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ACOUSTICAL LETTER

Perception of long vowels in Japanese by Children

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1. Introduction

Studies have shown that the acquisition of reading depends on such phonological processes as verbal short-term memory and the temporal processing of speech [1–4]. An inability to encode phonological representations orthographically may cause reading disabilities, such as dyslexia. Kobayashi *et al.* [5] pointed out that all aspects of phonological processing play an important role in children's early reading, and it is known that phonological awareness, phonological memory, and phonological access to lexical storage are needed for reading.

In Japanese, the development of the ability to read *kana* characters is associated with phonological awareness [6]. Children with reading disabilities have weak phonological awareness [7,8]. The acquisition of the ability to read special mora types, such as long vowels, geminate obstruents, and mora nasals, is delayed compared with that in the case of regular consonant-vowel (CV) morae [6,9]. Therefore, for children with reading disabilities, the acquisition of the ability to read such special mora types is difficult.

It has been reported that children with reading disabilities also have problems with speech perception [10–12]. Differences between dyslexic and normal children in the categorical perception of several consonant continua have also been reported [13–15]. Therefore, our ultimate goal is to develop a standard based on the abilities of normal children for use in evaluating the abilities of children with reading disabilities.

Normal children acquire awareness of the special mora types at approximately 4 to 6 years of age [16,17]. This is before they acquire the ability to read *kana* characters [18–20]. We have investigated the development of the ability to perceive geminate obstruents and mora nasals for normal children [21–23].

In our study, we focused on long vowels in Japanese. Interestingly, normal children acquire the ability to read long vowels after acquiring the ability to read other mora types. According to Shimamura and Mikami's data [9], five-year-old children can read CV morae and mora nasals with 95% accuracy. In comparison, they can read geminate obstruents with 73% accuracy. However, for long vowels, the accuracy is only 55%. Adults categorically perceive long and short vowels [24,25]. In other words, the performance of a discrimination test using a continuum between long and short vowels by adults becomes high around the boundary of long and short vowels obtained from an identification test. That is, adults can discriminate long and short vowels well, while they poorly discriminate a pair with different durations within the long-vowel or short-vowel category.

In this study, we investigated the development of a categorical perception of long vowels in Japanese. We also tried to determine its relationship with the development of phonological awareness and the development of the ability to spell words containing long vowels.

2. Experiments

Before conducting our main experiments, we conducted a "Picture Vocabulary Test" (PVT) to measure children's language development. Some children were not able to perform well on PVT, and we excluded such children's data. Experiment 1 was a categorical perception task. Normal adults also participated in this experiment. Experiment 2 was a phonological awareness task.

2.1. Experiment 1

In Experiment 1, a continuum between long and short vowels was presented to the children to evaluate their categorical perception. They were asked to identify the vowel length in the continuum. The first vowel in each stimulus word was set to vary in length. The stimuli were based on the nonsense word /ba:bo/ recorded by a male speaker. The duration of the vowel /a:/ was artificially varied from 54 to 232 ms in 15 steps. We manipulated the speech waveform using the method used by Kasuya and Kato [26].

One hundred and twenty-five children participated in Experiment 1. Thirty-four were 5 years old, 36 were 6 years old, 26 were 7 years old, and 29 were 8 years old. Twenty-five adults also participated. They were 20 to 57 years old, with an average age of 28.2.

In the conditioning session, the children were taught the names of long and short caterpillars: ba:bo and babo. In the main session, the participants listened to 15 stimuli randomly presented three times (45 stimuli in total). For each stimulus, they were asked to judge whether they perceived a long or short vowel by pointing to pictures of the creatures.

