How Does Distraction Task Influence the Interaction of Working Memory and Long-Term Memory?

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Abstract. The present study addressed the influence of distraction task on the interaction of working memory and long-term memory by using available long-term memory tasks with or without distraction task. The results showed that: (a) Distraction task had significant effect on the availability of LTM facilitated by prior attention-driven processing in WM, and (b) the pattern of semantic priming effects observed was reversed between the condition with and without distraction task. These findings support the hypothesis that the semantic activation is implicit automatic process, and less attention resource focused on the process will benefit the semantic activation of LTM.

Keywords: working memory, availability of long-term memory, semantic activation, semantic priming.

1 Introduction

The theoretical concept of working memory (WM) assumes that a limited attentional capacity system, which temporarily maintains and stores information, supports human thought processes by providing an interface between perception and long-term memory [1] [2]. However, relatively small capacity of WM fails to explain complex cognitive activities such as language comprehension, and the greatly expanded working memory capacity of experts and skilled performers [3]. Alternative conceptualizations of WM have been proposed that there should be active long-term memory (LTM) elements in WM. And the active LTM elements are temporarily available for processing, but not in the current focus of attention. These alternative models postulate that a large subset of information or semantic related knowledge in LTM is activated due to prior attention-driven WM processes or well-learned knowledge structures. They also assumed both attention-driven WM processes and automatic LTM activation effectively define capacity limits that constrain complex processing activities [10].

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1.1 Automatic LTM Activation in WM Models

Several researchers have proposed alternative WM models emphasizing the role of automatic LTM activation in cognitive activities.

Ericsson and Kintsch [3] have proposed that working memory should include two components. One is the temporary storage of information that they refer to as short-term working memory (ST-WM). Another is based on skilled use of storage in long-term memory (LTM), and they refer to as long-term working memory (LT-WM). Information in LT-WM is stored in stable form, and reliable access to it may be maintained only temporarily by means of retrieval cues in ST-WM. Hence LT-WM is distinguished from ST-WM by the durability of the storage and the need for sufficient retrieval cues. Well-learned knowledge structures and acquired memory skills enables individuals to use LTM as an efficient extension of ST-WM in particular domains and activities after sufficient practice and training. Therefore, LT-WM reflects domain-specific skills of automatically accessing related LTM elements.

Oberauer proposed a model distinguishing three states of representations in WM: the activated part of LTM, a capacity limited region of direct access, and a focus of attention [5]. Oberauer proposed that only one chunk of information was assumed to be directly in the focus of attention at any time. However, a limited number of additional chunks were assumed to be in a state of direct access. Beyond information in a direct access state that based on attention-driven WM, there was a segment of LTM that held some degree of accessibility, but its access would depend on prior attention-driven process.

Woltz and Was further proposed that the content and complexity of attention-driven processing in WM determine the subsequent availability of semantically related elements in LTM [10]. They developed available long-term memory task (ALTM task) to test their hypotheses. In ALTM tasks, semantically mediated priming effects are taken to indicate temporary increases in the availability of LTM. They found a close link between the amount and type of attention-driven processing in WM and the resulting accessibility of semantically related memory structures. Their research also suggested ALTM mediated the relationships of both WM and background knowledge with listening comprehension [9].

According to the previous researches, the interaction of WM and LTM is the foundation of many cognitive activities. Automatic LTM activation facilitated by prior attention-driven processing in WM would influence the concurrent cognitive process.

1.2 The Effects of Additional Mental Load

Working memory is commonly described as a system for simultaneous storage and processing of information, and the two functions share limited common cognitive resource [5]. Evidence from neuropsychological studies showed that working memory, executive control, and focusing of semantic retrieval share a common neural substrate in the prefrontal cortex and are functionally linked [4]. However, dual task studies provide evidence against the resource-sharing hypothesis. A study on visual search suggested that reducing reliance on executive control processes and increasing reliance on rapid automatic processes could improve the efficiency of some difficult searches [8].

Another study on attentional blink also showed additional task load had beneficial effect on the attentional blink, and improved the participants' performance [6].

Since semantic activation produced by prior attention-driven processing is automatic and implicit, distraction tasks that occupy the cognitive resource should have beneficial effect on the availability of LTM. ALTM tasks with distraction task or without distraction task were used in the present study. Our hypotheses were that availability of LTM facilitated by prior attention-driven processing in WM changed with mental load, and additional task load should facilitate availability of LTM.

1.3 ALTM Task

The ALTM task has four trial components (See Fig. 1 for example) [9] [10]. The first component is a memory load that consists of a set of words presented one at a time for eventual recall. Within each memory load, some of the words (usually half) belong to one semantic category, and the remaining words belong to another category. Woltz and Was assumed that the memory load engaged participants' attention-driven WM processes for active rehearsal.

