STUDIA PHONOLOGICA IX (1975)

# A Comparative Study of Hemispheric Specialization for Speech Perception in Japanese and English Speakers

Katsumasa SHIMIZU

## I. Introduction

It is generally known that each hemisphere of the human brain has different functions in the perception of sounds, i.e., for most normal right-handed people, a left hemisphere is responsible for recognizing verbal stimuli, while a right hemisphere is responsible for recognizing non-verbal stimuli. This can be supported by the facts that damage to the left hemisphere of the brain impairs comprehension of spoken materails in most cases, while damage to the right impairs the perception of other kinds of materials such as tonal quality and pattern.

One of the research techniques widely used in studying cerebral dominance of acoustic stimuli is dichotic listening in which two different stimuli are simultaneously presented to right and left ears. Numerous dichotic listening experiments have shown that the left hemisphere is specialized in processing digits (Kimura, 1961), backward speech (Kimura & Folb, 1964), CV syllables (Shankweiler & Studdert-Kennedy, 1967, 1970), and tones in Thai (Van Lancker & Fromkin, 1973), etc. Among major acoustic stimuli, it has been shown that a right ear advantage (REA) is significant for consonants, while not for steady-state vowels. The findings on consonants are interpreted that they are perceived as more speech-like sounds. Although much discussion has been made on lateralization of vowels, no convincing evidence has been shown on cerebral dominance of vowels.

Most of the findings on lateralization of consonants and vowels are based on natural sounds in English and little has been reported on natural sounds in other languages. Based on a different research technique, however, Tsunoda (1973) examined the cerebral dominance of the Japanese speakers by using the vowel /a/ in Japanese. His experiment is based on the delayed auditory feedback method and he reports that vowel /a/ in Japanese is consistently perceived in the left hemisphere by the Japanese speakers. This finding is contrary to the ones in the perception of English vowels by English-speaking subjects and may indicate that Japanese may utilize different strategies in perceiving vowels.

The purpose of the present study is to examine the differences of perception modes between English and Japanese speakers by dichotic listening. Specifically, we would like to examine whether there is any difference between Japanese and

Katsumasa SHIMIZU (清水克正): Research Associate, Dept. of Linguistics, Kyoto Univ., and also a faculty member of Nagoya Gakuin Univ. The author is doing research in linguistics as a research associate under the direction of Prof. Tatsuo Nishida.

English speakers in the lateralization of consonants and vowels, whether perceptual difficulty will elicit an ear preference in vowels, and how English speakers show the ear preference to consonants and vowels in a language other than English.

## II. Experiment Method[1]

1) Subjects: There were twenty-four subjects, twelve Japanese subjects (6 female and 6 male subjects) and twelve English subjects (5 female and 7 male subjects), ages 17–35, most of the subjects were from the UCSD community. All subjects except MF were right-handed, as were their immediate family members. All subjects had normal hearing, as measured by audiometric test, and had no neurological problems.
2) Stimuli: There are three sets of stimuli, 1) a vowel set consisting of five vowels/a, i, u, e, o/, 2) a set of vowels masked with white noise, and 3) a set of six syllables consisting of consonants/p, b, t, d, k, g/ and vowel /a/. A male, native speaker of Japanese, majoring in linguistics at UCSD, recorded several utterances: each of the five vowels and each of six monosyllabic words /pa, ba, ta, da, ka, ga/. The recording was made in the sound-proof IAC room. The recorded materials were stored on LINC computer tape and were editted by various computer programs of PDP-12. In editting the waveforms of vowels, the duration and amplitude of vowels were adjusted to their respective specifications.[2] For CV stimuli, the amplitudes of each stimulus were equated roughly in sampling to LINC tape and the vowel duration was adjusted to be 250 msec. In preparing vowel/noise stimuli, white noise from a commercial noise generator was used to mask the vowels and the approximate signal/noise ratio was set as $-10$ dB. Thus we prepared the following sets of stimuli for experiment:

