DEVELOPMENT OF SPEECH PERCEPTION AND PRODUCTION SKILLS OF /R/ AND /L/ IN JAPANESE LEANERS OF ENGLISH

Kyoko Masuda, Linda Norrix, and Kerry Green
University of Arizona

Perception and production of /r/ and /l/ by Japanese learners of English have been extensively investigated. Some studies have found that production can exceed perception (Goto, 1971, Sheldon & Strange, 1982), while others have demonstrated that perception and production develop interdependently (Bradlow et al. 1995; de Jonge 1995). However since the previous studies used different experimental tasks and since learners from different proficiency levels were tested cross-sectionally, it is difficult to make a direct comparison between perception and production skills. The current longitudinal study explores development of perception and production skills of Japanese learners of English over a study period of six months. The following questions are addressed: 1) how do Japanese learners of English develop their skills in perceiving and producing /r/ and /l/ over time? and 2) how does phonological environment (the position of /r/ and /l/ in a word) affect perception and production for Japanese learners of English? Five native Japanese adults learning English in the United States participated in the study. The results indicate that perception and production skills of Japanese learners of English can develop at different rates. In addition, the position of /r/ and /l/ in a word had a large effect on successful production and perception of these sounds over the study period of six months.

INTRODUCTION

Recent studies have uncovered the important complexities of Second Language (L2) Interlanguage Phonology by focusing on the relationship between production and perception.[1] Previous studies have examined perception and production skills for the English /r/ and /l/ sounds in a group of native Japanese learners who were learning English (JLE). Although some studies suggest that production skills exceed perception skills of the English liquids (Goto, 1971; Sheldon & Strange, 1982), others suggest that perception and production skills develop interdependently (Bradlow et al., 1997; de Jonge, 1995). For instance, de Jonge (1995) examined data from JLE who had various levels of English proficiency. Results indicated that learners with good perception also had good production skills, while those with poor perception had poor production skills.[2] de Jonge suggested that perception and production abilities for L2 phonology are linked. Few researchers, however, have examined how both perception and production skills develop over time by tracking the same individuals who are learning the target language. The present study attempts to explore the development of perception and production skills of /r/ and /l/ in five Japanese participants, over a six month period of time, who were learning English in the United States. Since the number of the participants in this study is small, it is hard to make strong generalizations; however, the data from the individual participants provide qualitative descriptions of the potential relationship between the development of L2 perception and production skills.

The present study also addresses the question of whether the position of the liquid in a word influences perception and production abilities. Previous studies have found that the position of the English liquids does indeed influence the degree of difficulty of perception and production for JLE (Mochizuki, 1981; Sheldon & Strange, 1982; Dissosway-Huff et al.,1982). For example, liquids are easiest to perceive where they are the most difficult to produce—in word final position. In this study we examine how phonological positions affect perception and production for JLE over time.

PRESENT STUDY

The present study addresses the following two questions:

1. Do perception and production skills in JLE develop interdependently?

2. How does phonological environment influence perception and production of English liquids for JLE over time?

Research Design

Five Japanese speakers who were newcomers to the United States participated in one production and two perception tasks. The tasks and test items were employed at two different times (Session 1 and Session 2). Session 1 occurred 4-6 months after initial arrival in the United States, and Session 2 occurred about 6 months after Session 1. The same test items were employed in both sessions.

Participants and Judges

Five Japanese adults (three males and two females) participated in this study. Their ages ranged from 18 to 29 years (M=25.8). All participants started learning English when they were in junior high school in Japan, and their proficiency levels ranged from intermediate to advanced. Their TOEFL (Test of English as a Foreign Language) scores ranged from 493 to 590. Two of the five participants had lived in an English speaking country prior to arrival in the United Sates in 1998. One stayed in the United States for 6 months about two and a half years prior to this study, and one stayed in the United States for 6 months 18 years prior to this study. Seven English native speakers participated in this study to judge the production skills of the JLE. The judges were all part of the subject pool from the Psychology Department at the University of Arizona. In addition, five English native speakers participated in one of the perception tasks.

