# PRELEXICAL REPRESENTATIONS IN JAPANESE: EVIDENCE FROM THE STRUCTURAL INDUCTION PARADIGM

Kiyoko Yoneyama & Mark A. Pitt
*The Ohio State University, Columbus OH, USA*

**ABSTRACT**

The study examined the proposal that word segmentation is influenced by listeners' sensitivity to language-universal syllabic structure as well as language-specific rhythmic structure. This hypothesis was tested in Japanese, which can be described in terms of syllabic (universal) and moraic (language-specific) units. The results of Experiment 1 showed that Japanese listeners exhibit minimal sensitivity to syllabic structure. Experiment 2 demonstrated that a modification in methodology was not the cause of the results found in Japanese. Findings provide little evidence in favor of a universal segmentation strategy, suggesting instead that listeners use only language-specific segmentation strategies.

## 1. INTRODUCTION

A traditional view of how spoken words are recognized holds that sublexical units (e.g., syllables, phonemes, etc) are combined to access a word's representation in memory. Over the past ten years, research has begun to build that suggests that these units might not be universal across languages, but rather specific to the particular rhythmic characteristics of the language. In tasks such as word spotting and syllable monitoring, differences in performance across languages such as French, English, Spanish and Japanese have provided compelling evidence to support this position [1][2][5][6][7]. In the present paper, we carried out another test of this claim using a paradigm that has identified commonalities across a subset of these languages.

In the structural induction paradigm, listeners monitor for phonemes in bisyllabic words that occur in one of two syllabic positions, the coda of the first syllable or the onset of the second. The probability of the target phoneme occurring in these syllabic locations is varied (0.8 vs. 0.2). Even though the target phoneme is always in the third serial position in the words (e.g., *neu-tral* vs. *nut-meg*), listeners show a sensitivity to the probability manipulation, responding faster when the target phoneme occurs in the high-probability than low-probability syllable position. Interestingly, this outcome was found to be true for French, Spanish, and English listeners, who had previously been shown to exhibit differential sensitivity to structural characteristics across languages [3][8][9]. If this outcome reflects a commonality in processing across languages, then similar results should be found when the experiment is run in a non-European language, such as Japanese. We explored the hypothesis that listeners are sensitive to language-universal syllable structure.

Japanese is an ideal language in which to address this question because it can be described equally well in terms of moraic units and syllabic units [4][13]. For example, *Honda*, the name of a famous car company, is a 3-mora word (*Ho.n.da*) as well as a 2-syllable word (*Hon-da*). If the commonalities found across languages with the structural induction paradigm are indicative of a language-universal processing unit, then Japanese listeners should perform similarly to English/French/Spanish listeners, and show sensitivity to syllable structure. If language-specific processes take priority, and Japanese listeners are sensitive to moraic not syllabic structure, then a different pattern of results should be found.

Predictions for these two outcomes are as follows: Sensitivity to syllabic structure should show up as faster responses to target segments that occur in the syllabic position (onset or coda) that is most probable in the stimulus list. Thus, listeners in the coda induction condition (0.8 probability of the target segment occurring in the coda of the first syllable) would be significantly faster at detecting the target [n] in *sen-ta-ku* than in *ya-na-gi*. In the onset induction condition (0.8 probability of the target segment occurring in the onset of the second syllable), faster response times should be found when the target [n] occurs in *ya-na-gi* than in *sen-ta-ku*. Such a pattern of data would indicate that listeners have access to the onset and the coda equally within the syllable.

In contrast, if Japanese listeners are sensitive to moraic structure only, then a different pattern of results should emerge. Specifically, they should show no sensitivity to the probability manipulation in the onset induction condition, but hypersensitivity in the coda induction condition. These predictions are based on a consideration of how the onset and coda map onto mora. The coda is a moraic unit, whereas the onset is a submoraic unit. Japanese listeners more easily detect complete consonant moraic units (i.e., codas: *se.n.ta.ku*) than submoraic units (i.e., onsets: *ya.na.gi*), the latter being possible perhaps only after the mora is decomposed into phonemic constituents. Since the target in the onset position is a part of the CV mora, listeners might not be sensitive to the probability manipulation. However, if the target segment is a mora itself, as it is most of the time in the coda induction condition, listeners should be sensitive to the probability manipulation. Thus, this whole-part relationship between subsyllabic units and mora should show up in the data if Japanese listeners are sensitive only to mora structure, with the probability manipulation affecting response times in the coda/moraic induction condition but not in the onset/sub-moraic induction condition.