1) Five-vowel set (5V) No. of trials: 100
2) Five-vowel set masked with white noise (5V/N) No. of trials: 100
3) Six CV syllables (6CV) No. of trials: 120

3) Design: Every stimulus was paired with every other, in both orientations, i.e., (1, 2) and (2, 1), for a total of 20 pairs in the 5 stimulus-conditions and 30 pairs in the 6 stimulus-conditions. The 5 stimulus-conditions had five repetitions of 20 pairings for a total of 100 trials and the 6 stimulus-conditions had four repetitions of 30 pairings for a total of 120 trials.
4) Procedure: Subjects were asked about their handedness and that of their parents and about neurological problems. They were given the hearing test on a Beltone 9-D audiometer. They were tested one at a time in the IAC booth. The subjects were informed of the number of stimuli in each group of stimulus-sets and were asked to identify the stimuli by pushing two buttons on the response panel. The buttons on the panel were labelled as a ア, i イ, u ウ, e エ, o オ for five vowels with or without noise and ba バ, pa パ, ta タ, da ダ, ka カ, ga ガ for

six CV syllables. We also informed that the stimuli in each pair were always different and the next pair of stimuli would be given when they push two buttons. Among three sets of stimuli, the 5V set was presented first to every subject, and other two sets were presented in the order of either 6CV-5V/N or 5V/N-6CV. About 20 trials were given for practice to each subject.

## III. Results

### 1. Overall Performance

Table I summarizes the raw data for three sets of stimuli. Overall performance on both ears for 5V was considerably higher than that of other sets of stimuli. This applied to both groups of subjects. There was no significant difference between both groups of subjects in overall performance of 5V/N and 6CV.

Table I. Overall performance: 5V, 5V/N and 6CV.

| | Test | No. of stim. presentations per ear, per subj. | No. of subjects | No. of stim. presentations (both ears) | Total correct |
|---|---|---|---|---|---|
| Japanese subjects | 5V | 100 | 12 | 2,400 | 2,136(89.0%) |
| | 5V/N | 100 | 12 | 2,400 | 1,337(55.7%) |
| | 6CV | 120 | 12 | 2,880 | 1,593(55.3%) |
| English subjects | 5V | 100 | 12 | 2,400 | 2,202(91.8%) |
| | 5V/N | 100 | 12 | 2,400 | 1,263(52.6%) |
| | 6CV | 120 | 12 | 2,880 | 1,616(56.1%) |

### 2. Ear Advantage

Table II (a, b) represents the overall accuracy, laterality index and phi for individual subjects in both groups. Laterality index and phi represent the ear

Table IIa. Total Correct (T.C.), Laterality Index (L.I.) and phi for Japanese subjects.

| Sub. | 5V | | | 5V/N | | | 6CV | | |
|---|---|---|---|---|---|---|---|---|---|
| | T.C. | L.I. | phi | T.C. | L.I. | phi | T.C. | L.I. | phi |
| K S | 98.50% | −100.00 | −0.041 | 63.00% | 62.50 | 0.414 | 53.33% | 13.51 | 0.084 |
| Y A | 98.50 | 33.33 | 0.041 | 78.50 | 2.45 | 0.012 | 71.67 | 21.43 | 0.111 |
| K O | 96.00 | 100.00 | 0.204 | 78.00 | 15.00 | 0.072 | 51.67 | 0.00 | 0.000 |
| K I | 67.00 | − 3.45 | −0.021 | 48.00 | 12.90 | 0.080 | 47.08 | − 3.70 | −0.025 |
| KK | 79.50 | − 17.07 | −0.087 | 51.00 | −11.11 | −0.080 | 52.50 | 27.03 | 0.167 |
| I H | 96.00 | 0.00 | 0.000 | 51.50 | −11.11 | −0.070 | 54.17 | 2.63 | 0.017 |
| MR | 86.50 | − 40.74 | −0.161 | 59.50 | 13.85 | 0.092 | 56.25 | 15.66 | 0.109 |
| TM | 81.50 | 2.86 | 0.013 | 41.50 | 1.70 | 0.010 | 52.94 | − 8.86 | −0.058 |
| K F | 85.00 | − 33.33 | −0.140 | 45.00 | −16.67 | −0.101 | 60.42 | −11.39 | −0.077 |
| Y O | 87.50 | − 36.00 | −0.136 | 41.50 | −19.30 | −0.112 | 52.92 | 13.04 | 0.075 |
| KSe | 94.50 | 9.09 | 0.022 | 54.00 | 28.13 | 0.181 | 52.50 | 13.51 | 0.083 |
| Y S | 97.50 | 60.00 | 0.096 | 57.00 | 3.23 | 0.020 | 58.33 | − 2.50 | −0.017 |
| Mean | 89.00 | − 2.11 | −0.018 | 55.71 | 6.80 | 0.043 | 55.32 | 6.70 | 0.039 |

