Cross-language sensitivity to phonotactic patterns in infants

Sachiyo Kajikawa

NTT Communication Science Laboratories, NTT Corporation, 2-4 Hikari-dai, Seika-cho, Souraku-gun, Kyoto 619-0237, Japan and Tamagawa University Research Institute, 6-1-1 Tamagawagakuen, Machida, Tokyo, 194-8610, Japan

Laurel Fais

Infant Studies Centre, University of British Columbia, 2136 West Mall, Vancouver, British Columbia, V6T 1Z4 Canada

Ryoko Mugitani

NTT Communication Science Laboratories, NTT Corporation, 2-4 Hikari-dai, Seika-cho, Souraku-gun, Kyoto 619-0237, Japan

Janet F. Werker

Infant Studies Centre, University of British Columbia, 2136 West Mall, Vancouver, British Columbia, V6T 1Z4 Canada

Shigeaki Amano

NTT Communication Science Laboratories, NTT Corporation, 2-4 Hikari-dai, Seika-cho, Souraku-gun, Kyoto 619-0237, Japan

(Received 23 December 2005; revised 11 July 2006; accepted 25 July 2006)

This study explored sensitivity to word-level phonotactic patterns in English and Japanese monolingual infants. Infants at the ages of 6, 12, and 18 months were tested on their ability to discriminate between test words using a habituation-switch experimental paradigm. All of the test words, neek, neeks, and neekusu, are phonotactically legitimate for English, whereas the first two words are critically noncanonical in Japanese. The language-specific phonotactical congruence influenced infants’ performance in discrimination. English-learning infants could discriminate between neek and neeks at the age of 18 months, but Japanese infants could not. There was a similar developmental pattern for infants of both language groups for discrimination of neek and neeks, but Japanese infants showed a different trajectory from English infants for neekusu/neeks. These differences reflect the different status of these word patterns with respect to the phonotactics of both languages, and reveal early sensitivity to subtle phonotactic and language input patterns in each language. © 2006 Acoustical Society of America. [DOI: 10.1121/1.2338285]

PACS number(s): 43.71.Ft, 43.71.Hw [MSS]

Pages: 2278–2284

I. INTRODUCTION

The speech perception of humans is tuned to their native language. Infants as young as 6 months of age have already started acquiring native vowel categories, and they process their native consonant categories effectively at around the end of the first year of life (review: Kuhl, 2004; Saffran et al., 2006). This has been demonstrated in previous studies using words of a single syllable in which the target sounds are in word-initial position. As a result of this perceptual accommodation, for example, 10- to 12-month-old English-learning infants come to ignore a non-native contrast such as the Hindi retroflex versus dental stop contrast, even though they discriminate the same contrast at 6–8 months (W Werker and Tees, 1984). During the same age period, infants show improvement in their discrimination of phonetic contrasts used in the native language (Kuhl et al., 2006). Similar developmental changes in phoneme perception have been observed also in infants who learn other languages, such as Spanish and Swedish (Kuhl et al., 1992; Bosch and Sebastián-Gallés, 2003).

In addition to phoneme categories, each language has its own set of phonotactic rules, that is, acceptable patterns of phoneme sequences. One kind of phonotactic rule involves the possible positions for phonemes or phoneme sequences in words. For example, the /dl/ cluster is not allowed in word-initial position in French (Hallé et al., 1998), and /zd/ sequence is never observed in word-initial position in English (Mattys and Jusczyk, 2001). Another kind of phonotactic rule is concerned with the combination of phonemes. For example, the combination of [k] and [n] in this order within a syllable is illegitimate in English (Friederici, 2005).