METHODS

Production

First, the Japanese participants read 46 sentences, each containing an English target word with /r/ or /l/ in one of four different word positions, or a filler item. The positions were word initial (e.g. right-light), word final (e.g. core-coal), initial consonant cluster (e.g. brush-blush) and intervocalic (e.g. berry-belly). Each participant read a sentence such as "Please make room for her". There were 32 target words and 14 filler words, taken from Strange and Dittman (1984) (see the words list in Appendix A).

Second, two words including the target word from each sentence (e.g. "make room") were digitized and presented to the native English speakers for identification and goodness ratings. The judges, using headphones listened, to the words pronounced by the Japanese speakers. After they heard the phrase, they identified whether an /r/ or /l/ occurred in the phrase and evaluated the goodness of the production. A six-point rating scale which appeared on the computer screen was used to record their judgments (see the scaling and the instructions in Appendix B). This scaling method was selected in this experiment with the rationale that the judges were expected to be sensitive to small differences in production (improvement or not) over time. The software program used to design and run the experiment was PsyScope (Cohen et al., 1993).

Perception

There were two perception tasks: i) Minimal Pair Identification Task, and ii) Synthetic Speech Identification Task. In i), a native speaker of English was recorded saying 2 instances of the 32 /r/ and /l/ minimal pair words used in the production task. Similar to Strange and Dittman (1984), filler items were also recorded (2 productions for each of 14 filler items, see Appendix A). The Japanese participants were asked to listen to the words in isolation and indicate whether the word contained /r/ or /l/ by circling one of the minimal pair words provided on an answer sheet. In ii), a continuum of twelve stimuli ranging from /ra/ to /la/ was created. The stimuli had a three-formant pattern and were generated with a version of the Klatt software synthesizer (Klatt, 1980) implemented on a PC computer. The stimuli only differed in the initial stationary frequency of F3 and F2 and their subsequent transition to the steady state frequency appropriate for the vowel /a/. The frequencies of the initial value of F3 varied in 12 nearly equal steps between 1800 Hz and 3000 Hz for /ra/ and /la/, respectively. F2 onsets ranged between 1000 Hz and 1232 Hz for /ra/ and /la/, respectively. Each of the 12 stimuli was presented ten times for a total of 120 test trials. Participants were asked to identify each test stimulus (presented in a random order) as /ra/ or /la/. Earphones were used for presentation of the sounds. As a control group five native speakers of English also participated in the synthetic speech identification task.

Word Familiarity

A word familiarity task was conducted approximately two months after Session 2. This task was included to examine lexical effects on word perception (Yoshida et al., 1988; Matsumoto, 1989; Takagi 1993; de Jong 1995). The data obtained from each participant served as an index of his/her familiarity of the minimal pair words used in the production and perception tasks. Participants were provided a printed list of the words that were used in the perception and the production tasks, and asked to indicate their familiarity with each word by circling a number on a seven-point scale.

RESULTS AND DISCUSSION

Results of Production by Individuals

Table 1 shows accuracy in production by participants in the two different sessions. The first column indicates the participants, and the second and the third columns indicate the accuracy rates in Session 1 and in Session 2, respectively. First, this table shows that overall pronunciation of /l/ and /r/ words by 4 out of 5 Japanese speakers, as judged by native speakers of English, improved in Session 2 compared to Session 1. The improvement ranged from 23% to 2%. Second, the decrease for participant [C] was 7% and it was largely due to difficulties producing /r/ in intervocalic position. Third, the largest improvement was for participant [A] who had the most difficulty producing /r/ and /l/ words in Session 1.

Table 1. Accuracy in production by individuals

	Session 1	Session 2
Participant [A]	56%	79%
Participant [B]	88%	92%
Participant [C]	91%	84%
Participant [D]	84%	93%
Participant [E]	90%	92%

Results of Perception by Individuals for Minimal Pair Words

Table 2 shows accuracy in perception of the minimal pair words by individuals in the two different sessions. Again, the second and the third columns show accuracy rates in Session 1 and Session 2, respectively. First, it is clear that all but one participant [C] showed greater accuracy in perceiving /r/ and /l/ words in Session 2 compared to Session 1. This may indicate that for participant [C], phonemic categories for all word positions had not become stable. Second, although participant [A] showed a great improvement in production, as shown in Table 1, perception skills improved only slightly over the 6 month interval. This suggests that perception and production can develop at different rates. In section 3.3, we examine the results for identifying synthetic speech syllables from 2 participants: participant [A] who showed the poorest performance in perception and production and participant [B] who showed the best performance in these tasks.

