International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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A Pilot Study Phonological Processing in a Logographic Language: A Case Study of a Slow Reader in Japanese

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Abstract: The importance of phonological processing is well documented in alphabetical languages, particularly in English. The present study investigated whether the importance of phonological processing underlies in the Japanese language, which is logographical. Twenty-one junior and senior high school students and one slow reader student were recruited in Japan. They completed several tests including reading Japanese phonology, Japanese phonological tasks and cognitive standardized tests. The ANOVA, Regression analyses and Correlations revealed that the slow reader student could read Japanese phonology but at a significantly slower speed than the control group. He showed poor performance in the phonological tasks, whereas the control group showed a ceiling effect. The results indicate the importance of phonological processing in Japanese, supporting the phonological representation hypothesis.

Keywords: phonological processing, Kanji, Hiragana, Katakana, phonological representation hypothesis

Introduction

Phonological processing is very important in developing reading skills. It is well documented that poor phonological skills cause reading difficulty in the English language (e.g., Ellis, 1991; Bradley, & Bryant, 1983; Goswami, & Bryant, 1986; Rack, Snowling, & Olson, 1992; Shaywitz, 2003; Snowling, 2000). Children with reading difficulties demonstrate poor performance in a variety of phonological tasks, such as a rhyming task, e.g., rhyming "ten, pen and man", a deletion task, e.g., saying the word "cat" without the first sound, as "at", and an oddity detection task, e.g., indicating which word is different from others, as in "h**i**ll, p**i**g, and c**o**t". English phonology uses inconsistent phoneme-grapheme mapping, i.e., the phonology is opaque, and in English, many words, particularly irregular words, do not follow English phonological rules. As a result, children cannot rely on one-to-one phoneme-grapheme mapping to read a word.

In contrast, children who speak transparent languages which have consistent phoneme-grapheme mapping, such as German, Italian, or Spanish, do not show as many reading problems as English speaking children do. They demonstrate, however, their reading difficulty with reading speed rather in decoding problems (Burani, Marocoini, Luca, & Zoccolotti, 2008; Davies, Cuetos, & Glez-Seijas, 2007; Landerl, 2003; Nikolopoulos, Goulandris, & Snowling, 2003). Goswami (2002), however, argued that in these transparent languages, children also demonstrated phonological problems in a variety of tasks in which phonological systems are required, such as phonological awareness tasks (e.g., spoonerisms in which children exchange the initial letter of two words to create a new word, man-hat → [han] – [mat]), an oddity detection task, short term memory tasks, and speeded naming tasks (e.g., Bradley & Bryant, 1983; Denckla & Rudel, 1976). She then proposed the phonological representation hypothesis stating that reading

International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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difficulty primarily stems from poor phonological representation in the mental lexicon in all languages, although the degree of the deficit varies depending on its phonological consistency. These studies indicate that phonological skills are essential in all alphabetical languages.

This raises the question – are phonological skills essential in non-alphabetical languages, such as Chinese and Japanese? Ho (2003) found that phonological skills are important to acquire reading skills in Chinese. She argued that reading difficulty equally occurs among Chinese, Japanese and English because reading is derived from speech, which is phonology; thus, phonological skills are universally important for reading. In contrast, Wydell and Butterworth (1999) argued that reading difficulty is very rare in Japanese because its phonology is a perfect one-to-one mapping of phoneme-grapheme, and the phonology is invariant regardless of the position in a word (e.g., ne-**ko**, cat; **ko**-do-mo, children), and thus it is very easy to learn to read. Makita (1967) reported that the prevalence of reading problems in Japanese is only 1%. Since Japanese writing systems use both logographic scripts (kanji/Chinese characters) and phonological scripts (kana) in combination, it is of interest to investigate the role of phonology in Japanese writing systems.

Because the Japanese language is very different from alphabetical languages, it is useful to describe its characteristics.