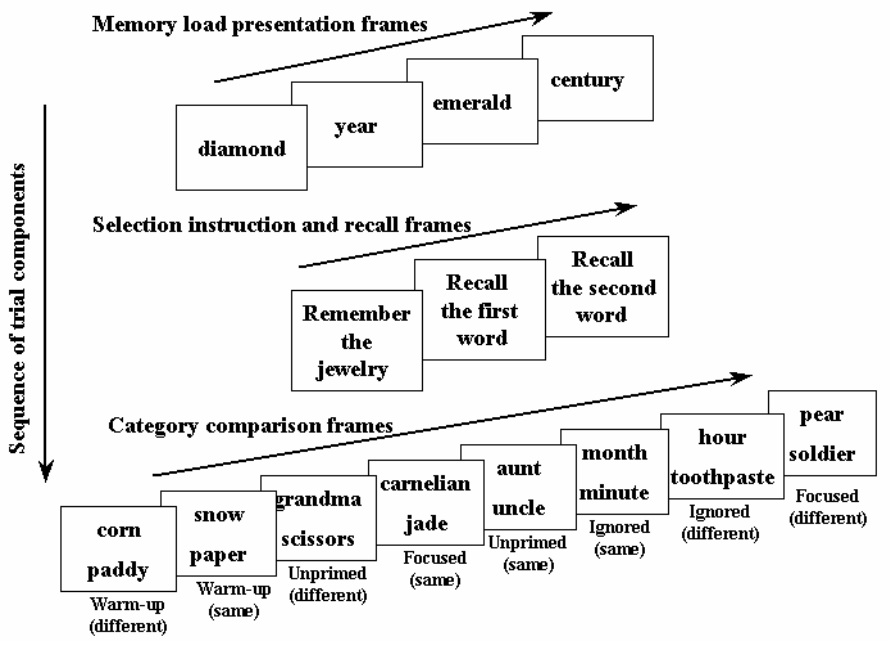

Fig. 1. Example trial of the ALTM task proposed by Woltz and Was [10] used in the present study

The second trial component is the selection instruction. An instruction to remember the words from just one of the categories is presented to participants. This component engages attention-driven category identification processes for one category, and

subsequent rehearsal processes also only focus on the target category exemplars. Therefore, more attentional resources are presumably devoted to the target category.

In the present study, there were two kinds of instruction. One conducted participant to remember the words in the presented category. In this condition, the category was focused target category. The other instruction conducted participant to remember the words that were not in the presented category. In this condition, not target category name but ignored category name was presented to participants.

The third trial component requires participants to recall the words that were remembered. This manipulation verified that individuals were adequately performing the task demands represented in the first two components.

The final type of trial component consists of same-different category membership comparisons that assess semantic priming or availability of the categories represented in the memory load. Within each trial, there were new exemplars from three categories: the focused category in the memory load (i.e., the category that was identified for eventual recall), the ignored category in the memory load, and an unprimed category that was not represented in the memory load. Increased response speed for comparisons representing the two memory load categories (focused and ignored categories), relative to the unprimed category indicated the availability of LTM.

Using ALTM task, the present study investigated the influence of distraction task on the availability of LTM facilitated by prior attention-driven processing in WM.

2 Method

2.1 Participants

Seventy-six undergraduates with a mean age of 22 years (range, 17-25) participated in the experiment (42 men and 34 women) in return for monetary payment. All of them were native speakers of Chinese.

All participants were divided into four groups equally. Two groups were asked to do distraction task before category comparison, while the other two groups were not asked to do. One group with distraction task was instructed with the category identification to be remembered in selection instruction, and another one with distraction task was instructed with the category identification to be ignored. As for the two groups without distraction task, it was the same to the groups with distraction task.

2.2 Apparatus

The participants performed the experimental task on Lenovo microcomputers with standard keyboards. The experiment was programmed with E-Prime software [7].

2.3 Materials

Most of the stimuli used in the experiment were Chinese words with two characters, and a few of them were words with three characters or single character. The semantic categories and exemplars were obtained primarily from the research of Woltz and Was [10], but some of them were revised because of the cultural difference.

All of the categories were organized in 24 sets, with each set containing three categories. For each participant, one category from each set was assigned to be the focused category in the memory load, one was assigned to be the ignored category in the memory load, and the remaining one represented a category not found in the memory load. Six versions of the experiment were created that represented a complete counterbalancing of triplet category assignment to priming condition (focused, ignored, and unprimed). Therefore, each comparison item had ever been under each priming condition twice. In each group, about three participants performed one of the six counterbalanced versions.

