for 5 minutes. The participants were instructed to solve the problems as correctly and as quickly as possible during the five minutes. After the distractor task, the evaluation test was performed, which involved recalling all of the 60 word pairs. The duration of the experiment was about 35 to 40 minutes in the Pretest group, and 25 to 35 minutes in the No-Pretest group.

Results

In the Pretest group, the percentage of target words retrieved from their cue words (i.e. the generated word was the target word) in pretests was 6.0%. The cue words from which the target words were retrieved in the pretests were excluded from the analysis.

Pre-test effect. An unpaired t test was conducted to examine whether there was a difference in mean score between the Pretest and No-Pretest groups to investigate the effect of pretesting (Figure 1). The proportion of recalling correct target words was 0.88 ($SD = 0.11$) in the Pretest group and 0.72 ($SD = 0.18$)

in the No-Pretest group. The cued-recall accuracy was significantly higher in the Pretest group than in the No-Pretest group（$t(20.18) = 2.64$, $p < .05$）.

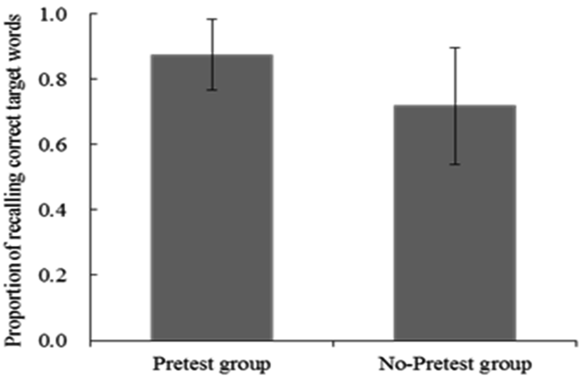

Figure 1.　Proportion of recalling correct target words in Experiment 1（Error lines denote standard deviation）

Relationship between distractor task score and the pretest effect. To investigate whether personal difference affected the pre-test effect or not, Pearson product-moment correlation coefficients were calculated between the scores of the distractor task and recall scores in the evaluation test for each group. A positive correlation of an intermediate degree was found in the No-Pretest group between the ratio of correct answers in the distractor task and proportion of recalling correct target words（$r = 0.49$, Figure 2）.

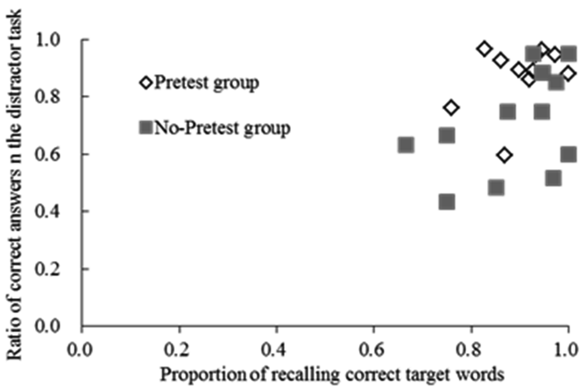

Figure 2.　Correlation between the ratio of correct answers in the distractor task and the proportion of recalling correct target words

Participants who scored higher and lower than the median during the study phase were classified as high- and low-score groups, respectively（those whose score was on the median were excluded）. A two-way analysis of variance was conducted on recall score in the evaluation test（Table 1）for the group in the study phase（2: Pretest group, No-Pretest group）× distractor task score（2: high-score group, low-score group）. Only the main effect of the group in the study phase was found to be significant（$F(1, 17) = 6.28$, $p < .05$）, and the main effect of the distractor task score and interaction were not significant（$F(1, 17) = 2.28$, n.s. and $F(1, 17) = 0.01$, n.s., respectively）.

Table 1
Proportion of recalling correct target words for each score group in the distractor task

Group		Number of participants	Proportion of recalling correct target words	
			Mean	SD
Pretest	High-score	3	.93	.04
	Low-score	7	.76	.19
No-Pretest	High-score	4	.83	.15
	Low-score	6	.65	.19

Discussion

Pre-test effect by Japanese stimulus word. An objective of Experiment 1 was to confirm whether the results by Kornell et al.（2009）is reproducible even when Japanese stimulus words are used and to determine the stimulus words to use in subsequent and future studies. A comparison of recall scores between the groups in the study phase showed that the Pretest group scored better in the evaluation test than the No-Pretest group, confirming the enhancement of memory by pretesting as in preceding studies. The Japanese words used in Experiment 1 were thus likely to have been appropriate stimuli for investigating the pre-test effect.