In Japanese, there are 112 basic phonologies (Kindaichi, 1991). Each has a distinct sound and each sound is represented by a distinct symbol (Kana), with the result that Japanese phonology has perfect one-to-one mapping of phoneme-grapheme. There are two types of Kana: Hiragana and Katakana. Each script has exactly the same sound (e.g., やya Hiragana, ヤ ya, Katakana), but the usage is different. Hiragana is usually used for names and grammatical or morphological support, while Katakana is used for foreign names, such as “John” or “computer”. In addition, Japanese has Kanji (Chinese characters). There are two ways of reading Kanji: On-reading and Kun-reading. On-reading was derived from spoken Chinese and represents only sounds, e.g., **san** for 山**,** while Kun-reading was derived from the original Japanese spoken language and represents meaning, e.g., **yama** (mountain) for 山. Most Kanji characters can be read by both On-reading and Kun-reading. When a single Kanji character represents a word, mainly Kun-reading is used, e.g., 山**yama.** When a single Kanji character is combined with other Kanji character(s) to form a word, On-reading is mainly applied (e.g., 山脈**san**myaku, mountains). Japanese written language uses both Kana and Kanji in combination in a sentence. Kanji is applied for nouns, verbs, adjectives and adverbs while Hiragana is mainly used for grammatical support.

How do Japanese children learn to read Kana and Kanji? Young children first learn Hiragana because it is easy to learn, and they gradually replace Hiragana words as they learn Kanji words (e.g., や **(ya)** ま**(ma)**, Hiragana → 山**(yam),** Kanji). Ishii (2004) reported that most Japanese preschoolers can read Hiragana and 60% of them can write Hiragana before elementary school. When they enter elementary school, they start learning Kanji beginning with easy Kanji words and progressing to more complex ones. The Japanese Ministry of Education has specified 1006 Kanji words to be learned by elementary school children (grades 1-6) and 939 Kanji words for junior high school students (grades 7-9). Approximately 3000 Kanji words are necessary to read

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3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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a Japanese newspaper. Since Kanji cannot be phonetically broken down into components as an alphabetic word can, Kanji learning relies solely on rote memory or penmanship. It is thus very important for both elementary and high school students to keep practicing Kanji in order to write Kanji words and select correctly between On-reading and Kun-reading.

According to Ishii (2004), little research (including nationwide surveys) has been conducted on reading difficulty in Japanese. She further reported that a recent survey of students in grades 1 to 6 in two cities with populations of 400,000 and 50,000, respectively, indicates that the prevalence of reading difficulty is 1% for Hiragana (phonology) and 2-3% for Katakana (phonology), while the prevalence of writing difficulty is 2% for Hiragana, 5% for Katakana, and 7-9% for Kanji (Chinese characters). As shown in the survey, the prevalence of reading difficulty varies depending on the type of Japanese script. Thus, when reading tests focus only on Kana reading (either Hiragana or Katakana phonology), the prevalence of reading difficulty is shown to be low (1%). However, when reading tests include Kanji, and in particular writing Kanji, its prevalence becomes high (7 - 9%).

Since there has been little research on the role of phonology in reading in Japan, the present study was conducted as a pilot study. The goal of the study was to investigate whether Japanese phonology is involved in reading skills in Japanese.

Methods

Participants

The participants for the study were recruited in a Japanese city through Girl Scouts and Boy Scouts organizations, through a Buddhist temple, and from the researcher's acquaintances. Twenty-one junior and senior high school students (13 males and 8 females; *M* age = 14.8 years), who were enrolled in a general class, voluntarily participated in the study. The questionnaire showed that none of the students had reading problems. One junior high school student (age = 15.8, male), who was enrolled in a Special-Ed class, voluntarily participated in the study. He was professionally tested in Grade 2 (age 7), and the results showed his verbal and non-verbal performance was between 1 and 2 standard deviation from the norm. He was transferred to a Special-Ed class at Grade 5 (age 11) because he could not keep up with his classmates. It is not clear whether the student's reading difficulty stemmed from his lower cognitive abilities or from a lack of phonological reading skills; however, we decided to treat him as a slow reader. The other 21 students served as a control group. All participants were paid twenty thousand yen (about $20 in U.S.) for their participation. The profile of the participants is shown in Table 1.

