Effects of L1 Phonotactic Constraints on Learning Novel Words

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ABSTRACT

In this study, it was examined whether native Japanese speakers learn novel phonotactics that violates L1 phonotactic constraints. In Experiment 1, it was investigated whether native Japanese speakers generalize syllable position regulations of restricted consonants that occur word medially (e.g., in ba**F**.**P**ev, ti**D**.**Z**ek) to novel words in which the consonants occur at word edges (e.g., **Z**ɪb.tə**F**). The Japanese participants learned regulation of phonotactics at the syllable level rather than at the word level. In Experiment 2, it was examined whether the participants track the co-occurrence of consonants across syllables within a word. They discerned test items with the same co-occurrence of consonants between syllables (e.g., FP as in bɛ**F**.**P**ək) as in the training items (e.g., ba**F**.**P**ev) from those with different co-occurrence of consonants (e.g., FZ as in bɪ**F**.**Z**ət). The Japanese speakers also learned the co-occurrence restrictions of consonants across syllables within a word.

Keywords: L1 phonotactic constraints, syllable structure, L2 word learning

1. INTRODUCTION

Syllable structures and phonotactic constraints differ depending on the language. Infants are able to identify patterns of phonotactics of given words by being exposed themselves to speech [1][2][3]. This pattern finding skill is considered to be an essential ability for infants acquire language. It was reported that 4-year-old children used the combination of talker variability and multiple word types to generalize phonotactics [4]. Learning phonotactic regulations facilitates word learning since there is no apparent acoustic cues for word boundaries [5][6][7][8]. It is not clear whether phonotactic learning is caused by top-down processing that is mediated by the lexicon [9][10] or by experience of exposure to speech without storage of abstractions [11][12].

Dupoux, Kakehi, Hirose, Pallier, and Mehler [13] reported that phonotactics of the listener's first language affected speech perception. Native Japanese speakers perceived a vowel inside consonant clusters (VCCV) and recognized /ebzo/ as /ebuzo/, and the proficiency of the foreign language did not affect the effect of epenthesis. Dupoux et al. concluded that not only are L2 sounds assimilated into the inventories of listeners' first language but that they are distorted to conform to their L1 phonotactic regulations.

On the other hand, Trapman and Kager [14] also reported that L2 learners are able to access the phonotactics of the target language they learn. They tested L2 learners who learned L2 syllable structures that are not allowed in their first language using three different language groups: Russian, Dutch, and Spanish. Even Spanish speakers, whose legal syllable structures were fewer than those of the other two languages, were able to learn some L2 phonotactic structures that are illegal in their L1. As L2 proficiency increases, they discriminated legal codas and illegal codas in L2 similarly to the native speakers of the target language. The results can be accounted for by the episodic theory that proposes that perceptual and contextual details of each incident are stored in a listener's mental lexicon [15].

Bernard [16] reported that native English speakers learned the regularities of syllable structures when they were given non-words in an experiment and argued that phonotactic constraints can be represented as a unit of syllable. Subsequently, Bernard [17] investigated whether listeners solely depend on phonotactics at the syllable level when they learn novel words. Bernard examined whether native English speakers use information on co-occurrence of consonants across syllables when syllable positions of the consonants are invariant. In the training phase, the participants listened two times to bisyllabic non-words that included four restricted consonants (F, P, D and Z) in onset and coda positions (e.g., ba**F**.**P**ev, ti**D**.**Z**ek). In the test phase, novel words with the same co-occurrence of consonants across syllables as in the training items (e.g., bɛ**F**.**P**ək) and those with different co-occurrence (e.g., bɪ**F**.**Z**ət) were provided along with repeated training items and fillers. The participants judged whether they heard the words before and the false recognition rates were compared. Bernard found that the listeners generalized the syllable position of consonants to a novel word. Since Bernard tested the learning of artificial words using native English speakers, the question as to whether native Japanese speakers can learn novel phonotactics as native English speakers

do when it violates L1 phonotactic constraints remains unanswered.