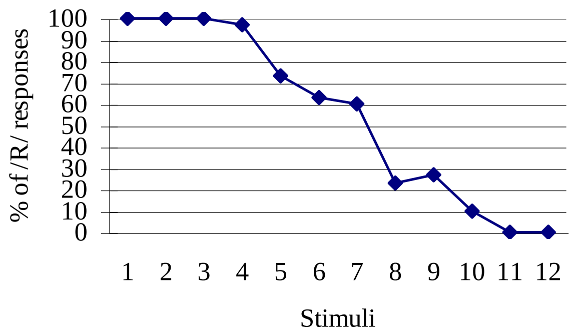
Table 2. Accuracy in perception by individuals

	Session 1	Session 2
Participant [A]	67%	72%
Participant [B]	93%	97%
Participant [C]	93%	82%
Participant [D]	74%	85%
Participant [E]	78%	82%

Individual Participant Sample (Synthetic Speech Identification Task)

Figure 1 shows identification of synthetic speech by 5 English native speakers. For each of the 12 synthetic stimuli (ranging from /ra/ to /la/), the percentage of time the participants responded "r" was calculated. The vertical scale represents the percentage of /r/ responses, while the horizontal scale represents the 12 different synthetic stimuli. Stimulus 1 was the most /r/-like sound, while stimulus 12 was the most /l/-like sound. As Figure 1 shows, identification responses for the English native speakers illustrate a near-sharp category boundary between stimuli 7 and 8. The endpoint stimuli 1, 2, and 3 were identified with 100% consistency as /ra/, and stimuli 11 and 12 were identified with 100% consistency as /la/.

Figure 1. Identification of the synthetic speech by 5 English native speakers



Figures 2-a and 2-b show identification of the synthetic speech by participant [A] for Session 1 and 2, respectively. Recall that participant [A] had most difficulty in perception and production. Rather flat curves indicate that this participant had difficulty in identifying synthetic /ra/ and /la/ syllables in both sessions. Figures 3-a and 3-b show identification functions for participant [B] whose perception and production were most accurate. This participant did not have prior experience living in an English-speaking country, and yet her identification patterns were similar to those of native English speakers. The stimuli that were most /l/-like, however, were not perceived as /l/ with 100% accuracy, indicating that the perceptional system of this Japanese participant for /r/ and /l/ is still qualitatively different from that of native speakers of English. Overall, the data from participants [A] and [B] suggest a correspondence between perception skills for natural words and identification of synthetic speech.

Figure 2-a. Identification of the synthetic speech by Participant A (Session 1)

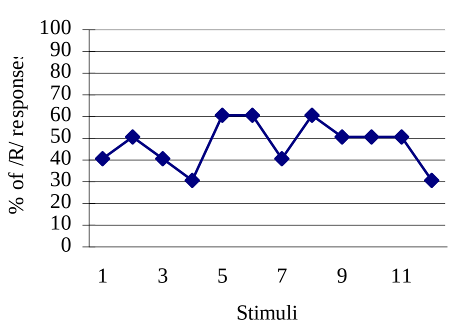


Figure 2-b. Identification of the synthetic speech by Participant A (Session 2)

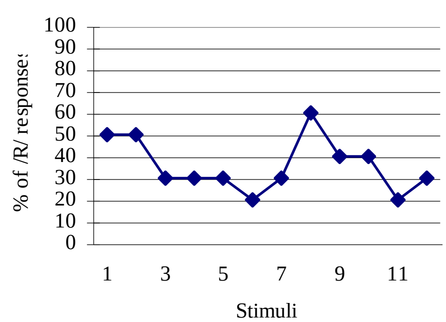


Figure 3-a. Identification of the synthetic speech by Participant B (Session 1)