Procedure

Each participant was individually tested in a quiet room of a Buddhist temple in a city in Japan. Since all the participants were under 18 years of age, a letter was given to parents to explain the study and voluntary informed consent was obtained from the participants and their parents before the study began. The participants were first asked questions about their school grades in Math, English, and Japanese, and how much they enjoyed these subjects including reading (Appendix A). The testing was conducted in the following order: (1) RAN Test-Color, (2) RAN Test-Number, (3) RAN Test-Object, (4) Cube Test (from the Universal Non-Verbal Intelligence

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3(14): 414 - 427 (2010)
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Test/UNIT), (7) Visual Memory Test (UNIT), (8) Reading test in Hiragana (phonetics), Katakana (phonetics), and Kanji (Chinese characters). The time required for testing was about 1 hour and 15 minutes.

Table 1
Profile of participants

	Slow Reader	Control
Number	1	21
Mean age (years)	15.8	14.8 (*SD* = 1.01)
Grade	9	8 - 11
Gender	male	male = 13 female = 8
School	Special-Ed class	General class
Reading problem	yes	no

* Results of the K-ABC IQ test at Grade 2
Sequential processing: 80 ± 10
Simultaneous processing: 66 ± 7
Cognitive processing: 71 ± 6
Achievement : 72 ± 5

Testing materials

- The RAN Test (Rapid Automatized Naming Test, Denckla & Rudely, 1976; Wolf & Denckla, 2006) measures the speed of the naming retrieval process. Previous studies (Wolf, 1999) have demonstrated that the test scores are well correlated with reading ability in English and other languages, e.g., German.
- The Cube Test from the UNIT (Universal Nonverbal Intelligence Standardized Test, Bracken, & McCallum, 1998) measures nonverbal fluid reasoning.
- The Visual Memory Test from the UNIT measures memory for visual objects which may relate to knowledge about Kanji symbols.
- Phonological Tasks in Japanese
- A deletion task: to delete an initial or final sound in a word, e.g., ねこ/cat →こ
- An odd-one-out task: to find a different sound in a group, e.g., とり, とし, いけ →いけ
- A rhyming task: to find the words rimed, e.g, たこ、はこ、いろ → いろ
- Reading aloud 32 Hiragana and 32 Katakana words (Appendix A)
- Reading aloud Kanji words on a list in 45 seconds (Appendix C)
- Writing five easy Kana and three easy Kanji words

Statistical analyses

The raw scores were used for all analyses. An Analysis of Variance (ANOVA), Regression, and Correlations were used for the data analysis.

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Results

Overall analysis

An ANOVA was separately performed on the dependent variables of time and test scores to see the group differences. The first One-Way ANOVA was run on the time required to complete the task: (1) RAN-Color, (2) RAN-Number, (3) RAN-Object, (4) Reading Hiragana words, and (5) Reading Katakana words. The second ANOVA was run on the scores: (1) Cube (UNIT), (2) Visual Memory (UNIT), and (3) Reading Kanji words.

The first ANOVA (time) revealed that there were significant group differences in all timed task variables, i.e., RAN-Color: Slow reader (M = 43.16) vs. Control (M = 24.83, SD = 3.24), F (1, 20) = 30.57, $p < .0001$; RAN-Number, Slow reader (M = 30.30) vs. Control (M = 15.34, SD = 1.96), F (1, 20) = 55.36, $p < .0001$; RAN-Object: Slow reader (M = 40.38) vs. Control (M = 30.80, SD = 4.36), F (1, 20) = 4.61, p = .044; Reading Hiragana: Slow reader (M = 93.00) vs. Control (M = 19.72, SD = 5.19), F (1, 20) = 190.45, $p < .0001$, and Reading Katakana: Slow reader (M = 93.00) vs. Control (M = 21.35, SD = 6.00), F (1, 20) = 136.24, $p < .0001$. It is important to note that no participants in the Control group made any reading errors in Hiragana and Katakana reading, while the slow reader made 5/32 reading errors with the Hiragana words and 8/32 reading errors with Katakana words. These results apparently suggest that the slow reader was able to read Kana (Japanese phonology) accurately but at a significantly slower speed compared to the Control group.