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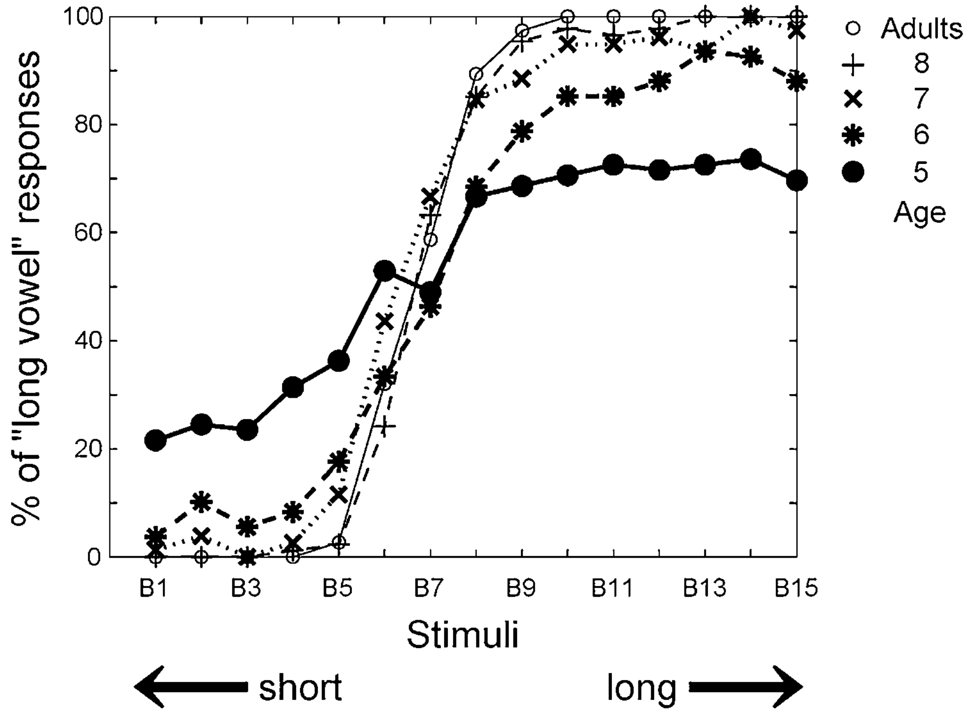

Fig. 1 Results of Experiment 1.

2.2. Experiment 2

The goal of Experiment 2 was to test whether the children were aware of the length of the target vowel in a set of multisyllabic words. In Experiment 2, the children were asked to compose syllabic structures of stimulus words containing a long vowel using wooden blocks with a "long" or "square" shape. For example, for "bo:shi," or cap in English, the correct answer is the long block followed by the square block. The stimuli were composed of 14 words containing a long vowel. The 14 words consisted of six 3-mora words, seven 4-mora words, and a 5-mora word, and they were independent from the words used in PVT. We played the recorded speech sample and presented the corresponding picture at the same time. The same group of children participated in both this experiment and Experiment 1.

3. Results and discussion

3.1. Experiment 1

Figure 1 shows the results of Experiment 1. The vertical axis indicates the percentage of "long vowel" responses. For the adults, an abrupt transition was observed between the stimuli B6 and B8. The largest difference was between the adults and the five year olds. As age increased, the results of the children tended to become more like the results of the adults.

We fitted the following sigmoidal function to the results of each participant and obtained the slope a as an indicator of categorical perception:

$$f(x) = \frac{1}{1 + e^{-a(x-b)}}.$$

Here the stimuli B1 through B15 were uniformly allocated within the range of [1,15] on the x-axis. Figure 2 shows the percentage of children within subgroups for each age group. The subgrouping was based on the slope a: less than 0.5, between 0.5 and 1.0, between 1.0 and 1.5, and greater than 1.5. Statistical analysis for these slopes showed that the differences between the 5 year olds and all the other groups were significant ($p < 0.001$). The differences between the 6 and 8 year olds, as well as between the 6 year olds and adults were also significant ($p < 0.05$). The largest improvement was observed between the performances of the 5 and 6 year olds. It is possible that the improvement between the performances of the 6 and 7 year olds was due to children's acquisition of the ability to read *kana* characters at approximately the age of 7. Interestingly, we observed the largest improvement before that age.

3.2. Experiment 2

Figure 3 shows the results of Experiment 2. The vertical axis is the number of correct responses. As you can see, the number of correct responses increased with age. Statistical analysis showed that the differences between the 5 and 7 year olds, and the 5 and 8 year olds were significant ($p < 0.001$). The differences between the 6 and 7 year olds, and the 6 and 8 year olds were also significant ($p < 0.001$). The largest improvement was observed between the performances of the 6 and 7 year olds, possibly because they started learning how to write and read *kana* characters. These results contrast with those of Experiment 1, in which the largest improvement was observed between the 5 and 6 year olds. However, further investigation is needed to determine how the results are affected by acquiring the ability to read *kana* characters.

