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The Relationship between Phonological Short-Term Memory and Vocabulary Acquisition in Japanese Young Children

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Abstract

We confirmed the proposal made by Gathercole & Baddeley (1989, 1993), in experiments using the Japanese language, in which little contribution from phoneme-level phonological sensitivity is involved in vocabulary acquisition. They claimed that the capacity for of phonological short-term memory is the foundation of vocabulary acquisition, and that phonological short-term memory can be measured by nonword repetition tasks. Bowey (1996), moreover has argued that both phonological short-term memory and phoneme-level phonological sensitivity contribute to vocabulary acquisition. Thus, we have conducted two studies using the Japanese language, which has little contribution of phoneme-level phonological sensitivity. In study 1, we experimented 92 five-year-old to examine the relationship between vocabulary acquisition and phonological short-term memory using Japanese nonword. The correlation coefficient between vocabulary acquisition and Japanese nonword was $r = .31$. By applying the results to structural equation modeling, we confirmed Baddeley's working memory model. In study 2, we experimented 90 five-year-old to test both Japanese nonword and English nonword as well as phonological sensitivity tasks in both Japanese and English in order to examine their correlation with vocabulary acquisition. We have found that there are significant correlations between vocabulary acquisition and Japanese nonword, as well as between vocabulary acquisition and Japanese phonological sensitivity ($r = .27$ with Japanese nonword, $r = .30$ with Japanese phonological sensitivity, whereas $r = .17$ with English nonword and $r = .17$ with English phonological sensitivity), which indicates that phoneme-level phonological sensitivity (i.e. English phonological sensitivity) has low involvement in vocabulary acquisition for Japanese children. In addition, we further discuss the relationship between vocabulary acquisition and phonological sensitivity that is unique to each specific language.

Keywords

Phonological Short-Term Memory, Phonological Sensitivity, Nonword Repetition, Vocabulary Acquisition, Working Memory Model, Japanese Young Children

1. Introduction

There are many studies which have examined the relationship between vocabulary and phonological abilities of the young children who speak English. Among these various studies, Gathercole and her colleagues have claimed that phonological short-term memory capacity is the foundation of vocabulary development and that it can be measured by nonword repetition tasks (e.g. Gathercole & Baddeley, 1989, 1993; Gathercole & Pickering, 2000; Baddeley, Gathercole, & Papagno, 1998; Gathercole, 2006). This claim is important not only in terms of studying the mechanism of vocabulary development but also of investigating the cause and treatment of language development disorder in children.

However, there are many counterarguments to this claim falling mainly into two categories: first, there are arguments that the causality proposed by Gathercole et al. is the opposite of what is actually taking place (e.g. Melby-Lervåg, Lervag, Lyster, Klem, Hagtvet, & Hulme, 2012). The other category argues that not only phonological short-term memory but also phonological sensitivity contribute to the process of vocabulary development in the English language (e.g. Bowey, 1996; de Jong, Seveke, & van Veen, 2000).

Based on the proposal by Gathercole et al. and various arguments surrounding it, this study will repeat their experiments in young children who speak Japanese, a language which is thought to require little contribution of phonological sensitivity. We predict that by using Japanese, we can separate phoneme-level phonological sensitivity from phonological short-term memory. Hereinafter, we will describe the details of previous studies, as well as the details regarding the reasons why we chose the Japanese language, and the purpose of this study.

2. Literature

2.1. Proposal by Gathercole and Baddeley

Many studies have examined the relationship between vocabulary and phonological ability in young children who speak English. Among these studies, Gathercole and Baddeley have claimed that phonological short-term memory, one of the phonological abilities, is related to vocabulary development (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1989, 1993; Gathercole & Pickering, 2000; Gathercole, 2006). This idea was developed based on the concept of working memory, which is an extension of short-term memory (Baddeley, 1986; Baddeley & Hitch, 1974). The working memory model assumes three systems as its components: two subsystems, the phonological loop and the visuospatial sketchpad, and a central executive that controls the two subsystems. Gathercole and Baddeley focused particularly on the phonological loop and examined its relationship with vocabulary development. Their research led them to claim that the development of phonological short-term memory is the foundation of vocabulary development and that later vocabulary ability can be predicted by measurement of phonological short-term memory (Gathercole & Baddeley, 1989, 1990, 1993). In their study, phonological short-term memory is often measured by nonword repetition tasks. In these tasks, children are required to accurately repeat nonword, and it has often been regarded as a genuine measurement of phonological temporary retention (Gathercole & Baddeley, 1989, 1990; Hansen & Bowey, 1994). They have also used these nonword repetition tasks to screening language development disorders among young children, and researchers have claimed its effectiveness as a practicable tool (Gathercole & Baddeley, 1989; Gathercole, Willis, & Baddeley, 1991; Gathercole, 1995).

2.2. Counterarguments against Gathercole Model

There are many counterarguments against the claims of Gathercole and Baddeley, however. These fall into two categories. First, there are arguments that the causality proposed by Gathercole et al. is the opposite of what is actually taking place. Snowling, Shiat, and Hulme (1991) have argued that knowledge of structures of English words underpins the accuracy of nonword repetition, so existing vocabulary knowledge contributes to the result of nonword repetition tasks. Thus, there are many additional studies that claim the opposite causality, with regard to phonological short-term memory and vocabulary, to which Gathercole et al. have proposed (Dollaghan, Biber, & Campbell, 1995; Estes, Evans, & Else-Quest, 2007; Melby-Lervåg, Lervag, Lyster, Klem, Hagtvet, & Hulme, 2012; Monica, Arne, Solveig-Alma, Marianne, Bente, & Charles, 2012). Gathercole herself has admitted that the causality inverts after five years of age (Gathercole & Adams, 1993; Gathercole et al., 1992), but claimed that, in a study of four- and five-year-old that carefully reviewed the content of nonwords which were used, vocabulary knowledge and nonword repetition mutually interact developmentally (Gathercole, 1995).

The other category of counterarguments claims that not only phonological short-term memory but also phonological sensitivity contributes to the process of vocabulary development (Bowey, 1996; Bowey, 2001; Metsala, 1999; Majerus et al., 2006a, 2006b; de Jong & van der Leij, 1999; de Jong, Seveke, & van Veen, 2000; Hansen & Bowey, 1994; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner, Torgesen, & Rashotte, 1994). These studies used nonword repetition, digit span, and phoneme-identification tasks to examine the relationship between phonological sensitivity, phonological short-term memory, and vocabulary, concluding that both phonological short-term memory and phonological sensitivity contribute to vocabulary development in English. For example, de Jong, Seveke, & van Veen (2000) measured phonological sensitivity by using paired associative tasks, naming dolls with familiar names (Thoms/Robbert/Martin/Stefan) and unfamiliar names (Mobbart/Stomes/Rafin/Thetan), examining how accurately children can pronounce them at phoneme level. They showed that phonological sensitivity has a higher correlation with the learning of phonologically unfamiliar words than with the learning of familiar words, indicating that phonological sensitivity is useful in acquiring new words. In addition, Bowey (1996) measured phonological awareness using a phoneme-identification task, namely, by showing picture cards such as (sock/sun/ball) and asking children to extract the phoneme from the head of the word and then to choose another word that has the same phoneme. In English, phonological awareness is the ability to accurately analyze and manipulate phonemes within words, which means that phoneme-level phonological sensitivity is required as a basic ability. Bowey examined whether phonological short-term memory or phonological sensitivity is more significant in vocabulary development by measuring phonological awareness, but that study did not obtain results showing that phonological short-term memory is significant, as Gathercole and Baddeley have claimed. Instead, they concluded that both phonological abilities, i.e. phonological short-term memory and phonological sensitivity, are dependent on a singular underlying latent ability.