Table IIb. Total Correct (T.C.), Laterality Index (L.I.) and phi for English-speaking subjects.

| Sub. | 5V | | | 5V/N | | | 6CV | | |
|---|---|---|---|---|---|---|---|---|---|
| | T.C. | L.I. | phi | T.C. | L.I. | phi | T.C. | L.I. | phi |
| J V | 91.50% | 52.94 | 0.161 | 49.00% | 7.41 | 0.040 | 61.67% | 9.09 | 0.069 |
| F W | 100.00 | —— | —— | 58.00 | 0.00 | 0.000 | 60.00 | −13.89 | −0.085 |
| M F | 90.00 | 22.22 | 0.067 | 45.50 | 1.59 | 0.010 | 60.42 | 6.49 | 0.043 |
| A B | 97.00 | 0.00 | 0.000 | 53.00 | 3.23 | 0.020 | 57.92 | −13.43 | −0.076 |
| P M | 96.00 | − 50.00 | −0.102 | 54.00 | − 3.33 | −0.020 | 46.67 | 26.19 | 0.184 |
| S H | 84.50 | − 22.58 | −0.097 | 36.50 | −19.30 | −0.114 | 54.58 | 1.27 | 0.008 |
| M V | 90.00 | 11.11 | 0.033 | 51.50 | − 8.48 | −0.050 | 47.50 | 4.44 | 0.033 |
| C S | 87.50 | 21.74 | 0.076 | 49.50 | 18.64 | 0.110 | 55.00 | 43.90 | 0.302 |
| W M | 100.00 | —— | —— | 90.50 | − 5.88 | −0.017 | 61.25 | 3.89 | 0.026 |
| B H | 96.00 | 0.00 | 0.000 | 51.00 | − 3.13 | −0.020 | 52.92 | −29.58 | −0.175 |
| S S | 69.00 | − 27.59 | −0.173 | 41.00 | 0.00 | 0.000 | 58.75 | − 1.45 | −0.008 |
| D C | 99.50 | 100.00 | 0.071 | 52.00 | − 3.45 | −0.020 | 56.67 | 28.95 | 0.185 |
| Mean | 91.75 | 10.78 | 0.004 | 52.63 | − 1.06 | −0.005 | 56.11 | 5.49 | 0.042 |

preference of the subjects; the formulae are developed by Shankweiler & Studdert-Kennedy and Kuhn.[3] Laterality index ranges from 0 to $\pm 100$ with negative value indicating a left-ear advantage (LEA), positive value a right-ear advantage (REA). The significance of the index is represented by phi; the higher the phi score is in either negative or positive, the more significant the index is.

For 5V set, the overall accuracy is quite high in both groups of subjects. Among the Japanese subjects, two subjects (KO and YS) show significant REA, while four subjects (KK, MR, KF and YO) show relatively significant LEA. In the case of English subjects, one subject (JV) shows the REA, while three (PM, SH and SS) show the LEA. Other subjects did not show any significant ear advantage.