## 2. EXPERIMENT 1

### 2.1. Method

Experiment 1 consisted of two parts (1A & 1B) which were exactly the same except for the target words. The target segment was always the alveolar nasal [n] in Experiment 1A and the bilabial nasal [m] in Experiment 1B. The experimental design is shown in Table 1.

| | Location condition | |
|---|---|---|
| Induction condition | Onset/Sub-moraic condition CV.CV.CV | Coda/Moraic condition CV.C.CV.CV |
| Onset/Sub-moraic induction condition | 0.8 | 0.2 |
| Coda/Moraic induction condition | 0.2 | 0.8 |
| Baseline condition | 0.5 | 0.5 |
| Location condition: within subjects; Induction condition: between subjects | | |

Table 1: Probability with which the target segment occurred in each location condition in each induction condition (targets + inductors)

The location conditions (onset/sub-moraic and coda/moraic) differed in the structural location (but not serial position) of the target segment in trisyllabic words. Induction conditions (onset/sub-moraic, coda/moraic, and baseline) differed in the frequency with which a particular word structure occurred in a stimulus list, and hence the syllable position (and moraic status) of the target segment.

In each induction (and baseline) condition, there were 60 words that were divided into targets (N=20) and inductors (N=40). Targets, the stimuli of primary interest, served in the location conditions, and therefore remained the same across the induction and baseline conditions. These stimuli underwent statistical analysis. Example target words used in Experiment 1A were *hantoshi, rentaru* for the coda/moraic location condition, and *yanagi, kinoko* for the onset/sub-moraic location condition. Inductors differed across induction conditions because the probability manipulation was achieved with these items. They had the same syllable/moraic structure as the target words in the location condition with the corresponding name. In the baseline condition, there was an equal number of inductors with each structure.

The orthographic representation of the target segment was presented visually immediately prior to presentation of each word. Subjects were told to press a button if the target segment was contained in the spoken word presented over headphones, and told not to respond if they did not hear the target segment in the word. 72 undergraduates (24 participants per condition) and 87 undergraduates (29 subjects per condition) at Dokkyo University in Japan participated in Experiments 1A and 1B, respectively. They were all native speakers of Japanese.

**2.2. Experiment 1A Results ([n] target segment)**

Reaction times (RTs) were measured from onset of the target segment, which was determined with the use of a waveform editor using both auditory and visual criteria. Incorrect responses or unusually fast (<100 ms.) or slow (>1800 ms.) correct RTs and errors were discarded from the data (less than 1%).

As a first step in analyzing the data, performance in the baseline condition was subtracted from that in the two induction conditions. The logic of the procedure parallels its application in the attention literature, where the effect of attentional expectancies are measured by subtracting performance in a baseline condition, in which expectancies are not manipulated, from performance in conditions in which expectancies are manipulated [10]. The procedure must be used in order to remove RT differences due to different acoustic realizations of the target segment (i.e., allophonic variation). For example, Sato reported that in Japanese an alveolar nasal in the coda is significantly longer than that in the onset [11]. Because comparisons between location conditions are of primary interest in the experiment, removal of these differences is necessary to measure induction effects accurately. Without a subtraction procedure, one cannot know whether RT effects obtained across location condition are due to the induction manipulation or to allophonic variation. ANOVAs were performed on the subtracted RT and error data. Mean subtracted RTs and errors are shown in Figure 1. Only the RT data will be discussed, as the error data were less informative and did not contradict the RT data.