2.3. The Relationship between Vocabulary and Nonword Repetition

As this summary has shown, there are many studies in English examining the interpretation of nonword repetition tasks, but these have not led to a firm conclusion. However, if we focus on the relationship between vocabulary and nonword repetition ability, many studies have confirmed a strong correlation between the two and together promote the conclusion that we can predict vocabulary ability by measuring nonword repetition tasks (de Jong & van der Leij, 1999; Hansen & Bowey, 1994; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner, Torgesen, & Rashotte, 1994; de Jong, Seveke, & van Veen, 2000). On the basis of these results, many researchers have developed tests to screen for language disorders such as specific language impairment and articulation disorder among young children using nonword repetition tasks (Dollaghan & Campbell, 1998; Estes, Evans, & Else-Quest, 2007; Shriberg, Lohmeier, Campbell, Dollaghan, Green, & Moore, 2009; Dollaghan, 2011). For example, Dollaghan and Campbell (1998) have pointed to the constraints of audio memory among children with language development disorders, especially their weakness in memorizing consonants. These research results have confirmed that nonword repetition task is a valid and practical indicator of vocabulary ability.

Comparing linguistic characteristics of English and Japanese

According to Kubozono and Honma (2002), letters are formed in phoneme units in English, making it a language with complex syllable structures. Each syllable is a gathering of sounds centered around vowels (V), and in English, multiple consonants (C) can join a single vowel. For example, the word “strength” has a complex phoneme array of CCCVCCC. Positions of both vowels and consonants follow a strict rule called "phoneme inventory," so we cannot randomly assign the position of a phoneme. As a result, all English nonwords that are used in nonword tasks share the same phonological prosodical characteristics that real words possess. Thus, in order to complete English nonword tasks, phonological sensitivity to the minimum phoneme level and complex audio processing abilities are required. Owing to these characteristics of the English language, some researchers have claimed that, in English, not only phonological short-term memory but also phonological ability and phonological sensitivity contribute to vocabulary knowledge (de Jong, Seveke, & van Veen, 2000).

To shed new light on this debate, we replicated some of these experiments in young speakers of Japanese, a language which is thought to require little contribution from phoneme-level phonological sensitivity to build vocabulary. We aimed to reveal the relationship between phonological short-term memory and vocabulary by dissociating phonological sensitivity and measuring genuine phonological short-term memory.

Our study design requires an explanation of some characteristics of the Japanese. Trubetzkoy (1969) classified English as a syllable language and Japanese as a mora language. The mora is a unit of measure for the length of a word or a syllable, and Japanese uses the mora, a smaller unit than the syllable as used in English, as the basis of measurement for the length of each word. Unlike English, Japanese is a language that has a rhythmic mora-beat with mora-isochronous, and one mora is basically a unit of a set of CV. Japanese is pronounced in a simple rhythm called mora-beat. For example, the number of syllables and mora of the word "Tokyo," the capital of Japan, is as follows. When we divide this word into syllables, it is To-kyo, with two vowels and thus two syllables. However, when we pronounce this word in Japanese, it is To-o-kyo-o, which is four mora long. Thus, the mora is a smaller unit than the syllable (Kubozono, 2002). Furthermore, the two languages have a vastly different number of vowels. Although English has 20 vowels (Wells, 1990), Japanese has only five (Kubozono, 1995a, 1995b). The large number of vowels in English is a cause of phonological complexity, in contrast to the small number of vowels in Japanese which allows for a much simple phoneme array. Owing to this simple phoneme array, the Japanese language does not require its speakers to dissociate vowels from consonants at the phoneme level when memorizing or pronouncing Japanese words. On the basis of these linguistic characteristics, when we compare English nonwords made by Gathercole et al. and Japanese nonwords made by Saito, Saito, & Yoshimura (2000), we can see a significant difference in the complexity of phoneme array in the two languages. For example, if we disintegrate the four-syllable English nonword "empliforvent" into consonants and vowels, it has a complex array of VCCCVCVCCVCC. In contrast, the four-mora Japanese nonword "sa-he-mo-sa" is CVCVCVCV, which is a simple repeat of CV. There is another difference related to producing nonwords as follows. In English, we cannot make a nonword by randomly replacing or joining arbitrary syllables. This is because, in order to produce a nonword that shares the phonological and prosodical characteristics of actual words, a phoneme array that constitutes a syllable must meet certain conditions. To explain this in a more concrete manner, we will compare reshuffling the syllables of the above-mentioned four-syllable English nonword "e/mpli/for/vent" and the four-mora Japanese nonword "sa/he/mo/sa". When we switch the order of the first and last pairs of syllables of "empli-forvent" to make the new nonword "forvent-empli", the syllables change to "forven-templi", and the positions of the consonants and vowels in the syllables change from VC-CCV-CVC-CVCC (em-pli-for-vent) to CVC-CVC-CVCC-CV (for-ven-temp-li). To put it plainly, simply relocating syllables in English is impossible, since phoneme units constitute each of the syllables. In comparison, when we switch the order of the first and last pairs of four-mora Japanese nonword "sahe-mosa" and make a new nonword "mosa-sahe," the position of consonants and vowels in each mora is CVCV-CVCV and does not change. As we have described, a CV unit in a mora is tight, and each mora functions as an independent minimum unit of sound so that replacing or joining mora is possible, thus allowing the easy production of new nonword by reshuffling mora easy.

Phonological cognition in young children in English start to develop around five years old beginning with syllable analysis ability, followed by analysis ability of onset and rhyme and then subordinate factors of syllables, leading to the development of phoneme analysis ability (e.g. Goswami & Bryant, 1990; Liberman, Shankweiler, Fischer, & Carter, 1974; Treiman & Zukowski, 1996). On the other hand, young children in Japanese start to divide morae within words and extract syllables from the head or tail of words around four and a half years old (see Amano, 1986). On the basis of their review of phonological sensitivity in Japanese young children, Yuzawa, Sekiguchi, and Li (2007) discussed that they are unlikely to develop cognition for phonological units smaller than syllables, that is phonemes. Then, we can say that young children in Japanese are raised in a linguistic environment where phoneme-level phonological cognition ability and phonological sensitivity are slower to develop than they are in young children in English. Japanese-speaking young children are in the language environment where phoneme-level phonological recognition and phonological sensitivity are difficult to develop compared to English-speaking young children. Although Nakayama et al. (2015) investigated using serial order short-term memory tasks that replaced combination and order of the C and V, and clarified that the Japanese was controlled by the sublexical phonological rules as well as other languages. The influence of subsyllabic element in Japanese is thought to be weak compared with English. This is because Japanese word composition is basically a repetiti2 on of CV mora, and syllable structure does not change only by rearranging syllables like English. The connection between C and V is strong in the Japanese. Therefore, the element of the sublexical phonology in Japanese has phonemes with a simple CV structure, and it is not likely to be a more refined phoneme like English (see, Yuzawa, Sekiguchi, & Li, 2007).

2.4. Research Using Japanese Nonword Repetition Tasks

There are also studies examining the relationship between nonword repetition tasks and vocabulary in Japanese. Tanaka et al. (2001), who focused on Specific Language Impairment in Japanese-speaking children, obtained results similar to those seen in English-speaking children, revealing that they have difficulty acquiring vocabulary owing to their weakness in auditory short-term memory. Kakihana et al. (2009) focused on examining mora awareness in typically developing children. In their study, high correlation between vocabulary and mora awareness was confirmed, but neither nonword repetition nor digit span showed high correlation with vocabulary. Thus, there has been some research examining the relationship between nonword repetition and vocabulary in Japanese, but the number of these studies is small, and their results are mixed. In addition, the relationship between vocabulary and phonological short-term memory has not been clarified.

2.5. Purpose of This Study

As outlined above, we have reviewed the proposal made by Gathercole et al. and the various arguments that have emerged in response to it. We took notice of the counterargument to Gathercole's original claim that not only phonological short-term memory but also phonological sensitivity contributes to the process of vocabulary development in English (e.g. de Jong, Seveke, & van Veen, 2000) and decided to examine this relationship using the Japanese. We will explain our reasons for choosing Japanese below.