For 5V/N set, five Japanese subjects (KS, KO, KI, MR and KSe) show the REA, while four (KK, IH, KF and YO) show the LEA. Among the English subjects, however, only subject (CS) shows the REA, while other subject (SH) shows the LEA. Most English subjects did not show any significant ear advantage for this set of stimuli. The overall accuracy is considerably lowered in both groups and that of English subjects is more variable than that of Japanese subjects.

For 6CV set, the mean score of laterality index is 6.70 for Japanese subjects and 5.49 for English subjects. Of Japanese subjects, laterality index is positive for six subjects (KS, YA, KK, MR, YO and KSe); for four subjects (KI, TM, KF and YS) the index is negative but not significant. In English subjects, for three subjects (PM, CS and DC) the index is positive and significant, for five subjects (JV, MF, SH, MV and WM) the index is positive but not significant; for three subjects (FW, AB and BH) the index is negative and significant.

3. Ear difference for individual consonants and vowels

In order to examine whether consonants and vowels have different degree of ear difference, the data for 5V/N and 6CV sets were broken down by phonemes and percentages for individual phonemes per ear were computed. Table III presents the results for each stimulus group.

Table III. Ear differences for individual vowels (%).

| | /a/ | | /i/ | | /u/ | | /e/ | | /o/ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | L | R | L | R | L | R | L | R | L | R |
| Japanese subjects | 61.3% | 63.3% | 65.4% | 59.6% | 43.8% | 54.2% | 57.9% | 66.7% | 37.9% | 42.2% |
| English subjects | 54.6 | 50.4 | 65.8 | 62.5 | 37.1 | 42.2 | 61.7 | 59.2 | 44.6 | 46.5 |

Ear differences for individual consonants (%).

| | /p/ | | /b/ | | /t/ | | /d/ | | /k/ | | /g/ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | R | L | R | L | R | L | R | L | R | L | R |
| Japanese subjects | 32.1% | 30.4% | 25.8% | 30.0% | 42.5% | 50.4% | 80.4% | 82.9% | 86.7% | 84.6% | 48.8% | 58.3% |
| English subjects | 35.4 | 32.1 | 41.3 | 50.0 | 42.9 | 48.8 | 69.2 | 73.3 | 62.9 | 65.4 | 70.0 | 72.9 |

L=left ear R=right ear

For Japanese subjects, the REA is present for all vowels, except /i/, though not significant for vowel /a/. For English subjects, on the other hand, the REA is present for two vowels /u/ and /o/, though not significant for /o/, while the LEA is present for other three vowels.

In the case of six consonants, Japanese subjects showed the REA for four consonants /b/, /t/, /d/ and /g/, and the LEA for /p/ and /k/, while English subjects showed the REA for all consonants, except /p/, significant ear advantage for /b/ and /t/.

4. Identification of phonetic feature values

Shankweiler and Studdert-Kennedy (1970) demonstrate that phonetic features are separately extracted and independently processed in dichotic listening. They also show that feature-sharing pairs are more correctly perceived than the pairs with no shared features.[4] We would like to examine whether their claim can be held in the present experiment. As generally recognized, each consonant in 6CV set can be specified in terms of features such as voicing and point of articulation. Table IV shows that when the pair shares one of the phonetic features, both responses are more likely to be correct than when no feature is shared. This can be applied to both groups of subjects. Furthermore, better performance can be seen when place is shared than when voicing is shared in both groups of subjects. These results show that the phonetic features are separately

Table IV. Percentage of correct responses as a function of feature composition.

| | Feature shared by dichotic pair | Both correct | Neither correct |
|---|---|---|---|
| Japanese subjects | Place | 34.7% | 6.3% |
| | Voicing | 24.3 | 5.9 |
| | Neither shared | 17.7 | 21.8 |
| English subjects | Place | 35.1% | 10.4% |
| | Voicing | 28.1 | 6.4 |
| | Neither shared | 13.2 | 15.3 |

processed and the identification of voicing features is partially dependent on the one of place features and vice versa.

