

The Effects of Working Memory Load on Word Frequency

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작업기억 부하가 단어빈도에 미치는 효과

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요약 본 연구는 단어 재인에서 작업 기억의 역할을 규명하기 위하여 진행되었다. 단어 재인에서의 작업 기억 역할 규명을 위하여 단어 빈도와 작업 기억 부담을 조절한 명명 과제 실험을 실시하였다. 실험 결과 단어 빈도는 작업 기억 부담에 영향을 받는 것으로 분석되었다. 작업 기억의 부담은 고빈도 단어 재인에서보다 저빈도 단어 재인에서 더 높은 영향을 미쳤다. 이러한 결과는 작업 기억이 저빈도 단어 재인에서 더 많은 영향을 갖음을 시사하는 것이다.

Abstract This study was conducted in order to investigate the role of working memory in word recognition. As a preliminary step in tackling this topic, word frequency and working memory load were manipulated in a naming task. The results showed that word frequency is significantly involved with the working memory load. The effects of working memory load were greater in low-frequency word processing than in high-frequency word processing. These results indicate that working memory is involved more in the processing of low-frequency words. The implications for the teaching of children at the early reading acquisition stage are discussed in this paper.

Key Words : Reading, Word Recognition, Working Memory, Word Frequency

1. Introduction

The relationship between working memory and language processing has been a primary interest of psycholinguists. After Just and Carpenter (1980) proposed the capacity theory of comprehension, many studies argued that short-term memory or working memory capacity is a reliable predictor of individual differences in reading comprehension[1,4,5]. Working memory also is related to writing skill. Specifically, articulatory suppression impairs sentence writing[2,8,9,10], and overloading visual-sketch pad impairs writing efficiency, having a greater impact

on descriptive text than on argumentative text[6]. In sum, reading and writing that include higher levels of cognitive processing are influenced by working memory functions.

A subsequent question is whether working memory can influence lower-cognitive-level reading or writing, such as word recognition, or not. Word recognition was traditionally assumed to be quite automatic, meaning unconscious, fast, and not requiring cognitive resources. Due to this assumption, many psycholinguists hypothesized that working memory, a representative higher-cognitive function, is not significantly related to word processing[2].

That assumption, that word recognition is quite automatic,

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was challenged by several studies. For example, McCutchen (2000) found that skilled writers were also fast and accurate in lexical decision-making, an indicator of word recognition[11]. If writing that includes higher-cognitive processing is related to lexical decision-making performance, there is a possibility that word recognition might also include components of higher-cognitive processing. In addition, Reynolds and Besner (2006) found that early components of lexical processing require the processing capacity of attention[12]. Further, if the attention capacity requires cognitive resources, so too does lexical processing, which indicates that lexical processing is not quite automatic. In sum, if word recognition is not quite automatic, it is very likely that it, the most basic of reading processes, is related to working memory capacity.

This preliminary study was conceived for the purposes of investigating the relationship between working memory and the word frequency effect, the primary indicator of word recognition. According to Sternberg's logic in [13], if manipulation of working memory capacity affects the processing of high-frequency words and low-frequency words by different degrees, then working memory somehow plays a role in the early processing of word recognition[13]. In the present experimentation, working memory was manipulated by means of a digit span task. In this task, subjects are requested to memorize a certain series of digits presented on a computer screen, after which they are to read aloud a displayed word.

The digit span task used is a variant of the one developed by [4]. Digit span task performance reflects the phonological processing of the working memory functions, which is the main component of working memory.

Nonetheless, word frequency is the main predictor of word processing. Word frequency has been found to explain about 40% of total reaction-time variance in word

processing. Thus, in the present study, if the digit span task performance correlates with word frequency, we could argue that the working memory component plays a role in word recognition.

This study used the lexical decision task for words with different frequencies while conducting the working memory task. The method section described these related procedures and stimuli more specifically. The results and discussion section provided the corresponding results as a table and a figure, and discuss about the results as well as comparing with previous studies.

2. Method

Subjects Sixty students enrolled in the Introductory Psychology class at Pusan National University participated in the experiment. All of subjects had normal vision.

Materials Forty-eight Korean target words were selected from the Korean Frequency Database[7]. Half of these words were 2-syllabic words and the other half were 3-syllabic words. The two length types were selected in order to generalize the data. Half of the words, of each length type, were high-frequency words (average = 233.7 [std = 174.1] for 2-syllabic words; average = 235.2 [std = 175.7] for 3-syllabic words), the other half being low-frequency words (average = 2.27 [std = 0.9] for 2-syllabic words; average = 2.38 [std = 1.0] for 3-syllabic words).