For all the positive match category comparison items, there were five kinds of comparison items: (1) belonged to the focused category with category name, (2) belonged to the focused category without category name, (3) belonged to the ignored category with category name, (4) belonged to the ignored category without category name, (5) belonged to the unprimed category. Unprimed condition was a baseline compared with other four conditions.

2.4 Procedure

For the group without distraction task, the experimental task consisted of four sequential components: memory load presentation, selection instruction, memory load recall, and category comparison frames. Each of 24 trials contained the four components in the described order. The sequence of the 24 trials was randomized, and there were 30 seconds interval for participants to have a rest between trials.

Each trial began with the instruction to read words. Then, four words were presented on the display sequently in random order (e.g., diamond, emerald, year, and century). Each word set was preceded by a fixation displayed for 750 ms in the location of the words (center of screen) and then a blank screen for 1 sec. Each word was displayed for 1,500 ms, followed by a blank screen for 500 mss.

Following was an instruction frame that directed participant to remember only two of the four terms in memory load. The instruction to half of participants always named the category to be remembered, (e.g., Remember words that are jewelry). And the instruction to another half of participants always named the category to be ignored, (e.g., Remember words that are not unit of time). The participants could take as long as needed to identify and rehearse the two target exemplars (e.g., diamond and emerald) in the memory load. They were instructed to press the space bar when ready to recall the words.

With the selection instruction frame disappearing, the participants were prompted to recall the two words held in memory with typing the spelling in Pinyin of each Chinese word they were recalling.

Following the second recall frame, there was the instruction to compare words. The participants were instructed to rest their forefingers on the F and J keys, and decide whether the two exemplars in each comparison came from the same category (F response) or different categories (J response). This instruction was self-paced to allow the participants to prepare for the comparison frames.

Each comparison frame began with two asterisks presented for 500 ms, one on top of the other at the location where the two stimulus words would appear. The stimuli remained on the screen until participant responded by pressing either the F or the J

key. There was a total of eight category comparison frames in each trial. The first two frames were warm-ups that contained words unrelated to the contents of the memory load and the unprimed category in the stimulus set. The remaining six frames were presented in random order for each participant. They consisted of positive match frames and negative match frames with the three categories of the stimulus set (focused, ignored, and unprimed).

For the group with distraction task, the experimental task consisted of five sequential components: memory load presentation, selection instruction, memory load recall, distraction task and category comparison frames. Each of 24 trials contained the five components in the same order as the group without the distraction task, except there was a distraction task before category comparison frames. The sequence of the 24 trials was randomized. The distraction task was an arithmetic problem with continuously subtracting a digit (3, 4, 5, and 7 randomly), and lasted 3 minutes.

3 Results

3.1 Accuracy of Recalling and Distraction Task

All of the participants selected and recalled the focused category words from the initial memory loads with high accuracy (100%). This result showed all participants could correctly recall the exemplars that the instruction required to be remembered. For the group with distraction task, the average accuracy rate of arithmetic problem was 76.43%. It suggested the distraction task was much more difficult than memory load task.

3.2 Accuracy of Category Comparisons

The average accuracy rate of positive match condition and negative match condition was 93.60% and 97.70%, respectively. The Pearson's correlation between response time and accuracy rate showed there was no significant speed accuracy trade-off effect in the present study, $r = 0.297$, $p > 0.05$.

3.3 Response Time for Positive Match Category Comparisons

The response time for the positive match category comparisons was showed in Fig. 2.

With items as a random factor, a repeated measure ANOVA was conducted. Priming type (focused or ignored), category identification (category name displayed or not), and distraction condition were three repeated measures. The results showed that the main effect of distraction condition was significant, F_2 (1, 71) = 76.17, $p < 0.001$, $\eta^2 = 0.52$. The three-way interaction of priming type by category identification by distraction condition was significant, F_2 (1, 71) = 78.79, $p < 0.001$, $\eta^2 = 0.53$. Other main effects and interactions were not significant, $F_2 s < 2.5$, $p > 0.05$. The analysis of simple effect showed the role of distraction on hastening response time of comparison under the condition of ignored category and displaying the category name was significant, F_2 (1, 71) = 65.66, $p < 0.001$, and the role of distraction on hastening response time of comparison under the condition of focused category and not displaying the category name was also significant, F_2 (1, 71) = 77.85, $p < 0.001$.

