Korean Listeners' Perception of English /i/, /ɪ/, and /ɛ/*

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ABSTRACT

In this study I investigate how native Korean listeners perceive English vowels /i/, /ɪ/, and /ɛ/. I extend Flege et al's (1997) study with synthesized /i/-/ɪ/ and /ɪ/-/ɛ/ continua, and apply the results to Flege's (1995) Speech Learning Model (SLM). The statistical results show that native speakers of English rely more on spectral steps than on vowel duration when they identify the /i/-/ɪ/ continuum, whereas native speakers of Korean rely more on vowel duration than on spectral steps when they identify the same continuum. In the case of the /ɪ/-/ɛ/ continuum, both groups rely on spectral steps when they identify the /ɛ/, which supports the SLM; Koreans identified the /ɛ/ categorically since Korean has the equivalent vowel. However, there was not statistical difference between Korean subjects with more English experience (KE) and those with less English experience in the identification of both continua. This contradicts the SLM, which posits that experienced L2 learners are better than inexperienced L2 learners in perception of L2 sounds. The exact nature of this should be further investigated in the SLM.

Keywords: Korean, perception, English, front vowel

1. Introduction

The present study investigates how Korean listeners perceive English vowels /i/, /ɪ/, and /ɛ/ using synthesized beat-bit (/i/-/ɪ/) and bit-bet (/ɪ/-/ɛ/) continua. I check the results with Flege's (1995) Speech Learning Model (SLM). The results support the SLM in that the English /ɛ/ was identified categorically since Korean has the equivalent vowel. However, the results contradict the SLM in that there was no statistical difference between Koreans with more English experience (KE) and those with less language experience (KI) in the identification of both continua, considering the basic assumption in the SLM is 'a learning effect'. According to the SLM, it is expected that experienced L2 learners are better than inexperienced L2 learners in perceiving L2 sounds..

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1.1 The Speech Learning Model

Current L2 learning theories posit that native languages' (L1) phonemic contrasts affect L2 learners' production and perception of L2 sounds (Lado 1957, among others). The basic assumption in the SLM is that L2 learners' production and perception of L2 sounds are modified even in adulthood. The SLM (and any other L2 learning models) also assumes that L2 learners production of L2 sounds reflect their perception of them, and vice versa.

In the SLM L2 sounds are classified into three classes: identical, similar, and new sounds. Examples of 'identical' sounds are English and German /m/'s (Bohn and Flege 1990); they are identical to English and German listeners' ears, and do not cause learning problems, hence are not of interest in L2 production and perception studies. Examples of 'similar' sounds are English and French /u/'s. They are phonetically close to each other but slightly differ in their F2 values (Flege 1987). French /y/ (a high front tense rounded vowel) is an example of a 'new' sound to native speakers of English because this vowel is not found in English (Flege 1987).

The SLM also states that there is a learning effect in production and perception of the 'similar' and 'new' L2 sounds; as their L2 experience increases, their production and perception of the similar and new L2 sounds become closer to the same L1 sounds produced and perceived by the L1 speakers. The L2 learners eventually develop the similar and new L2 sounds into new phonological categories (Flege 1987).

1.2 Previous Research

In the literature of Korean phonology many researchers such as H.-B. Lee (1971) and Magen and Blumstein (1993) among others claim that the Seoul dialect has lost its vowel length distinction. B. Yang (1996) compared vowels of American English and Korean. He observed that the Korean /i/ overlapped with the English /i/, and the Korean /ɛ/ overlapped with the English /ɛ/. Jun and Cowie (1994) report that the English /ɪ/'s produced by native speakers of English do not overlap with Korean vowels such as /i/ and /ɛ/ in a vowel space based on formant values although their edges are slightly overlapped. Thus, Jun and Cowie consider the English /ɪ/ as a 'new' vowel based on Flege's SLM. In their study the Koreans with more English experience (KE) produced the English /ɪ/ more accurately than the Koreans with less English experience (KI). Thus the 'learning effect' was observed.

Ingram and Park (1997) report that Koreans' production of the English vowels /i/ and /ɪ/ were overlapped in a formant chart regardless of the English experience. Both KE and KI groups heavily relied on vowel duration; their /i/'s were longer than their /ɪ/'s. Flege

et al. (1997) report that both experienced and inexperienced Koreans rely on vowel duration when they produce the English vowels /i/ and /ɪ/. However, the experienced Koreans (KE) rely on duration less than the inexperienced Koreans (KI) do. Based on this observation, Flege et al. suggest that this may be evidence for the learning effect; the KE subjects may have learned spectral difference between these vowels. However, when they perceived these vowels, they both relied heavily on vowel duration.

