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Phonological short-term memory and early foreign language reading¹

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Introduction

The purpose of this study was to investigate which system of working memory beginners depend more on to process foreign language reading, the phonological loop or the central executive. The phonological loop is responsible for translating written information into a phonological code (Baddeley, 1986)

Daneman & Carpenter (1980) proposed that a simple memory task such as the recall of digit or word sequences could not account for complex cognitive activities since these tasks could only measure phonological short-term memory (STM). Skilled readers, thus, become less dependent on phonological codes (Davelaar et al., 1978), that is, more reliant on the central executive than the phonological loop. In Onaha (2006), there was no correlation ($r=.253$, $p>.05$) between phonological STM and scores on the reading section of a Test of English as a Foreign Language (TOEFL), which is designed to assess the English proficiency of those who are planning to study at universities in countries where English is spoken as the native language. That confirmed Daneman & Carpenter's results.

However, researchers have made progress toward understanding early development of reading ability in the native language (Connors, Atwell, Rosenquist & Sligh, 2001; Gathercole & Baddeley, 1993; Passenger et al., 2000). They claim that the development of early

reading ability owes much to the phonological loop, which represents phonological STM and the rehearsal process.

Many studies have reported on a relationship between the phonological STM abilities and the basic reading skills of those who have language impairment (Botting, Simkin & Conti-Ramsden, 2006; Catts, Tomblin & Zhang, 2002; Conti-Ramsden & Durkin, 2007). Reports on these studies suggest that some impairment in the STM component hinders some component of language development. Conti-Ramsden & Durkin (2007) carried out experiments to investigate the relationship between language, literacy, and phonological STM skills. They used nonword repetition and digit span tests to assess the phonological STM capacity of 80 children with specific language impairment (SLI) at age eleven, and again three years later at fourteen years of age. The correlation among measures at eleven and fourteen years of age revealed that scores on nonword repetition and digit span tests were significantly related to scores on basic reading and reading comprehension. The results at eleven years of age were $r=.555$ between nonword and basic reading scores, and $r=.514$ between nonword and reading comprehension scores. The results at fourteen years of age were $r=.551$ between nonword and basic reading scores, and $r=.401$ between nonword and reading comprehension scores. The digit span also showed significant correlations to basic reading, $r=.549$ at age eleven and $r=.594$ at age fourteen, and to reading comprehension, $r=.455$ at age eleven and $r=.597$ at age fourteen. All were at .001 levels. Although there was evidence of development of phonological STM capacity throughout early normal adolescence, in this study, there was no evidence of development of phonological STM capacity in children with SLI between the ages of eleven and fourteen. The study showed that within the group of SLI, the more severe the

reading difficulty, the poorer the phonological STM.

Conners et al. (2001) investigated other aspects of intellectually disabled children on possible causes of unsuccessful reading and suggested that the ability to rehearse or refresh codes in the phonological loop plays an important role in learning to read. Cain et al. (2004) further claimed that complex memory performance that assesses central executive function can be dissociable from general verbal abilities. Mukoyama (2008) made similar assertions. Her experiments were conducted on learners of Japanese as a second language (JSL). She used the ability to analyze language and working memory as a predicting tool for learners' language aptitude and found that the ability to analyze language and phonological STM could predict the beginning stage of language achievement in JSL learners, whereas scores on the reading span test did not predict language achievement.

In Baddeley (1986), storing information for a short period of time and rehearsing phonological codes are the major functions that demand more storage in the phonological loop (Baddeley originally referred to it as the articulatory loop), while processing or comprehending information demands more of the central executive in working memory (Gathercole, Alloway, Willis & Adams, 2006). The storage component stores information only in the form of phonological codes so that auditory information goes directly to the phonological store. In contrast, written information is first encoded acoustically in the articulatory control process and then goes into the phonological store (Baddeley, 1990).