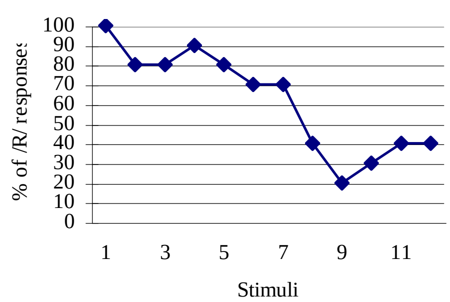
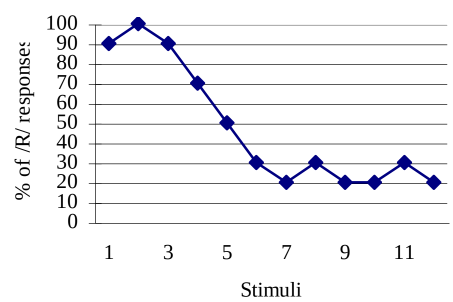


Figure 3-b. Identification of the synthetic speech by Participant B (Session 2)



Results of Production: Accuracy Rates in Different Phonological Environments

Table 3 shows accuracy rates of Japanese speakers' production as a function of phonological environment. Recall that the Japanese productions were judged and rated by native-English speakers. The results from Mochizuki (1981) are included as a comparison. Mochizuki's study included the same word positions used in the present study; however, words were not identical across studies. Like Mochizuki's study, the present study shows that the position of /r/ and /l/ in a word had a large effect on successful production. Table 3 demonstrates that /r/ was easier to produce than /l/ regardless of session. The greatest improvements were observed in two positions: in intervocalic /l/ where accuracy increased from 71% to 88%, and initial consonant cluster /l/ where it increased from 58% to 87%. Differences between Mochizuki (1981) and the present study, particularly for the initial consonant cluster word position, likely result from the use of different /r/ and /l/ clusters as test stimuli.

Table 3. The Affect of Phonological Environments on Production

Word Positions		This Study	Mochizuki (1981)
		Session 1/ Session 2	
[a]CC /r/ (e.g., grow)	*Easier*	98%/ 91%	61%
Final /r/ (e.g., war)	↑	94%/ 97%	96%
Intervocalic /r/ (e.g., berry)		91%/ 91%	93%
Initial /r/ (e.g., read)		90%/ 95%	100%
Initial /l/ (e.g., lead)		79%/ 82%	99%
Intervocalic /l/ (e.g., belly)		**71%/ 88%**	93%
Final /l/ (e.g., wall)	↓	71%/ 75%	95%
[a]CC /l/ (e.g., glow)	*More difficult*	**58%/ 87%**	95%

[a]CC = initial consonant cluster

Results of Production: Goodness Scaling

Table 4 summarizes the results of the goodness rating for the production task. The vertical scale represents the difference score between actual production and rating. The first column represents phonological environments, and the second and third columns indicate data from Session 1 and Session 2, respectively. Difference scores were calculated as follows: if a target word contained /l/ (e.g., "alive") and a judge pressed 1 indicating 'good L', then the difference score between the actual production and the rating was zero. If the judge pressed 3 for the same word, then it was still accurately judged as /l/, but the difference score would be 2. If the judge pressed 6 indicating 'good R' for the same word, then it was no longer accurately identified, and the difference score would be 5. The possible scores ranged from zero to five with the smaller numbers on the vertical scale indicating better pronunciation (see the scaling and the instructions in Appendix B).

Table 4 reveals that the greatest improvements in production were found for initial consonant cluster /l/ and intervocalic /l/ positions. This was also noted in Table 1, indicating a close correspondence between the identification and rating tasks.

