Concentric: Studies in English Literature and Linguistics
27.2 (June 2001): 35-52

The Effect of Vowel Duration on the Perception of Postvocalic Voiced/Voiceless Consonants

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Two experiments were administered to examine the effect vowel length has on the perception of the voicing of the following consonant. In the perceptual experiment, pairs of real words differing with each other only in the voicing of the final consonants were selected and recorded by a native speaker. The stimuli were subsequently modified by lengthening the vowels before voiceless consonants and shortening the vowels before voiced consonants. These stimuli were submitted to first and second language learners for judgment. The results showed that there existed a general tendency for the subjects to choose "voiced" answers for words ending in voiceless consonants when the preceding vowels were lengthened. The subjects were also required to read a passage in English, and were judged by two native speakers on their pronunciation. The results showed that the subjects perceptual performances correlated with their pronunciation proficiency.

Key words: vowel duration, voiced/voiceless consonants, perception, pronunciation teaching

1. Introduction

It is generally agreed that an adult's perception of speech is patterned to some extent by the system of phonemic oppositions found in his or her native language (L1). Therefore, while learning a second language (L2), the learners usually have difficulty perceiving sounds that are only found in L2 but not in L1. For a given sound that exists in both L1 and L2 but with different distributions in the two languages, the L2 distributions may be hard to distinguish for the learners.

Several studies have shown that foreign language learners differ from native speakers in the perception of L2 phonetic contrasts which differ acoustically from a similar contrast in L1 (Flege *et al.*, 1987; Flege, 1989). For instance, unlike English in which obstruents can occur syllable finally, Mandarin Chinese allows obstruents only in syllable initial position. That is to say, voicing contrast between word-final obstruents does not exist in Mandarin Chinese. Therefore, most Mandarin Chinese EFL (English as a foreign language) learners have difficulties producing and perceiving voicing contrast of word-final obstruents in English.

It is a universal tendency for vowels to be longer before voiced consonants than before voiceless consonants. Such tendency has been confirmed for English in various studies (House & Fairbanks, 1953; Peterson & Lehiste, 1960; House, 1961; Chen, 1970; Kluender *et al*,1988). In fact, it was found that differences in vowel length are sufficient to cue the perceptual distinction between voiced and voiceless consonants in English (Denes, 1955; Raphael, 1972). Therefore, if native Mandarin Chinese speakers could observe this vowel length effect and master it effectively, it might be easier for them to produce and perceive postvocalic consonant voicing in English.

1.1 Purposes of the study

Since Mandarin Chinese does not have word-final voicing contrast, it is our interest to investigate whether native Mandarin Chinese speakers are aware of this vowel length effect in English word-final voicing distinction. In other words, we want to find out whether or not Mandarin Chinese speakers use vowel length as a perceptual cue for syllable-final voicing judgment. A perceptual experiment is carried out for the purpose. Moreover, we want to see if such realization correlates with their fluency in English. That is to say, we would like to see if the auditory perceptual ability correlates with the ability to pronounce native-like English.

2. Review of literature

2.1 Vowel length effect

The duration of the preceding vowel is often cited as an important cue to the voicing feature of word-final consonants in English. Denes (1955) first drew attention to this fact by using real-speech stimulus *use* (n.) /jus/ and *to use* (v.) /juz/. The results showed that subjects tended to judge the final consonant of the CVC stimuli as /z/ if the vowels were lengthened or the fricative noises were shortened. Moreover, Flege and Hillenbrand (1986) examined the extent to which native speakers of French, Swedish, Finnish, and English used vowel and fricative duration as perceptual cues to the English /s/-/z/ contrast. The results suggested that lengthening vowel duration increased /z/ judgments in all four groups of subjects. On the other hand, shortening the fricative duration significantly decreased /z/ judgments only by the English and French subjects. The Swedish and Finnish subjects did not use fricative length as a cue for the voicing judgment, even those who had lived for one year or more in an English-speaking country. His findings raised the question whether adults who learn a foreign language can acquire the ability to use numerous acoustic cues to a phonetic contrast which does not exist in their native languages.

In addition, Peterson & Lehiste (1960) noted that in many minimal pairs of the CVC type in English, differing with respect to the voicing of the final consonant, the vowel followed by a voiced consonant is longer than the same vowel followed by a voiceless consonant by a ratio of approximately 3:2. Denes and Peterson & Lehiste positively confirmed the crucial status of vowel length as a cue for postvocalic consonant voicing distinction in English.