Since English is a phoneme-level language and since young children are required to develop phonological sensitivity to the smallest unit of their language, complex phonological processing is necessary in order to acquire English vocabulary. Therefore, phoneme-level phonological sensitivity contributes to nonword repetition, making it difficult to examine the simple relationship between vocabulary and phonological short-term memory, which is Gathercole and Baddeley's original claim. On the other hand, children who use Japanese as their native language receive little contribution from phoneme-level phonological sensitivity in acquiring vocabulary (Yuzawa, Sekiguchi, & Li, 2007). Although in English there are mixed results with regard to these two phonological abilities, i.e. phonological short-term memory and phonological sensitivity (Bowey, 1996; Bowey, 2001; Metsala, 1999; Majerus et al., 2006a, 2006b; de Jong & van der Leij, 1999; de Jong, Seveke, & van Veen, 2000; Hansen & Bowey, 1994; Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner, Torgesen, & Rashotte, 1994), we presumed that the use of Japanese would enable us to exclude the contribution of phoneme-level phonological sensitivity and directly examine the relationship between phonological short-term memory and vocabulary. If we can confirm high correlation between Japanese nonword repetition, which has little contribution from phoneme-level phonological sensitivity, and vocabulary, we will be able to replicate the simple relationship between vocabulary and phonological short-term memory originally claimed by Gathercole and Baddeley and propose a new idea in the debate started by Bowey (1996) regarding English language learning.

Recent studies of working memory have developed the Baddeley model on the following two points: some studies developed a computational model and tried to clarify the relationship between vocabulary acquisition and auditory short-term memory based on their theoretical frameworks (e.g. Burgess & Hitch, 2006; Gupta & MacWhinney, 1997), and other studies clarified the strong relationship between sequential short-term memory processing and lexical learning using the serial order STM tasks, which further elaborated the traditional short-term memory tasks (e.g. Burgess & Hitch, 1999; Gupta, 2003; Majerus et al., 2006a, 2006b; Majerus et al., 2008). While these studies have made an important contribution in refining the Baddeley model, the relationship between nonword repetition and vocabulary acquisition in childhood development, and the clam by Gathercole & Baddeley (1989, 1990, 1993) and the objections against it (e.g. Bowey, 2001; Metsala, 1999; Majerus et al., 2006a, 2006b; de Jong, Seveke, & van Veen, 2000) are not intended to give a binding.

For example, Majerus et al. (2008) separated the nonword repetition into the linguistic and memory aspects of bilingual adult subjects, and clarified that each influence the learning of a novel word. Although it is possible to artificially separate these two in adults, since these two are developed in parallel in developing young children, it is difficult to consider by artificially separated them like bilingual adults. In present study, we propose the method of using two phonological abilities of the nonword repetition, distinguishing phonological short-term memory from phonological sensitivity in vocabulary acquisition of the early childhood using another language that the contribution of the phonological sensitivity ability is greatly different. Since the Japanese-speaking young children are in a language environment of poor phoneme-level phonological recognition and phonological sensitivity (Yuzawa, Sekiguchi, & Li, 2007), we conduct vocabulary and phonological short-term memory tasks in Japanese. Even in Japanese, if there is a high correlation between vocabulary and phonological short-term memory, it is possible to support the claims of Gathercole & Baddeley (1989, 1990, 1993). However, if there is no correlation between them, the correlation between nonwords and vocabulary in English speaking young children can be interpreted as the influence of phoneme-level phonology, i.e. and lexical knowledge can explain the results of nonword repetition task. The purpose of the present study is to investigate the relationship between phonological short-term memory and phonological sensitivity in vocabulary acquisition.

Therefore, we performed studies 1 and 2 as explained below. In study 1, we examined the relationship between nonword repetition ability and vocabulary using Japanese nonword, among young children whose native language is Japanese. There is a debate among many researchers working with English in regard to the relationship between vocabulary and phonological short-term memory, but most studies have confirmed a consistent high correlation between nonword and vocabulary. On the basis of these results, we will examine the relationship between vocabulary and phonological short-term memory in Japanese by using research methods similar to what Gathercole et al. employed. In addition, we performed nonword as well as digit span in order to measure phonological short-term memory in a more accurate manner. Digit span tasks are regarded as one of the most common measuring method of phonological short-term memory. Furthermore, in Baddeley's working memory model, they presume the existence of visuo-spatial sketch pad that temporarily retains visuo-spatial information along with phonological loop that temporarily retains linguistic information (Baddeley & Hitch, 1974). In order to confirm Baddeley's working memory model, we measured visual short-term memory in study 1. As we have explained above, the main purpose of study 1 was to reveal the relationship between vocabulary and phonological short-term memory in Japanese while examining Baddeley's working memory model at the same time.

In study 2, we performed measurements to confirm that there is little contribution from phoneme-level phonological sensitivity in the process of vocabulary development in young children who speak Japanese. As a follow-up to study 1, we examined the relationship between vocabulary and phonological short-term memory, first by assessing vocabulary and nonword in Japanese in addition to English nonword. Next, we assessed Japanese and English phonological awareness to measure phonological sensitivity and phonological awareness. Thus, in study 2, we performed new English tasks to examine how differences in language affect measurements. The purpose of study 2 is to examine the results of the aforementioned five measurements in order to reveal there is little contribution from phoneme-level phonological sensitivity in the process of vocabulary development in young children who speak Japanese, thus confirming the simple relationship between vocabulary and phonological short-term memory, which is the original proposition of Gathercole and Baddeley.

3. Study 1

We investigated the relationship between Japanese nonword repetition task and vocabulary in Japanese-speaking young children using a method very similar to that of Gathercole et al. (1992). We also used digit span, a common measure of phonological short-term memory. The working memory theory of Baddeley assumed the existence of the visuospatial sketchpad, which temporarily holds visuospatial information in addition to a phonological loop, which temporarily holds auditory information (Baddeley & Hitch, 1974). In this study, we also measured visual short-term memory and confirmed the working memory model of Baddeley.

3.1. Methods

3.1.1. Participants

The participants were 92 children (61 boys and 31 girls) from the private kindergarten in the suburban area in Osaka, Japan. The age of the children ranged from 64 to 75 months; the average age was 71.37 months.

3.1.2. Materials

Twenty-five nonwords were selected from the nonword phonological standard table from Saito, Saito, and Yoshimura (2000). The digit span (forward and backward) and visual memory span (forward and backward order of continuous tapping) tests from the Japanese edition of the WMS-R were used as short-term memory tasks. In addition, we also used a meaningful word repetition task. We used Picture Vocabulary Test (Ueno, Utsuo, & Iinaga, 1991) to measure the vocabulary. We used the block design task in Wechsler Preschool and Primary Scale of Intelligence, WPPSI (1969) to examine the relation between visual short-term memory and spatial cognition.

3.1.3. Procedure

1) Word Repetition Task

A repetition task was conducted using as stimuli words that the children were expected to be familiar with on the basis of the words used by Yuzawa & Saito (2006). The words used were 1) five words of two mora; kame (turtle), kutsu (shoes), umi (sea), neko (cat), and basu (bus), 2) five words of three mora; bōshi (cap), hasami (scissors), ichigo (strawberry), tsukue (desk), and sakana (fish), 3) five words of five mora; sakuranbo (cherry), suberidai (slide), mizuasobi (play with water), koinobori (carp shaped streamers), and kurisumasu (Christmas). The children were asked to repeat each word right after the examiner read it. The examiner read the words at a rate of one mora per second. A score of one point per word was given, with a maximum score of 15 points.

2) Nonword Repetition Task

Twenty-five nonwords were selected from the nonword phonological standard table given by Saito, Saito, and Yoshimura (2000). The nonwords used were 1) five nonwords of two mora (*rehe*, *nuyo*, *piga*, *hoha*, *rini*), 2) five nonwords of three mora (*yuhahe*, *ruhosa*, *toeshi*, *isachi*, *dotai*), 3) five nonwords of four mora (*poropase*, *rikosari*, *makidore*, *sahemosa*, *yuzekashi*), 4) five nonwords of five mora (*pamirakuke*, *tsusufuteno*, *hetsuedase*, *niyosamaro*, *beresesata*), and 5) five nonwords of five mora with contracted sounds (*rohikegyasu*, *ryamomachinu*, *hisaabarya*, *eokajaku*, *yamarikyō*). The examiner orally presented nonwords at a rate of one mora per second and told the child to repeat them. The number of correct repetitions was totaled with a maximum score of 25 points.