Previous studies have shown that infants before one year of age are already sensitive to phonotactic features of their native language. Friederici and Wessels (1993) reported that 9-month-old Dutch infants have started learning the phonotactic structure of word boundaries. Infants presented with nonsense words /muk/, and /ksmu/ preferred listening to /muk/, which is a legal pattern in Dutch, rather than /ksmu/,
which is an illegal pattern. Infant knowledge of phonotactic patterns has also been revealed in discrimination between native language words and non-native language words. In another study, English-learning 9-month-old infants were presented with two language word lists, English and Dutch (Jusczyk et al., 1993). There are some phonetic differences in English and Dutch, but only phonemes that are allowed in both languages were used in one of a series of experiments. For example, the word “knevel” is a legal form for Dutch but an illegal pattern for English, even though each phoneme is legal in both Dutch and English. In these experiments, English-learning infants preferred legal word patterns for English to word patterns that were legal only for Dutch. This result demonstrated that infants’ ability to discriminate word lists can be based on phonotactic features.

Nine-month-old English-learning infants are also sensitive to the probability of sound combinations even within the native language (Jusczyk et al., 1994). That is, infants preferred words consisting of frequent sound combinations to those consisting of rare sound combinations. Indeed, infants can even learn to prefer a particular syllable structure (e.g., CVCV over CVCCVC) following only a brief pattern induction phase (Saffran and Thiessen, 2003).

The knowledge of phonotactic patterns also plays an important role in speech segmentation. When infants were presented with target words embedded in a sentence with good phonotactic word boundary cues, they could recognize words (Mattys and Jusczyk, 2001). CVC target words were surrounded by consonants, yielding C-CVC-C forms with C-C clusters at word-initial and word-final positions (V: vowel, C: consonant). The C-C clusters used in one condition frequently occur in word-medial position in a child-directed corpus. Therefore, these C-C clusters would be good cues for word boundaries. In another condition, C-C clusters that frequently appear in word-medial position were placed in word-initial and word-final positions. In this case, infants tended to interpret the C-C combination as a sequence within a word, and they failed to find the target words. Infants can learn these phonotactic regularities by being exposed to speech stimuli for just a few minutes. Saffran, Newport, and Aslin (1996) reported that infants recognized “words” embedded in phoneme sequences without prosodic cues. In their study, only distributional regularities were controlled and were available to be used as a cue for word boundaries.

The knowledge of native phonotactic patterns has an influence on speech perception in adults. One language-specific perception that is based on native phonotactic patterns is Japanese speakers’ auditory illusion of an epenthetic vowel between the consonants in a voiced consonant cluster in words of the form VCCV, like “ebzo” (Dupoux et al., 1999). In this case, Japanese speakers hear /u/ between /b/, and /j/, and their representation of “ebzo” becomes “ebu zo.” This auditory illusion relates to the fact that CC clusters are noncanonical in Japanese. Consonants are always followed by vowels except for some special morae. That is, most words containing a CC cluster, such as tabemono (correctly tabemono, food), are not acceptable as Japanese words. Therefore, in Dupoux et al.’s study, Japanese speakers automatically perceived a vowel which actually did not exist between the two voiced consonants. In another study, it was shown that French speakers “misperceive” illegal word-initial /dl/ and /tl/ clusters as legal /gl/ and /kl/ (Hallé et al., 1998). This kind of auditory illusion or perceptual assimilation of illegal clusters to legal patterns may promote speech processing in cases in which sounds are omitted or pronounced ambiguously.

Despite the fact that in Japanese, consonant clusters are not canonical, these clusters are actually observed and accepted in some contexts of fluent speech. High vowels (/i/, /u/) tend to be devoiced when they appear between voiceless consonants or between a voiceless consonant and a pause (e.g., k(i)sha, steam train). When speakers of the Tokyo dialect produce words containing such devoicing contexts, vowel devoicing occurs at a rate of 70%–80% (Imaizumi et al. 1999). Japanese speakers are able to recognize the acoustic difference between the canonical pattern (e.g., “wakakusa” fresh grass) and the devoiced pattern (“wakaka”), and they recognize the canonical pattern as a better exemplar of Japanese words than the devoiced pattern (Fais et al., 2005). Because of the devoicing process, however, Japanese speakers do not find a difference in meaning between the two forms.