Distractor task score and the pre-test effect. A positive correlation of an intermediate degree was found in the No-Pretest group between the recall score in the evaluation test and distractor task score（mental arithmetic）, showing that persons who scored better in the distractor task scored high in cued-recalling in the No-Pretest group. Working memory capacity has been reported to be deeply involved in mental arithmetic（e.g. Saito & Miyake, 2000）. Based on the knowledge, in Experiment 1, participants of high distractor task score, or of high working memory, scored high in cued-recalling even under No-Pretest condition. Participants who had low working memory scored lower in cued-recalling than those who had high working memory when there were no pretests, but scored similarly when they received pretests. Pretesting was likely to have improved the recall scores.

Strategies used to memorize word pairs were asked to high-score participants in the No-Pretest group. They mentioned that they grouped the presented word pairs based on some standards, such as the cue and target words have a similar meaning and the target word is a *katakana* conversion of the cue word, and used the standard as a clue for recalling the correct target word. This supports the idea mentioned by Endo & Osaka（2012）that people having larger working memory can better select and use a strategy effective for memorizing. On the other hand, participants who had low working memory scored low under No-Pretest condition, in which strategy was not presented. Their scores improved to a degree similar to those of participants with high working memory by the pretests, which presented strategy for remembering. In other words, it was suggested that the pre-test effect is possibly more effective for those who have low working memory than those who have high working memory.

Effects of working memory capacity on the pre-test effect（Experiment 2）

Objectives

The results of Experiment 1 suggested that pretesting（presentation of learning strategy）may not affect the recall score of people of high working memory but may improve the score of people having low working memory by presenting strategy for assisting memorization. In Experiment 2, it was investigated whether the effect of pretesting on word recall score differs by working memory capacity or not.

Reading span test developed by Daneman & Carpenter（1980）is a most widely used method for measuring working memory capacity（Saio & Miyake, 2000）. However, it has been indicated that it is better to combine two or more span tests to correctly measure working memory（e.g. Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005; Endo & Osaka, 2012; Otsuka & Miyatani, 2007）. In Experiment 2, working memory was measured by using the reading span test and the operation span test（Turner & Engle, 1989）.

Methods

Participants. 71 undergraduate and graduate students（consisting of 17 males and 54 females）of 4 universities in total in two prefectures paticipated in this experiment.

Their age was 18 to 25 years old (mean: 21.8 years, SD=1.61). The participants were randomly divided into Pretest group (36 persons including 9 males) and No-Pretest group (36 persons including 8 males). The contents of the experiment was explained orally, and their written consents were obtained.

Assignment. Experiment 2 consisted of two working memory tests (span tests) and the word pair learning task described in Experiment 1. An automated version of the operation span test developed by Unsworth, Heintz, Schrock, & Engle (2005) and a Japanese translation version of the reading span test were used.

The word pair learning task was the same as that in Experiment 1. During the study phase, the Pretest group was assigned to perform pretests and paired-associate learning task, and the No-Pretest group had paired-associate learning task only. Both groups then performed the distractor task and took the evaluation test.

Procedure. The two kinds of span test were performed first, and word pair learning followed. The order of the operation span test and reading span test was determined randomly on a participant-by-participant basis. After the span tests, the word pair learning task followed, which consisted for the study phase, distractor task and evaluation test as in Experiment 1. The duration of Experiment 2 was about 70 and 60 minutes for the Pretest and No-Pretest groups, respectively.

Results

Span test score. Traditional span scores proposed by Daneman & Carpenter (1980) have been widely used. However, the traditional span scores have been indicated to strongly reflect the relationship between the ability of the person and the difficulty of the questions because the scores are determined by the final item size (Conway et al., 2005). In this study, the proportion of correct answers (the mean ratio of correct answers during the trial), which has been shown valid by several studies, was calculated for each span test. The mean scores of the span tests were 0.78 (SD = 0.12) and 0.80 (SD = 0.13) for the reading span and operation span tests, respectively. The correlation coefficient between the span tests was $r = 0.64$ ($p < .01$). The average of the scores of a person was adopted as the "composite span score" of the person. An analysis was conducted between the span test scores and the scores of the distractor task (the number of answers, the number of correct answers and the ratio of correct answers) to examine their correlation, but the correlation coefficients were not significant (Table 2). In the subsequent analysis, the composite span score was used as the working memory score of the person.