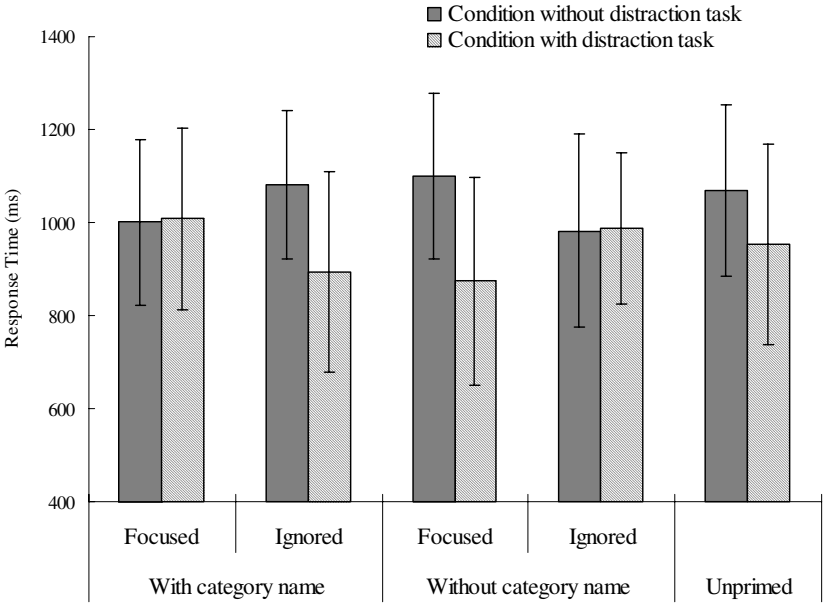

Fig. 2. Mean response time for positive match category comparisons

Because the significant three-way interaction was complicated, Paired-Samples T Tests between four experimental condition and their baselines (unprimed condition) were also performed to explore the reason of interaction.

The results of Paired-Samples T Tests showed: (a) Under the condition without distraction task, if the comparison items belonged to focused category with category name, the participants were significantly faster than the corresponding baseline, $t = -3.01$, $p < 0.01$; (b) under the condition without distraction task, if the comparison items belonged to ignored category without category name, the participants were also significantly faster than the corresponding baseline, $t = -6.09$, $p < 0.001$; (c) under the condition with distraction task, if the comparison items belonged to focused category without category name, the participants were significantly faster than the corresponding baseline, $t = -4.34$, $p < 0.001$; (d) if the comparison items belonged to ignored category with category name, the participants were significantly faster than the corresponding baseline, $t = -6.09$, $p < 0.001$; and (e) other Paired-Samples T Tests were not significant. The results showed that distraction task had significant influence on the priming effects of ALTM task.

4 Discussions

Evidence from the experiment demonstrated distraction task had significant influence on the interaction of working memory and long-term memory. These findings support the hypothesis that the semantic activation is implicit automatic process, and fewer attention resources focus on the process will benefit the semantic activation of LTM.

4.1 Semantic Activation

The results of ALTM task without distraction task showed when the comparison items belonged to the focused category with category name, the responses were significantly faster than the comparison items belonging to the unprimed category. This result suggested there was a significant semantic priming effect, and rehearsal and category identification could facilitate semantic activation of target category. Wshen the comparison items belonged to ignored category without their category name, the responses were also significantly faster than the comparisons belonging to the unprimed category. This result suggested even minimal processing and rehearsal in WM (participants just read the two words belonging to ignored category in memory load presentation) produced significant priming effect. These results were consistent with the found of Woltz and Was [10].

However, the results of ALTM task without distraction task showed that neither the condition of ignored category with category name nor the condition of focused category without category name produced significant priming effect. These phenomena could due to the complex switch the words to be recalled from ignored category name to focused category name. Under these two conditions, much more cognitive resource was involved in the switching process, and inhibited the automatic semantic activation.

4.2 The Role of Distraction Task

The results of the present study showed distraction task had significant influence on the interaction of working memory and long-term memory. The role of distraction task on the availability of LTM facilitated by prior attention-driven processing in WM was observed by ALTM task.

The pattern of semantic priming effects observed was reversed between the condition with and without distraction task. The results of ALTM task c showed when the comparison items belonged to focused category and their category name was not presented, the responses were significantly faster than the comparison items belonged to the unprimed category. And the comparison items belonged to the ignored category and their category name was presented, the responses were also significantly faster than the comparisons belonged to the unprimed category. These results accorded with other researches about the effects of additional mental load [6] [8]. It suggested that distraction task occupied the cognitive resource, and increased the mental load before category comparison. Under these two conditions, there were no more resources to control the category switch. So, rapid automatic process was free from executive control, and it improved the category switch, and produced significant semantic priming effect.

However, the other two conditions presented didn't get significant priming effect. These phenomena might be due to decay of the activation with time lasting. Although, the semantically mediated priming effects were relatively long lasting, 3 minutes delay set in the present study was too long to maintain the activation.

In conclusion, the findings of the present study suggest the semantic activation facilitated by prior attention-driven processing in WM is implicit automatic process, and less attention resource focus on the process will benefit the semantic activation of LTM.

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