Later, Chen (1970) reported that the vocalic segments produced by native speakers of Korean, English, French, and Russian were significantly longer before voiced consonants than they were before voiceless ones. He observed a remarkable duration difference in English, that is, the vowels before voiceless consonants were only 61% length of their counterparts before voiced consonants. Moreover, he claimed that there were large differences among these languages in the magnitude of the contrast, with native English speakers showing the greatest contrast, followed, respectively, by French, Russian, and Korean. Therefore, Chen tentatively concluded that:

> (a) it is presumably a *language-universal* phenomenon that vowel duration varies as a function of the voicing of the following consonant, and
> (b) the extent to which an adjacent voiced or voiceless consonant affects its preceding vowel durationwise is determined by the *language- specific* phonological structure (p.139).

In addition to these previous studies showing the ratio and percentage of vowels before voiced/voiceless consonants, Raphael (1972) studied the exact timing boundary. In an experiment utilizing synthetic speech, Raphael constructed synthetic tokens of several minimal pairs of monosyllables containing different vowels and ending in a variety of consonant clusters. As a result, he found that the voiced/voiceless boundary occurred between 200 and 300 ms for syllables ending in obstruents. In other words, the obstruent following any vowel of less than about 200 ms was identified as [- voice], while that following a vowel of more than 300 ms tended to be recognized as [+ voice]. Thus, Raphael concluded that vowel duration was the primary and 'necessary' cue for the perception of the voicing feature in post-vocalic consonants.

Based on the conclusions from a perceptual experiment, O'Kane (1978) also confirmed that the length of preceding vowel is more salient than vowel-consonant transition as a cue for the perception of final consonant voicing. He recorded several CVC minimal pairs and varied them by first removing the entire stop closure and then truncating the vowel from right to left. That is, he cut away the spectral properties of the vowel transition and at the same time reduced vowel length. The results were the same as those in previous studies: listeners tended to perceive shorter vowels as being followed by voiceless stops and longer vowels as being followed by voiced stops.

Echoing those early studies, Krause (1982) conducted an experiment to examine the development of vowel length as a cue to phonological voicing in word-final consonants among children. Unlike Raphael's (1972) tokens, Krause's stimuli varied only on vowel length. Krause found that as the age of the subjects increased, the vowel lengths required to shift a subject's judgment of a word-final consonant from voiceless to voiced gradually shorten. That is to say, it seems that English speakers appear to *learn* the use of vowel length as a voicing cue as they become older.

In short, previous studies have supported the hypothesis that vowel duration is an important property in distinguishing between voiced and voiceless postvocalic consonants.

2.2 Performances of Chinese speakers

Although the duration of preceding vowel has been shown to be an effective perceptual cue to final consonant voicing for native speakers of English, it was usually hard to be observed by speakers of other languages. In this section, we discuss some related issues on the performances of Chinese speakers.

It has been agreed by most that if a language possesses only one stop consonant series, it is likely to be the voiceless /p, t, k/ rather than the voiced /b, d, ɡ/ (Maddieson, 1984; Keating, 1984). Besides, Smith (1979) and Flege & Port (1981) also found that speakers generally produce voiced stops in postvocalic position only if they are also able to produce voiceless counterparts. This suggests that the difficulty to produce /b, d, ♑/ in postvocalic positions is probably because voiced stops require some additional control parameter not required for voiceless stops. Mandarin Chinese, however, has neither voiceless nor voiced stops in syllable-final position; thus, it is even harder for native Mandarin Chinese speakers to produce or perceive word-final voicing contrast in English.

Owing to lack of voice contrast in syllable-final consonants in Mandarin Chinese, Chinese EFL learners have impediment producing voice contrast of syllable-final consonants in English (Crowther & Mann, 1992; Chang 1994). Therefore, a difference between native Chinese and English speakers might arise when Chinese learners of English fail to recognize the contrast between /p, t, k/ and /b, d, ♑/ and thus do not attempt to distinguish them in production (Flege *et al.*, 1987). Transcriptional data from several studies have also shown that Chinese speakers tend to devoice the English /b, d, ♑/, delete voiced and voiceless stops, and add vowels following syllable-final stops (Tarone, 1980; Eckman, 1981; Weinberger, 1987; Flege *et al.*, 1987).