Table 2

Correlation between span test scores and distractor task score

	Number of answers	Number of correct answers	Ratio of correct answers
Reading span	-.01	.04	.17
Operation span	.05	.09	.16
Composite span	.02	.08	.18

Pre-testing effect. In the Pretest group, the percentage of cue words from which target words were retrieved in pretests was 5.2%. Those words were excluded from the analysis.

An unpaired t test was conducted to examine whether there was a difference in mean score between the Pretest and No-Pretest groups to investigate the effect of pretesting.

The proportion of recalling correct target words was 0.81 (SD = 0.09) in the Pretest group and was 0.72 (SD = 0.21) in the No-Pretest group, showing a significantly higher score in the Pretest group ($t(44.63) = 2.37$, $p < .05$). Significant pre-test effect was observed also in Experiment 2.

As in Experiment 1, correlation coefficient was calculated between the pretest effect and distractor task score. In Experiment 2, a weak positive correlation was found in the Pretest group, and a weak negative correlation was observed (particularly with the number of correct answers) in the No-Pretest group (Table 3).

Table 3
Correlation between evaluation test and distractor task scores

	Number of answers	Number of correct answers	Ratio of correct answers
Pretest	.28 *	.32 *	.16
No-Pretest	-.30 *	-.30 *	-.08

*$p < 0.10$

Effects of working memory capacity on pre-test effect. To investigate the effect of working memory capacity on the pre-test effect, the participants whose composite span scores were higher and lower than the median were classified as high- and low-score groups, respectively. The median of the composite span score was 0.82, and persons whose score was on the median were excluded from the analysis.

To examine whether the pre-test effect differed by working memory or not, a two-way analysis of variance was conducted for the group in the study phase (2: Pretest group, No-Pretest group) × composite span score (2: high-score group, low-score group). Only the main effect of the group in the study phase was found to be significant ($F(1, 63) = 4.43$, $p < .05$,), and the Pretest group showed higher recall scores than the No-Pretest group. The main effect of the span score and interaction were not significant ($F(1, 63) = 0.38$, n.s and $F(1, 63) = 0.04$, n.s, respectively). The number of participants, mean score and SD of each group are shown in Table 4.

Table 4
Proportion of recalling correct target words for each study phase group and each composite span score group

Group		Number of participants	Proportion of recalling correct target words	
			Mean	SD
Pretest	High-score	14	.79	.10
	Low-score	20	.83	.08
No-Pretest	High-score	19	.71	.20
	Low-score	14	.73	.25

Discussion

The objective of Experiment 2 was to investigate the possibility of working memory capacity affecting the effect of pretesting on improving word recall scores.

Working memory. A high correlation was observed between the reading span score and operation span scores showing that these two span tests measured the same aspect. However, there was almost no correlation with the distractor task score (mental arithmetic), showing a result different from preceding studies (e.g. Hecht, 2002). This was possibly because the mental arithmetic task in this study was a distractor task performed in the middle of a memorization task. The participants may have solved the arithmetic problems while saving their resources for the coming evaluation test, and this may have hidden the correlation. It was also possible that the span test used in

Experiment 2 measured a working memory dimension little involved in mental arithmetic. There are still many discussions and interpretations on the mental process reflected by each of diverse span tests（Saito & Miyake, 2000）. It is necessary to further investigate whether the span tests used in Experiment 2 are appropriate or not for studying personal difference in pretest effect.

Pre-test effect. Experiment 2 also showed the pre-test effect, or better recall scores in the Pretest group than in the No-Pretest group. On the other hand, unlike in Experiment 1, a weak positive correlation and a weak negative correlation were observed between the distractor task score and recall score in the Pretest and No-Pretest groups, respectively. In other words, pretesting was more effective in people of higher working memory, and the difference in recall score between the study phase group was smaller in people of lower working memory than in those of higher working memory. The reason for the difference from the result in Experiment 1 is discussed in General Discussion.