3) Digit Span (forward digit span and backward digit span)

The digit span test from the Japanese version of WMS-R was used. As the test was designed for adults, such tasks begin with three digits, so two-digit tasks were added so that the test was adapted for children. Two additional one-digit tasks were used as a trial or warm-up. As the backward task in the WMS-R begins at two digits, this subtest was used as it was. The examiner read the numbers at a rate of one per second. Participants were given two trials for each digit task, e.g. two tasks of two digits, two tasks of three digits, and so on. The test ended when the subject failed in both tasks of the same number of digits. The scores for forward and backward were calculated according to the total number of tasks each participant correctly repeated.

4) Visual Memory Span (forward tapping and backward tapping)

The visual memory span test from the Japanese version of WMS-R was used. In this test, white cards 14 cm long × 21.5 cm wide with eight 1-cm colored squares printed on them at random were used as pictorial stimuli. The examiner would tap on the squares in succession, and the children would tap on the same squares immediately afterward. The task was for the children to tap the squares in the same sequence in the forward tapping task and in the reverse sequence in the backward tapping task. The children began with a one-square task as a warm-up. The participants were instructed to wait for two seconds after the examiner tapped the squares at a pace of one per second and then tap them in the same sequence (or the reverse sequence for the backward sequence task). Participants were given two attempts at each number of squares. The test ended when the participants failed in both tasks of the same number of squares. The number of squares began at two and ended at eight in the forward sequence task and began at two and ended at six in the backward sequence task. The score was given according to the total number of correct responses, with a maximum score of 14 in the forward task and 12 in the backward task.

5) Block Design

Block design, a subtest of WPPSI (Japan Psychological Aptitude Research Institute, 1969), was conducted to test visual information processing and manipulation. The highest possible score (estimated score) is 20 points.

Japanese Picture Vocabulary Development Test. Using the vocabulary score as an indicator, we separately administered the picture vocabulary scale (Ueno, Utsuo, & Iinaga, 1991). The maximum total score for this test was 68.

3.2. Results and Discussion

3.2.1. Validity of Test Results

Table 1 indicates the mean and standard deviation of the scores for each task. The raw score was used for block design. The mean result in vocabulary, converted to vocabulary age, was five years and nine months, whereas the mean chronological age of participants was five years and eleven months. This suggests that the participants are children with average vocabulary. In addition, there was a ceiling effect in the original word repetition task, with the participants scoring over 14 out of 15. Therefore, we excluded the word repetition task from further analysis. The mean and standard deviation for each task are shown in Table 1.

3.2.2. Correlations

The correlation coefficients between tasks are shown in Table 2. The correlation between vocabulary and nonword repetition ability was .307 ($p < .01$), whereas the correlation in English-speaking children of the same age was .492 ($p < .01$) in

Table 1. Means and standard deviations each task in study 1.

Measure	Maximum possible score	Mean	*SD*
Word repeptition	15	14.84	.58
Nonword repetition	25	19.73	3.29
Forward digit span	14	7.14	1.59
Backward digit span	12	2.83	1.70
Forward tapping	16	7.63	1.36
Backward tapping	12	4.85	1.77
Block design	20	16.93	2.31
Vocabulary	68	27.84	7.77

The score of block design is not an evaluation point but a raw score.

Table 2. Correlation between tasks in study 1.

Variable	1	2	3	4	5	6
1. Nonword repetition	-					
2. Forward digit span	.602**	-				
3. Backward digit span	.372**	.496**	-			
4. Forward tapping	.122	.292**	.304**	-		
5. Backward tapping	.024	.215*	.240*	.510*	-	
6. Block design	.087	.309**	.415**	.447**	.480**	-
7. Vocabulary	.307**	.443**	.381**	.176	.223*	.291**

*$p < .05$; **$p < .01$.

the study by Gathercole and Baddeley (1989) and .524 ($p < .01$) in the study by Gathercole, Willis, Emslie, and Baddeley (1992).

Compared to these other studies, the value of this correlation in this study was low although significant. In Japanese, without intervening phonological sensitivity at the phoneme level, we could demonstrate a simple relationship between vocabulary andphonological short-term memory.

English nonword are created in accordance with the rigid rules known as the phonemic inventory, and they have the phonological and prosodic characteristics of actual words. In addition, their creation requires phonological sensitivity at the phoneme level as well as the ability to process complex phonetics. Japanese nonword, in contrast, lack the wordlikeness as is the case of English, because they are pronounced with a simple repetitive rhythm that is called a moraic beat. This is the reason why the correlation between vocabulary and nonword is high in English, although the correlation with vocabulary for Japanese children is lower than English. The correlation with the vocabulary, which is higher than with nonword repetition task, was digit span (.443) and backward digit span (.381). The result of the correlation between vocabulary and digit span was comparable with that found by Gathercole, Willis, Emslie, and Baddeley (1992), where the correlation of 80 six-year-old children was .439.

The correlations between items other than vocabulary, those between nonword and forward digit span among phonological short-term memory tasks had the highest correlation (.602); similarly, those between forward digit span and backward digit span was .496, and between forward and backward visual short-term memory tasks was .510. In short, the correlations between scores on tasks measuring phonological short-term memory such as nonword repetition, digit span, and backward digit span, and the tasks of visual short-term memory are high, although the correlations between phonological tasks and visual tasks are not high. Then, we clarified the relation of each tasks using factor analysis.

3.2.3. Factor Analysis

The results of factor analysis of the seven tasks via maximum likelihood method and promax rotation are shown in **Table 3**. The eigenvalue changes were 2.653, 1.416, .642, .490, .454, and .345, and we decided that a two-factor construct was most valid. The correlation between factors was .367, and the cumulative contribution ratio was 52.75%. The factors were interpreted as follows. The first factor included the three variables of forward tapping, backward tapping, and block design and predicted visual short-term memory and visual cognitive abilities. As seen here, all the three items related to vision had a high positive loading effect on this factor. The second factor included the three variables of nonword repetition, forward digit span, and backward digit span, and all three items related to auditory short-term memory had a high positive loading effect on this factor. Then, we conducted confirmatory factor analysis using a structural equation model to confirm the results of the two-factor model; the first factor represents visual memory which includes forward tapping, backward tapping, and block design, and the second factor represents phonological memory which includes nonword, forward digit span, and backward digit span.

3.2.4. Structural Equation Modeling

We utilized a part of Baddeley's (Baddeley, 1986; Baddeley & Hitch, 1974) working memory model to construct a framework for the first model. Baddeley and

Table 3. Factor analysis of seven tasks via maximum likelihood method and promax rotation.

Variables	ML1	ML2	h2
Nonword repetition	−.209	.835	.613
Forward digit span	.117	.776	.683
Backward digit span	.291	.463	.398
Forward tapping	.652	.047	.45
Backward tapping	.774	.133	.542
Block design	.67	.056	.479

Inter-factor correlation: .367; Cumulative contribution ratio: 52.75%; 2-Factors, Promax-rotated, Maximum-likelihood method.

colleagues hypothesized that working memory consists of a phonological loop that temporarily preserves auditory information, a visuospatial sketchpad that temporarily preserves visual information, and a central executive, the main system that controls the two subordinate systems. For Model 1, we drew a path from phonological loop (pl) to three items related to auditory short-term memory: nonword (NW), forward digit span (FD), and backward digit span (BD). Next, we drew a path from visuospatial sketchpad (v) to the three items related to visual short-term memory and visual cognitive ability: forward tapping (FT), backward tapping (BT), and block design (BL). Furthermore, we drew a bidirectional path between pl and v. This path diagram was composed on the basis of the working memory model. Model 1 has a path diagram as seen in **Figure 1**. The goodness of fit indexes are as follows: $\chi^2 = 17.328$, $df = 8$, $p = .027$, CFI = .933, and RMSEA = .113. The initial path analysis model is shown in **Figure 1**. Model 2 adds the picture vocabulary scale (PV) to the variables. A path is drawn from pl to PV, resulting in the diagram in **Figure 2**. The goodness of fit indexes are as follows: $\chi^2 = 20.851$, $df = 13$, $p = .076$, CFI = .951, and RMSEA = .081. Accordingly, this model fits the data better than Model 1 does.