Table V represents the percentage of individual pairs in 6CV set. In the case of Japanese subjects, the pair d-k, which shares no phonetic features, shows the highest performance. Among feature-sharing pairs, the place-sharing pairs of t-d and k-g show better performance than others, but the pair p-b is not so significant in performance, though place feature labial is shared. In the case of English subjects, the pairs d-g and k-g show better performance than other pairs. Among feature-sharing pairs, b-g and p-k show weak performance, compared with others.

Table V. Percentage of both correct of individual pairs in 6CV set.

| | | Japanese subjects | English subjects |
|---|---|---|---|
| Place-shared | p — b | 16.7% | 27.1% |
| | t — d | 47.9 | 37.5 |
| | k — g | 40.6 | 40.6 |
| Voicing-shared | d — b | 18.8 | 34.4 |
| | b — g | 19.8 | 19.8 |
| | d — g | 38.5 | 41.7 |
| | p — t | 18.8 | 33.3 |
| | p — k | 25.0 | 14.6 |
| | t — k | 25.0 | 25.0 |
| Neither-shared | b — t | 3.1 | 12.5 |
| | b — k | 19.8 | 12.5 |
| | p — d | 9.4 | 8.3 |
| | p — g | 5.2 | 9.4 |
| | t — g | 9.4 | 14.6 |
| | d — k | 59.4 | 21.8 |

In the place-sharing pairs, there is some correlation between the two groups of subjects, but in the voicing-sharing pairs, both subject-groups show different performance for the pairs.

5. Lateralization of feature perception

Table VI. Percentage of correct responses on each feature value for each on trials with at least one correct response.

| | | Japanese subjects | | English subjects | |
|---|---|---|---|---|---|
| | | L | R | L | R |
| Place | Labial | 28.9% | 30.2% | 38.3% | 41.1% |
| | Alveolar | 61.5 | 66.7 | 56.1 | 61.1 |
| | Velar | 67.7 | 71.5 | 66.5 | 69.2 |
| Voicing | Voiced | 51.7 | 57.1 | 60.1 | 65.6 |
| | Voiceless | 53.8 | 55.1 | 47.1 | 48.1 |

In order to examine whether there is any ear difference in feature perception, the raw data from 6CV set was reanalyzed for each ear. The results are given in percentage in Table VI.

From Table VI, we notice that the right ear has approximately the same advantage over the left ear in the cases of voiced, alveolar and velar features in both groups. For voiceless and labial features, the REA is present but not significant in either groups. As far as we examine ear difference in terms of phonetic features, both groups show the REA for consonants.

Vowels may also be specified in terms of phonetic features such as backness, frontness, and height. In order to examine whether there is any ear difference in the perception of such features, the data was reanalyzed for each ear and the results are shown in Table VII. Japanese subject showed the REA for such features, but English subjects did not.

Table VII. Percentage of correct responses on each vowel feature for each on ear on trials with at least one correct response.

| | Japanese subjects | | English subjects | |
|---|---|---|---|---|
| | L | R | L | R |
| Front (i, e) | 61.7% | 63.1% | 63.8% | 60.8% |
| Back (u, o) | 40.8 | 48.1 | 40.8 | 44.4 |
| High (i, u) | 54.6 | 56.9 | 51.5 | 52.3 |
| Middle (e, o) | 47.9 | 54.4 | 53.1 | 52.9 |

L=left ear R=right ear

6. Confusion among stimuli

In examining the data in previous sections, we notice that some stimulus segments were more correctly identified than others. Table VIII shows the number of confusion among segments in the 5V/N and 6CV sets. The overall pattern of confusion reflects the patterns by individual subjects.

In the difficult listening condition in which vowels are masked with noise, vowels /u, o/ are quite often confused with vowels/i, e/ in both groups of subjects.