Effects of working memory capacity on the pre-test effect. The participants were classified by their working memory capacity, and the difference in pre-test effect was investigated. No significant interaction was observed, and there was no difference in pre-test effect by working memory capacity. Based on the results by Leding（2012）and Endo & Osaka（2012）, it is unlikely that there is no correlation between working memory capacity and pre-test effect. The absence of such a correlation in Experiment 2 is possibly attributable to either of the following reasons.

The first possibility is that the span tests used in this experiment could not measure the working memory dimension that affected the pre-test effect. As described above, the span tests and mental arithmetic were likely correlated to different dimensions of working memory. Similarly, the span tests may have measured a working memory dimension that differed from the dimension that affects the pre-test effect. However, it is also possible that the span and mental arithmetic scores did not correlate with each other because mental arithmetic was performed as a distractor task as described above. Tests other than the span tests used in this experiment need to be tested to investigate the relationship with the pre-test effect.

Another possibility is that the pre-test effect is not affected by working memory capacity because it does not involve source monitoring or presenting memorization strategy. Bixter & Daniel（2013）investigated the relationship between false memory and working memory and reported that there was no relationship between working memory and word recall score unless the participants were informed that the word list presented was designed so as to generate false memory. This is believed to occur because people allot little attention to source monitoring unless they notice the false-memory generating characteristic of a word list. In this Experiment, it was entrusted to the participants to decide by themselves how to use the incorrect information presented in the pretest during the evaluation test. Therefore, the participants did not monitor the information source for correctness and use it as a clue for the evaluation test. Because little attention was allotted to source monitoring in this study, working memory capacity was not related to the pre-test effect. Thus the results may imply that personal differences, such as abilities of monitoring and using strategies and others abilities determined by working memory, do not affect the pre-test effect, or in other words, the effect of pretesting in improving memory retention is a strategy independent from personal difference. However, if source monitoring was not used during the evaluation test, it is difficult to conclude that there was pre-test effect involving activation of a network of candidates containing various information as proposed by Grimaldi & Karpicke（2012）. Therefore, further investigation is needed on how people use incorrect information during an evaluation test.

General Discussion

The objectives of this study were to 1） confirm the presence of the pre-test effect even when Japanese stimulus words are used, and 2） investigate the effects of personal differences on the pre-test effect from the viewpoint of working memory. It was found that there is no relationship between the pre-test effect and working memory, suggesting that the pre-test effect is a phenomenon independent from personal differences. Pretesting is thus probably effective for improving memory retention also for pupils and students who have low working memory, for whom it has been believed that pretesting lowers the scores of final test, as mentioned, for example, by Butler & Roediger（2007）. However, to actually use pretests in schools, the mechanisms of the pre-test effect should be further investigated such as by identifying most efficient testing methods.

The relationship between the word recall score and the score of mental arithmetic problems used as the distractor tasks was inconsistent between Experiments 1 and 2. In Experiment 1, pretesting was suggested to have presented a strategy for memorization and thus improved the recall score in participants who scored low in mental arithmetic. On the other hand, Experiment 2 showed a possibility that source monitoring is an important aspect of pretesting as it improved the recall scores in participants of high mental arithmetic scores. To solve such an inconsistency, it will be necessary to thoroughly investigate how people use incorrect information presented in pretests in an experimental paradigm for investigating the pre-test effect. The possibility of working memory having both promoting and preventing effects on the pre-test effect should also be considered.

In a study on the effects of personal working memory differences on the testing effect, Brewer & Unsworth（2012）investigated not the pre-test effect but the effects of testing after learning（testing effect）on evaluation test score and of personal differences such as working memory, attention function and other recognition abilities on the testing effect. No effect was observed by individual working memory difference on the testing effect, and they reported a weak negative correlation between episodic memory and general fluid intelligence. Their results suggested that individual differences in recognition function do not directly affect the testing effect, but testing has an indirect effect in people of low recognition function by assisting them learn a more effective strategy. In Experiment 1 of this study, the pre-test effect was more apparent in the group of low distractor task score than in the counterpart. Experiment 2 did not show relationship between working memory capacity and the pre-test effect. Therefore, like the testing effect mentioned by Brewer &

Unsworth（2012）, the pre-test effect is likely to be effective for all persons regardless of their working memory capacity but enhanced memory retention to a larger extent in the people of low working memory than in those who have high working memory because pretesting presented a strategy for learning.