In Model 3, a path is added from v to PV, resulting in the diagram in **Figure 3**. The goodness of fit indexes are as follows: $\chi^2 = 19.723$, $df = 12$, $p = .073$, CFI = .952, and RMSEA = .084. Examining the above results, we compared Model 2 with Model 3, as these models had the closest goodness of fit indexes among the three models. Model 3 had slightly better indexes of fit, but the path between PV and v in Model 3 had a low partial regression coefficient at .14 and was not significant. Accordingly, we adopted Model 2 as the path diagram that best fits the data. The paths in Model 2 were all statistically significant, and the path between the phonological loop and forward digit span had the highest value. The next highest values were between the visuospatial sketchpad (visual short-term memory) and forward and backward tapping. The path coefficient between the phonological loop and nonword repetition was slightly low at .66 compared with the

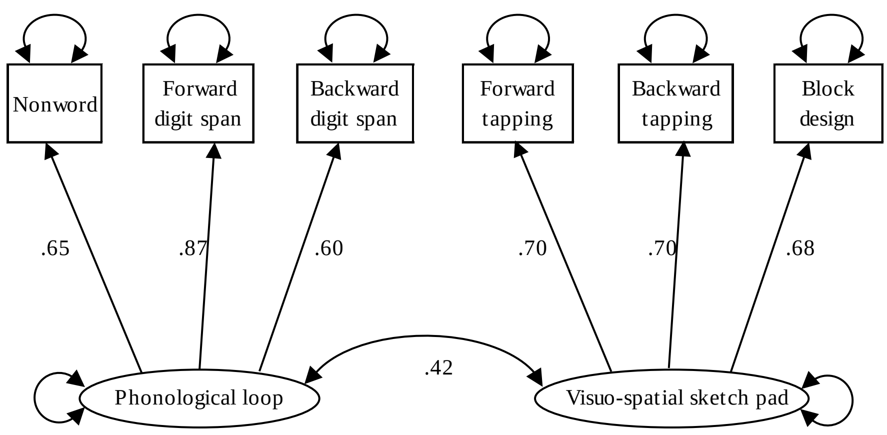

Figure 1. The model of initial path analysis. It shows the relationship between six subtests, phonological short-term memory and visual short-term memory. All partial regression coefficients were significant ($p < .01$).

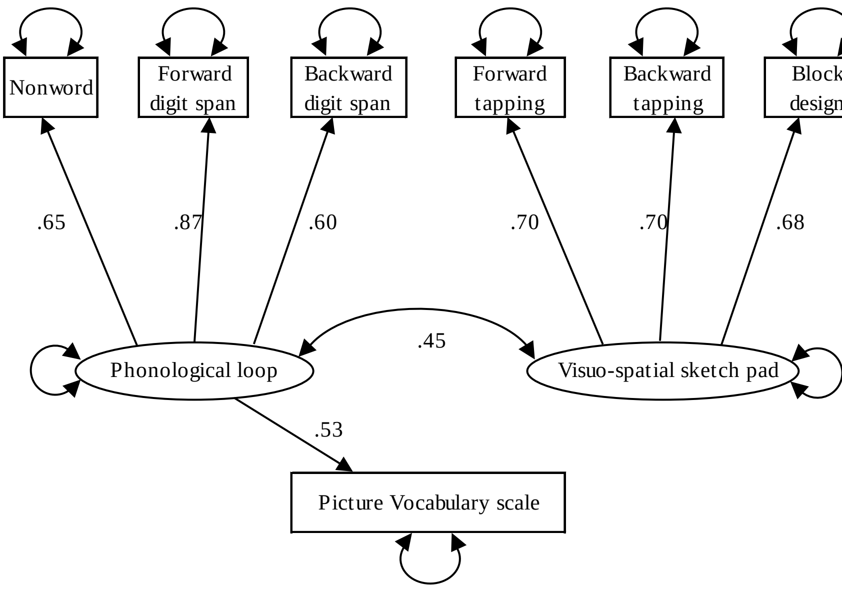

Figure 2. In path model 2, picture vocabulary scale (PV) was added to the variable and a path was drawn from phonological loop (pl) to PV. All partial regression coefficients were $p < .01$.

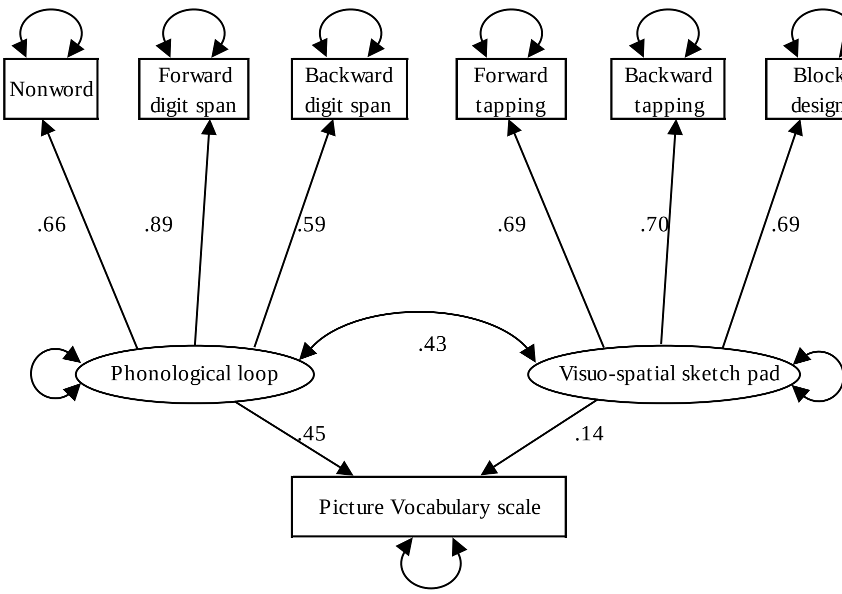

Figure 3. In path model 3, another path was drawn from visuospatial sketchpad (v) to PV. Partial regression coefficient was .14, not significant. Other were significant ($p < .01$).

path coefficient of the forward digit span (.89), but it was still significant. Furthermore, as the path between the phonological loop (auditory short-term memory) and the picture vocabulary development test was also significant, and study 1 supports Gathercole and Baddeley (1989, 1993) original model.

4. Study 2

The Japanese nonword in study 1 reflects phonological short-term memory, but does not reflect phonological sensitivity at the phoneme level. Therefore, if we can demonstrate that phonological sensitivity at the phoneme level has low relation with vocabulary for Japanese children, we can conclude that vocabulary is dependent not on phoneme-level phonological sensitivity but rather on phonological short-term memory as Gathercole & Baddeley (1989).

Therefore, in study 2, we measured phonological awareness and nonword of both Japanese and English, in addition to vocabulary in Japanese children. Through examining these five metrics, we confirmed that phonological sensibility at the phoneme level is less involved in acquiring vocabulary in Japanese-speaking young children than it is in English-speaking children. The main purpose of study 2 then was to demonstrate the simple relationship between vocabulary and phonological short-term memory as suggested in the original model by Gathercole & Baddeley. Furthermore, we confirmed the reliability of the correlation between vocabulary and Japanese nonword correlation in Japanese-speaking young children obtained in study 1.

4.1. Method

4.1.1. Participants

The participants were 90 children (42 boys and 48 girls, ranging from 69 to 82 months old, with an average age of 74.87 months) from the private kindergarten in the suburban area in Osaka, Japan.

4.1.2. Materials

English nonword repetition tasks were conducted by presenting a recording of each of the 10 items in the CNRep's (Gathercole, Willis, Baddeley, & Emslie, 1994) two- and three-syllable tasks for a total of 20 items. A Japanese repetition task was conducted by presenting recordings of 25 nonwords from Saito, Saito, and Yoshimura's (2000) list of nonword syllables. The Picture Vocabulary Development Test (Ueno, Utsuo, & Iinaga, 1991) was also administered. Phonological awareness in English was assessed using English phonological awareness tasks for preschool children (de Jong, Seveke, & van Veen, 2000) which had been audio-recorded by a Japanese English-language teacher who had been trained in English phonology. Phonological awareness in Japanese was evaluated by conducting the three Japanese phonological awareness tasks (Amano, 1986) of extraction, substitution, and backward recall. Next, to examine the relationships between short-term memory, phonological awareness, and vocabulary acquisition, the Picture Vocabulary Development Test (Ueno, Utsuo, & Iinaga, 1991) was conducted.