Flege (1988) has reported that native Chinese speakers produced a relatively small vocalic duration contrast between vowels preceding /-p/ and /-b/ than native English speakers. Hsieh & Kuo (1999) clearly stated that "the Chinese EFL students do not produce enough vowel duration contrast preceding word-final voiceless and voiced consonants" (p. 488). Flege *et al.* (1992) also found similar results. He determined that even experienced Mandarin speakers of English could not master the production of /t/ and /d/ in word-final position of English. Flege (1989) examined the identification of word-final English /t/ and /d/ by Chinese subjects with different native languages, including Peking, Taiwanese, Shanghainese, and Hakka. The results showed that Chinese subjects performed as well as native English adults and children for words that were unedited; however, they performed poorly for words from which final release bursts had been removed. This suggests that removing closure voicing had some effect on Chinese but not on English subjects' sensitivity. Flege also demonstrated that if a speaker's native language does not contain final stop consonants, then he or she may have difficulty using the vocalic cues to final consonant voicing in English. Thus, the fact that native speakers of Mandarin Chinese show little use of vocalic duration is primarily because of their lack of experience with final stop consonants.

Moreover, Flege (1993) assessed Chinese subjects' production and perception of the word-final English /t/ - /d/ contrast. He found that non-native speakers who learned English in childhood closely resembled native speakers in both production and perception of word-final voicing contrast in English. On the other hand, most of those who had learned English as a second language in adulthood, performed differently from native English speakers. According to the results of his experiments, Flege claimed that "L2 (second language) production accuracy is limited by the adequacy of perceptual representations for sounds in the L2" (p. 1589).

More recent works have been done by Chang (1994, 1995). Chang (1994), constructed a production experiment with 32 English words of C(C)VC type ending in voiced and voiceless stops, and 8 words of CVC type ending in voiced and voiceless fricatives. Subjects included 35 college students in Taiwan and a native speaker of English. The subjects were asked to read the test stimuli onto a tape, which were subsequently measured. The results from Chinese subjects showed that the vowels preceding word-final voiced obstruents were significantly longer than the vowels preceding word-final voiceless obstruents. However, compared with the results of the native speaker, Chinese subjects "did not lengthen the vowel before voiced obstruents in any way as long as native speakers would" (p.96).

Chang (1995) was a perceptual experiment. Ten pairs of CVC syllables ending in **unreleased** obstruents served as test data. The vowels of these syllables were sliced and pasted to be 2:1 length ratios. Twenty-five native speakers of English and 60 Chinese university students participated in this experiment. The Chinese students were subdivided into two groups: 23 of them majored in foreign language and the others majored in science. The results showed that, first, Chinese students and native English speakers behaved differently in using vowel duration as a cue for the judgment of word-final stop voicing; and second, long vowels were more salient than short vowels when used as a perceptual cue for word-final stop voicing. In other words, while hearing a long vowel, it was very likely for subjects to make a voiced judgment; however, while hearing a short vowel, subjects might not necessarily make a voiceless judgment. Sex was not found to be a significant factor, but the major fielf of study of the subjects was. She found that science students used vowel duration as a perceptual cue more effectively than students majoring in foreign languages.

In this study, we are interested in finding whether proficiency in English has influence on the ability to use vowel length as perceptual cue. That is, since previous studies have established the significance of vowel length as a cue for final consonant voicing, we are interested in knowing whether English proficiency would contribute to the perception of vowel length.

3. Perceptual experiment

3.1. Subjects

Since we wanted to find out if the auditory ability correlates with the English ability of the speaker, we therefore recruited subjects with various degrees of fluency in English in our experiment, ranging from intermediate to advanced learners of English to native English speakers.

A total of three groups of subjects were established. The subjects participated in the experiment voluntarily and received a small amount of payment for participating. They were categorized primarily according to their English abilities. Table 3.1 shows the background of the subjects.

Table 3.1. Background Information of the Subjects

	Intermediate English Learners	Advanced English Learners	Native English Speakers
Native Language	Chinese	Chinese	English
School	NTHU	Both NTHU and NCTU	NEHS
Number	20	20	20
Age	19.1 (range=18.5-20.6)	19.2 (range=18.7-20.6)	17.0 (range=16.6-17.6)
Sex	5M / 15F	1M / 19F	7M / 13F

Intermediate English learners were freshman students majoring in Economy in National Tsing Hua University. As such, they constituted a more or less homogeneous group of intermediate EFL learners in Taiwan. The advanced English learners were represented by freshman students of the Departments of Foreign Languages in both National Tsing Hua University and National Chiao Tung University, who obtained their admissions through the special channel of recommendation examination. Their English abilities were considered better than others in the same department and thus form a group of advanced English learners. The third group was composed of the 11th grade students from the Bilingual Department of National Experimental High School at Hsin Chu Science-Based Industrial Park. Among those 20 subjects, 13 of them had English as their first language and most of the others had lived in an English-speaking country (U.S.A. or Canada) for years. Hence, they were regarded as native speakers of English.