This study investigated the influence of native phonotactic characteristics on infants’ perception of words. In particular, we focused on C pause and CC clusters in word-final position for Japanese-learning and English-learning infants. CVC and CVCC sequences are violations of canonical Japanese phonotactic rules. However, because of the process of devoicing, CVC and CVCC forms are not only accepted but occur at a high rate in fluent Japanese speech. On the other hand, both CVC and CVCC sequences fit English phonotactic rules. Infants’ performance was explored from two points of view in our study. The first involved the discrimination of a CVCC word, neeks, and a CVCCVC word, neekusu. Because the last two morae of neekusu constitute devoicing contexts in Japanese, neeks is a possible, fluent speech pronunciation of the word neekusu. Therefore, neeks and neekusu could be perceived as the same word for Japanese infants. This hypothesis is supported by the work done by Dupoux and colleagues on the auditory illusion of an epenthetic vowel in CC environments (Dupoux et al., 1999). However, in a study in which Japanese adults rated the goodness of these words, most of the Japanese adult participants discriminated neeks and neekusu (Fais et al., 2005). In the study, Japanese speakers rated the canonical and noncanonical forms differently; further, they rated those with devoicing contexts significantly differently from those without devoicing contexts. This demonstrated that adults are sensitive to the possible acceptability of some final Cs or CC’s. Therefore Japanese-learning infants might discriminate neeks and neekusu according to their knowledge of sequence acceptability in Japanese. Thus, there are two possible predictions for Japanese infants: they might fail to distinguish neeks and neekusu based on their recognition that these two forms can be related by vowel devoicing and thus constitute the “same” word, or they might discriminate the two forms on the basis of their surface phonetic differences. English-learning infants, in whose language environment neeks and neekusu are
definitely different words in legal forms, are predicted to discriminate these two forms.

The second point is the discrimination of a CVCC word, neeks, and a CVC word, neek. It might be the case that these two words will be considered different by Japaneselarning infants because there is no process, like vowel devoicing, that could relate the two words in Japanese. Thus, both Japanese and English-learning infants will discriminate these two forms. On the other hand, these two words could be difficult for Japanese infants to discriminate since both words are non-canonical Japanese forms. As previous studies have shown, infants before one year of age are sensitive to phonotactic patterns, preferring legal word forms to illegal forms. This predicts that Japanese infants would show clear discrimination of neeks/neekusu because neeks is phonotactically illegal and neekusu is legal. However, it makes no prediction in the case of neek/neeks, in which both forms are illegal. For English infants, both pairs are legal-legal combinations and they should show good performance in discrimination for both combinations.

TABLE I. The makeup of the Japanese and English groups.

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Mean age</th>
<th>Age range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>14M 10F</td>
<td>6m 19d</td>
<td>6m 5d–7m 4d</td>
</tr>
<tr>
<td>12 months</td>
<td>11M 13F</td>
<td>12m 9d</td>
<td>12m 0d–12m 27d</td>
</tr>
<tr>
<td>18 months</td>
<td>11M 13F</td>
<td>17m 26d</td>
<td>17m 10d–18m 17d</td>
</tr>
<tr>
<td>English</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 months</td>
<td>12M 12F</td>
<td>6m 16d</td>
<td>6m 0d–7m 4d</td>
</tr>
<tr>
<td>12 months</td>
<td>12M 12F</td>
<td>12m 18d</td>
<td>11m 24d–13m 3d</td>
</tr>
<tr>
<td>18 months</td>
<td>12M 12F</td>
<td>17m 27d</td>
<td>17m 10d–18m 14d</td>
</tr>
</tbody>
</table>

*M: male.  
*F: female.  
*m: month.  
*d: day.