4.1.3. Procedure

1) English Nonword Repetition

English nonword tasks were conducted to assess phonological sensitivity and phonological short-term memory at the phoneme level. Among the tasks in the CNRep (Gathercole, Willis, Baddeley, & Emslie, 1994), which range from two to five syllables, only two- and three-syllable tasks were used. The number of syllables was limited because a preliminary study found that it is difficult for Japanese children to repeat English words that have many syllables. Therefore, the tasks consisted of a total of 20 items consisting of 10 two-syllable and 10 three-syllable items, and the sum of all correct recalls was scored. The highest score was 20 points.

2) English Phonological Awareness (Phoneme Identification) Tasks

Using the audio-recording of the English phonological awareness tasks for preschool children (de Jong, Seveke, & van Veen, 2000), the task was conducted. First, the English word in question was repeated two times. Next, two English words that could be chosen as the answers were repeated two times each. In this task, the children answer by selecting the word that has an ending consonant with the same sound as the English word in question. They choose from two English words that are suggested after the initial word. For example, the English word "map" is repeated out loud two times. Next, suggestions such as 1) "tap" and 2) "nail" are each repeated two times. The children then choose the word that has the same ending consonant as "map" from among these choices. There were 16 questions, and the correct answers were scored. The highest score was 16 points.

3) Japanese Nonword Repetition

The same tasks as those in study 1 were used. In study 2, however, the words were audio-recorded at a speed of one letter per second. Although the tester presented the questions orally in study 1, because English nonword tasks in study 2 were presented on an audiotape, a taped presentation was used as well. The sum of correct recalls was scored, and the highest score was 25 points.

4) Japanese Phonological Awareness (Mora Awareness) Tasks

We used the three phonological awareness tasks: mora segmentation, extraction, and substitution. In each task, a picture of the target word was displayed with the number of circles below it that matched the number of morae in the target word. For example, if the word was ki-no-ko (mushroom), then a flash card was used, which displayed a picture of a kinoko with three circles below it. In the extraction task, after a flash card had been presented and named, one specific circle was suggested, and children were asked to provide the corresponding sound. Depending on the question, the position of the circle to be pronounced differed. For example, if the first circle was suggested, the correct answer would be/ki/, whereas if the third circle was suggested, the correct answer would be /ko/ and so on. Substitution was a task in which, after a flash card had been presented and named, one specific circle was pointed out and pronounced, and children were asked to tell what word was created if a different sound that was specified was used in place of that sound. For example, children were asked to answer ya-ka-n (kettle) when replacing /mi/ in mi-ka-n (orange) to /ya/. In the backward recall task, after a flash card had been presented and named, subjects were asked to recite that word backward. We used three- to five-syllable words and scored correct answers, with a total of 15 items containing five items each of extraction, substitution, and backward recall. The highest score was 15 points.

5) Japanese Picture Vocabulary Development Test

As in study 1, the Picture Vocabulary Development Test (Ueno, Utsuo, & Iinaga, 1991) was conducted individually.

4.2. Results and Discussion

Table 4 indicates the mean and standard deviation of the scores for each task.

Of the three Japanese phonological awareness tasks, the extraction task showed a ceiling effect in its results, so we omitted them from further analysis. We standardized the scores of the substitution and backward repetition tasks and added them to use as variables for Japanese phonological awareness tasks. Mean of nonword in English was low, but it was not considered to be floor effect because its range was 0 - 13 and only 7 children had zero point. Means and standard deviations acquired from such manipulations are shown in Table 4.

4.2.1. Validity of the Results

We reviewed the validity of our results by converting the average score of vocabulary test to vocabulary age and then comparing it with the average chronological age of the participants. The average chronological age of participants was 6 years 3 months, while the average vocabulary age was 6 years 0 months. This suggests that the participants were children with average vocabularies.

4.2.2. Mean and Standard Deviation

In this study, the mean score of the two-syllable English nonword task was 2.30 (*SD* = 1.77) out of 10, whereas the mean score of the three-syllable English nonword task was 1.81 (*SD* = 1.63) out of 10. According to Figure 2 (p = .111) of Gathercole, Willis, Baddeley, and Emslie (1994), children at age 5, which is the same age as participants in this study, answered correctly on approximately 80% of questions in the two-syllable English nonword task and approximately 60% of questions in the three-syllable English nonword task. Children at age 4, one year younger than participants in this study, also answered correctly on approximately 70% of questions in the two-syllable English nonword task and

Table 4. Mean and standard deviation of each task in study 2.

Variable	Mean	*SD*	Maximum possible
Nonword in Japanese	17.77	3.975	24
Phonological awareness in Japanese			
Extraction	4.86	.484	5
Replacement	4.14	1.313	5
Backward repetition	2.27	1.638	5
After standardization	0	1.664	2
Nonword in English	4.11	3.077	20
Phonological awareness in English	13.76	3.081	16
Vocabulary	28.13	9.579	68

approximately 50% of questions in the three-syllable English nonword task. It is clear, therefore, that the Japanese-speaking young children in our study scored conspicuously lower than English-speaking children on English nonword tasks. There could be two explanations for this. One is that phonological short-term memory of Japanese-speaking children is significantly lower than that of English-speaking children. The other is that this result is due to the difference between languages. When we examine the scores for tasks in Japanese in **Table 4**, the participants answered correctly on approximately 97% of questions in the two-syllable Japanese nonword task and approximately 93% of questions in the three-syllable Japanese nonword task, so it is not likely that Japanese-speaking children simply have weak phonological short-term memory. Therefore, we considered that the low scores on English nonword tasks were due to the difference between the Japanese and English language. Since Japanese-speaking children have not developed sufficient phoneme-level phonological sensitivity for English, English nonword tasks were quite difficult for them, and their scores on these tasks were accordingly low.

Next, when we compare our results (86% answered correctly) on English phonological awareness to those of de Jong, Seveke, & van Veen (2000) (39% answered correctly), participants in this study scored higher, contrary to the results for English nonword tasks. We assume that this difference is due to the difference between our tasks and those in the previous paper. Although we used two-choice questions for English phonological awareness tasks, de Jong, Seveke, and Marjo used four-choice questions. This may explain why Japanese-speaking children with low phoneme-level phonological sensitivity for English could have achieved higher scores in this study.

4.2.3. Correlations

The correlation coefficients between tasks are shown in **Table 5**. The correlation between the Japanese vocabulary and Japanese nonword task was .27 ($p < .01$), which is similar to the correlation in study 1 (.31 ($p < .01$)). When we compare our results to the results from the same age group in English-speaking children (Gathercole & Baddeley, 1989; Gathercole, Willis, Emslie, & Baddeley, 1992), the correlation in the present study is lower though still significant. The results of study 2 have thus proved that the simple relationship between vocabulary and

Table 5. Correlation between tasks in study 2.