There was an interaction between the induction condition and the target location condition ($F1[1,46] = 17.52$, $p < .01$; $F2[1,18] = 10.43$, $p < .01$). In both induction conditions, targets were detected more quickly in the coda/moraic position than in the onset/sub-moraic position, although not reliably by items in the onset/sub-moraic induction condition (coda/moraic induction condition: $F1[1, 23] = 49.877$, $p < .0001$; $F2[1,18] = 9.473$, $p < .01$; onset/sub-moraic induction condition: $F1[1, 23] = 9.799$, $p < .005$; $F2[1,18] < 1$ ). Note that the size of the induction effect was more than three times larger in the coda/moraic induction condition (149 ms.) than in the onset/sub-moraic induction condition (41 ms.).

**2.3. Experiment 1B Results ([m] target segment)**

The subtracted data are shown in Figure 2. In the coda/moraic induction condition, targets were detected 123 ms. more quickly in the coda/moraic location than in the onset/sub-moraic location ($F1[1, 28] = 60.604$, $p < .0001$; $F2[1,18] = 5.194$, $p < .0035$). In the onset/sub-moraic induction condition, targets were detected 43 ms. more quickly in the onset/sub-moraic location than those in the coda/moraic location, but this difference was not significant by items. ($F1[1, 28] = 5.414$, $p < .0274$, $F2[1, 18] < 1$). There was an interaction between the induction condition and the target location condition ($F1[1, 56] = 21.32$, $p < .01$; $F2[1,18] = 3.47$, $p < .078$).

**2.4. Discussion**

Response patterns in the coda/moraic induction condition were consistent and robust across Experiments 1A and 1B. Japanese listeners detected targets in the coda/moraic location significantly faster than those in the onset/sub-moraic location. In addition, the size of the induction effect was enormous (149 ms. and 123 ms., respectively). On the other hand, Japanese listeners showed inconsistent response patterns in the onset/sub-moraic condition in both experiments. They detected targets in the coda/moraic location faster than those in the onset/sub-moraic location in Experiment 1A and vise versa in Experiment 1B. The size of the induction effect was comparatively smaller than that observed in the coda/moraic induction condition in Experiments 1A and 1B, being 41 ms. effect and 43 ms., respectively. Collectively, these data indicate that Japanese listeners are sensitive to moraic structure only. If they were sensitive to syllable structure, listeners should have exhibited induction effects (i.e., RT advantages) of equal magnitude in the two induction conditions.

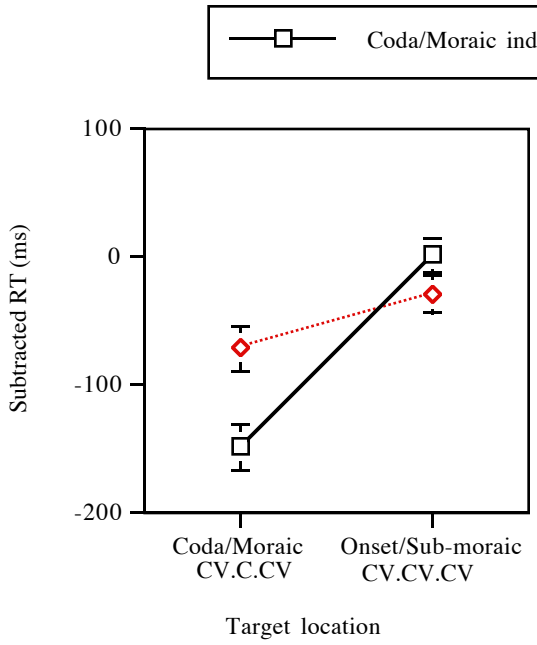


Figure 1: Subtracted RT with standard error bars, Japanese listeners, Experiment 1A (the [n] target segment).

