Memory Encoding: Effect of Cognitive Approaches on Memorizing Abilities

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ABSTRACT
The neuroanatomical basis study of the memory process investigated that the left inferior prefrontal cortex was associated with memory processing and activated preferentially. This study further demonstrated the most efficient memory process for memorization tasks based on the above experiment. Twenty-five participants performed in this experiment, the age range is between 20 and 56. There were three kinds of memory tests: orthography, word property, and semantics. Each test corresponded to a question respectively: the question of the orthographic test was "*Does this word contain 'A'*", word property test was "*Is it a countable noun*", the last one was "*Is it a living creature*", and then participants were asked to recall if they had seen the presented word on the screen. The results showed that participants were more impressed by the words they remembered through word property and semantics. In other words, processing memory through thinking about word property and word meaning can be more effective than the orthographic process. This experiment is dedicated to contributing to the field of education, advertising, and memory recovery therapy development.

Keywords: *Memory process, Orthography, Word Property, Semantics, Memorization task.*

1. INTRODUCTION

Memory is a framework for storing information in our lives [1]. There are three processes for dealing with all information we receive from our lives, which are called memory processes. The memory processes consist of encoding, storage, and retrieval [2]. Encoding is the demonstration of getting information into a memory framework, storage can retain the information, and retrieval is the process that recollecting information [1]. It can be assumed that memorization tasks are correlated to memory processes. Many previous studies have shown the importance of memory processes in various aspects. Memory encoding is pervasive, can be encouraged and activated in different kinds of cognitive tasks [3]. Besides, semantic storage plays a key role in children's reading comprehension, and Karpicke suggested that retrieval is a powerful tool for understanding and enhancing learning [4, 5].

Our study was inspired by Kapur and his colleagues' research about the connection between neural systems and memory processes. Kapur demonstrated that the encoding process in episodic memory involved prioritized activation of the structures in the left inferior prefrontal cortex [6]. Episodic memory is a neurocognitive system that enables human beings to remember previous experiences [7]. Researchers have designed two memory tests: spelling test and semantic test. The spelling test required the participants to judge whether the word contains the letter "a".; The semantic test required the participants to determine if the word was a living creature by its meaning. The technology of positron emission tomography (PET) would monitor participants' brains at the same time, which could measure regional cerebral blood flow and helped researchers monitor which part of the brain activated while processing memory. In this experiment, the significant activation of PET images of these two tests in the left inferior prefrontal cortex was shown. In addition, the study also reflected better recognition memory for nouns in semantic tests [6].

The study of neural activity during memory processing has been extended in subsequent studies. A few researchers have developed the role of encoding and retrieval in age-related memory decline by using functional magnetic resonance imaging (fMRI), which is an imaging method aimed to monitor regional, time-varying changes in brain metabolism [8, 9]. The results of reduced performance of memory in the elderly may be caused by medial temporal lobe (MTL) dysfunction during encoding, and ageing does not affect the actual recovery of information, were concluded in the study [8]. Besides, the new findings of how different processing levels affecting the interconnection among brain regions involved in episodic memory encoding have been investigated in recent years. Researchers have tested the central changes of the communication patterns in brain regions while subjects processed tasks deeply. They suggested that the centrality changes reflected the processes of supporting memory encoding in the deep level of processing [10].

Although previous studies noted both the importance of memory processes and the connection between neural systems and memory processes, their study didn't delve into the efficiency of different memory processes on memorization tasks. Not only for the sake of improving the research gap from previous studies, but also for achieving the contribution to the field of education. Thus, this study was explicitly designed to explore which of the three kinds of memory processes is the most helpful for word recall tasks. Kapur's experiment has already provided both Orthographic and Semantic tests. This experiment has added a Word Property test based on Kapur's study to make our experiment more completed [6]. The results from participants would be recorded automatically. The hypothesis is that participants would remember the words on the Semantic test better than they did on the other two tests, which means that thinking about the semantics of words was the most effective process for the word recall task.

2. METHOD

2.1. Participants

Participants were 20-56 years old adults (5 males, 20 females). They were all bilingual Chinese, speaking Mandarin and English. Two participants were dropped from the data as outliers since they failed to understand the task correctly. All the participants agreed with the informed consent before the experiment.

2.2. Materials

The task consisted of three kinds of word memorization processes, Orthography, Word Property, and Semantics. There were three questions for these three processes, "*Does this word contain 'A'?*" for Orthography, "*Is it a countable noun?*" for Word Property, and "*Is it a living creature?*" for Semantics. The answer to the question was "yes" or "no".

