Episodic Memory Inhibition and Spreading Activation Duration: Further Evidence of Episodic Inhibition Using the Think/No-Think Task

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ABSTRACT

In two experiments, we examined whether inhibiting target words intentionally could impair memory for words semantically related to these targets. University students studied 42 pairs of unrelated words, before engaging in the think/no-think task. During the think/no-think task, participants were presented with the cue word of a pair either 0 times (baseline) or repeatedly 12 times. In the repeated condition, participants either recalled the target word paired with the cue a word 12 times, or were asked to avoid thinking of the target word paired with a cue word 12 times. In the test phase, participants were given a recognition test in which they were asked to decide as quickly and accurately as possible whether each word was previously studied, either immediately after the think/no-think phase (Experiment 1), or after a one-week delay (Experiment 2). The recognition test words consisted of: (1) studied target words, (2) nonstudied words semantically related to target words, or (3) nonstudied words unrelated to target words. Results from both experiments showed that more target words were recognized correctly in the baseline condition than 12 repetitions under the no-think instruction. Results also showed that participants were slower in rejecting nonstudied words that were semantically related to target words under the 12 repetitions involving no-think instructions, compared to the baseline condition. These findings suggest that the episodic inhibition of "no-think" words might spread to nonstudied words semantically related to the target words.

Key words : inhibition, spreading activation, think/no-think paradigm, reaction time, delay of recognition tests

I The Aim

Empirical studies have shown that people can suppress specific memories when engaged in the think/no-think task (Anderson & Green, 2001). The think/no-think task

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consists of three phases: (1) a paired-associates study phase, (2) a think/no-think instruction phase, and (3) a memory test phase.

First, participants typically study a list of 42 word-pairs such as camera-cup, cropper-cooking, and consultation-swimming. Then, during the think/no-think task, each cue item studied earlier (e.g., camera-?, cropper-?, and consultation-?) is repeatedly presented, usually 0, 1, 8, or 16 times. Under the "think" instruction, cues are presented to participants, and they recall the target item paired with each cue. If this occurs once, it would be designated a 1-time repetition. The 0-times repetition means that participants only study cue-target pairs, but have no further exposure to them during the think/no-think phase. In the present article, we use this 0-times repetition as the baseline. In the no-think instruction, each cue studied before is presented to participants and they are asked not to think about a target item paired with each cue. In the test phase, they are instructed to recall the corresponding target items to the cues, irrespective of the prior think/no-think instructions.

The main results of Anderson and Green (2001) showed that participants in the no-think instruction with 16 repetitions recalled fewer target items than those with 0 repetitions. Using 0 repetitions as the baseline means that the cue is not presented during the think/no-think instruction phase. In the baseline, participants study cue-target pairs during the study phase and are asked to recall target items during the test phase. Repeatedly being asked to suppress thinking of target items leads to forgetting them.

The present study addresses the question of whether the no-think instruction also has inhibition effects on items semantically related to target items in addition to those obtained on target items. Its main purpose is to examine whether inhibiting memory material intentionally impairs recognition memory and, in an extension to the work of Anderson and Green (2001), to determine if it also increases recognition latencies for related material. In earlier work, Neumann, Cherau, Hood, and Steinnagel (1993) have demonstrated semantic inhibition effects using a different memory task. They observed that selectively recognizing a target memory among related memories requires some degree of inhibitory control over potentially interfering and competing semantic memories. Here we use the think/no-think task in two experiments to test the generalizability of semantic inhibition effects in memory.

Several implications have emerged from retrieval-induced forgetting studies (Bauml & Kuhbandner, 2003; Storm, Bjork, Bjork, & Nestojko, 2006). It appears that episodic retrieval recruits inhibitory processes to suppress competing traces (e.g., Anderson, 2003). Inhibitory processes may also be involved in causing semantic memory lapse associated with to-be-suppressed memory (Johnson & Anderson, 2004). For example, Bauml and Kuhbandner (2003) compared the effects of retrieval practice on critical nonpresented items of associatively structured lists using DRM lists (Roediger & McDermott, 1995). They found that retrieval-induced forgetting is caused by inhibitory processes. Storm et al. (2006) presented participants with 48 category-exemplar pairs and conducted the

experiment based on the same procedure in typical retrieval-induced forgetting studies (Anderson, Bjork, & Bjork, 1994). They also showed that the attempt to retrieve can produce retrieval-induced forgetting, using a procedure in which some cues posed an impossible retrieval task for participants.