To determine the relative importance of various sources of variance in the goodness scaling study (e.g., judges, liquid types, sessions, participants, phonological positions), estimated variance components were obtained for each of the effects of interest. This was done using an ANOVA framework in which mean squares for each effect were obtained. Estimates of the expected value of each variance component were obtained through use of the formulas for expected mean squares for a random-effects design. The estimates were obtained using PROC VARCOMP in SAS.[3] If judges were reliable, or consistent with each other in their ratings, their variance component should be small relative to effects that should exhibit greater variability (e.g., liquid types, participants). Results of this analysis yielded the effects shown in Appendix C. Negative variance components, while meaningless in the actual world, are possible because of the methods used to obtain the variance component estimates. Generally, these are simply interpreted as suggesting a zero or very small positive population values for the effect. In this study, the variance component for judges was .035, approximately half the magnitude of the variance component for liquid (.076) and seven times smaller than the variance component for subject (.236). Variance components representing the interaction of judges with other effects were also small indicating that the judges were consistent and showed good agreement in their ratings.

Table 4. Goodness Scaling of Production (Phonological Environments)

Word Positions	Session 1	Session 2
Final /l/	1.9	1.7
Final /r/	0.7	0.7
Initial /l/	1.4	1.0
Initial /r/	1.0	0.7
Initial consonant cluster /l/	2.2	1.0
Initial consonant cluster /r/	0.7	0.9
Intervocalic /l/	1.7	1.0
Intervocalic /r/	1.0	1.0

Results of Perception: Accuracy Rates in Different Phonological Environments

Similar to the production data, Table 5 shows that the position of /r/ and /l/ in a word had a large effect on Japanese participants' ability to identify sounds in the two sessions.

Table 5. The Effect of Phonological Environments on Perception

Word Positions		This Study	Mochizuki (1981)
		Session 1/ Session 2	
Final /l/	*Easier*	98%/ 95%	98%
Final /r/	↑	92%/ 95%	96%
Intervocalic /r/		**88%/ 97%**	77%
Initial /r/		87%/ 80%	90%
[a]CC /l/		80%/ 86%	73%
Intervocalic /l/		80%/ 75%	69%
Initial /l/	↓	**70%/ 80%**	86%
[a]CC /r/	*More difficult*	**60%/ 80%**	64%

[a]CC = initial consonant cluster

The liquids were easiest to distinguish in word final compared to other positions. Notice that over a six-month period, words containing a liquid in word final position remained the easiest to identify. Large improvements over time were observed for intervocalic /r/, initial /l/, and initial consonant cluster /r/. In this experiment, the word initial position was more likely to be identified as /r/, while initial consonant cluster as /l/. For example, “load” was misidentified as “road,” and “broom” was misidentified as “bloom.” This finding, although only observed for Session 1, is consistent with Mochizuki (1981), Sheldon & Strange (1982), and Dissosway-Huff et al. (1982). One possible reason for these biases is word familiarity (Yoshida et al., 1988; Takagi, 1993). Listeners tend to identify a less familiar word (e.g., “lead”) as a more familiar word (e.g., “read”). The current study cannot rule out this possibility because the word familiarity test was only given to participants approximately two months after Sessions 2. Further studies should evaluate this possibility by using non-words as well as words containing /r/ and /l/ (cf. ‘consonant identification task’ in de Jonge, 1995). If biases such as those found in the current study disappear when using non-words, then word familiarity likely contributes to these biases.

Finally, JLE had very few difficulties perceiving /l/ or /r/ in final word position. One possible explanation is that in Japanese consonants do not occur in word final position (with the exception of /N/). Therefore, perception in word final position may be easy since there are few native Japanese phonemes in final word position that can interfere with the perception of English /r/ and /l/. Although consonant clusters are not permissible in Japanese phonology, the difficulties that JLE exhibited for consonant cluster position, compared with the ease of perception in final position, might also be explained by an acoustic phonetic interpretation. JLE might need longer duration acoustic cues to accurately perceive the /l/ and /r/ distinction (Dissosway-Huff et al., 1982; Henly & Sheldon, 1986). Dissosway-Huff et al. and Henly & Sheldon employed an acoustic analysis of a sample of their test stimuli, and reported that /r/ and /l/ in the word-final position have longer durations than do those in consonant clusters. Further studies using synthetic speech and that manipulate the duration of the /r/ and /l/ formants are needed to investigate this possibility.