A specific group of words was assigned to each question and remained the same throughout the test. At the second phase, the words from the new word list were not encoded through processing by the three set questions and were not shown before. There were 24 words within each group. All the words were common concrete nouns, lengthening 3 - 7 letters. Among them, half answered "yes" to the assigned question and the rest was "no" (e.g., for orthography process, the question asked whether there was an "A" in the word, and half of the word on the list contained "A" while the other did not.).

2.3. Procedures

The task was adapted from a previous study conducted by Kapur and his colleagues [6].

Before starting, the informed consent with an announcement of deception was displayed. To avoid the participants intentionally memorizing the presented words, the instruction stated that participants would only need to answer the simple question relating to a word, presenting simultaneously. The experiment ended with a debrief explaining the actual purpose of the experiment.

The experiment was designed and operated by the PsychoPy software on personal computers. After confirming the informed consent by pressing "space" on the keyboard, the participants would accept the deception and could exit whenever they want.

The experiment had two phases, a Question Phase, and a Recall Phase. At the Question Phase, a question would be presented on the top of the screen. A word paired to it was displayed just below the question. Participants need to answer the question by pressing "Y" on the keyboard for "yes" or "N" for "no" (e.g., If the question was "Is this a living creature?" and the word presented was "dog", the participant should press "Y"). Once pressed "Y" or "N", the instruction stating that pressing "space" to continue would be shown. There were 72 question trials at the Question phase. Among them, one-third were Orthography questions, one-third were Word Property questions, and the rest were Semantics questions. The question-and-word pairs from three process types were randomly displayed.

At the next phase, the screen would only display one word at the centre of each trial. Participants should recall whether they had seen the word at the Question Phase, pressing "Y" for "Yes, I have seen it at the Question Phase", and "N" for "No". Participants need to press "space" to continue the experiment. The Recall Phase contained 96 words. New words and all the words from the Question Phase would be presented one at a time randomly.

By the end of the experiment, a debrief clarified the actual purpose of this study, which was to learn about the effectiveness of three process types by analyzing the accuracy of recalling the processed words.

2.4. *Data analysis*

Participants' data were collected by the PsychoPy software and stored in excel individually.

The independent variables were the process types participants used when encoding the words at the Question Phase, implying by the question given to the participants. The dependent variable was participants' correct memorization rate at the Recall Phase.

Researchers selected the excel columns of correct answers under Orthography, Word Property, Semantics, and New Word conditions at the Recall Phase, averaging the correct memorization rates on all participants for four conditions. The correct memorization rates for new words were designed as the benchmark.

A one-way ANOVA was used to analyze the data. Higher mean correct memorization rates under Semantics and Word Property conditions compared to Orthography condition represented higher effective memorization on these two process types and vice versa.

3. RESULT

Participants' performances under three conditions (Word Property group, Semantics group, and Orthography group) at the Recall Phase were compared with the percentages of correctness on recognizing the new words (see Table 1). These percentages are used as the dependent variable measure.

Two Outliers have been withdrawn from this study due to two participants' confession of the misunderstanding of the tasks after experiments. The correct memorization rates for recalling whether the new words have been shown before were 0% and 4% for these two participants, while the data for the other participants was about 100%.

All percentages of correct answers were subject to single factor Analysis of Variance (ANOVA). The percentages of correctly recalling words from the Word Property group that appeared at the Question Phase were significantly greater than correctly recognizing words that did not appear at the Question Phase ($F(1,23) = 6.59$, $M = 92.75\%$, $p = .01$, $\eta 2 = 0.31$). Participants also had significantly better performance when they memorized words based on semantics feature ($F(1,23) = 4.96$, $M = 91.67\%$, $p = .03$, $\eta 2 = 0.35$). The result obtained from these two groups indicated that thinking about word property and semantics did influence the participants' performance on memorization tasks. In contrast, their percentages of correct memorization were significantly lower under the Orthography condition than the control group, $F(1,23) = 18.73$, $M = 55.80\%$, $p < 0.01$, $\eta 2 = -0.54$, which means simply focus on the structure and constitution of the word had a negative impact on memorization with a negative effect size. We set the new word group as the control group ($M = 0.83$, $SD = 0.17$).

The standard deviation of 0.09 was gained under the Word Property condition, 0.10 under Semantics condition, 0.25 under Orthograph condition, and 0.17 under the New Word condition. It indicates that the dispersion of participants' performance relative to its mean is small.

Table 1. Analysis of Variance of the Percentages of Correct Memorization Under Three Conditions

Groups	M	SD	F	P-values
Word Property	92.75%	0.09	6.59	0.01
Semantics	91.67%	0.10	4.96	0.03
Orthography	55.80%	0.25	18.73	0.00

4. DISCUSSION

This study aims to explore the effect of three different processes (Orthography, Word Property, and Semantics) on the accuracy of the word recall task. The hypothesis is that using a semantic process, the accuracy for word recall will be higher compared to the other two processes. The data partially supported the hypothesis. After data analysis, a similar mean correct memorization rate on recalling the words was found in the Word Property condition and Semantics condition.