Table VIII.

a) Confusion matrix for 5V/N.

| Stim. \ Resp. | Japanese subjects | | | | | English subjects | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | a | i | u | e | o | a | i | u | e | o |
| a | (298) | 21 | 23 | 49 | 24 | (254) | 32 | 23 | 39 | 35 |
| i | 17 | (302) | 32 | 35 | 23 | 26 | (308) | 33 | 28 | 14 |
| u | 15 | 79 | (239) | 50 | 25 | 28 | 54 | (189) | 49 | 33 |
| e | 19 | 35 | 34 | (306) | 28 | 24 | 30 | 24 | (292) | 37 |
| o | 31 | 50 | 23 | 96 | (192) | 31 | 47 | 29 | 51 | (220) |

b) Confusion matrix for 6CV.

| Stim. \ Resp. | Japanese subjects | | | | | | English subjects | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | p | b | t | d | k | g | p | b | t | d | k | g |
| p | (155) | 23 | 85 | 38 | 68 | 41 | (161) | 43 | 95 | 35 | 44 | 26 |
| b | 65 | (135) | 63 | 68 | 24 | 25 | 41 | (221) | 68 | 47 | 14 | 20 |
| t | 56 | 23 | (226) | 16 | 58 | 26 | 67 | 38 | (222) | 35 | 53 | 28 |
| d | 5 | 11 | 20 | (397) | 14 | 15 | 24 | 17 | 34 | (348) | 10 | 13 |
| k | 10 | 3 | 9 | 1 | (414) | 8 | 18 | 6 | 45 | 12 | (315) | 11 |
| g | 32 | 14 | 33 | 24 | 29 | (266) | 23 | 11 | 19 | 25 | 20 | (349) |

The figures in parenthesis represent the number of segments correctly identified on trials with at least one correct response. The circled figures mark high degrees of confusion.

Although the confusions among stimuli are often discussed in terms of formant transitions, the transitions are hardly recognizable when vowels are masked with noise at a ratio of $-10$ dB. In 6CV set, labial consonants are often confused with other consonants by both groups of subjects. What is common to both groups is that the voiceless consonants are often confused with other voiceless consonants, for instance, /t/ is confused with /k/ or /p/, and /p/ is confused with /t/ or /k/. Consonant /k/ is most correctly identified by Japanese subjects, though it is confused with /t/ by English subjects.

## IV. Discussion

One of the purposes in the present study is to examine whether there is any significant difference between two groups of subjects in lateralization of consonants and vowels in Japanese. The data shows that no significant difference is found in consonants, as far as the mean scores of the laterality index and phi are concerned. Also there is no big difference between both groups of subjects in case of steady-state vowels, as shown in the mean phi scores of both groups. In examining individual subjects in 5V set, five Japanese subjects show the REA and the same number of English subjects show it, including the ones with non-significant REA.

When vowels are masked with noise, the REA was drawn in eight Japanese subjects and in four English subjects. This means that the REA may be drawn by masking with noise in Japanese subjects, but not in English subjects. Generally, however, these numbers of subjects include non-significant REA and it does not seem that the hypothesis of perceptual difficulty should be upheld in the present experiment. The data also indicates that it is sometimes difficult to characterize ear preference when the subjects are assembled at random.

In examining the ear difference for individual phonemes, there are some differences between both groups for subjects. In the analysis of vowels for each ear, the REA is present for vowels /a, u, e, o/ in Japanese subjects, while it is found for vowels /u, o/ in English subjects. In the analysis of six consonants, the REA is found for all consonants except /p/ in English subjects, while in Japanese subjects the REA is present for four consonants /b, t, d, g/. As shown in Table III, individual segments are not equally lateralized. Although Shankweiler and Studdert-Kennedy (1970) mention that the initial consonants in English are all significantly lateralized in the left (or language dominant) hemisphere, the present results of 6CV set are not in agreement with their previous findings.[5] It is not clear why Japanese subjects did not show significant laterality for their consonants, despite the fact that the initial stop consonants are considered to demonstrate the most pronounced ear advantage and the most clearly categorical perception.