3.3. Relationship between results of Experiments 1 and 2

We looked at the relationship between the results of Experiments 1 and 2 by comparing the slopes obtained from Experiment 1 with the performances obtained in Experiment 2

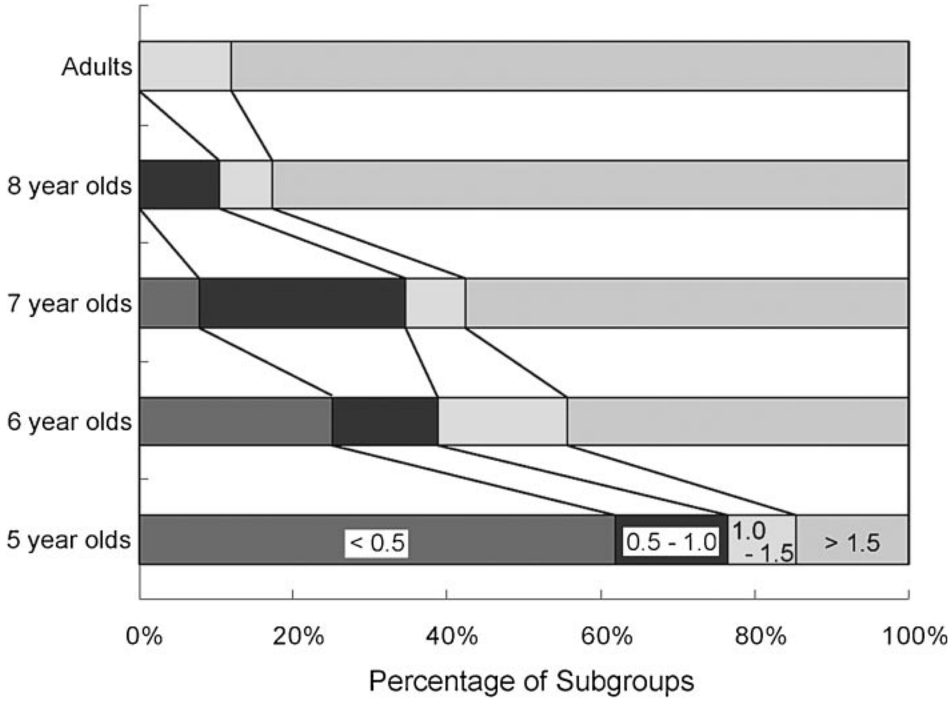

Fig. 2 Percentage of children within subgroups for each age group. The subgrouping was based on the slope a of the sigmoidal function.

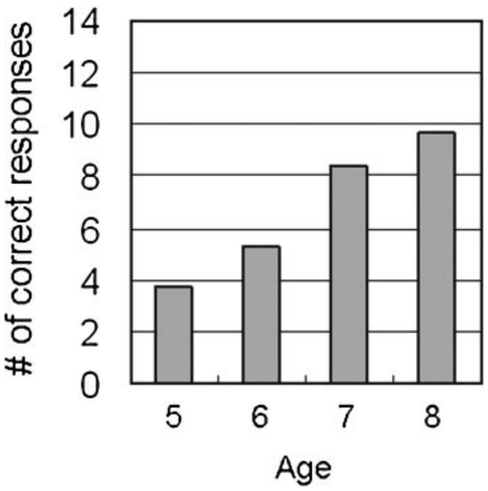

Fig. 3 Results of Experiment 2.

for each age group. There was a significant, but moderate correlation between the results for Experiments 1 and 2 (Spearman's rank correlation coefficient $(r_s) < 0.526$, $p < 0.001$). We also performed a Chi-square test. In this case, we divided the participant group into two for each experiment. For Experiment 1, we divided the group on the basis of the slope of the psychometric (sigmoid) function, and if the slope was steeper than the adults' worst case, we placed the participant in Group 1a. The rest were placed in Group 1b. For Experiment 2, we divided the group on the basis of performance. When participants scored 6 (the median) or greater, we placed them in Group 2a. The rest of the participants were placed in Group 2b. As shown in Table 1, this test revealed a significant difference between the two groups ($p < 0.005$, $df = 1$). From this, we observed the tendency that those who performed better in Experiment 1 also performed better in Experiment 2.

Table 1 Number of children used for Chi-square test.

	Group 2a	Group 2b	Total
Group 1a	47	21	68
Group 1b	17	40	57
Total	64	61	125

4. Conclusions

The results of Experiment 1 indicate that there is a large developmental change in perception between the ages of 5 and 6. The positive correlation between the results for Experiments 1 and 2 indicate that there is a developmental relation between the perception and awareness of long vowels. The results for Experiments 1 and 2 also show that the development of perception tends to precede the development of long vowel awareness.

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