

Discrimination and identification of Japanese /ba-/da/ continuum within a sentence by Japanese-speaking listeners *

© Kanako Tomaru and Takayuki Arai (Sophia Univ.)

1 Introduction

Ability of identifying and discriminating native speech segments have long been discussed especially in terms of categorical perception [1]. In the study of categorical perception, a series of continuum, e.g., a continuously changing stimuli from /ra/ to /la/, to be tested are presented to listeners in mono-syllabic context in isolation, e.g. /ra/ syllable alone out of the /ra-/la/ continuum, or a word “rock” alone from a “rock”-“lock” word continuum [2-4]. When a /ra-/la/ continuum is perceived categorically, for example, we see an S-shaped curve in percentage response of /ra/ in its identification function [1-4]. That is, /ra/ is heard for the first half of the continuum then suddenly /la/ is heard for the subsequent stimuli in the continuum. The point where the percentage response of /la/ suddenly overcomes that of /ra/ is called “the categorical boundary.” In addition, the evidence of categorical perception can also be seen in the discrimination function. That is, accuracy to discriminate a pair of syllables in the continuum reaches a peak when a paired stimuli crosses the boundary (discrimination peak) [5].

In the study of Tomaru and Arai [6,7], the characteristics of the discrimination function in perception of a series of /ra-/la/ continuum was tested under non-isolated condition, i.e., within a sentence. In their experiment, each syllable of the continuum was presented to native speakers of English in a sentence, e.g., “Clear /ra/ is appreciated.” The results of their experiment suggested that the characteristics of the discrimination function in the non-isolated condition differed from those in the isolated condition. That is, the peak of discrimination accuracy was not observed for the pair that crosses the categorical boundary in the sentence condition.

In this study, we attempt to replicate their findings with different stimuli, i.e. a /ba-/da/ continuum, presented within a sentence to listeners with different language background, i.e., Japanese. A series of /ba-/da/ continuum was selected for the present purpose because a number of former studies found the categorical perception of the /ba-/da/

continuum (for example, [1]). First, we investigated Japanese listeners’ perception of the /ba-/da/ continuum presented in isolation, i.e., the isolated condition (Experiment 1). Next, we examined the perception of the same stimuli presented within a sentence, i.e. the sentence condition.

2 Stimuli

For the current experiment, we created a series of /ba-/da/ continuum using the cascade-formant synthesizer designed by Klatt and Klatt [8]. Synthetic syllables were created on the bases of a recorded sentence, i.e., “sorekara /ba/ ga arutoomimasu,” produced by Japanese male. The parameter values are illustrated in Table 1. The parameter values were adjusted so that the created syllables sounded as if they were uttered by the recorded speaker. The syllables had to be similar to the voice of the speaker because all they were to be inserted back into the original sentence to create stimuli for Experiment 2 which aims to investigate perception of the /ba-/da/ continuum in a sentence. Synthesized syllables had a variation on F1 and F2 trajectories in nine equal steps from /ba/ configuration (Step 1) to /da/ configuration (Step 9). See Fig. 1 for the trajectories of the first five formants (F1, F2, F3, F4 and F5). Created syllables were called I-step 1, ..., I-step 9 when presented in isolation. When inserted into the blank part of the sentence, i.e., “sorekara __ ga arutoomimasu,” for Experiment 2, the stimuli were called S-step 1, ..., S-step 9.

3 Experiment 1

In Experiment 1, we examined the identification and the discrimination functions of a /ba-/da/ continuum presented in isolation. I-step 1 to I-step 9 were used as stimuli.

3.1 Participants

Ten native speakers of Japanese (6 males and 4 females) with normal-hearing participated in the experiment (mean age= 28.3 years old).

*日本語話者による文中の日本語/ba-/da/の弁別と識別について、渡丸嘉菜子, 荒井隆行 (上智大・理工).

Table 1 Values of main parameters.

Parameter Name	Value
F0	125-135 Hz
F1 / B1 (F1 bandwidth)	790 Hz / 60 Hz
F2 / B2 (F2 bandwidth)	1190 Hz / 105 Hz
F3 / B3 (F3 bandwidth)	2640 Hz / 150 Hz
F4 / B4 (F4 bandwidth)	3700 Hz / 200 Hz
F5 / B5 (F5 bandwidth)	4800 Hz / 1000 Hz
OQ (voicingopen/period)	80 %
TL (tilt, dB down at 3 kHz)	8 dB

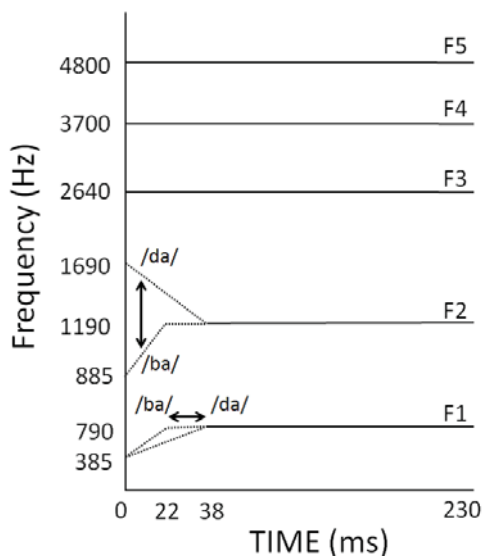


Fig. 1 Trajectories of the first five formants.