**II. METHODS**

A. Participants

Japanese and Canadian infants at the ages of approximately 6, 12, and 18 months were tested (Table I). All the infants were born after a 37-week gestational period and had had no problems in vision or hearing based on parental report. The parents of Japanese participants were Japanese native speakers living in the Kinki (western) area of Japan and those of Canadian participants were English native speakers living in Vancouver, Canada. Twenty-four infants were assigned to each age group of the two language groups. Most of the Japanese infants had opportunities to hear English speech from TV programs or CDs, but they had never lived with nor exposed to Japanese language. Data from an additional 25 infants of the Japanese group and 48 of the English group were excluded in the analysis because of infants’ inappropriate condition (crying, sleeping, fussing, etc.), failure to reach the criterion for number of habituation trials (>6 trials), or technical problems with the experimental equipment.

B. Stimuli

The stimuli were three nonsense words: neek (ni:k/) a CVC word, neeks (ni:k:s/) CVCC, and neekusu (ni:k:ku:s/) CVCVCV. Canonically, CVC and CVCC words do not follow Japanese phonotactic rules, but they are possible words in devoicing contexts in fluent speech. On the other hand, CVCVCV words do follow Japanese phonotactic rules. For English, all the words are legitimate word forms.

The acoustic difference between neeks and neek is a single consonant (/s/) in word-final position and the difference between neeks and neekusu is the presence of two vowels (/u/ and /u/) in word-medial and -final positions. Both neeks and neek are possible forms in Japanese fluent speech, derived by vowel devoicing from canonical forms neekusu and neeku, respectively. Neeks and neekusu could be the same word for Japanese speakers, related in the same way as [kaks] (hide) and /kakusu/ (hide). In terms of English phonology, neeks, neek, and neekusu are all possible forms. For English speakers, neeks and neek could be related morphologically, as singular/plural, present third person, or possessive.

The stimulus words were produced by a female English-Japanese bilingual speaker 18 years of age, who had grown up in an American English-speaking family and had lived in Japan for 13 years, attending Japanese schools throughout that time. The words were presented to the speaker in English spelling because there is no kanji or katakana for some of the word forms. The speaker was instructed to pronounce the words with Japanese articulation of the consonants, but with no epenthetic vocalic material at the end of neek or in the devoiced vowel positions in neeks. It was necessary to use a bilingual speaker because it is difficult for native Japanese speakers to refrain from introducing vocalic material in these positions. The speaker produced multiple tokens of each word until the canonical form neekusu was judged to be “natural-sounding” Japanese by three native speakers of Japanese (see Fais et al. 2005 for Japanese adults’ ratings of these forms). The speaker produced words in an infant-directed style. The words were recorded into a computer at a sampling rate of 16 bit, 44.1 kHz. Five intonational variations of each word were selected and the variations were matched across the three words. Speaking rates were almost the same among the stimulus words.

C. Procedure

The infants were tested in a habituation-switch paradigm (Stager and Werker, 1998). The experiments were conducted in a sound-attenuated booth, whose inside wall was covered with black cloth. An infant sat on the parent’s lap and faced a 19 in. PC display. Behind the center cloth, a loudspeaker and a video camera were hidden. An experimenter outside the booth controlled the presentation of audio and visual stimuli and recorded the infant’s response by monitoring eye direction using the Habit 2002 program (Cohen et al., 2002).

In the beginning of each trial, an attention getter appeared on the display. When the infant looked at the display, the trial was started and a red-black checkerboard appeared. During each 14 s trial, an audio stimulus was presented...
through a loudspeaker. During a trial, a word was presented seven times, using five different intonational variants, with approximately 1 s intervals between words. When the infant looked at the display, the experimenter pushed a key and recorded looking time on the computer. The total looking time was summed as the data for a given trial.

A session consisted of a habituation phase and a test phase. In the habituation phase, a CVCC word (neeks) was presented. The habituation phase ended when the total looking time of the last three trials was less than 65% of the total looking time of the block of three trials that had the highest looking time. If the number of habituation trials reached 27 without reaching the 65% criterion, the habituation phase automatically ended and the test phase started. These cases were not included in the analyses. In the subsequent test phase, three stimuli were presented: CVCC (neeks), i.e., the same stimulus as that of the habituation phase, CVCVCV as switch 1, and CVCCVCV (neekusu) as switch 2. The test order was counterbalanced among infants.