References

Bixter, M. T., & Daniel, F.（2013）. Working memory differences in illusory recollection of critical lures. Memory & Cognition, 41, 716-725.

Brewer, G. A., & Unsworth, N. （2012）. Individual differences in the effects of retrieval from long-term memory. Journal of Memory and Language, 66, 407-415.

Butler, A, C., & Roediger, H. L. （2007）. Testing improves long-term retention in a simulated classroom setting. European Journal of Cognitive Psychology, 19, 514-527.

Conway, A. R. A., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W.（2005）. Working memory span tasks: A methodological review and user's guide. Psychonomic Bulletin & Review, 12, 769-786.

Daneman, M., & Carpenter, P. A.（1980）. Individual differences in working memory and reading. Journal of Verbal Learning & Verbal Behavior, 19, 450-466.

Endo, K., & Osaka, M.（2012）. Individual differences in strategy use in the Japanese Reading Span Test. The Japanese Journal of Psychology, 82, 554-559.（in Japanese）

Endo, M.（2007）. Testing effect with free recall tests. Journal of Kinki Welfare University, 8, 37-41.（in Japanese）

Grimaldi, P. J., & Karpicke, J. D.（2012）. When and Why do retrieval attempts enhance subsequent encoding? Memory & Cognition, 4, 505-513.

Hays, M. J., Kornell, N., & Bjork, R. A.（2013）. When and why a failed test potentiates the effectiveness of subsequent study. Journal of Experimental Psychology: Learning, Memory, Cognition, 39, 290-296.

Hecht, S. A.（2002）. Counting on working memory in simple arithmetic when counting is used for problem solving. Memory & Cognition, 30, 447-455.

Kornell, N., Hays, M. J., & Bjork, R. A.（2009）. Unsuccessful retrieval attempts enhance subsequent learning. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35, 989-998.

Leding, J. K.（2012）. Working memory predicts the rejection of false memories. Memory & Cognition, 20, 217-223.

Mizuno, R.（Ed）（2011）. Association frequency tables: Three-mora kanji, hiragana, and katakana words. Kyoto: Nakanishiya Shuppan.（in Japanese）

McNamara, D. S., & Scott, J. L.（2001）. Working memory capacity and strategy use. Memory & Cognition, 29, 10-17.

Osaka, M.（2006）. Working memory（1）. Clinical Electroencephalography, 48, 691-696.（in Japanese）

Otsuka, K., & Miyatani, M.（2007）. Target words and sentences for Japanese version of the reading span test. Hiroshima Psychological Research, 7, 19-32. （in Japanese）

Pyc, M. A., & Rawson, K. A.（2010）. Why testing improves memory: Mediator effectiveness hypothesis. Science, 330. 335.

Richland, L. E., III, & Karpicke, J. D.（2006）. The power of testing memory: Basic research and implications for educational practice. Perspectives on Psychological Science, 1,

181–210.
Richland, L. E., III, Kornell, N., & Kao, L. S. (2009). The pretesting effect: Do unsuccessful retrieval attempts enhance learning? Journal of Experimental Psychology: Applied, 15, 20-27.
Saito, S., & Miyake, A. (2000). A systematic evaluation of six hypotheses on reading span test. Japanese Psychological Review, 43, 387-410. (in Japanese)
Tajika, H. (2008). The influence on testing long-term retention of learning materials. Bulletin of Kobe Shinwa Women's University Graduate School of Literature, 4, 57-65. (in Japanese)
Tsuchida, Y. (2009). What is working memory capacity?: Individual difference and influence on cognitive performance. Bulletin of Faculty of Education, Hokkaido University, 109, 81-92. (in Japanese)
Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? Journal of Memory and Language, 28, 127-154.
Unsworth, N., Heintz, R. P., Schrock J. C., & Engle, R. W. (2005). An automated version of the operation span task. Behavior Research Methods, 37, 498-505.

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