Procedures. The participants were sat down at a Pentium III PC, and the stimuli were presented, singly in sequence, on the center of the computer screen. All of stimuli were presented as white characters on a dark background. The digit span task we used was a variant of the one by[14]. Word naming was interpolated between the two main steps

[Table 1] Lexical Decision-making Latencies (ms) and Error Rate (%) across two SOA conditions in experiment 1

	2 syllable		3 syllable	
	Load	Control	Load	Control
Low Freq.	665(1.4)	466(0.9)	599(1.6)	442(1.3)
High Freq.	565(1.1)	392(0.8)	552(1.4)	420(1.2)

() Error rates

of the digit span task. In other words, the 7 digits that were to be memorized were presented on the computer screen first, with 1000 ms SOA (Stimulus Onset Asynchrony). Subsequently, the word to be named was presented with 4000 ms SOA. A voice recorder measured the reaction time of the first phoneme pronounced by the subject. After 1000 ms of word naming, the memory test was conducted. After the memory test was scored, only the words that were correct in the trial were analyzed.

In the course of word naming, an experimenter sat beside the subject and identified the pronunciation errors and hesitations.

3. RESULTS AND DISCUSSION

The data of three subjects were discarded owing to poor performance in the digit span test. Latencies above and below three standard deviations of the means of each participant were also excluded. The pronunciation and hesitation errors were quite low (all error rates were less than 1.6%). The mean RT and naming error rates for each condition are summarized in [Table 1].

The reaction time responses for words were analyzed by ANOVA. Error analysis was not performed, because the rates were too low for every condition. The ANOVA design was a 2 X 2 X 2 within factor design, with variables of Length (2 syllable & 3 syllable), Memory load (load, control), and Word frequency (high, low).

Frequency and length were statistically significant in the analysis, $F(1, 26) = 82.6$, $p < .0001$, for frequency, and $F(1, 26) = 35.7$, $p < .0001$, for length. More importantly, there was significant interaction between the frequency and memory load, $F(1, 26) = 17.2$, $p < .0001$. The working memory load affected low-frequency word processing more than high. In 2 syllable condition, the reaction time difference between low and high frequency word condition for working memory load condition was 100ms, where that for control condition was just 74ms. Similarly, In 3 syllable condition, the reaction time difference between low and high frequency word condition for working memory load condition was 47ms, where that for control condition was just 22ms. This indicates that working memory affects the degrees of word frequency effects as well as increasing the overall

average. The interaction between length and frequency was marginally significant, $F(1, 26) = 3.3$, $p < .08$. This pattern of results is in the similar vein as the studies done by Lee's group on word length in which more length effect was there for low frequency words than high. None of the other effects, including that of three-way (length, memory load, word frequency) interaction, were statistically significant.

The interaction found between frequency and memory load indicates that working memory somehow plays a role in word processing. Based on the dual-route word recognition model, which posits two routes, the visual route and the phonological route, in word recognition[3], working memory can influence both routes. This model assumes that the visual route is the direct connection between the visual form of a word and the corresponding meaning, and that the phonological route is the connection between phonemes and the corresponding meaning. By way of the phonological route, the phonemes are recognized by the grapheme-to-phoneme correspondence rule. The efficiency of final calculation for both routes is based on how often a word appears in daily life. If we postulate that the processing of low-frequency words requires cognitive resources because they are not experienced often in daily life, it is matter of course that working memory is involved in the processing of low-frequency words. This possible involvement of working memory in the processing of low-frequency words elicits an interaction between the working memory load and word frequency.

Previous studies, using the digit memorization task, showed that low frequency irregular words are significantly affected by the task[1, 7]. Specifically, significant regularity effects were vanished when a reader read a word with digit memorizing. These results were interpreted as that the assembly route in the dual route was inhibited so that the conflict between the visual route and the assembly route was weakened[1,7]. Although these results indicate that word processing can be influenced by the working memory task, the focus of these studies were limited to irregular words.

This, in turn, has implications for the teaching of children at the early stage of reading acquisition. Children at this stage would learn all words with a significant amount of working memory resources, except for only a relatively few high-frequency words. Thus, we would

need to develop a kind of program for children by which they can train to use working memory resources more efficiently, leading to better learning of new words. Early working memory training such as that involving digit memorization, dealt with in the present study, would strengthen children's working memory resources, eventually leading to more efficient reading acquisition.

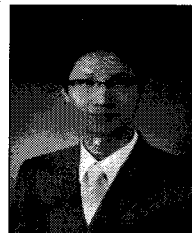
The current study showed that working memory somehow plays roles in word processing. This also indicates that word processing is not totally automatic, requiring no cognitive resources. Further studies are needed in order to clarify the specific role of working memory.

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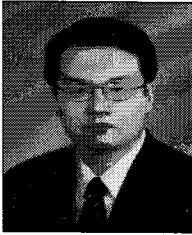
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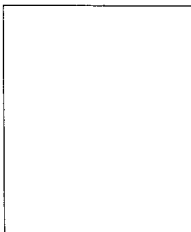
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