In order to examine the effect of phonotactics on novel word learning by native Japanese speakers, the following research questions were raised:

1. Do native Japanese speakers generalize regularities of syllable positions when they learn novel words whose phonotactics is illegal in their L1?
2. Do native Japanese speakers track co-occurrence of consonants across syllables?

If they learn words at the syllable level, they will generalize the syllable positions regardless of the word positions of consonants.

2. EXPERIMENT 1

2.1. Methodology

In the present study, the methodology used by Bernard [17] was replicated, and experiments were conducted employing native Japanese speakers. In Experiment 1, it was investigated whether native Japanese speakers generalize regulations of syllable positions of restricted consonants that occur in medial positions in non-words and apply them to novel words with consonants that occur at the positions of word edges.

2.1.1. Participants

Sixteen native Japanese speakers, who are undergraduate students in Japan, participated in the experiment. Seven of them were male and nine were female and their mean age was 20.6 years. Two of them had visited Canada for one months, but the others had no experience of being in English-speaking countries. None of the participants reported a hearing impairment.

2.1.2. Design

In the training phase, following Bernard [17], artificial words composed of two consonant-vowel-consonant (CVC) syllables with four restricted consonants (/d/, /f/, /p/, and /z/) in the onset and the coda position to occur word medially (e.g., ba**F**.**P**ev, ti**D**.**Z**ek) were repeated twice (24 items x 2 conditions x 2 cycles), so that the participants were allowed to track syllable-position restrictions (e.g., P and Z as onsets with D and F as codas) and co-occurrence restrictions (e.g., FP clusters and DZ clusters: oPZ/cDF).

In the subsequent test phase, novel items with the restricted consonants in word-edge positions were presented under two conditions: items with the same syllable positions as those in the training items (e.g., **Z**ɪb.tə**F**) and items with different syllable positions from those in the training items (e.g., **F**ɪb.tə**Z**). The novel items were intermixed with two additional repetitions of the training items and presented to the participants. The participants were asked whether the items were repeated or novel. The rates of false recognition for the novel items with the same syllable positions (Same Test items) and those with different syllable positions (Different Test items) were compared. It was predicted that the participants would falsely recognize the test items with the same syllable positions more often than those with different syllable positions if they track the restricted consonants at the syllable level. This experiment made it possible to determine whether native Japanese speakers identify consonants at the syllable level rather than linear order occurrence.

2.1.3. Materials

Following Bernard's study [17], four restricted consonants (/d/, /f/, /p/ and /z/) and five vowels were used in the present study. The first syllable consisted of a lax vowel (/ɪ/, /ʌ/, /ɛ/ and /æ/), while the second syllable always had a schwa (/ə/). Two types of syllable-position restrictions and two types of co-occurrence restrictions (2 x 2) were used. One of the types of syllable-position restriction had /p/ and /z/ in the onset position (oPZ) and /d/ and /f/ in the coda position (cDF), and the other had /d/ and /f/ in the onset position (oDF) and /p/ and /z/ in the coda position (PZ). One of the types of co-occurrence restrictions was /f/ that occurs with /p/ and /d/ with /z/ (FP/DZ) (e.g., bɛ**F**.**P**əv) and the other had /f/ with /z/ and /d/ with /p/ (FZ/DP). Eight consonant-to-role-assignments were created with each restricted consonant that occurred with an equal frequency to onset and coda positions, and co-occurrence of restricted consonants was thus equally frequent. Four of them had the restricted consonants in word medial positions (e.g., ba**F**.**P**ev), while the other half had the restricted consonants in word edge positions (e.g., **P**ɪb.tə**F**). Each consonant-to-role assignment had four conditions and each condition consisted of 24 items, and thus 768 non-words were created (8 consonant-to-role assignments x 4 conditions x 24 items). Each restricted consonant occurred with an equal frequency to onset and coda positions. A native English speaker from the United States pronounced the 768 bisyllabic non-words with the stress on the first syllables in a recording studio. The recordings were stored in a computer and a phonetician who is also a native English speaker checked whether the sound stimuli were pronounced as intended. The program of the experiment was written using E-prime 3.0 [18].