3.2 Procedure

Participants had a familiarization session prior to identification and discrimination tasks.

Experiments were carried out using Praat [9] and headphones (ATH-M50).

3.2.1. Familiarization

In the familiarization session, participants were instructed to get used to stimuli they were to hear for the experimental tasks.

First, the participants heard five repetitions of /ba/ (I-step 1) and then /da/ (I-step 9), which were the edge stimuli of the continuum. Next, the concurrent series were presented to the half of the participants in order from I-step 1 to I-step 9, and to another half in order from I-step 9 to I-step 1. During the familiarization session, a participant adjusted the listening level to his/her comfortable level.

3.2.2. Identification task

Participants reported they heard “ba” or “da” by clicking on the button appeared on a computer screen. Each syllable of the continuum was repeated ten times in a random order.. Thus, the participants

made 90 judgments (9 stimuli \times 10 repetitions = 90 judgments). No practice was conducted.

3.2.3. Discrimination task

We employed an AXB discrimination paradigm where participants were to judge whether the second sound (X) matched the first sound (A) or the third (B). The stimuli were paired such that each pair (AB) differed by two steps in the continuum, i.e., I-step 1 with I-step 3, and so on. Paired stimuli were arranged into four permutations, i.e., AAB, ABB, BAA and BBA. Each permutation was presented to participants in a random order. We had three repetitions of each permutation. The inter-stimulus duration was 300 ms. The total number of discrimination judgments were 84 (7 pairs \times 4 presentations \times 3 repetitions = 84 judgments). In order to get used to the AXB paradigm, participants had a short practice session prior to the main task.

3.3 Results of Experiment 1

Because one participant reported that he was not able to recognize the stimuli as either of Japanese syllables, /ba/ or /da/, this participant was excluded from the analysis.

3.3.1. Identification task

The overall percentage of /ba/ response was calculated over the nine participants (Fig. 2). As Fig. 2 indicates, participants heard /ba/ for the first four stimuli along the continuum; then the perception changed to /da/ for I-step 6 and the subsequent stimuli. I-step 5 was rather heard to be in-between /ba/ and /da/. This identification function suggests that the categorical boundary is located somewhere near I-step 5. Thus, if we are to observe the categorical perception for this continuum, we expect to obtain the discrimination peak for the stimulus pair 4-6.

3.3.2. Discrimination task

The percentage of the correct responses are summarized in Fig. 3. As Fig. 3 shows, discrimination accuracy reached the peak for the stimulus pair that crosses the boundary, i.e., near I-step 5, indicated by the identification function, i.e. the pair 4-6. Assuming that the pair 4-6 is the only pair crosses the categorical boundary, it is reasonable to divide the stimulus pairs into three groups according to the phonetic labels which are assumed to be assigned to the stimuli of the pair: 1) the pairs that are labelled as /ba/, i.e., the pairs 1-3, 2-4 and 3-5 (within-/ba/ pairs), 2) those labelled as /da/, i.e., the pairs 5-7, 6-8 and 7-9 (within-/da/

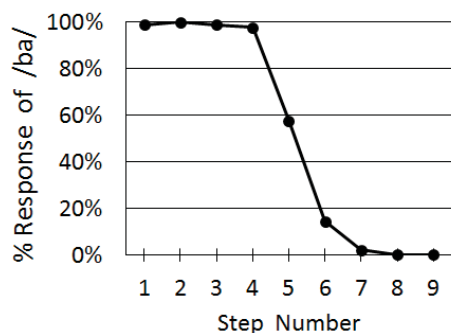


Fig. 2 Identification function under the isolated condition.

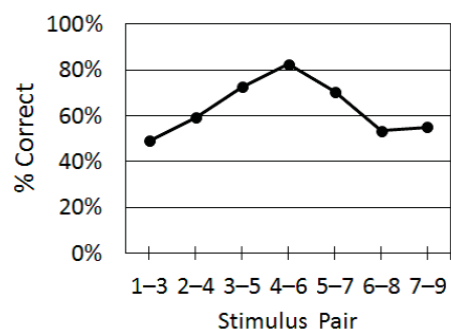


Fig. 3 Discrimination function under the isolated condition.

pairs) and 3) the pair with different labels, i.e., the pair 4-6 (cross-boundary pair). The ANOVA with repeated measures revealed the main effect of the group ($F(2, 16) = 33.63, p < .01$). A post hoc multiple comparison with the Bonferroni correction indicated that the percent correct of the cross-boundary pair and that of the within-/ba/ pairs was significantly different ($p = .001$). Similarly, the difference between the cross-boundary pair and the within-/da/ pairs was also significant ($p < .01$).

3.4 Summary of Experiment 1

Experiment 1 found that, as indicated by the former studies, identification and discrimination functions of /ba/-/da/ continuum follow the characteristics of the categorical perception.