There have been a few studies on the listening skills of advanced learners, investigating the relationship between phonological STM and listening comprehension in a foreign language. Call (1985) examined

the relationship between auditory STM and listening comprehension in university ESL (English as a second language) learners in the U.S.A. Her findings included a correlation between random digit memory and listening comprehension ($r=.34$). Onaha (2004) investigated the relationship between phonological STM and university EFL (English as a foreign language) student listening comprehension ability. Significant correlations were found between unfamiliar word repetition and listening ability in Study 1 ($r=.50$, $p<.01$) and between the digit span test and listening ability in Study 2 ($r=.48$, $p<.001$). These studies suggest that phonological STM plays an important role in the listening ability of advanced learners of ESL/EFL.

The data collected from normative as well as SLI children imply that the phonological STM can play an important role in early stages of learning to read. However, few studies have focused on early development of reading skills in EFL learners. Studies in experimental and developmental child psychology give us a great hint of what aspects of memory function play a crucial role in developing reading skills for EFL beginners.

Based on studies of variations between learners, including English-speaking children with language impairments, the current study conducted experiments on EFL beginners to determine whether the phonological STM is crucial for EFL readers to process English text. More specifically, a traditional digit span test was used to measure the capacities of the phonological store. Accordingly, the experiments predict that there are correlations between the phonological STM span and scores on reading and listening tests of EFL beginners.

Methods

Participants. The participants were a group of EFL beginners who were third-year junior high school students from a local school, in Okinawa. The students took a forward and a backward digit span tests, and listening and reading tests.

Participants and tests. A total of 103 third-year junior high school students took the listening and reading sections of a Level 4 standardized test of English proficiency (STEP). On a different day, digit span tests (both forward and backward) were administered to the same group of students. From this total, the scores of 78 students who took all three tests were analyzed.

There are two reasons to use a digit span test to assess phonological STM in this study: One is that the correlation between digit span tests and reading tests in the study by Conti-Ramsden & Durkin (2007) is higher than that of nonword repetition. The digit span test was correlated to shadowing exercises, which require rapid repetition, at .52 ($p < .01$) (Onaha, 2004). The other is a digit span test is much easier to conduct in Japanese public school classrooms.

This study follows the same procedure used in the study by Onaha (2004) as follows. The digit span test consists of a sequence of digits that was sampled randomly and recorded by a native speaker of English. The sequence is increased in increments starting with two digits and continuing to ten digits. The first sequence consists of two digits, such as 9, 1, the second sequence three digits, such as 8, 0, 6, the third sequence four digits, such as 7, 1, 5, 2, and so on up to a sequence of ten digits. The native speaker read the two digits in about one second, or approximately one digit every 0.5 seconds. After he read the first sequence of digits, he paused and then read the second

sequence of digits.

The participants were told to write down the digits in the same order on a piece of paper immediately after they heard the sequence of digits. The same task was repeated until they had heard and had written down each sequence of digits. The experimenter made a brief stop right after each sequence to make sure all the participants finished writing. Before the final digit span tests, preliminary tests for both forward and backward digit span were conducted using two, three and four digits to make sure they understood what to do. The participants were also told to raise their faces when they were listening to a sequence of recorded digit numbers in order to prevent the participants from writing while listening.

Scoring of the digit span test was as follows: If participants correctly remembered and wrote down the two-, three-, and four-digit sequences, they got four points; if they correctly remembered and wrote down the two-, three-, and five-digit sequences, but not the four-digit one, they got 3.5 points. Their score was the longest consecutive sequence that they correctly wrote down. For example, if they correctly wrote down all the sequences through five digits, they got five points, and for all the sequences through six digits, they got six points.

Results

Table 1 shows the descriptive statistics on tests.

Table 1
Descriptive statistics for tests (N=78)

Measure	M	SD	Maximum Score
Memory Span Task			
Forward	4.08	0.96	10
Backward	3.87	1.08	10
English tests			
Reading	8.14	3.73	15
Listening	18.71	6.07	30

Table 2 provides correlation coefficients between the reading, listening, forward, and backward digit span test scores.