2.1.4. Procedure

After filling in a questionnaire regarding their language background, each participant sat in front of the computer and followed an instruction written on the screen. The volume of the sound given through the headphone was adjusted to a comfortable level by individual participants. In the experiment, a sound file of non-words was given and the question "Have you heard it before?" with an answer of "1 for Yes" and "0 for No" appeared on the screen in Japanese after each non-word. The participants were asked to respond as to whether the word was presented before or not in the experiment using *Chronos*, a psychology software tool [19]. As soon as the response was made, the next trial was presented automatically. After the participants practiced 9 trials using filler items, they were given an opportunity to clarify what they should do in the experiment. The main session consisted of a training phase and a test phase, though transition between them was not noticeable for the participants.

In the training phase, the participants listened to 2 cycles of the training items (48 items x 2) and filler items (24 items x 2), and thus half of correct responses were "Yes" and the others were "No." In the test phase, Same Test items (24 items) and Different Test items (24 items) were intermixed with two additional repetitions of training items and fillers and they were randomly presented. Since the test items were novel, the correct responses for them were "No," while those for training items and filler items were "Yes."

2.2. Results

Table 1 shows the mean ratio of "Yes" responses for each type of items: fillers, Training items, Same Test items, and Different Test items. Since the training items and the fillers were repeatedly presented, the correct answers for them were "Yes", while the correct answers for the test items were "No". Therefore, responses for the test items indicate that the participants falsely recognized the novel test items.

Item	Syll-pos	Co-occ	Yes-recog
Filler			0.85 (0.10)
Training			0.90 (0.09)
Test	Same	Different	0.50 (0.22)
	Different	Different	0.42 (0.18)

Table 1: Ratio of "Yes" responses for each type of items

The participants differentiated the repeated items (0.89) from the test items (0.46). The "Yes" recognition ratios were 0.90 for the training items, 0.85 for the fillers, 0.50 for Same Test items, and 0.42 for Different Test items. Thus, the participants were able to differentiate Same Test items from Different Test items. Analysis using the linear mixed model was performed for the responses to the test items in order to test the effect for test type (i.e., Same Test items or Different Test items). The model included Test type (Same or Different), Training syllable position restrictions (oPZ/cDF or oDF/cPZ), and Training co-occurrence restrictions (FP/DZ or FZ/DP). The model's fit was significantly improved by the inclusion of the fixed effect of Test-type (F (1, 15) = 6.4, $p < 0.05$). The participants tracked the syllable positions in the word medial positions and differentiated the test items with the same syllable positions from those with different syllable positions, suggesting that they generalized syllable positions to the novel words even when the restricted consonants appeared at word edges.

3. EXPERIMENT 2

3.1. Methodology

In Experiment 2, the methodology used by Bernard [17] was replicated to examine whether native Japanese speakers can track co-occurrence restrictions when syllable-position restrictions were maintained.

3.1.1. Participants

Sixteen native Japanese speakers at college in Japan who did not participate in Experiment 1 were recruited as participants. Fourteen of them were female and two were male. Their mean age was 19.4 years. None of them had experience staying in English-speaking countries for more than two weeks. None of the participants reported a hearing impairment.

3.1.2. Design

Non-words that had restricted consonants in word medial positions were used in Experiment 2. One type of co-occurrence restrictions was /f/ followed by /p/ and /d/ followed by /z/ (FP/DZ) (e.g., bɛ**F**.**P**əv) and the other had /f/ followed by /z/ and /d/ followed by /p/ (FZ/DP) (e.g., bæ**F**.**Z**ət). Each restricted consonant occurred with an equal frequency to onset and coda positions and the co-occurrence of restricted consonants was thus equally frequent. In the training phase, the participants heard two repetitions of non-words with either type of co-occurrence restriction above (24 items x 2 conditions x 2 cycles) (e.g., ba**F**.**P**ev, ti**D**.**Z**ek) and were given chances to track syllable-position restrictions (e.g., oPZ and cDF) and co-occurrence restrictions (e.g., FP/DZ). In the test

phase, novel items with the same co-occurrences as those in the training items and novel items with different co-occurrences from those in the training items were intermixed with two additional repetitions of the training items and presented to the participants. It was investigated whether the participants track co-occurrence restrictions when the syllable-position restrictions were maintained.