3.2 Stimuli

In designing our test data, we used words of the canonical form of C(C)VC. We chose [♓], [✌], [✍], [✈], and [◆][1] as stimulus vowels, combined with alveolar stops [⧫], [♎] and labiodental fricative [♐], [❖] in postvocalic positions. Therefore, we selected

[1] We selected these vowels to contain high front, high back, low front, low back and mid vowels.

nine minimal pairs of real words, as shown in Table 3.2:

Table 3.2. The Minimal Pairs for the Perceptual Experiment

Vowel / Consonant	[♓]	[✌]	[✍]	[✈]	[◆]
[⧫] vs.[♎]	beet/bead	pot/pod	cut/cud	bat/bad	boot/booed
[♐] vs. [❖]	leaf/leave	*	duff/dove	calf/calve	proof/prove

*There are no CVC minimal pairs containing vowel [✌] and [♐] , [❖] as final consonants.

Then, we designed a carrier sentence for each minimal pair so that our target words could be naturally produced and perceived without extra stress or intonation problems. The carrier sentences varied among the pairs of stimuli. They are shown as follows.

1. Mary showed me her beet/bead this morning.
2. The pot/pod fell on the floor.
3. Say cut/cud now.
4. Say bat/bad now.
5. What does boot/booed mean?
6. He took a leaf/leave and went home.
7. I saw the duff/dove behind the lake.
8. I don't want to see her calf/calve yet.
9. How can I pronounce 'proof'/ 'prove' correctly?

The stimuli were designed in such a way that the target words were followed immediately by a consonant rather than a vowel[2] so that the consonant-vowel coarticulation effect could be reduced. The target words were placed consistently in sentence middle position so as to avoid stress differences.

An adult native speaker of American English was invited as our informant. He was asked to read the 18 (9×2) sentences once in normal speed and intonation. These stimuli

[2] Only sentence No. 6 did not follow this regulation. In this sentence, our target word was positioned at the end of the first clause and was linked to another clause by a conjunction "and". Since our informant treated them as two separate clauses and did not have liaison between our test word and the conjunction "and", we

were digitized and recorded into the computer with Creative Wave Studio.

Creative Wave Studio was again used to edit these sound files. First, the observable release bursts at the end of our test words were removed. Then we manipulated the lengths of the vowels. As mentioned previously, Chang (1995) manipulated only two kinds of vowel lengths in her experiment, viz. 2:1. To cover more varieties, we lengthened the vowel preceding voiceless obstruents into 1.2, 1.4, 1.6, 1.8, and 2 times of the original length, and shortened the vowel preceding voiced one into 0.9, 0.8, 0.7, 0.6, and 0.5 times of the original length.

The editing of the tokens was done by copying or deleting single cycles on the wave form from zero amplitude to zero amplitude. To achieve this, the length and the number of cycles of the vowel were first calculated, and then the number of cycles to be cut or reproduced was determined. For instance, the [u] in *boot* was found to be 99 ms and 18 cycles. In order to make a token with a vowel 1.2 times that of the original, one in every five cycles was copied. On the other hand, the [u] in *booed* was found to be 32 cycles. In order to make a token with a vowel 0.9 times that of the original, one in every ten cycle was deleted. All these original and modified tokens were put into carrier sentences, making up a total of 108 sentences [(2+10)×9].

3.3 Procedures

The subjects were tested in groups in a language lab at NTHU. The subjects were each seated in a booth, facing an answer sheet. The stimuli were played through an earphone. The items were randomized and presented to the subjects through a tape recorder. In the presentation of each item, the sentence was repeated twice, followed by a 4-second silence during which time the subjects were to choose from between two alternatives listed on the answer sheet. The subjects were asked to listen carefully to the tape and select from the sentence which they thought they heard. The whole experiment lasted about 17 minutes.

3.4. Results and Discussions

In order to see whether the performances of perceptual abilities among these three groups reached statistic significant level, the frequencies of "voiced" choices were

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decided to keep it in our stimuli.

submitted to a one-way ANOVA with *Post-hoc* Scheffe tests. The results revealed that out of 17 valid vowels 15 were significant in one-way ANOVA test,[3] which means the perceptual abilities are very different among these three groups. More precisely, the *Post-hoc* Scheffe tests indicated that the performances between (1) intermediate English learners & native English speakers, (2) advanced English learners & native English speakers, usually yield significant differences (p<.05). However, the performances between intermediate English learners and advanced English learners did not reach significance. That is to say, the perceptual abilities are distinctly different between non-native and native English speakers, yet such ability does not show a great difference between intermediate and advanced English learners.