In contrast to the results of perception, production of /l/ in word final position was difficult. This finding may be related partly to the fact that JLEs have minimal native motoric experience producing final consonants. Producing /r/ in final position is perhaps an easier task than /l/ in this position, given that there are large amounts of articulatory variability known to result in similar acoustic patterns for /r/ (Alwan et al. 1997; Westbury et al.1998). As suggested by Westbury et al., "From a production point of view, /r/ may therefore afford speakers an unusual degree of latitude" (p. 204). This possibility is consistent with the overall finding that, regardless of word position, /l/ was less accurately produced compared with /r/˙.

Results of Word Familiarity on Perception of Minimal Pair Words

Spearman's rank correlation was calculated to determine if there was an association between word familiarity scores (32 scores) and the average perception accuracy scores for the 32 /r/ and /l/ words from Session 1 and Session 2. A significant correlation coefficient was $r_{s} =$ 0.49, p=.004. This suggests that although the participants in this study were intermediate and advanced learners, lexical information can, to a certain extent, influence perception, as pointed out by Yoshida et al. (1988). This finding does not support de Jonge (1995), who found that word familiarity did not influence the ability to perceive L2 phonemes correctly. Further studies, using a large number of participants with diverse language skills, are needed to determine how language proficiency and word familiarity influence L2 word identification.

CONCLUSION

Although the number of participants was small and it is difficult to generalize the present findings, we can tentatively draw the following conclusions. First, we observed that for participant [A] production improved greatly but only small changes in perception were noted. This suggests that perception and production skills of JLE can develop at different rates. Second, phonological environments are crucial for both perception and production in different manners. For both sessions, /l/ in word final position was easiest to perceive, while difficult to produce. Third, the word positions that showed the greatest improvements in production (i.e. intervocalic /l/ and consonant cluster /l/) were different from those that showed the greatest improvement in perception (i.e. intervocalic /r/, initial /l/, and consonant cluster /r/). This suggests that perception and production of the liquids in various word positions develop at different rates. Fourth, participant [C] was the only one to show poorer performance in production and perception in Session 2 compared with Session 1. The decreases were due to difficulties in a particular phonological environment (intervocalic /r/ for production and consonant cluster /r/ for perception). This suggests that phonemic categories were not stable across all phonological environments for this participant and highlights the need for further longitudinal studies, extending beyond a six-month period of time. Fifth, a significant correlation between perception and word familiarity was found. This suggests that even for intermediate and advanced learners, lexical information affects the perception ability to some extent. In addition to future longitudinal studies extending beyond a six-month period of time, studies should also examine how production and perception develop in spontaneous speech. Finally, acoustic analysis of JLE’s production data might also yield interesting differences over time.

NOTES

1. See 'Interlanguage Phonetics and Phonology' by Major (1998).

2. de Jonge (1995) used a minimal pair test and a consonant identification task for perception. The reason she utilized the latter was to remove the effect of word familiarity. For production, this researcher used an imitation task and an oral reading task.

3. de Jonge (1995) used a minimal pair test and a consonant identification task for perception. The reason she utilized the latter was to remove the effect of word familiarity. For production this researcher used an imitation task and an oral reading task.

4. SAS is the registered trademark of SAS Institute, Inc., Nary, NC, U.S.A.

ACKNOWLEDGEMENTS

Special thanks are extended to the five Japanese individuals who kindly and patiently participated in the experiment. We thank Dr. Patricia Jones (Department of Educational Psychology) at the University of Arizona for running the variance components analysis for the goodness rating study. An earlier version of this paper was presented at Spring SLAT colloquium in March 2000 and Sophia Linguistics conference, Tokyo, in June 2000, and it will appear in *Sophia Linguistica* 46/47. We wish to express appreciation to the audience at SLAT colloquium as well as at Sophia Linguistic conference for their invaluable suggestions. We also thank people in the speech perception lab for their help and support at the data collection stage in 1998-1999. This study is respectfully dedicated to the memory of the late Dr. Kerry Green.

REFERENCES

Alwan, A., Narayanan, S., & Haker, K. Toward articulatory-acoustic models for liquid approximants based on MRI and EPG data: Part II: The rhotics. *Journal of Acoustic Society of America*, *101*, 1078-1089.