When we consider that not only retrieval-induced forgetting, but also intentional suppression observed in the think/no-think task is cued by an inhibitory mechanism (e.g., Anderson, 2003; Anderson & Green, 2001), then surrounding memories related to to-be-suppressed memories may also be suppressed (see also Neumann, et al. 1993). To our knowledge, however, there are no published experiments that have directly examined this issue. The following paragraph posits how intentional suppression effects might generalize from target items to semantically related memory representations.

As stated above, participants first study a corresponding unrelated word to a cue (e.g., camera-cup, consultation-swimming, and cropper-cooking), then during the think/no-think task, they recalled the target item (camera-?) for 12 times (think instruction/12-times repetition) or avoided thinking of the corresponding target item to the cue (consultation-?) for 12 times (no-think instruction/12-times repetition). In the test phase, we used a recognition test in which reaction times were also measured. Participants were presented with (a) target items (e.g., cup and swimming), (b) semantically related items to the target items (e.g., glass and backstroke), and (c) distractors (e.g., sun and pencil).

The main purposes of our experiments were threefold. First, we aimed to replicate the findings of the previous suppression studies by showing that intentional suppression effects can be obtained by using a recognition test and recognition latencies. On the recognition test, recognition of suppressed items would be worse than that of the baseline. Recognition latencies to target items (e.g., swimming) in the 12-times repetition/no-think instruction may also be slower than those in the baseline (e.g., in the no-think instruction/0-times repetition).

Second, we aimed to examine whether inhibiting target items intentionally would impair recognition memory for items semantically related to the target ones. According to the spreading activation idea, for example, which is a prominent assumption in associative models of memory, items semantically related to the target items might be suppressed as well as target items. That is, participants recognize the items (e.g., backstroke) semantically related to the target items (e.g., swimming) as correctly rejected items. Recognition latencies to these related items in the 12-times repetition/no-think instruction might be slower than those in the baseline (e.g., in the no-think instruction/0-times repetition).

Third, we manipulated retention intervals (immediately or a one-week delay after the think/no-think task). We aimed to examine whether intentional suppression effects would be maintained for one week. If suppressed items only temporarily impair recognition memory, then intentional suppression effects should disappear over the delay. On the other hand, if intentional suppression effects are maintained, suppressed items should continue to impair recognition memory, even if after a one-week delay.

II Experiment 1

Aim

The purpose of Experiment 1 was to examine whether inhibiting target items intentionally could impair immediate recognition memory of nonstudied items semantically related to the target ones.

Method

Participants. Participants were twelve university students (8 women, 4 men; ranged in age from 18 to 24 years).

Design. The experiment used a 2 (instruction: think, no-think) x 2 (number of repetitions: 0, 12) within-subjects design.

Materials. Participants studied forty-two semantically unrelated word pairs, which consisted of 32 target pairs and 10 filler word pairs. A target pair consisted of a cue item and a target item. Thirty-two cue-target pairs were divided into 4 groups during training the 0-times or the 12-times repetition under the think or no-think instruction. As a result, eight target pairs were assigned into each of the four group (think/0-times, think/12-times, no-think/0-times, or no-think/12-times).

The recognition test materials were seventy-four words, with 26 studied target items consisting of 16 target items and 10 filler items. Half of the target items which had been presented at the study phase were not used on the recognition test. The remaining 48 words were not presented at the study phase. Sixteen of these words were items semantically related to the target items which were not presented on the recognition test. The remaining 32 words were unrelated to the target words (see Table 1).

Table 1 Examples for materials used in Experiments 1 and 2.

Cue Words	Targets	Words Semantically Related to Targets
camera	cup	glass
consultation	swimming	backstroke
cropper	cooking	preparation
dolphin	society	company

Procedure. Each participant was tested individually. First, the participants memorized forty-two unrelated noun pairs. The Presentation software, version 9.70, controlled the presentation of all of them. Each noun pair was presented for 6000 ms with an intertrial interval (ITI) of 5600 ms.