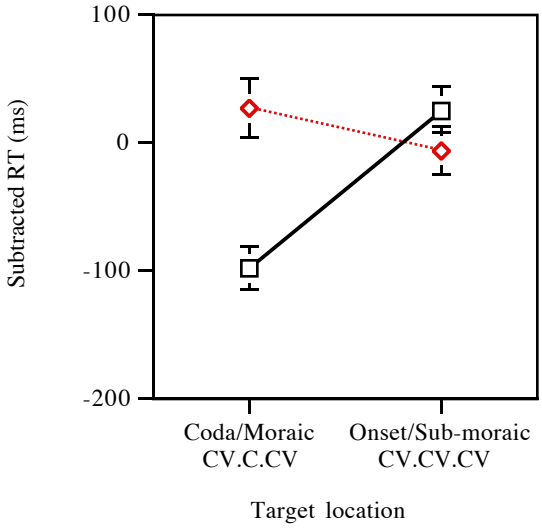


Figure 2: Subtracted RT with standard error bars, Japanese listeners, Experiment 1B (the [m] target segment).

## 3. EXPERIMENT 2

The results of Experiment 1 differ from those obtained with English, Spanish, and French listeners. A slight change in methodology may be the cause of the disparate outcome, and Experiment 2 was conducted to discount it. Prior induction studies included two types of inductors, those in which the target segment occurred in the high-probability syllabic position (fillers) and those in which no response was required (foils). Only the latter was included in Experiment 1. If exclusion of the former is responsible for the novel outcome in Japanese, then a similar pattern should be found if fillers are removed in an experiment conducted in English.

### 3.1. Method

The design of Experiment 2 was similar to that of Experiment 1. There were 40 two-syllable CVCCVC(C) English pseudoword targets, 20 in which the target phoneme occurred in the onset-location condition (CV-CCVC; *nublide, sebreen*), and 20 in the coda-location condition (CVC-CVC; *nubdue, mubmit*). The decision to use pseudowords was arbitrary, as words and pseudowords have yielded very similar results in the induction paradigm [9][12]. There were 80 two-syllable CVCCVC(C) pseudowords that served as inductors in each induction condition. The items. in both induction conditions (and the baseline) were balanced for stress so that half of the items. had primary stress on the first syllable. 48 Ohio-State University undergraduates (16 per condition) participated in the experiment in exchange for course credit.

### 3.2. Results and Discussion

The subtracted RTs were submitted to ANOVAs, and are shown in Figure 3. Targets were detected faster in the coda location than in the onset location in the coda-induction condition, and vise versa in the onset-induction condition (onset-induction condition: $F1[1,15] = 7.7$, $p < .02$; $F2[1,38] = 3.49$, $p < .069$; coda-induction condition: $F1[1,15] = 4.97$, $p < .05$; $F2[1,38] = 3.95$, $p < .054$). The two-way interaction was reliable ($F1[1,31] = 12.25$, $p < .005$; $F2[1,38] = 14.82$, $p < .001$).

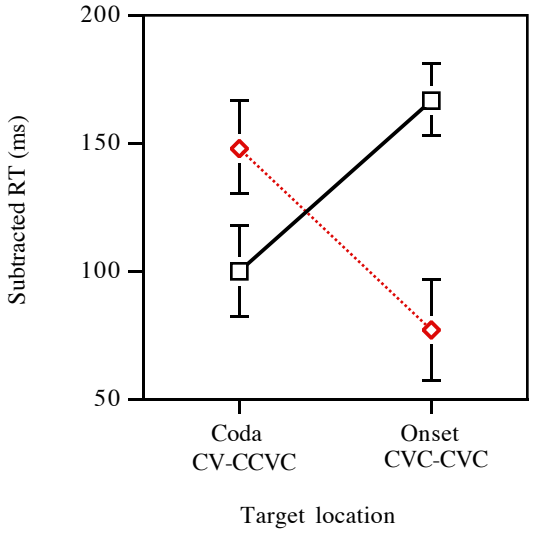


Figure 3: Subtracted RT with standard error bars, English listeners, Experiment 2.

These data suggest that listeners were sensitive to the induction manipulation, responding faster when the target phoneme occurred in the structurally most probable syllable location. The size of the induction effect in both induction conditions was similar: 62 ms. for the coda-induction condition and 67 ms. for the onset-induction condition. The current data replicate prior results obtained in English [3][9][12].