The second ANOVA (test scores) revealed that the UNIT Cube Test (non-verbal fluid reasoning) showed close to a statistically significant level (α = .05), between Slow reader (M = 24.00) and Control (M = 42.52, SD = 9.21), F (1, 20) = 3.86; p = .064. There were significant group differences in the UNIT Visual Memory Test and Reading Kanji: Visual Memory Test: Slow reader (M = 12.00) vs. Control (M = 22.52, SD = 2.79), F (1, 20) = 13.62, p = .001, and Reading Kanji: Slow reader (M = 19.00) vs. Control (M =76.95, SD = 16.94), F (1, 20) = 11.17, p= .003. The result of the UNIT Cube Test indicated that the non-verbal intelligence, as measured by a fluid reasoning visual task, of the slow reader was just below the border line of the normal distribution. The data are summarized in Table 2.

Phonological processing in Japanese

An ANOVA was performed on the Japanese phonological tasks (a deletion task, an odd-one out task, and a rhyming task) to see the group differences. The results showed significant group differences in all tasks, the deletion task: Slow reader (M = 4.00) vs. Control (M = 9.95, SD = .22), F (1, 20) = 710. 23, $p < .0001$; the odd-one-out task: Slow reader (M = 5.00) vs. Control (M = 9.52, SD = .81), F (1, 20) = 29.51, $p < .0001$ and the rhyming task: Slow reader (M = 2.00) vs. Control (M = 9.67, SD = .48), F (1, 20) = 240.46, $p < .0001$. Since the participants in the Control group demonstrated the ceiling effect, suggesting that the tasks were fairly easy. Thus, the significant group difference in the phonological tasks suggests that the slow reader demonstrates poor phonological skills (Table 2).

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3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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Writing Hiragana and Kanji

It became clear that the test material was too easy for all participants. Even the slow reader scored 5/5 in writing Hiragana words and 4/5 in writing Kanji words.

Table 2
Results of the One-Way ANOVA

	Task	*p* value
Overall	**DV = Time**	
	RAN-Color	
	Slow reader: *M* = 43.16, Control: *M* = 24.83 (*SD* = 3.24), *F* (1, 20) = 30.60	.000**
	RAN-Number	
	Slow reader: *M* = 30.30, Control: *M* = 15.34 (*SD* = 1.96), *F* (1, 20) = 55.36	.000**
	RAN-Object	
	Slow reader: *M* = 40.38, Control: *M* = 30.80 (*SD* = 4.26), *F* (1, 20) = 4.61	.044*
	Reading Hiragana	
	Slow reader: *M* = 93.00, Control: *M* = 19.72 (*SD* = 5.19), *F* (1, 20) = 190.45	.000**
	Reading Katakana	
	Slow reader: *M* = 93.00, Control: *M* = 21.35 (*SD* = 6.00), *F* (1, 20) = 136.24	.000**
	DV = Raw test scores	
	Cube Test (standardized non-verbal IQ test)	
	Slow reader: *M* = 24.00, Control: *M* = 42.52 (*SD* = 9.21), *F* (1, 20) = 3.86	.064 ns
	Visual Memory Test (standardized non-verbal IQ test)	
	Slow reader: *M* = 12.00, Control: *M* = 22.52 (*SD* =2.79), *F* (1, 20) = 13.62	.000**
	Reading Kanji	
	Slow reader: *M* = 19.00, Control: *M* =76.95 (*SD* = 16.94), *F* (1, 20) = 11.17	.003**
Japanese phonological tasks	Deletion task	
	Slow reader: *M* = 4.00, Control: *M* = 9.95 (*SD* = .22), *F* (1, 20) = 710.23	.000**
	Odd one-out-task	
	Slow reader: *M* = 5.00, Control: *M* = 9.53 (*SD* = .81), *F* (1, 20) = 29.51	.000**
	Rhyming task	
	Slow reader: *M* = 2.00, Control: *M* = 9.67 (*SD* = .48), *F* (1, 20) = 240.46	.000**

Regression analyses

A regression analysis was separately performed on time and test scores to see which independent variable was the best predictor of the group membership. The STEPWISE method was used to select models to find the best predictors among the independent variables. First, the timed tasks