When contrasted to mean percentages of correctly recognizing, this proved to be the case: The obtained data clearly show that participants have significantly better performance when the shown words paired with questions used to make them think based on words' property and the semantic feature (i.e., living creature; non-living creature). In comparison, they have poorer

memorization when the questions are asked about words' orthography (Semantics = 91.67%, Orthography = 55.80%). Also, a similar result was noticed in the comparison between Word Property and Orthography. The mean correct memorization rate for recalling the words was higher when participants were implied to process the words with the question asking whether the given word was a countable noun (Word property = 92.75%, Orthography = 55.80%).

There are four possible explanations for the final data. First, if more brain regions are used to process, the words will be memorized more effectively. According to Kapur and his colleagues [6], the PET scanning image shows there are more regions used for semantic process (deep process) compared. Further experiments for the Word Property process are needed to support the hypothesis. Second, when being asked the Orthographic question, participants may only process the word partially. If being asked "*Does this word contain the letter 'A'?*", the participants may look for an "A" rather than reading through the whole word. Third, if more information is recalled with the word, the word may be remembered better. From Guthrie's repetition theory, a firmer link will be formed between stimulus and response if more stimuli are related to the original stimulus [8]. In our case, taking the question "*Is it a living creature?*" and the word dog as an example, participants may relate the word dog to other information such as run, breath, sleep, and bark, then decide whether the dog represents a living creature. Memorization for the word dog may be firmer compared to when only looking for whether there is a letter 'A' in the target word. Fourth, using both working memory and long-term memory from the modal model to process the question and word, participants can remember well [12]. The orthographic process only requires the participants to use working memory to process, while word property and semantic process, containing contents from prior knowledge and experience, ask for both working memory and long-term memory.

This experiment has some limitations. The exposure time to question and the word was not controlled. From the final data, more time was taken for the Word Property and Semantics questions. In this case, participants spent more time processing the word, which may be a potential confounding variable for a higher recall performance. Also, the words chosen for the three processes were different. It is possible that participants were more familiar with the words chosen for Semantics and Word Property so that they had better accuracy at the Recall Phase. Individuals may have their structures of encoding and personal constructs [13, 14]. If failed to control words chosen for different groups, it is hard to ensure that the between-group difference came from the independent variables, which were process types, or word groups themselves. During data analysis, two sets of data were dropped since the participants failed to understand the instruction correctly. An example trial is needed before the real trials, in order to ensure that the participants read the instructions carefully and get familiar with the following trials. Finally, the result may fail to generalize well to other populations. Researchers used convenience sampling to invite participants. Participants aged from 20-56 years old are teachers who come from the same primary school in Shenzhen, China. The results of this study need to be validated in more diverse samples.

More process types can be added into the studying, such as pronunciation. Also, the words chosen for this study were all concrete nouns lengthening 3-7 letters. Other kinds of words such as abstract words or even non-words can be included. The original study suggested that a deeper process was found in Semantics since there were more brain regions activated, which may explain why the mean correct memorization rate was higher [6]. Since there were only PET sources for Semantics and Orthography processes, whether the Word Property questions can activate more brain regions than Orthography remains unknown. functional magnitude resonance imaging (fMRI) can also be implied in the future study, scanning brain activity while processing.

Our experiment is related to the field of education. According to feedback from teachers who attended our experiment, they believe that the result can improve the way students understand and remember the course contents. One Chinese teacher took the ancient Chinese poems as examples. When students recite the poems without knowing the meaning of the poems, the accuracy will drop significantly, and the memorization of the poems will not last for long. Our experiment result supports that reciting along with understanding may be a more effective studying approach.

The result of the study can also be applied to advertising. By implying the consumers through semantics and word property in the advertisement, consumers can memorize the content of the advertisement and products better. Furthermore, higher profits can be expected in this case.

After brain surgeries or therapies relating to memorization, the result can also be used to assist the patients' recovery. More semantics- and word-property-related implying tasks can be used before the orthography tasks during recovery. Patients may process deeper and have better training on word memorization through semantics and word property processes.

5. CONCLUSION

This research provides evidence that semantics and word property process to the easy concert English noun can help memorize the words through episodic memory better than only orthographically processing them. The finding can be used in education. Schools can promote the teaching and studying method by requiring more understanding and grammar-related knowledge on the

course content. The more complex content can be studied based on this experiment. Rather than a single word, the encoded and recalled target can be a poem or even the content of a theory. Whether the complexity of the target item will influence the accuracy of memorization remains uncertain. More experiments are looking forward to improving and learning more complex content may be more helpful for the application of the study.

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