Experiment 2 examined whether a procedural modification of the structural induction paradigm was the cause of the disparate Japanese and English findings. The similarity of the present data to those of past studies using English [9] indicates that the methodological modification is not responsible for the different patterns of results in English and Japanese.

## 4. DIISCUSSION

The purpose of this study was to explore the proposal that listeners are sensitive to universal syllabic structure as well as language-specific rhythmic structure. Previous induction studies suggested that the structural induction paradigm might reveal commonality in processing across languages. This hypothesis was tested in Japanese, which can be described in terms. of syllabic (i.e., universal) and moraic (language-specific) units.

The results provided no supporting evidence for the universality hypothesis, as the Japanese data looked nothing like those found with English, Spanish, and French listeners. In the latter three languages, the induction effect is generally of equal magnitude in both induction conditions or larger in the onset- than coda-induction condition. In Japanese, just the opposite was found. The induction effect was quite large in the coda/moraic-induction condition, but much smaller and inconsistent across experiments in the onset/submoraic-induction condition. The Japanese data are right in line with what is expected if listeners were sensitive primarily to moraic structure. Thus, the present study found no support for the language-universal hypothesis, but continued support for language-specific segmentation strategies.


### ACKNOWLEDGMENTS

This work was supported by a summer research fellowship from The Center for Cognitive Science at The Ohio State University, and by Grant R29 DC01774 from the National Institute on Deafness and Other Communication Disorders, National Institute of Health. We thank Mary Beckman, Keith Johnson, Katherine Smith, and Takashi Otake for their help.


### REFERENCES


[1] Cutler, A. & Norris, D.G. 1988. The role of strong weak syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human Perception & Performance*, 14, 113-121.

[2] Cutler, A. & Otake, T. 1994. Mora or Phoneme? Further evidence for language-specific listening. *Journal of Memory & Language*, 33, 824-844.

[3] Finny S.A., Protopapas, A., & Eimas, P.D. 1996. Attentional allocation to syllables in American English. *Journal of Memory & Language*, 35, 893-909.

[4] Haraguchi, S. 1996. Syllable, Mora and Accent. In T. Otake & A. Cuter (eds.), *Phonological structure and language processing: Cross-linguistic studies*, 45-76, Mouton de Gruyter: Berlin.

[5] Mehler, J., Dommergues, J.-Y., Frauenfelder, U. & Segui, J. 1981. The syllable's role in speech segmentation. *Journal of Verbal and Learning Behavior*, 20, 298-305.

[6] Otake, T., Hatano, G., Cutler, A. & Mehler, J. 1993. Mora or syllable? Speech segmentation in Japanese. *Journal of Memory and Language*, 32, 258-278.

[7] Otake, T., Hatano, G., & Yoneyama, K. 1996. Japanese speech segmentation by Japanese listeners. In T. Otake & A. Cuter eds., *Phonological structure and language processing: Cross-linguistic studies*, 183-201, Mouton de Gruyter: Berlin.

[8] Pallier, C., Sebastian-Galles, N., Felguera, T., Christopher, A. & Mehler, J. 1993. Attentional allocation within the syllabic structure of spoken words. *Journal of Memory and Language*, 32, 373-389.

[9] Pitt, M.A., Smith, K.L., & Klein, J.M. 1998. Syllabic effects in word processing: Evidence from the structural induction paradigm. *Journal of Experimental Psychology – Human perception and Performance*, *24, 1596-1611*.

[10] Posner, M.I., & Snyder, C.R.R. 1975. Facilitation and inhibitation in the processing of signals. In P.M.A. Rabbitt & S.Dornic (eds.), *Attenion and performance V*. New York: Academic Press.

[11] Sato, Y. 1993. The durations of syllable-final nasals and the mora hypothesis in Japanese. *Phonetica*, 50, 44-67.

[12] Smith, K.L., & Pitt, M.A. in press. Phonological and morphological influences in the syllabification of spoken words. *Journal of Memory and Language*.

[13] Vance, T. 1987. *An Introduction to Japanese Phonology*. City University of New York Press: New York.