Variable	1	2	3	4	5
1. Nonword in Japanese	±				
2. Phonological awareness in Japanese	.293**	±			
3. Nonword in English	.392**	.253*	±		
4. Phonological awareness in English	.340**	.360**	.182	±	
5. Vocabulary	.274**	.301**	.171	.171	±

*$p < .05$; **$p < .01$.

phonological short-term memory originally noted by Gathercole & Baddeley in English-speaking children also applies in the Japanese language, where phoneme-level phonological sensitivity does not intervene. Japanese vocabulary and Japanese phonological awareness also had significant correlation (r = .301), which is at par with the results in English-speaking children (Bowey, 1996, 2001; Metsala, 1999). Correlations between Japanese vocabulary and English nonword (r = .17, p = .11), as well as between Japanese vocabulary and English phonological awareness (r = .17, p = .11), were non-significant. This is due to the difference between the two languages, since phoneme-level phonological short-term memory and phonological sensitivity, both of which are unique to English, do not affect Japanese vocabulary. Japanese phonological awareness (mora-awareness) had low correlation but significant correlation with Japanese vocabulary (r = .30, p < .01) and with Japanese nonword (r = .29, p < .01). Japanese phonological short-term memory and nonword are tested based on mora-units, so the significance of the correlations between Japanese phonological awareness with both vocabulary and nonword suggest that there may be an aspect of phonological sensitivity that is unique to the Japanese language. In other words, as in English, two phonological abilities, i.e. phonological short-term memory and phonological sensitivity, are simultaneously involved in vocabulary development in Japanese. Thus, we can conclude that phonological sensitivity is necessary for Japanese vocabulary, as is the case in English-speaking children. However, the involvement of phonological sensitivity is unique to each language, so we cannot say that phoneme-level phonological sensitivity is universally involved in vocabulary in all languages. The correlations between the same tasks in the two different languages, English and Japanese, were .39 (p < .01) for nonword tasks and .36 (p < .01) for phonological awareness tasks. These results insist that the scores for these tasks reflect a single ability that underlies both languages. Although there are unique language-specific characteristics with regard to units, there are commonalities with regard to the abilities required to solve certain tasks. Interestingly, correlation between the scores for English nonword and English phonological awareness tasks was insignificant (r = .182, p = .086), even though both were performed in the same language. Clarifying this lack of correlation will be a challenge for future studies.

To summarize, there were three findings from study 2. First, it was proved that phoneme-level phonological sensitivity has a low involvement in the vocabulary development of Japanese-speaking children, unlike English-speaking children. Second, there were indications of the existence of a phonological sensitivity unique to Japanese. In Japanese, however, the unit for phonological sensitivity is the mora-unit, which is unique to Japanese, rather than the phoneme. In study 1, we used Japanese nonword tasks to measure phonological short-term memory, but we have indications that these tasks may have also measured Mora-unit based phonological sensitivity, which is unique to Japanese. Third, as there were correlations between scores for English nonword tasks and Japanese nonword tasks, we have proved that there is a single ability underlying the two languages which is needed during these tasks.

5. General Discussion

This study was designed based on the proposal made by Gathercole et al., as well as various discussions made in regard to this proposal, while using Japanese, a language thought to have little linkage with phoneme-level phonological sensitivity in contrast to English. In study 1, we examined the relationship between Japanese nonword repetition task and vocabulary among Japanese-speaking children, which showed significant correlation. From this result, we confirmed that a simple relationship between vocabulary and phonological short-term memory, which was originally proposed by Gathercole & Baddeley, exists even in Japanese, a language where phoneme-level phonological sensitivity does not intervene. By applying the results to structural equation modeling, we confirmed Baddeley's working memory model. In study 2, we tested Japanese vocabulary among Japanese-speaking children while also conducting nonword repetition tasks and phonological awareness tasks in both Japanese and English. From the results of study 2, we confirmed that phoneme-level phonological sensitivity has low involvement in vocabulary for Japanese-speaking children, unlike English-speaking children. At the same time, we obtained indications of the existence of a mora-unit based phonological sensitivity, which is unique to Japanese.

Gathercole's proposal is based on the working memory model in that it distinguishes different cognitive functions of short-term memory. Their working memory model is made up of three systems: a phonological loop, a visuospatial sketchpad, and a central executive which controls these two subsystems (Baddeley, 1986; Baddeley & Hitch, 1974). Evaluation of this model has revealed that the central executive has unique correlations with the results of vocabulary, literacy and numeracy tests, whereas the phonological loop has a unique correlation with vocabulary knowledge (e.g. Gathercole & Pickering, 2000). On the basis of this result, Gathercole et al. claimed that phonological short-term memory capacity is the basis of vocabulary development and that it can be measured by nonword repetition tasks (e.g. Gathercole & Baddeley, 1989, 1993). There are many counterarguments saying that the causality proposed by Gathercole and Baddeley is the opposite of what is actually taking place (e.g. Dollaghan, Biber, & Campbell, 1995). Gathercole has admitted that the causality inverts after the age of five (e.g. Gathercole & Adams, 1993), partially accepting these counterarguments, but has also claimed that, in a study of four- and five-year-olds that carefully reviewed the content of nonwords which were used, vocabulary knowledge and nonword repetition mutually interact developmentally (Gathercole, 1995), thus reaching a common ground with her rebutters.

Another counterargument to Gathercole's original claim is that not only phonological short-term memory but also phonological sensitivity are involved in the process of vocabulary development in English (e.g. Bowey, 1996). Although

Gathercole admits that there are indications that phonological abilities such as phonological awareness exist, she argues that vocabulary can be explained by phonological short-term memory (Gathercole & Baddeley, 1989). Throughout the dispute on this topic (e.g. Bowey, 1997) that has unfolded in subsequent years, Gathercole et al. have stuck to this claim (e.g. Gathercole & Baddeley, 1997).

In the present study, we used Japanese to examine this second counterargument to Gathercole's original claim, where the dispute between two sides has not yet been settled. If we can confirm high correlation between nonword repetition ability and vocabulary in Japanese, a language that has low involvement of phoneme-level phonological sensitivity, we will be able to prove the simple relationship between vocabulary and phonological short-term memory on which Gathercole and Baddeley have insisted and, thus present a new suggestion to their dispute with Bowey (1996) and others.

The proposal made by Gathercole et al., the counterargument against it, and study 1 and study 2 are all verified using simplified diagrams.

Figure 4 is a simplified figure depicting the claims made by Gathercole et al. and their English-speaking counterparts. Arrow [1] represents the claims made by Gathercole et al. that phonological short-term memory strongly affects vocabulary and that phonological short-term memory can be measured by nonword repetition (Baddeley, Gathercole, & Papagno, 1998; Gathercole & Baddeley, 1989, 1993; Gathercole & Pickering, 2000; Gathercole, 2006). Arrows [2] and [3] represent the counterarguments which recognize the high correlation between vocabulary and nonword repetition, but insist that nonword repetition is also an indicator of phonological sensitivity. Arrow [2] represents the claim made by

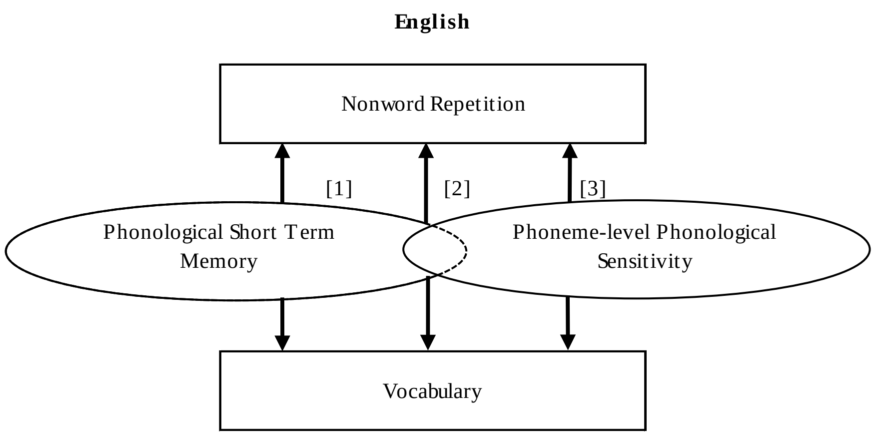

Figure 4. The proposal by Gathercole and the counterarguments to it. The long squares are the task title. The ellipse is a phonological ability as a constitutive explaining the correlation of those tasks. Thick solid arrows draw between high correlated tasks. Arrow [1] shows the claim by Gathercale and her colleagues that the high correlation between vocabulary acquisition (VA) and nonword repetition (NW) depends on phonological short-term memory (PM). Arrow [2] shows the claim by Metsala that the high correlation between VA and NW depends on phonological sensitivity (PS). Arrow [3] shows the claim by Bowey that the high correlation between VA and NW depends on both PM and PS.

Metsala et al. that only phonological sensitivity is involved in vocabulary and that phonological short-term memory is non-related (Metsala, 1999). Arrow [3] represents the claim made by Bowey et al. that both phonological short-term memory and phonological sensitivity are involved in vocabulary (Bowey, 1996; Bowey, 2001; de Jong, Seveke, & van Veen, 2000; Snowling, Chiat, & Hulme, 1991). Thus, there are two interpretations of the correlation in English-speaking children between vocabulary and nonword, and both sides have discussed which of the two phonological abilities, phonological short-term memory or phonological sensitivity, is more heavily involved in vocabulary development.