International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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were put into the equation, i.e., the RAN-Color, RAN-Number, RAN-Object, Reading Hiragana and Reading Katakana. The method chose only the Reading Hiragana for the best predictor: M = 23.05, SD = 16.42, F (1, 20) = 190.45, $p < .0001$, Adjusted $R^2 = .900$. Next, the odd-one-out task and a rhyming task were entered into the equation. The STEPWISE method chose only the Japanese deletion task for the best predictor: M = 9.68, SD = 1.29, F (1, 20) = 710.23, $p < .0001$, Adjusted $R^2 = .971$. The data are summarized on Table 3.

Table 3
Results of the Regression Analyses

	Task	*p* value
STEPWISE	**IDVs measured by time**	
Model 1	Hiragana: M = 23.05 (SD = 16.42), R^2 = .900, F (1, 20) = 190.45	.000**
Excluded variables	RAN-Color, RAN-Number, RAN-Object, Reading Katakana	
	IDVs measured by test scores	
Model 1	A deletion task: M = 23.05 (SD = 16.42), R^2 = .971, F (1, 20) = 710.23	.000**
Excluded variables	Cube, Visual Memory, Reading Kanji, An odd-one-out-task, A rhyming task	

Correlations
Since there was one slow reader, we decided to conduct Pearson bi-variable correlations on the data of the control group to see whether Japanese phonology (Hiragana and Katakana) was correlated with Kanji reading ability in normal reading. The correlation analysis revealed that both Hiragana and Katakana were significantly correlated with Kanji reading scores (r = -.689**; r = -.722*). The negative correlations were due to different measurements, i.e., the Hiragana and Katakana readings were measured by the completed time and the Kanji reading was measured by the number of kanji words read in 45 seconds. The correlations also revealed that Hiragana and Katakana were correlated with the RAN-test scores. The results were shown in Table 4.

Discussion

The purpose of the present pilot study was to investigate the importance of phonological processing in reading skills in Japanese. The importance of phonological processing is documented in opaque languages such as English (e.g., Ellis, 1991; Bradley, & Bryant, 1983; Goswami, & Bryant, 1986; Rack, et al., 1992; Shaywitz, 2003; Snowling, 2000). In transparent languages such as German and Italian, children with reading difficulty also demonstrate poor phonological skills when tested by phonological tasks (Burani, et al., 2008; Davies, et al., 2007; Landerl, 2003; Nikolopoulos, et al., 2003). These studies indicate that the importance of phonological processing underlies the acquisition of reading skills in alphabetical languages. Is it also important in logographic languages, such as Chinese and Japanese? The present study explored this question.

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3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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Table 4
Pearson Correlations among variables

	RAN color	RAN number	RAN object	Cube	Visual Memory	Hiragana	Katakana	Kanji	Deletion	Odd-one-out	Rhyming
RAN color	1.00										
RAN number	.525*	1.00									
Sig.	.014										
RAN object	.417	.329	1.00								
Sig.	.060	.145									
Cube	-.241	.030	-.340	1.00							
Sig.	.293	.897	.131								
Visual spatial memory	-.264	.031	-.222	.297	1.00						
Sig.	.247	.893	.333	.192							
Hiragana	.541*	.636*	.403	-.382	-.351	1.00					
Sig.	.011	.002	.070	.088	.119						
Katakana	.578*	.644*	.612**	-.483*	.334	.901**	1.00				
Sig.	.006	.002	.003	.027	.139	.000					
Kanji	-.420	-.592**	-.510*	.349	.334	-.689**	-.722*	1.00			
Sig.	.058	.005	.018	.121	.139	.001	.000				
Deletion	.211	.102	.127	.212	.043	.197	.226	-.041	1.00		
Sig.	.359	.650	.583	.356	.856	.393	.325	.859			
Odd-one-out	.031	-.223	-.362	.035	-.105 .650	-.347	-.396	.336	-.134 .562	1.00	
Sig.	.893	.331	.107	.880		.123	.-75	.137			
Rhyming	.092	-.099	-.273	.311	-.198	.075	-.126	.035	.316	.085	1.00
Sig.	.691	.670	.231	.170	.389	.747	.585	.882	.163	.715	