4 Experiment 2

Experiment 2 was conducted to investigate the characteristics of identification and discrimination functions of the /ba/-/da/ continuum under the sentence condition. Stimuli were S-step 1 to S-step 9.

4.1 Participants

Twenty native speakers of Japanese served as participants (9 males and 11 females, mean age = 21.1

years old).

4.2 Procedure

Because the basic procedure and instructions were the same as in Experiment 1, the following sections include details that are specific to Experiment 2.

4.2.1. Familiarization

Participants were familiarized with S-step 1 to S-step 9 using the same procedure as in Experiment 1.

4.2.2. Identification task

Participants were instructed to report they heard /ba/ or /da/ in the blank part of the following sentence: “sorekara __ ga aruto omoimasu.” Other experimental condition was the same as in Experiment 1.

4.2.3. Discrimination task

In Experiment 2, participants were instructed to judge whether the blank part of the second sentence (X) matched that of the first sentence (A) or the third sentence (B). The other condition was identical to the Experiment 1.

4.3 Results of Experiment 2

Eight participants were excluded from the analysis because their percentages of the correct responses to one or more pairs in the discrimination task were below the chance level (50%). Their percentages of the correct responses ranged from 8% to 34%. Since this may imply that these participants made incorrect judgments deliberately, they were not included in the analysis.

4.3.1. Identification task

The percentage of /ba/ response was averaged over 12 participants (Fig. 4). Under the sentence condition, the categorical boundary seems to be located almost right at S-step 6; the boundary has moved toward /da/ compared to that under the isolation condition. Nevertheless, participants heard /ba/ or /da/ according to the change in the formant transitions.

4.3.2. Discrimination task

The percentages of the correct responses were averaged over 12 participants (Fig. 5). Based on the identification function, we expected to have a discrimination peak at the pair 5-7.

As in Experiment 1, we divided the stimulus pairs into the following groups: 1) the pairs that are labelled as /ba/ i.e. the pairs 1-3, 2-4 and 3-5 and 4-6 (within-/ba/ pairs), 2) those labelled as /da/, i.e., the pairs 6-8 and 7-9 (within-/da/ pairs) and 3) the

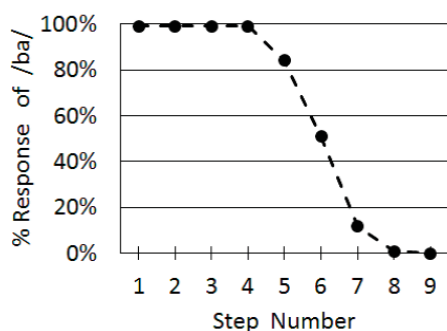


Fig. 4 Identification function under the sentence condition.

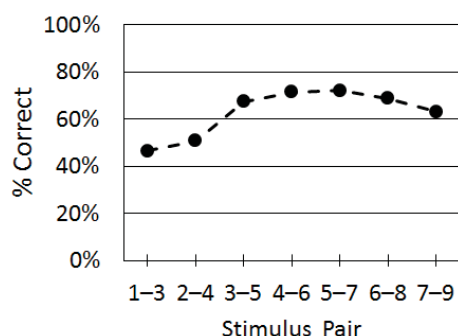


Fig. 5 Discrimination function under the sentence condition.

pair with different labels, i.e., the pair 5-7 (cross-boundary pair). The ANOVA with repeated measures revealed the main effect ($F(2, 22) = 4.207, p = .028$). However, a post hoc test with the Bonferroni correction revealed no significant difference between the cross-boundary pair and the within-/ba/ pairs ($p = .079$) as well as between the cross-boundary pair and the within-/da/ pairs ($p = .515$).

4.4 Discussion of Experiment 2

In the Experiment 2, we found that characteristics of the identification function under the sentence condition were similar to those under the isolation condition. However, the categorical boundary has shifted about one step toward /da/-side of the edge under the sentence condition. In the discrimination function, a discrimination peak was not observed in Experiment 2. That is, the characteristics of categorical perception are not seen in the discrimination function when a continuum is presented within a sentence.

5 Discussion

The results of the current experiments did not contradict to those of Tomaru and Arai [6,7]. That is, the current results suggested that the character-

istics of categorical perception can be “hidden” under the sentence condition. The results of the former study were replicated with different stimuli and participants with different language background. The replication of the former findings suggests that no discrimination peak under the sentence condition is observed cross-linguistically. This gives a supportive evidence on the hypothesis [7] that discrimination tasks cause a heavy perceptual burden during the automatic speech perception (ATP) [7]. The next step, as also suggested by Tomaru and Arai, is to clarify whether the discrimination peak is obtained when the stimulus interval is longer than 300 ms.

In addition, we need to discuss whether discrimination accuracy under the sentence condition is low or not. Although a discrimination peak is not observed, the discrimination performance can be seen as relatively good; the function indicates approximately 60 to 70 % of correct responses throughout (Fig. 5). Such “relatively good” discrimination is also reported by Tomaru and Arai [6,7]. The future research should dig further into this issue.

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