After the experiment, infants’ eye directions were labeled frame by frame in offline coding as either looking at the monitor or looking away from the monitor. Looking time obtained from this offline coding was used in the analysis. In the habituation-switch paradigm, recovery of looking to a switch stimulus is interpreted as showing that the infant could discriminate the switch stimulus and the habituated stimulus. Therefore, we calculated the recovery of looking during a switch trial and compared it to looking time to the “same” trial.

III. RESULTS

Figure 1 shows the mean recovery of looking time in each age group of Japanese and English infants. We conducted a two-way ANOVA in each language group (word by age mixed design, three word conditions: “same” trial CVCC, switch-neek trial CVC, and switch-neekusu trial CVCCVCV, and three age conditions: 6, 12, and 18 months). For the Japanese group, the effect of word was significant ($F(2,138)=21.26, p<0.01$). Neither the effect of age nor the word by age interaction were significant. Post hoc tests (LSD) showed that the infants recovered significantly when they were presented with CVCCVCV in a test trial ($p<0.01$, difference of mean looking times between “same” condition and switch-neekusu condition, 6 months: $diff=-2.05$, 12 months: $diff=-1.88$, 18 months: $diff=-2.42$). On the other hand, when the infants heard CVC in the switch-neek condition, the looking time was not significantly different.

For English infants, the main effect of word was also significant ($F(2,138)=27.19, p<0.01$). The effect of age and the word by age interaction was not significant. The differences of looking times between “same” condition and switch-neekusu CVCCVCV condition were significant in all age groups ($p<0.01$, 6 months: $diff=-2.24$, 12 months: $diff=-2.52$, 18 months: $diff=-4.21$). The differences between “same” condition and switch-neek CVC condition were also significant ($p<0.02$). When we tested these differences individually for each age group, only English 18-month-old infants looked longer in the switch-neek trial CVC than in the “same” trial ($diff=-2.25, p<0.01$). English 6-month and 12-month infants did not show this tendency, similar to Japanese infants.

The percentage of infants who showed recovery of looking time in the test trials is an index for developmental change in discrimination abilities. In the switch-neek condition, eight out of 24 infants showed recovery for neek after habituation to neeks in the 6-month group, 10 infants did so in the 12-month group, and 13 in the 18-month group. That is, the percentage of infants who discriminated neek from neeks increased gradually with age (Regression analysis: $x=age, y=percentage of infants, y=22.00+1.75x, F(1,2) =147.00, p=0.05$), as shown in Figure 2. This tendency is identical to that for the English group. For the English group, 10 infants showed recovery at 6 months, 13 at 12 months, and 16 at 18 months ($y=29.33+2.08x, F(1,2)=1875.00, p$...
The percentages of infants who showed recovery to *neek* from *neeks* were higher in the English group than in the Japanese group by 10%–13%. However, the percentages were not significantly different between the two language groups for each age (two-sample test for equality of proportions).

The result was different between the two language groups for the switch-*neekusu* condition than for the switch-*neek* condition, which was described above. The number of infants who showed recovery to *neekusu* in the Japanese group was 17 at 6 months, 16 at 12 months and 18 at 18 months. The percentage of Japanese infants showing recovery did not change with age ($\gamma = 67.00 - 0.33x$, ns). On the other hand, the number of infants showing recovery in the English group was 16 at 6 months, 19 at 12 months, and 22 at 18 months. The percentage clearly increased in this language group from 6 to 18 months of age ($\gamma = 54.33 - 2.08x$, $F(1,2) = 1875.00$, $p < 0.02$). In addition, the percentage of recovery in 6-month infants is almost the same in both language groups, but it is different in the 18-month group: 92% for the English group and 75% for the Japanese group.

Comparing the two switch conditions, *neek* and *neekusu*, in each age group, there was also a cross-linguistic difference. For the Japanese group, the difference between *neek* and *neekusu* in percentage of infants showing recovery became smaller and smaller with age (percentage difference between *neek* and *neekusu*: 38% at 6 months, 25% at 12 months, and 13% at 18 months). In contrast, for the English group, the difference of recovery percentage did not change with age: the differences were all 25%. In other words, the change with age in discrimination of *neek-neeks* and *neekusu-neeks* was parallel in the English group but not in the Japanese group.