3.1.3. Materials

The same sound stimuli as those in Experiment 1 were used, with restricted consonants occurring in the word medial positons.

3.1.4. Procedure

The same procedure as that in Experiment 1 was used.

3.2. Results

Table 2 shows the mean ratio of "Yes" responses for each type of items: fillers, Training items, Test items with the same co-occurrence (Same Test items), and test items with different co-occurrence (Different Test items). As in Experiment 1, the participants differentiated the repeated items (0.75) from the test items (0.58). False recognition ratios were 0.77 for the training items, 0.70 for the fillers, 0.64 for the test items with the same co-occurrences as the training items, and 0.53 for the test items with the different co-occurrences. The responses for the test items indicate that the participants falsely recognized the novel test items and were able to differentiate Same test items from Different test items.

Item	Syll-pos	Co-occ	Yes-recog
Filler			0.70 (0.21)
Training			0.77 (0.09)
Test	Same	Same	0.64 (0.27)
	Same	Different	0.53 (0.24)

Table 2: Ratio of "Yes" responses for each type of items

Analysis using a linear mixed model was performed for the responses to the test items in order to examine the effect for test type as in Experiment 1. The model's fit was significantly improved by the inclusion of the fixed effect of Test-type (F (1, 15) = 8.1, $p < 0.05$). The participants tracked the co-occurrence in the word medial positions and differentiated Same Test items from Different Test items, suggesting that they learned co-occurrence restrictions across syllables to occur word-medially.

4. DISCUSSION

The aim of the present study was to determine whether native Japanese speakers learn novel phonotactics even when it violates L1 phonotactic constraints. In both experiments in the present study, large proportions of the Japanese participants identified the training items and distinguished the same test items from the different test items with respect to syllable position and co-occurrence. As an answer to the first research question ("Do native Japanese speakers generalize regularities of syllable positions when they learn novel words whose phonotactics is illegal in their L1?"), the native Japanese speakers learned restrictions of syllable positions of artificial words with illegal phonotactics in their L1 even when the target consonants appeared in the different word positions (i.e., from the word medial positions to the word edges). The Japanese participants learned phonotactics at the syllable level rather than at the word level. Thus, they decomposed bisyllabic non-words into syllables and generalized syllable position of the consonants. As for the second research question ("Do native Japanese speakers track co-occurrence of consonants across syllables?"), the Japanese speakers tracked co-occurrence of the consonants across syllables as well. It is assumed that they learned novel words by relying on multiple factors available.

The results were in line with those of Bernard [17] in which native English speakers were employed. The results showing that the participants learned syllable positions and co-occurrence of consonants across syllables, despite L1 phonotactic constraints, through exposure to artificial words during training phase suggest that experience is a determinant factor in learning novel words rather than exertion of the L1 lexicon. That is, the Japanese participants did not distort their perception of illegal phonotactics in the non-words in the present study so that they could align them with their L1 inventory, which contrasts with the study by Dupoux et al. [13]. The results can be explained by the exemplar model [15] that advocates that a listener's memory of experiences for speech is stored as episodes in the listener's mental lexicon, since they were not affected by L1 phonotactic constraints. However, there is a possibility that the participants depended solely on onset without considering codas. Further study is required to examine whether native Japanese speakers track codas when onset is invariant. Furthermore, what unit native Japanese speakers track, onset followed by a vowel or by a rhyme, needs to be investigated.

7. REFERENCES

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