When we examine the pairs sharing phonetic features, pairs sharing point of articulation were more correctly identified than pairs sharing voicing, and this can be applied to both groups of subjects. These results agree with the previous findings by Shankweiler and Studdert-Kennedy (1970) that sharing of phonetic features is one of the advantages for better performance. However, when we look at the individual dichotic pairs, we notice that the pair d-k, sharing no phonetic feature, showed the highest performance in Japanese subjects, though this can not be applied to English subjects. Although this may be due to bias from high frequency of these segments in Japanese, some acoustic properties of these segments may be a factor for high performance. In examining the ear difference of each phonetic feature in 6CV set, as shown in Table VI, each feature shows the REA in both groups of subjects, though they are not equally lateralized.

The analysis in terms of phonetic features can be applied to vowels, as shown in Table VII. Japanese subjects showed the REA for each feature, while English subjects did not. The performance on individual vowel pairs may be written as in Table IX. The pairs which show higher performance than others are common to both groups of subjects. But the hypothesis that feature-sharing pairs are more likely to be correct than no feature-sharing does not seem to be explicitly applied in the case of vowels. For instance, the pair u-o, sharing feature backness, is very weak in performance in both groups of subjects. The hypo-

Table IX. Percentage of both correct for individual pairs in 5V/N set.

| | Japanese subjects | | English subjects |
|---|---|---|---|
| i — u | 40.8% | i — u | 32.5% |
| i — e | 36.7 | e — a | 31.7 |
| a — e | 35.8 | a — i | 30.8 |
| a — i | 35.8 | a — o | 29.2 |
| e — o | 30.0 | e — o | 27.5 |

thesis may be applied to the pairs of i-u, i-e and e-o, since they are characterized by high, front and mid, but it cannot be applied to the pairs such as a-e, a-i, since no feature is shared in these pairs. We may need to have other kind of criteria to characterize these pairs.

In examining the data from the present experiment, it is found that Japanese subjects show different performance in perceiving vowels from English subjects. They show the weak REA for individual vowels, except /i/, and for each phonetic feature, including non-significant ones. This may imply that Japanese subjects perceive vowels as more speechlike sounds than English subjects do. The question is why Japanese subjects perceive vowels in such a manner. Lateralization is often argued in terms of linguistic significance of speech sounds, and the appearance of a weak REA in Japanese subjects may indicate that vowels in Japanese are linguistically more significant to the Japanese subjects than vowels in English to English subjects. One of the reasons for linguistic significance of vowels is that there are some monosyllabic words consisting of a single vowel which have semantic referents in Japanese. For instance, /i/ means "stomach", /e/ "picture", /u/ "cormorant" and /o/ "tail". That is, Japanese subjects perceive vowels in connection with easily accessible semantic referents and linguistic roles of vowels in Japanese are more significant than that of vowels in English.

We can also consider the difference of perception modes for consonants and vowels. It is generally understood that consonants are categorically perceived, while vowels are continuously perceived by comparative judgement of acoustic features. If categorical perception is considered one of the factors to draw lateralization of consonants, the appearance of a weak REA for vowels in Japanese subjects may indicate that vowels in Japanese are perceived by categorical judgement rather than by continuous judgement.

## CONCLUSIONS

The present study on dichotically presented natural vowels, vowels masked with white noise (−10 dB S/N ratio) and six consonants in Japanese showed:
1. There is no significant difference in lateralization of consonants between Japanese and English subjects, and more than half subjects showed the REA, including non-significant ones, in both groups of subjects. But for vowels masked with

noise, Japanese subjects showed the weak REA for individual segments and for each phonetic feature, while English subjects did not.

2. Perceptual difficulty does not always elicit a consistent REA, although three Japanese subjects who did not show the REA in 5V set showed the REA in 5V/N set.

3. The pairs sharing place features were more correctly identified than the pairs sharing voicing features in 6CV. But in the case of vowels, it does not seem that the hypothesis of feature-sharing can be explicitly applied.