### IV. DISCUSSION

This study demonstrated some differences between Japanese-learning infants and English-learning infants in their sensitivity to phoneme patterns in words, as well as some common developmental trends. There are three factors determining infant performance of discrimination: phonetics, phonotactics, and surface input in the environment (the vowel devoicing context in this study). We discuss differences and similarities in Japanese and English language groups for two different cases, *neek/neeks* and *neekusu/neek*, according to these three factors.

#### A. Phonetics

From the viewpoint of phonetic discrimination, Japanese- and English-learning infants should perceive the stimulus words in the same way. In our experimental design, we compared infants’ responses to *neekusu* and *neeks*, and to *neek* and *neeks*. Acoustically, the test CVCCVC word, *neekusu*, is greatly different from the habituated CVCC word, *neeks*, especially as compared to the other test CVC word, *neek*. That is, the difference between *neekusu* and *neeks* is two vowels (/u/), which create two additional syllables, and the difference between *neek* and *neeks* is one consonant (/s/), with the number of syllables the same. Therefore, we might predict that *neekusu* is acoustically more discriminable from *neeks* than *neek* is for both language groups of infants. This prediction was supported by the results of our experiment: both Japanese- and English-learning infants could detect the change from one syllable to three in the test words.

In contrast, 6- and 12-month-old infants of both language groups could not discriminate *neek* from *neeks* (18-month-old infants will be discussed below). The percentage of infants who showed discrimination between *neek* and *neeks* increased linearly in both language groups. It is possible that the distinction between the sounds /k/ and /ks/ is a difficult one and may develop late, much as the /th/-/d/ distinction does for English-hearing babies (Polka et al., 2001). Alternatively, phoneme sequences at the ends of words may be less salient and thus more difficult to discriminate than those at the beginning of words (Jusczyk et al., 1999). By both of these accounts, the *neek/neeks* distinction is difficult for 6- and 12-month-old infants.

#### B. Phonotactics

Note that the stimulus words have different phonotactic status in Japanese and English, as described in Table I. CVC (*neek*) and CVCC (*neeks*) are phonotactically valid forms for English but not for Japanese. These language-specific phonotactic patterns were reflected in English and Japanese infants’ different performances. Only English-learning 18-month infants reached statistical significance testing looking time to *neek* and *neeks*. Despite the fact that the contrast was presented in a low-salience position (Jusczyk et al., 1999), the more language-experienced English-hearing 18-month-old infants were able to discriminate these two legal word forms. On the other hand, even though the percentage of Japanese infants who showed recovery of looking for *neek* increased with age, as might be expected for discrimination of a difficult phonetic contrast, Japanese infants did not show significant discrimination. They were not able to discriminate between two phonotactically illegal word forms.

The difference between *neekusu* and *neeks* should be clearly recognized by English infants since *neekusu* and *neeks* are phonotactically different word forms. Our results show that English-learning infants could discriminate these words from 6 months of age and the percentage of infants who discriminated these increased gradually with age. In Japanese, on the other hand, these two words might be interpreted as the same word, because *neeks* is a possible devoiced form of *neekusu*. However, Japanese infants did discriminate the two forms, and thus did not treat *neekusu* and *neeks* as the same word. This result supports our prediction that infants would be able to discriminate *neekusu/neeks* (legal/illegal contrast) based on their preference for legal over illegal word forms. However, note that this result also reflects salient differences at the phonetic level as discussed above.