Table 2
Correlation matrix for four cognitive tasks (N=78)

Measure	1	2	3	4
1. Reading	1.000	.614	.566	.517
2. Listening	.614	1.000	.569	.446
3. Forward	.566	.569	1.000	.614
4. Backward	.517	.446	.614	1.000

All correlations significant, $p < .001$

Discussion

The results in Table 2 indicate correlations between scores on the forward digit span and reading ($r = .566$, $p < .001$), between forward

and listening ($r=.569$, $p<.001$), and between reading and listening ($r=.614$, $p<.001$). The correlations are also shown between scores of backward and reading ($r=.517$, $p<.001$), and between backward and listening ($r=.446$, $p<.001$). These support the claim of this study that the phonological STM plays an important role for EFL beginners and underpins the developmental stage of reading skills as Alloway et al. (2004) have suggested. They specifically pointed out that "phonological STM may play a role in learning letter-sound correspondences... (p. 98)." It seems to be the root of children's learning how to read. They seem to learn by vocalizing a word to determine whether their vocalization matches the word they are learning. This kind of activity may refresh phonological STM and promote subvocalization (or inner speech) and at last lead to silent reading. According to the experiments of Hitch et al. (1991), English children in their study before the age of seven memorized words visually, with the words presented along with pictures. Children after that age, on the other hand, memorized the words phonologically and showed the phonological similarity effect even though the words were also presented with pictures. From these experiments, it seems that inner speech develops when they start learning how to read. In order to develop better reading skills and to be a good reader, it is necessary that inner speech be fully developed. Beggs et al. (1985) suggest that reading aloud might train phonological encoding before beginning readers start to develop silent reading.

Although the reading skills of intermediate and advanced learners of English were, minimally associated with phonological STM (Osaka & Nishizaki, 2000; Onaha, 2006), basic reading skills of EFL beginners were highly associated with phonological STM. These findings are consistent with the native language literacy skills of both normative

and SLI children (Alloway et al., 2004; Conti-Ramsden & Durkin, 2007).

Notes

1. I am grateful to Ms. Masae Yonamine and Itoe Kinjo who supported the study, and their students who participated. I also thank Professor Timothy Kelly for his invaluable comments.
2. An earlier version of this study was presented at the third Conference of the Japan Society of Working Memory at Kyoto University, 2006. A greater number of participants and a standardized reading test were used in the present study.

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音韻短期記憶と初級英語学習者の英文読解

論文要旨

本稿はワーキングメモリ理論の枠組みの1つである音韻ループと初級英語学習者の英文読解の関係性を、実験をとおして解明することを試みた。

読解を担っているのは、ワーキングメモリの中枢である中央制御機構であるというのが定説である。しかしながら学習障害児童や脳損傷患者の言語に関する研究や初期の母語習得において音韻ループと読解との関わりの重要性が解明されてきている。その先行研究を踏まえ、本研究では、音韻ループの1つを構成している音韻短期記憶が初級英語学習者の英文読解において重要な役割を担っているという仮説を立て、実験を行った。

実験参加者は中学3年生(78名)である。実験材料は読解力と聴解力を測定するために英検4級を使用し、音韻短期記憶を測定するためによく用いられている数唱記憶範囲課題(順唱と逆唱)を使用した。実験の結果、読解テストと順唱課題($r=.566$, $p<.001$)および逆唱課題($r=.517$, $p<.001$)には相関があることが証明された。したがって音韻ループの音韻短期記憶が、読解にはほとんど寄与していないという先行研究は、初級学習者の英語学習においては十分に説明しきれないことが判明した。英語学習が初級から上の段階へスムーズに移動するためには、初級の段階ですべき学習点や練習方法に音韻ループを活性化する音声教育を十分取入れなければならないということが示唆された。