Level (2-tailed), N = 21 (Only control group)

The present study found that no participants in the control group made even a single error in reading Hiragana and Katakana (Japanese phonology) and the slow reader also read them with few errors (i.e., 5/32 in Hiragana and 8/32 in Katakana). These results suggest that reading Japanese phonology is easy and they are consistent with previous survey, i.e., the prevalence of reading difficulty is 1% for Hiragana (phonology) and 2-3% for Katakana (Ishii, 2004). When reading speed was taken into account, however, the slow reader demonstrated significantly slower reading of Hiragana and Katakana than the control group. Furthermore, when phonological skills were tested by phonological tasks (i.e., a deletion task, an odd-one-out task, and rhyming task), the slow reader showed significantly poor performance in these tasks (i.e., M = 4.0, 5.0 and 2.0, respectively) compared to the control group (i.e., M = 9.95, 9.67 and 9.5, respectively), which demonstrated a ceiling effect. The results of the slow reader appear to be

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3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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similar to those demonstrated by children with reading difficulty in transparent languages (Burani, et al., 2008; Davies, et al., 2007; De Jong, 2003; Landerl, 2003; Nikolopoulos, et al., 2003) as well as those in Chinese (Ho, 2003). In addition, the regression analyses revealed that Hiragana (phonology) reading and the deletion task (a phonological task) scores dissociated the slow reader from the control group. Altogether, these results suggest that poor phonological skills may contribute to the poor reading skills of the slow reader, implying that the importance of phonological processing underlies reading skills in Japanese. The implication is supported by the correlation analysis performed on the data of the control group, i.e., Hiragana and Katakana readings were highly correlated with Kanji reading scores, i.e., r = -.689** and r = -.722**, respectively. Since knowledge of Kanji is essential to read Japanese, the correlations between the speed of reading Hiragana and Katakana and the accuracy of Kanji reading also indicate the importance of phonological processing in reading skills in Japanese. Regarding the RAN-test scores, Hiragana and Katakana reading are highly correlated with the RAN-test scores. Since previous studies (Wolf, 1999) have demonstrated that the RAN-test scores predict reading ability in English young children, the correlations suggest that the speed of reading Hiragana and Katakana may be able to predict reading skills in young Japanese children.

Conclusion

The present pilot study provides evidence that phonological processing underlies reading skills in a logographic language, supporting the phonological representation hypothesis (Goswami, 2002), which proposes that the importance of phonological processing is universal in acquiring reading skills across languages.

In order to conduct a larger study, several points would need to be considered. First, there was only one slow reader in the present study. Thus, the sample size needs to be larger. Second, it is not clear whether the slow reader's reading difficulty stemmed mainly from his relatively low intelligence or from his poor phonological skills. Thus, intelligence in slow readers needs to be within the normal distribution. Third, Japanese testing materials for writing need to be improved. The use of easy Hiragana and Kanji words for the writing test, which resulted in a ceiling effect. The test materials should include different levels of difficulty/complexity of Kanji words, so that slow readers can demonstrate the problems unique to the Japanese language. Fourth, a variety of phonological awareness tasks should be included in order to test the phonological representation hypothesis, e.g., spoonerisms in which children exchange the initial letter of two words. Fifth, standardized verbal and non-verbal intelligence tests in Japanese version should be included. Lastly, elementary school students, particularly those in Grades 1 and 2, need to be tested to compare their speed in acquiring different Japanese scripts (Hiragana, Katakana, and Kanji) and to spot students who are at risk of reading difficulty. This will greatly assist in identifying Japanese children with reading difficulty.

International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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Appendices

Appendix A

Questionnaire

I will ask you some questions. Please select one from the answers I will give you.