After 42 pairs were presented, each participant was asked to recall response items to ascertain the memorization level of each pair. This memorization task was assessed using cued recall tests by displaying each cue item on a computer screen until a participant had responded to an item aloud or until 5200 ms had elapsed. When the participant could not answer the item to the cue within 5200 ms, the participant was provided with feedback after a delay of 200 ms by displaying the correct target item for each cue in a blue font at

the center of a computer screen for 2000 ms, which was followed by the next trial with the ITI of 300 ms. Each of the 42 word pairs was presented repeatedly and the participant was asked to continue memorizing until they could correctly respond to the corresponding target item to the cue on two consecutive sessions. Once this criterion was reached, the memorization for that pair was terminated. The same memorization assessment task was conducted for all pairs.

After the memorization assessment task, the think and no-think instruction training was carried out. The think and no-think instruction training consisted of 22 trials, 18 response trials and 4 suppression trials using the 10 filler word pairs. The think instruction training had 18 response trials and the no-think instruction training had 4 suppression trials. Only one cue was assigned as the cue for the suppression trials.

After the think/no-think instruction phase, participants were presented with 8 cue items related to the target items during two minutes. These 8 cues were paired with target items suppressed at the no-think instruction. This was followed by the procedure of Anderson & Green (2001). Participants were asked to familiarize themselves with the cue items, so that, upon seeing the cue items in the think/no-think instruction phase, they would recognize them and know that they are supposed to suppress the associated target items. Participants were then asked to recognize these 8 cue items. When participants did not recognize them correctly, they were asked to memorize these cues. Following this task, participants were asked either to avoid thinking about the target item (suppression) or to recall it (response). The cues for suppressing and responding for 12 times were presented for a total of 192 trials. In addition, participants were presented with nine filler cues of the think instruction for 121 trials (nine filler cues for 12 times plus one of nine filler cues for one time and one filler cue for 12 times) to create an overall tendency to respond. Therefore, a total of 313 trials were presented followed by a 400 ms ITI for each trial in random order.

At the start of each trial, a small cross was displayed on the screen for 200 ms. After that, the cue was presented until a maximum duration of 3000 ms. When participants recognized the cue as the response cue, they recalled the response item for each cue as quickly as possible. When participants recognized the cue item as the suppression cue, they tried to suppress the response item. When participants responded incorrectly on a response trial, they had feedback. When participants made a wrong response on a suppression trial, they were instructed to avoid thinking of the target item again by the experimenter.

After the think/no-think instruction phase, participants were finally asked to recognize each of the target items as accurately and quickly as possible, irrespective of the prior think/no-think instruction. At the start of the final recognition test phase, a small cross was displayed on the screen for 200 ms. Seventy-four items (32 target items and 42 distractor items) were presented individually until a maximum duration of 4000 ms. Participants were asked to recognize each item. They pressed the key labeled "Y" when

they thought the item was a studied one. They pressed the key labeled "N" when they though the item was not studied one. Recognition latencies were recorded. This was followed by a 400 ms ITI for each final recognition test.

Results and Discussion

Table 2 shows the mean numbers of target items correctly recognized for the think instruction and the no-think instruction as a function of number of repetitions. The maximum number of target items recognized correctly is 4 in each cell. A 2 (instruction) x 2 (number of repetitions) within-subjects analysis of variance (ANOVA) was carried out on the results of Table 1. There was a marginal main effect of instruction ($F(1,11)=4.09$, $MSe=.37$, $p<.10$). Participants in the think instruction tended to recognize target items more than those in the no-think instruction. There was also a significant interaction between instruction and number of repetitions, $F(1,11)=20.39$, $MSe=.23$, $p<.01$. For the think instruction and the no-think instruction in the 0-times repetition, there was no difference in the number of target items recognized correctly. However, participants recognized more target items in the think instruction than those in the no-think instruction on the 12-times repetition. There was no significant main effect of number of repetitions.