Bradlow, R. A., Pisoni, B. D., Akahane-Yamada, R. & Tohkura, Y. (1997). Training Japanese listeners to identify English /r/-/l/: IV. Some effects of perceptual learning on speech production. *Journal of Acoustic Society of America*, *101*, 2299-2310.

Cohen, J., MacWhinney, B., Blutt, M., & Provost, J. (1993). PsyScope: An Introduction graphical system for designing and controlling experiments in the psychology laboratory using Macintosh computer. *Behav. Meth., Inst., and Comp*., *vol. 25*, 257-271.

Dissosway-Huff, P., Port, F. R., & Pisoni B. D. (1982). Context effects in the perception of English /r/ and /l/ by Japanese. *Research on Speech Perception Progress Report*, *8,* 277-288. Indiana University.

de Jonge, E. C. (1995). *Interlanguage phonology: Perception and production*. Unpublished doctorial dissertation, Indiana University.

Goto, H. (1971). Auditory perception by normal Japanese adults of the sounds 'L' and 'R'. *Neuropsychologia, 9*, 317-323.

Henly, E. & Sheldon, A. Duration and context effects on the perception of English /r/ and /l/: A comparison of Cantonese and Japanese speakers. *Language Learning. vol. 36,* 505-521.

Klatt, D. H. (1980). Software for a cascade/parallel formant synthesizer. *Journal of the Acoustical Society of America, 67,* 971-995.

Liberman, A.M., Cooper, F.S., Shankweiler, D. P. & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review*, *74*, 431-461.

Major, R. (1998). Interlanguage phonetics and phonology. *Studies in Second Language Acquisition*, *20*, 131-137.

MacKrain, K., Best, C., & Stragne, W. (1981). Categorical perception of English /r/ and /l/ by Japanese bilinguals. *Applied Psycholinguistics*, *2*, 369-390.

Masuda, K., Norrix, L. & Green, K. (to appear). The effect of linguistic experience: perception and production skills of /r/ and /l/ by Japanese learners of English. *Sophia Linguistica*, *46/47*, 1-15.

Matsumoto, Y. (1989). Developmental change in the 'lexical strategy' of sound perception in second language learners. *Sophia Linguistica*, *27*, 217-226.

Miyawaki, K., Liberman, M. A., Jenkins, J., & Fujimura, O. (1975). An effect of linguistic experience: The discrimination of /r/ and /l/ by native speakers of Japanese and English. *Perception and Psychophysics*, 18, 331-340.

Mochizuki, M. (1981). The identification of /r/ and /l/ in natural and synthesized speech. *Journal of Phonetics 9*, 283-303.

Sheldon, A., & Strange, W. (1982). The acquisition of /r/ and /l/ by Japanese learners of English: evidence that speech production can proceed speech perception. *Applied Psycholinguistics*, *3*, 243-261.

Strange, W., & Dittman, S. (1984). Effects of discrimination training on the perception of /r/-/l/ by Japanese adults learning English. *Perception & Psychophysics*, *36*, 131-145.

Strange, W. (1992). Cross-language studies of speech perception: A historical review. In S. Winifred (ed.), *Speech perception linguistic experience issues in cross-language research*. 3-45. Baltimore: York Press.

Takagi, N. (1993). *Perception of American English /r/ and /l/ by adult Japanese learners of English: A unified view*. Unpublished doctorial dissertation, University of California, Irvine.

Yoshida, K., Saito, M., Matsumoto, Y., Hayakawa, Y., Nemoto, C., Tanaka, M., & Yukiyoshi, I. (1988). Phoneme perception and lexical knowledge in second language acquisition. *Sophia Linguistica*, *26*, 237-243.

Westbury, R. J., Hashi, M., & Lindstrom, M. (1998). Differences among speakers in lingual articulation for American English /™/. *Speech Communication*, *26*, 203-226.