4. Production experiment

In order to find out if the perceptual ability correlates with the English proficiency of the speaker, we designed another production experiment.

4.1 Subjects

The subjects were the same 20 intermediate English learners, 20 advanced English learners, and 20 native English speakers who participated in the Perceptual Experiment.

4.2 Test data

In this experiment, we focused on the subjects' fluency in English. Consequently, a short article without any difficult or infrequent word was chosen to be our test data.

4.3 Procedures

The Production Experiment was also carried out in the language lab at NTHU. After the subjects finished doing the Perception Experiment, they took a short break and proceeded to the Production Experiment. The subjects were asked to read a short article in normal speed and clear pronunciation. Their reading was tape-recorded, and two native speakers of English were invited to judge the fluency and correctness of these readings. The correlation between the raters' scores was high (r=0.702), thus the scores were regarded as valid and reliable. The scores were subsequently averaged to represent

[3] The other two, p=.063 and .07, narrowly missed reaching significance.

the performance of each subject.

4.4 Results of the production experiment: reading score

A one-way ANOVA examining the different scores among each group yielded a significant difference (F=84.95, $p<.001$). *Post-hoc* Scheffe tests also revealed that the score differences among the three groups reached significance (all $p<.001$). As expected, native English speakers had the highest reading scores, followed, respectively, by advanced English learners and intermediately English learners.

5. General discussions

5.1 Relationship between the perceptual ability and the reading score

As revealed by the statistical results of the *Post-hoc* Scheffe tests in 3.4.2, no significant difference existed between intermediate and advanced English learners in terms of perceptual abilities. Hence, hereafter we considered them as one group, non-native English speakers, as opposed to the native ones.

In order to assess the relation between the perceptual ability and the reading score, correlation analyses with Kendall's tests were carried out. First, we wanted to see the correlations of these factors in non-native and native groups separately. The results are exhibited in Table 5.1.

Table 5.1. Kendall's Correlation Coefficients Between Perceptual Abilities and the Reading Scores in Non-native and Native Groups

	Beet	*Bead*	*Bat*	*Bad*	*Pot*	*Pod*
Non-native	.306*	-.036	-.007	-.053	.181	.064
Native	-.049	.156	.156	.111	-.300	.279
	Cut	*Cud*	*Boot*	*Booed*	*Leaf*	*Leave*
Non-native	.186	-.109	.040	.056	-.166	-.030
Native	-.346	.472*	-.237	.307	-.104	-.259
	Calf	*Calve*	*Duff*	*Dove*	*Proof*	*Prove*
Non-native	-.018	-.091	missing	.078	-.017	-.131*
Native	.025	-.180	missing	.150	-.118	-.020

*****$p<.05$

Obviously the results are very different in the correlations between the perceptual abilities and the reading scores in non-native and native English speakers. Though nine out of the 17 valid statistic values[4] demonstrated the opposite correlation values, we could not find any consistencies in these distributions. Only a few of them reached significance. Therefore, the scores of these two groups were collapsed and the same correlation procedure was run. As shown in Table 5.2, among the 17 valid correlation values, all but 4 reached significance.

Table 5.2. Kendall's Correlation Coefficients Between Perceptual Abilities and the Reading Scores Among All Subjects

Beet	*Bead*	*Bat*	*Bad*	*Pot*	*Pod*
-.179	.200*	-.276*	.304*	-1.56	.382*
Cut	*Cud*	*Boot*	*Booed*	*Leaf*	*Leave*
-.256*	.416*	-.337*	.429*	-.290*	.309*
Calf	*Calve*	*Duff*	*Dove*	*Proof*	*Prove*
-.345*	.169	Missing	.434*	.126	-.304*

*$p < .05$

An obvious picture emerges from this table. Among these correlations, the voiced stimuli all had positive values except *prove*, while the voiceless stimuli all had negative values except *proof*. This shows that the voiced stimuli were perceived better as the subjects' pronunciation fluency increased, but the same cannot be said of the voiceless stimuli.