## Acknowledgements

I wish to thank Dr. Tatsuo Nishida of Kyoto Univ. who has helped my study of linguistics in various ways and Dr. Timothy S. Smith of the Univ. of California, San Diego, for generous assistance in carrying out the experiment. I am also grateful to the Japan Society for the Promotion of Science for the fellowship to continue research at the Univ. of California, San Diego.


## Notes:

1. The present experiment was carried out at the Dept. of Linguistics of the Univ. of California, San Diego.
2. Sampling and editting of recorded verbal stimuli were made by digital computer programs such as WAVES, NORMLIZ, $ONSET and TADDER.
3. Laterality Index (L.I.) and phi are calculated by the following formulae:

$$\text{L.I.} = \frac{\text{SRC} - \text{SLC}}{\text{SRC} + \text{SLC}} \times 100 \quad \text{(by Shankweiler \& Studdert-Kennedy)}$$

$$\text{phi} = \frac{\text{RC} - \text{LC}}{\sqrt{(\text{RC}+\text{LC})(2\text{NT}-(\text{RC}+\text{LC})}} \quad \text{(by Kuhn)}$$

NT: number of trials

LC: number of trials correctly identified by left ear

RC: number of trials correctly identified by right ear

SRC: number of trials on which a single error was made, the right ear being correctly identified.

SLC: number of trials on which a single error was made, the left ear being correctly identified.

4. Studdert-Kennedy & Shankweiler, "Hemispheric specialization for speech perception", pp. 585–586
5. ibid., p. 584

## Bibliography:


Benson, P. J. (1974), *On some phonetic effects in dichotic listening*, unpublished doctoral dissertation, UCSD

Godfrey, J. J. (1973), "Perceptual difficulty, right ear advantage and tense-lax distinction", unpublished

Fujisaki, H. and Kawashima, T. (1971), "A model of the mechanisms for speech perception based on discrimination of synthetic speech sounds", *J. Acoust. Soc. Japan,* Vol. 27, No. 9

Kimura, D. (1961), "Some effects of temporal lobe damage on auditory perception", *Canad. J. Psycho.,* No. 15

Kimura, D. (1973), "The asymmetry of the human brain", *Scientific American,* Vol. 228, No. 3

Kimura, D. and Folb, S. (1964), "Neural processing of backward speech sounds", *Science,* No. 161

Kuhn, G. (1972) "The phi coefficient as an index of ear advantages in dichotic listening" Haskins Laboratory SR 29/30 pp. 75–82

Papçun, G., Krashen, S. and Terbeek, D. (1971), "Is the left hemisphere specifilized for speech, language or something else?" *UCLA Working Papers in Phonetics,* No. 19

Shankweiler, D. and Studdert-Kennedy, M. (1967), "Identification of consonants and vowels presented left and right ears" *Quart. J. Exp. Psychol.,* Vol. 19, part 1

Studdert-Kennedy, M. and Shankweiler, D. (1970), "Hemispheric specialization for speech perception", *J. Acoust. Soc. Amer.,* Vol. 48, No. 2

Tsunoda, T. (1972), "The qualitative difference in cerebral dominance for vowel sounds between Japanese and European languages" *Medicine and Biology,* 85 (4)

Tsunoda, T. (1973), "Nihon-go no tokuchou" (Some characteristics of Japanese), *Gengo,* Vol. 2 No. 6

Tsunoda, T. (1974), "The difference of recognition mechanism toward natural sounds between Japanese and Westerners, and the spiritual characteristics", *Medicine and Biology,* 88 (5)

Van Lancker, D. (1975), "Heterogeneity in language and speech: Neurolinguistics studies", *UCLA Working Papers in Phonetics,* No. 29

Van Lancker, D. and Fromkin, V.A. (1973), "Hemispheric specialization for pitch and "tone": Evidence from Thai", *J. of Phonetics,* Vol. 1

Weiss, M. S. and House, A. S. (1973), "Perception of dichotically-presented vowels", *J. Acoust. Soc. Amer.,* Vol. 53

(Aug. 31, 1975, received)