APPENDIX A: WORD LIST

<u>Initial</u>	<u>Consonant Cluster</u>
read-lead	breed-bleed
reader-leader	broom-bloom
room-loom	grow-glow
right-light	grass-glass

<u>Intervocalic</u>	<u>Final</u>
mirror-miller	dear-deal
berry-belly	core-coal
correct-collect	war-wall
arrive-alive	tire-tile

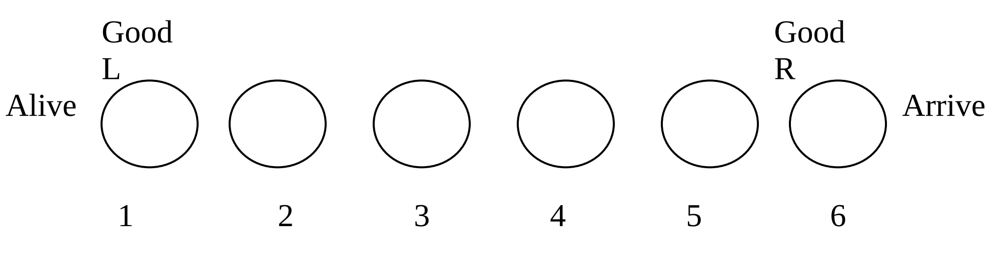
<u>Filler word</u>	
him-hip	swimming-swinging
mad-man	defend-descend
get-got	deep-keep
hope-soap	

APPENDIX B: SCALING & INSTRUCTION

You will hear a short utterance. One of the words in the utterance contains an “R” or “L”. Before the start of each trial the computer will tell you what the short utterance will be. After that the sound will play twice. After the second utterance pleases rate how good of an “R” and “L” you heard on a scale from 1 to 6.

If you heard an “L”, you will choose a green number (circles 1, 2, or 3). A very good “L” would be a 1. If you heard an “R”, you will choose a purple number (circles 4, 5, or 6). A very good “R” would be a 6.

Press the space bar when you are ready to begin the trials.



APPENDIX C: PROC VARCOMP

Table 6. The Results of PROC VARCOMP

Variance Component	Variance
[a]Syllable	0.07607
[b]Position	0.0087787
Position x Syllable	-0.01728
[c]Time	0.01034
Time x Syllable	0.14676
Time x Position	-0.06808
Time x Position x Syllable	0.06587
[d]Judge	0.03494
Syllable x Judge	0.0090577
Position x Judge	-0.02068
Position x Syllable x Judge	0.03623
Time x Judge	-0.0041698
Time x Syllable x Judge	0.0083447
Time x Position x Judge	0.01429
Time x Position x Syllable x Judge	0.0026145
[e]Participant	0.23618
Participant x Syllable	-0.05206
Participant x Position	-0.07646
Participant x Position x Syllable	0.0041543
Participant x Time	-0.0051463
Participant x Time x Syllable	0.06729
Participant x Time x Position	0.11172
Participant x Time x Position x Syllable	-0.07825
Participant x Judge	0.01466
Participant x Syllable x Judge	-0.0051670
Participant x Position x Judge	0.0093988
Participant x Position x Syllable x Judge	0.0088046
Participant x Time x Judge	0.01051
Participant x Time x Syllable x Judge	-0.01174
Participant x Time x Position x Judge	-0.03151
Participant x Time x Position x Syllable x Judge	0.04614
[f]Word [Position x Syllable]	0.06587
Time x Word [Position x Syllable]	0.04867
Word x Judge [Position x Syllable]	-0.01155
Time x Word x Judge [Position x Syllable]	0.01829
Participant x Word [Position x Syllable]	0.13986
Participant x Time x Word [Position x Syllable]	0.69618
Participant x Word x Judge [Position x Syllable]	0.01527
Error	0.83526

[a]Syllable refers to the target phoneme, e.g., /r/ or /l/.
[b]Position refers to the position of /r/ and /l/ in the word,
e.g., initial, final, inter-vocalic, consonant cluster
[c]Time refers to data collection session, e.g., Session 1 or Session 2
[d]Judge refers to English native speakers who judged the /r/ & /l/ productions.
[e]Participants refers to the Japanese native speakers.
[f]Word refers to separate words used for each case, e.g., four different words each containing /r/ in initial position.