5.2 Choices toward similar vowel length

Since in the Perceptual Experiment the vowel preceding voiced consonants were gradually shortened, and the vowel preceding voiceless consonants were lengthened, there were several test items of the same word pairs having similar vowel durations. In this connection we can compare the choices of similar vowel lengths in a pair of words. If the subjects' choices toward these words were the same, we can thus claim that vowel length was a crucial cue to final consonant voicing judgment. If their answers were

[4] Due to experimental errors, the data of the original vowel length of *duff* was invalid. Hence, there was no statistic values for the vowel *duff*.

different, there might exist some other factors that we had not considered in our experiment.

McNemar procedure was used to compare the numbers of subjects who made the 'voiced' choices for each item. The results are shown in Table 5.3

Table 5.3. Comparison of Choices Between the Similar Vowel Length

Test Item	Vowel Length (ms)	Native group "Voiced" Selection	Prob.
beet 1.6 *bead* 0.9	166 165	33 44	.035
bat 1 *bad* 0.8	192 196	23 54	.000
pot 1.2 *pod* 0.9	168 170	18 38	.001
cut 1 *cud* 0.9	105 103	9 37	.000
boot 1.2 *booed* 0.7	116 114	17 34	.010
leaf 1.2 *leave* 0.9	169 170	15 51	.000
calf 1 *calve* 0.9	188 191	24 54	.000
duff 1.4 *dove* 1	158 158	14 43	.000
proof 1.2 *prove* 0.9	154 159	13 35	.000

*p<.05

It is easy to see from the above table that subjects treated the words differently although the vowel lengths of the members in each pair were similar. For a closer examination of the results, the choices were compared separately among these two groups. The same statistic procedure was used. Table 5.4 shows these results.

Table 5.4. Comparison of Choices Between the Similar Vowel Length in Non-native and Native Groups

Test Item	Non-native Group "Voiced" Selection	Prob.	Native group "Voiced" Selection	Prob.
beet 1.6 *bead* 0.9	26 26	1.0	7 18	.001*
bat 1 *bad* 0.8	22 34	.012*	1 20	.000*
pot 1.2 *pod* 0.9	14 18	.454	4 20	.000*
cut 1 *cud* 0.9	9 19	.021*	0 18	.000*
boot 1.2 *booed* 0.7	17 14	.648	0 20	.000*
leaf 1.2 *leave* 0.9	13 31	.000*	2 20	.000*
calf 1 *calve* 0.9	23 36	.002*	1 18	.000*
duff 1.4 *dove* 1	14 23	.093	0 20	.000*
proof 1.2 *prove* 0.9	12 18	.238	1 17	.000*

*p<.05

As can be seen from the Table, the choice patterns between native and nonnative speakers are very different. Among these 9 pairs of words, 5 in non-native group did not have significant differences between choices of similar vowel length. However, choices of all 9 pairs in native group yielded significant differences. In other words, non-native English speakers had similar choices in more than half of these pairs, but native English speakers had significantly different choices in all these 9 pairs of words. Thus it seems that native speakers were able to use some other cues than vowel length to judge the voicing contract in the absence of an audible release.

In short, our discussion points to the conclusion that vowel length is not the only perceptual cue to postvocalic consonant voicing discrimination. Other factors might have played a role. These possible factors may include the presence of glottal stop, the duration of final consonants, and intonation differences in each carrier sentence. We will leave these for further investigations.

6. Conclusion

Since the preconsonantal vowel duration has long been cited as a crucial cue for the voicing feature of postvocalic consonants in English, we conducted a perceptual experiment to see whether native Mandarin Chinese speakers were aware of this vowel length effect in English word-final consonant voicing differentiation. The performances of native and nonnative speakers to perceive the voicing difference were compared. The results showed that there existed a general tendency for subjects to select "voiced" answer while the vowel length increased.

The subjects' perceptual abilities were also compared with their pronunciation proficiency. Significant correlations were found in the voiced stimuli, indicating that the subjects were better able to judge a voiced consonant as the vowel lengths increased. However, it was not the case for stimuli with voiceless final consonants. There actually existed negative correlations for most of the items. This negative correlation is hard to explain at best, and will be left for future studies.

Nevertheless, vowel length did seem to be a viable cue for distinguishing between voiced and voiceless final consonants. It is thus advisable to train Mandarin Chinese EFL learners to lengthen the vowels before word-final voiced obstruents so that the voice value could still be distinguished when the voice quality of the final consonant is hardly present, and the release is not audible. In that way, they might have a better control over the vowel length as the perceptual cue and at the same time improve the learners' pronunciation.

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[Received 19 October 2000;
revision received 8 May 2001;
accepted 14 May 2001]