Table 2 Mean Numbers of Correctly Recognized Items for the Think Instruction and the No-Think Instruction As a Function of Number of Repetitions in Experiment 1

	Number of Repetitions	
Instruction	0	12
Think		
Mean	3.58	4.00
SD	.89	.00
No-Think		
Mean	3.75	2.92
SD	.94	.73

Next, we analyzed the recognition results of the nonstudied items semantically related to the target ones. Participants have to recognize the nonstudied items correctly as "no", because the items are not presented at study. Correct rejection rates of these items were very high in each condition, .98 in the think/0-times repetition, .98 in the think/12-times repetition, .96 in the no-think/0-times repetition, .90 in the no-think/12-times repetition. We can see the suppression effect in the no-think/12-times repetition. However, these results seem to show the ceiling effect.

We analyzed the mean recognition latencies (in milliseconds) of target items correctly recognized as "yes" as a function of number of repetitions. The mean recognition latencies were, 894 ms (SD=298) in the think/0-times repetition, 786 ms (SD=271) in the think/12-times repetition, 858 ms (SD=315) in the no-think/0-times repetition, 944 ms (SD=355) in the no-think/12-times repetition. We can see the suppression effect as a function of

number of repetitions. A 2 (instruction) x 2 (number of repetitions) ANOVA showed a significant interaction between instruction and number of repetitions, $F(1,11)=5.75$, $MSe=9657$, $p<.05$. There were no significant main effects of instruction and number of repetitions.

Table 3 shows the mean recognition latencies (in milliseconds) of items correctly recognized as "no" as a function of number of repetitions. A 2 (instruction) x 2 (number of repetitions) ANOVA was carried out on the results of Table 3. There were no significant main effects of instruction and number of repetitions. However, there was a marginally significant interaction between instruction and number of repetitions, $F(1,11)=4.73$, $MSe=8799$, $p<.10$. When the number of repetitions increases, participants seem to respond to items semantically related to the target items more slowly.

Table 3 Mean Recognition Latencies (in Milliseconds) for the Think Instruction and the No-Think Instruction As a Function of Number of Repetitions in Experiment 1

	Number of Repetitions	
Instruction	0	12
Think		
Mean	951	960
SD	265	271
No-Think		
Mean	947	1117
SD	265	395

Ⅲ Experiment 2

Aim

The purpose of Experiment 2 was to examine whether inhibiting target items intentionally could impair recognition memory for nonstudied items semantically related to the target ones after a one-week delay.

Method

Participants and design. Twelve university students consisting of nine women and three men (age range: 18 to 25 years) participated in Experiment 2. The experimental design of Experiment 2 was similar to that of Experiment 1, except for the duration of the test interval. Participants received the final recognition test after a one-week delay.

Materials and Procedure. The materials and procedure were identical to those of Experiment 1 (see Table 1), with the following one exception. Participants received the final recognition test after a one-week delay. After participants performed the think/no-think instruction phase, they were told that the experiment was over. Participants returned to the laboratory after a one-week delay and were asked to recognize the response items as accurately and quickly as possible, irrespective of the prior think/no-think instruction.

Results and Discussion

Table 4 shows the mean numbers of target items correctly recognized for the think instruction and the no-think instruction as a function of number of repetitions. The maximum number of target items recognized correctly was the same as that in Experiment 1. A 2 (instruction) x 2 (number of repetitions) ANOVA was carried out on the results of Table 4. There was a significant main effect of instruction ($F(1,11)=12.67$, $MSe=.37$, $p<.01$). Participants in the think instruction recognized target items more than those in the no-think instruction. There was also a significant interaction between instruction and number of repetitions, $F(1,11)=17.60$, $MSe=.20$, $p<.01$. For the think instruction and the no-think instruction in the 0-times repetition, there was no difference in the number of target items recognized correctly. However, participants recognized more target items in the think instruction than those in the no-think instruction in the 12-times repetition. There was no significant main difference for number of repetitions.