#### C. Surface input

As described above, Japanese infants of all three ages discriminated *neekusu* from *neeks*. This result is consistent
with the adult ratings of these two words: adult Japanese speakers also discriminate these words in terms of goodness of form (Fais et al., 2005). However, as is the case with the adult data, there is a noteworthy tendency in Japanese infants’ responses that reveals infants’ sensitivity to the devoicing relationship between neekusu and neeks. The percentage of Japanese infants who showed recovery of listening to neekusu did not increase with age, whereas the percentage of English infants who showed recovery increased linearly. This tendency might be related to the surface input of devoicing forms in Japanese. Namely, the speech input that Japanese infants receive includes both CVCCVC and CVCC forms. Rather than getting better and better at differentiating these forms, then, Japanese infants show discrimination of the forms, but do not increase the degree of discrimination as English infants do. At the age of 18 months, Japanese learners may start to process CVCCVC and CVCC differently from English learners. This type of response could well underlie the fine-grained appreciation that Japanese adults develop for the acceptability of word forms that contain devoicing contexts.

To understand fully the results pertaining to Japanese infants’ understanding of devoicing contexts, it is necessary to know more about vowel devoicing rates and contexts in Japanese infant-directed speech. While no research has yet been done on that topic, other previous work has shown that teachers reduce vowel devoicing to hearing-impaired children (Imaizumi et al., 1995). To provide good exemplars to infants who are learning language, caregivers may in fact avoid vowel devoicing. If this speculation is true, the low frequency of devoicing input from mothers may impede young infants’ acquisition of vowel devoicing patterns. In any event, by the age of approximately 18 months, infants do show behavior that seems to be shaped by their understanding of phonotactic patterns and of the surface appearance of consonant clusters.

V. CONCLUSIONS

To explore the influence of native language phonotactic patterns on infant speech perception, we tested infants’ ability to discriminate phoneme sequences. The results demonstrated two points of influence from the native language: (1) if two illegitimate word form patterns are contrasted, it is more difficult for infants to discriminate the patterns than if two legitimate patterns are contrasted, (2) surface input of word form patterns, those involving devoicing contexts in this study, has begun to influence infant discrimination by the age of 18 months. The first point is supported by the results of discrimination for neek-neeks at 18 months of age. English-learning infants, for whom both neek and neeks are legitimate phoneme sequences, could discriminate these patterns, whereas Japanese-learning infants, for whom both are illegitimate patterns, could not. The second point is supported by the fact that the number of Japanese infants who discriminated neekusu and neeks did not increase from 6 to 18 months of age. In contrast, the number of infants who showed discrimination of these patterns did increase for the English-learning group. We interpret this result as reflecting the cross-linguistic difference in the phonotactic status of the surface input of phoneme sequences: in English, neekusu and neeks are legal, unrelated forms; in Japanese they are potentially related by the legitimate and common process of vowel devoicing. For Japanese infants, it was difficult to discriminate the two forms derived by vowel devoicing, neek and neeks. However, the number of infants who showed recovery of looking suggested that infants would get better in discrimination of these patterns, even though the number was still fewer than that of English infants. This is the expected pattern for development of discrimination of forms which represent different words in the language. On the other hand, Japanese infants did not show as robust a development in discrimination of neekusu and neeks as English infants did, although the number of infants who showed recovery at the age of 6 months was almost identical to that in the English group. This, we suggest, is the pattern for development of discrimination of forms that are related phonotactically in the language. Based on this interpretation, we suggest that Japanese infants are beginning to apprehend this relationship by 18 months of age.

ACKNOWLEDGMENTS

The author grateful to Hélène Deacon and Christiane Dietrich for helpful discussion and Tomoko Kawaguchi for her assistance. They also thank all the participants in the experiments.

1These exceptions include geminates such as the “ti” in kitte, “stamp,” and a syllabic nasal that may occur before another consonant. Neither of these patterns are included in the work reported here, and so will not be discussed further.

2As for the frequency of vowel devoicing, there is so far no research concerning infant-directed speech. As in teachers’ speech to hearing-impaired children, adults may tend to reduce the devoicing rate in speech to infants. We have evidence that Japanese mothers do produce devoiced vowels in infant-directed speech; the research regarding rates of devoicing in Japanese infant-directed speech is ongoing at the time of this writing (Fais et al., 2006).