1. Do you like English?
   - ☐ I like it very much
   - ☐ I like it.
   - ☐ Average
   - ☐ Don't like it.
   - ☐ I hate it.
2. Do you like Science?
   - ☐ I like it very much
   - ☐ I like it.
   - ☐ Average
   - ☐ Don't like it.
   - ☐ I hate it.
3. Do you like Math?
   - ☐ I like it very much
   - ☐ I like it.
   - ☐ Average
   - ☐ Don't like it.
   - ☐ I hate it.
4. Do you like Japanese?
   - ☐ I like it very much
   - ☐ I like it.
   - ☐ Average
   - ☐ Don't like it.
   - ☐ I hate it.
5. How is your grade in English?
   - ☐ Very good
   - ☐ Good
   - ☐ Average
   - ☐ Not so well
   - ☐ Bad
6. How is your grade in Science?
   - ☐ Very good
   - ☐ Good
   - ☐ Average
   - ☐ Not so well
   - ☐ Bad
7. How is your grade in Math?
   - ☐ Very good
   - ☐ Good
   - ☐ Average
   - ☐ Not so well

International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
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- ☐ Bad

8. How is your grade in Japanese?
   - ☐ Very good
   - ☐ Good
   - ☐ Average
   - ☐ Not so well
   - ☐ Bad
9. What subject do you mainly study at Juku?
   - ☐ English
   - ☐ Math
   - ☐ English and Math
   - ☐ Other _____
10. How much time do you spend on school work at home? _____ hour(s)
11. Do you have difficulty keeping up with classes?
12. ☐ English ○ No ○ A little ○ Very much
13. ☐ Math ○ No ○ A little ○ Very much
14. ☐ Japanese ○ No ○ A little ○ Very much
15. Do you like to spend a lot of time doing internet search and reading the information?
    - ☐ Very much
    - ☐ Average
    - ☐ I do not mind doing internet search but I do not like to read the information.
    - ☐ No, I do not like it at all.
16. Have you experienced a head injury?
17. ☐ Yes If yes, when was it? _____
    - ☐ No

Appendix B

Testing materials

Hiragana words (32 words)

やま	うみ	なつ	くるま	がっこう	めいげつ
おうじょ	にひゃく	せんちょう	しょうばい	しなもの	はいしゃ
がくしゅう	ゆうがい	ひょうほん	やさい	がっしゅく	りょうきん
ふうしゅう	ざんだか	さっそく	しばふ	しんぽ	にちじょうさはん
きおん	しゅっぱん	のうち	こうはく	きびん	せけん
けいかく	げんりょう				

Katakana words (32 words)

ハチ	ロバ	ネコ	チドリ	クラス	アイス
マンモス	ジュース	ネット	プリント	マンドリン	トンネル
ピンポン	チケット	メロン	リズム	テスト	パターン
ジャズ	クロール	クローバー	ハンバーグ	コンピュータ	モンタージュ
フットボール	ミュジック	ウェディング	イルミネーション	クッキングスクール	プロデューサー
ミニアチュア	コンディショニング				

International Journal of Arts and Sciences
3(14): 414 - 427 (2010)
CD-ROM. ISSN: 1944-6934
© InternationalJournal.org

Appendix C

Testing materials
A list of Kanji words (119 words)
Participants were required to read them as quickly and accurately as possible in 45 seconds. The levels of Kanji words are Grade 1 to Grade 5.

山	右	本	赤い	八日	二百	見る
夏	海	行く	近く	声	南	車
船長	午後	日記	生活	草花	左	遠足
川	店	水泳	鳥	虫	暑い	父
泳ぐ	氷	遠い	温度	勝つ	平たい	後ろ
歯医者	昔	深い	氷山	博物館	世界	花束
ご飯	低い	歌う	完成	利用	結ぶ	買う
勢い	情景	演説	設ける	残高	小判	布地
許可	存続	並ぶ	快適	補修	捨てる	処分
桜貝	指輪	略図	才能	厚い	貿易	副業
共同	脳	裏	正月	処分	除く	年月
指図	均等	出版	自治会	除去	合宿	光沢
原料	進歩	友好的	農地	風習	初夢	小判
過渡期	芝生	答える	手柄	風邪	輪郭	添削
得意	再生紙	衰える	機敏	効果	無料	捨てる
貢献	調べる	観客	皮膚	啓発	衝撃	解決
干渉	公邸	悪寒	利益	過剰	弁解	破棄