Figure 5 is a simplified figure depicting study 1. Following the previous research, we presumed that phoneme-level phonological sensitivity has low involvement in vocabulary of Japanese-speaking children (Yuzawa, Sekiguchi, & Li, 2007), and examined only phonological short-term memory [1] among the phonological abilities in study 1, and did not perform tests for phoneme-level phonological sensitivity [2]. The correlation between vocabulary and nonword was .307 ($p < .01$) in study 1, which is significant, although low in value, to prove the model claimed by Gathercole et al.

Figure 6 is a simplified figure depicting study 2. In study 2, we took one step further and measured phonological short-term memory and phonological awareness in both Japanese and English to examine their relation with vocabulary. Through this analysis, we confirmed that phoneme-level phonological sensitivity has low involvement in vocabulary of Japanese-speaking children, confirming the implicit assumption of study 1. We also found that mora-based phonological sensitivity has significant correlation with both vocabulary and Japanese nonword (see **Table 5**), thus confirming that mora-based phonological sensitivity is involved in vocabulary in Japanese, and the involvement of phoneme-level

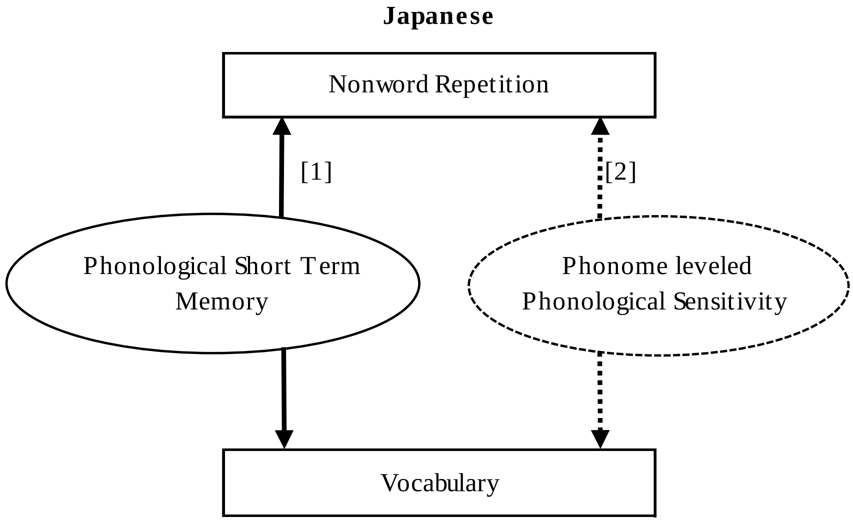

Figure 5. Study 1. The long squares are the task title. The ellipse is a phonological ability as a constitutive explaining the correlation of those tasks. Thick solid arrows draw between high correlated tasks. In study 1, we investigated only PM showed by arrow [1]. Phoneme level PS which we did not investigated showed dashed line.

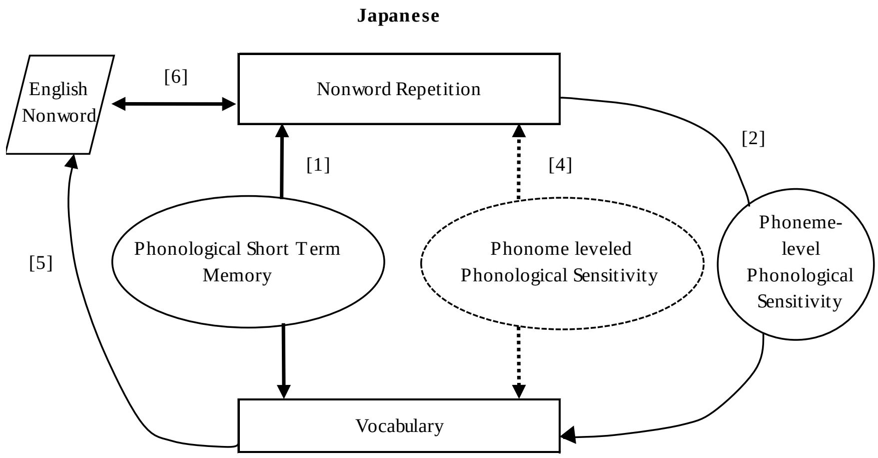

Figure 6. Study 2. The long squares are the task title. The ellipse is a phonological ability as a constitutive explaining the correlation of those tasks. Thick solid arrows draw between high correlated tasks. Low correlations were thin solid. In study 2, it was revealed that Japanese specific phonological sensitivity based in mora depended on VA. So, arrow [4] was added. Arrow [2] and arrow [5] were both low correlation.

phonological sensitivity is low. Therefore, we added Arrow [4] to Figure 6, showing correlation with mora-based phonological sensitivity. On the other hand, as we show in Arrow [5], correlation between English nonword and Japanese vocabulary was low, so we did not see high correlation between the combination of nonword and vocabulary in either language in this study. However, the correlation between English nonword and Japanese nonword was .39 ($p < .01$), indicating a singular ability that underlies the two languages.

Next, we examined what role phonological short-term memory plays in Figure 6, based on the results that we obtained in study 2. As we show in Figure 5, we only assumed the involvement of phonological short-term memory in the correlation between vocabulary and nonword in study 1. As a result, only Arrow [1] connects vocabulary and nonword. In study 2, however, we newly performed a test for Japanese phonological sensitivity and revealed that mora-based phonological sensitivity is involved in vocabulary. This raises the question of how the other phonological ability, phonological short-term memory, is involved. As we show in Table 5, the correlation between vocabulary and Japanese nonword was .274 ($p < .01$). The correlation between vocabulary and Japanese nonword was .204 ($p = .055$) after Japanese phonological sensitivity was partialed out. The reason for the decrease in this value is that phonological sensitivity and phonological short-term memory partially overlap, which means that phonological short-term memory is involved, validating Arrow [1]. From this result, we can assume that the two phonological abilities, phonological sensitivity that is unique to Japanese, and phonological short-term memory, are both simultaneously involved in the correlation between vocabulary and nonword in Japanese (Arrows [1] and [2] in Figure 6). Thus, in study 1, we focused on the involvement of phonological short-term memory, whereas in study 2, the purpose of which was to confirm the results of study 1, we further examined phonological sensitivity in both Japanese and English. From the two studies, it was revealed that both phonological sensitivity unique to each language and phonological short-term memory are necessary in vocabulary development, regardless of the difference in language. However, phonological sensitivity in Japanese is mora-unit based, unlike phoneme-level phonological sensitivity that operates in English. In addition, since phonological sensitivity and phonological short-term memory overlap, it was confirmed that these two phonological abilities partially overlap in Japanese as well, similar to English shown in the simplified depiction in **Figure 4**.

To summarize, we revealed that vocabulary and nonword have significant correlation in Japanese-speaking children in study 1 and showed that phoneme-level phonological sensitivity has low involvement in vocabulary of Japanese-speaking children in study 2. From the results of studies 1 and 2, we revealed that vocabulary and nonword have a significant correlation not only in English but also in Japanese.

As we noted in the Introduction, this result is important not only in terms of studying the psychological mechanism of vocabulary development but also in terms of investigating the causes and optimal treatment measures for language development disorders in children. In English, there have been many researches that confirm high correlation between vocabulary and nonword repetition ability, and there is a common understanding that vocabulary ability can be predicted by measurement of nonword repetition tasks. On the basis of these results, there have been many studies aimed at developing methods of screening for language disorders among young children using nonword repetition tasks (e.g. Dollaghan & Campbell, 1998). There has also been some research in Japanese examining the relationship between vocabulary and nonword repetition ability, which has obtained results similar to those of the English-language studies, revealing that children with specific language impairments have difficulty acquiring vocabulary owing to the weakness of their auditory short-term memory (Tanaka, 2001). We were able to find significant correlation between phonological short-term memory and vocabulary, although there are limitations since this study is cross-sectional. The results obtained in this study indicate that nonword repetition can be a valid index in screening for language disorders even in Japanese.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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