Table 4 Mean Numbers of Correctly Recognized Items for the Think Instruction and the No-Think Instruction As a Function of Number of Repetitions in Experiment 2

	Number of Repetitions	
Instruction	0	12
Think		
Mean	2.50	3.42
SD	.62	.85
No-Think		
Mean	2.42	2.25
SD	.60	.56

Next, we analyzed the recognition results of the nonstudied items semantically related to the target items. Participants have to recognize the items correctly as "no", because the items are not presented at study. Correct rejection rates of these items were also high in each condition, .88 in the think/0-times repetition, .83 in the think/12-times repetition, .92 in the no-think/0-times repetition, .85 in the no-think/12-times repetition. We can see the suppression effect in the no-think/12-times repetition. However, these results seem to show the ceiling effect.

We analyzed the mean recognition latencies (in milliseconds) of target items correctly recognized as "yes" as a function of number of repetitions. The mean recognition latencies were, 1088 ms (SD=371) in the think/0-times repetition, 1034 ms (SD=457) in the think/12-times repetition, 1190 ms (SD=395) in the no-think/0-times repetition, 1625 ms (SD=681) in the no-think/12-times repetition, respectively. We can find the suppression effect as a function of number of repetitions. A 2 (instruction) x 2 (number of repetitions) ANOVA showed there was a significant main effect of instruction, $F(1,11)=11.76$, $MSe=13243$, $p<.01$. There was also a significant interaction between instruction and number of repetitions, $F(1,11)=5.72$, $MSe=16799$, $p<.05$.

Table 5 shows the mean recognition latencies (in milliseconds) of items correctly

recognized as "no" as a function of number of repetitions. We may also realize the suppression effect as a function of number of repetitions. A 2 (instruction) x 2 (number of repetitions) ANOVA was carried out on the results of Table 5. There were no significant main effects of instruction and number of repetitions. However, there was a marginally significant interaction between instruction and number of repetitions, $F(1,11)=4.15$, $MSe=18471$, $p<.10$. When the number of repetitions increases, participants seem to respond to nonstudied items semantically related to the target items more slowly, as was the case in Experiment 1.

Table 5 Mean Recognition Latencies (in Milliseconds) for the Think Instruction and the No-Think Instruction As a Function of Number of Repetitions in Experiment 2

	Number of Repetitions	
Instruction	0	12
Think		
Mean	989	936
SD	510	374
No-Think		
Mean	1046	1156
SD	532	476

Ⅳ General Discussion

There is extensive evidence that people can suppress target items intentionally (e.g., Anderson et al., 1994; Anderson & Spellman, 1995; Anderson & Green, 2001). In the present study, our first purpose was to examine whether the findings of previous suppression studies can be also replicated by both a recognition test and through recognition latencies using the think/no-think task. We replicated the intentional suppression effects by using a recognition test. We obtained a significant interaction between instruction and number of repetitions, based on the results of the mean numbers of target items correctly recognized. Recognition of suppressed items was worse in the 12-times condition than in the baseline condition. We also obtained a significant interaction between instruction and number of repetitions, based on the results of the mean recognition latencies of target items correctly recognized. Suppressed target items were responded to more slowly in the 12-times condition than in the baseline condition.

The second and the third purposes of the present study were to examine whether inhibiting target items intentionally would impair recognition memory for nonstudied items which are semantically related to the target ones and to examine whether suppressed items would be maintained even after a one-week delay. The results of recognition latencies showed that there were significant interactions between instruction and number of repetitions in both experiments. When the number of repetitions increased from 0 times to 12 times in the no-think instruction, participants' recognition latencies were slower with 12 times than with 0 times. When participants suppressed target items intentionally,

nonstudied items which were semantically related to target ones were also suppressed not only on an immediate recognition test but also on a recognition test after a one-week delay.

Based on an extension of spreading activation, with an inhibitory component (Neumann, et al., 1993), it was predicted that nonstudied items which are semantically related to the target items might be suppressed as well as targets. The present results are consistent with the above prediction about semantic inhibition effects, and also show that the suppression of related items remains robust even after a week. Since nonstudied items were selected as being semantically related to the target items, it is possible that semantically similar representations may overlap with one another. The findings support the idea that not only spreading activation applies in memorized items, but also some form of spreading semantic inhibition from suppressed items.

V References

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VI Footnotes

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