1.3 Present Study

In this study I reinvestigate Flege et al's (1997) study on perception of the English vowel continuum /i/-/ɪ/. In Flege et al's (1997) study the KE subjects made less use of vowel duration than the KI subjects did when they produced these vowels. However, in their perception experiment on this continuum, not only the KI subjects but also the KE subjects relied heavily on vowel duration. These results contradict to the basic assumption of the Speech Learning Model (SLM); according to the SLM, L2 learners' production of L2 sounds reflect their perception of them, and vice versa. Thus, I reinvestigate the perception of this continuum.

In addition to the English vowel continuum /i/-/ɪ/, I include a continuum for English vowels /ɪ/ and /ɛ/. It is also of interest whether Korean listeners will be able to perceive the English /ɪ/ since Korean does not have an equivalent vowel to this. As shown in Jun and Cowie's (1994) research on production of English vowels by Koreans, the KE subjects' /ɪ/ is in between /i/ and /ɛ/ in a vowel chart based on formant values. The English vowels /i/ and /ɛ/ are considered as 'similar' vowels since their formant values are similar to the Korean vowels /i/ and /ɛ/, respectively. The English vowel /ɪ/ is considered as a 'new' vowel since an equivalent vowel is not found in Korean.

2. Perception Experiment

2.1 Hypothesis

Based on the previous researches mentioned above, I provide the following hypotheses.

(1) For the /i/-/ɪ/ continuum
   a. Both the KI and KE subjects will rely more on vowel duration than on spectral quality.
   b. They both will not identify this continuum as /ɛ/.
   c. The KE subjects will do better than the KI subjects.

(2) For the /ɪ/-/ɛ/ continuum

a. Both the KI and KE subjects will rely more on spectral quality than on vowel duration in identifying the /ɛ/.

b. The /ɛ/-like stimuli will be identified as /ɛ/, and the /ɪ/-like stimuli as either /i/ or /ɪ/.

c. The KE subjects will do better than the KI subjects.

2.2 Methods

2.2.1 Subjects

Three groups of subjects participated in the perception experiment; native speakers of English (NE) as a control group, the KI subjects, and the KE subjects. The following table illustrates the information about the subjects.

Table 1. Subjects and Their Information

Group	Gender	Number	Age (yrs)	Duration in the US
NE	Male	8	20-25, Mean = 22.75	Life Time
	Female	13	19-47, Mean = 24.73	Life Time
KI	Male	5	27-33, Mean = 31	1-11 months, M = 4.8 months
	Female	5	26-34, Mean = 28.8	4-12 months, M = 9 months
KE	Male	5	27-37, Mean = 33.4	6-13 years, M = 8.6 years
	Female	5	31-44, Mean = 34.6	6-10 years, M = 7.6 years

As shown above the control group is composed of 21 NE subjects. They were all born and grew up in the Washington state in the U.S. They were students at the University of Washington at Seattle at the time of the experiment.

Each of the KI and KE groups are composed of 10 subjects with five males and five females. At the time of the experiment, the KE subjects had stayed in the U.S. between six and 13 years, and the KI subjects between one and 12 months. They were all Seoul dialect speakers, and also students at the University of Washington at Seattle. All of the Korean subjects learned English in Korea from when they were middle school students.

2.2.2 Stimuli

The method used in this study is similar to the one used by Bohn and Flege (1990), Flege et al. (1997), and Y. Yun (2003). I made two continua for beat-bit (i.e., /i/-/ɪ/) stimuli and bit-bet (i.e., /ɪ/-/ɛ/) stimuli in parallel modes using commercial software Synthworks (see [www.sciconrd.com] for information). To develop the continua two parameters were manipulated. Duration of vowels had five linearly equal steps: 150, 200, 250, 300, and 350 ms including formant transitions. F1, F2 and F3 of vowels had nine

linearly equal steps. The F1, F2 and F3 nominal values for the end points of the /i/, /ɪ/, and /ɛ/ were obtained from those of the American male speakers' mean values for these vowels shown in Peterson and Barney (1952). F4 and F5 values were set at 3300 and 3850 Hz for the entire stimuli. The amplitude of the vowels was set at 60 dB. The f0 for the first half of the entire stimuli was set at 120 Hz, and it was interpolated to 100 Hz over the second half.

In the following table I provide the F1, F2, and F3 values for the /i/-/ɪ/ continuum.

Table 2. F1, F2, and F3 values for the vowels in the /i/-/ɪ/ (beat-bit) continuum

Stimuli	F1	F2	F3	
1	250	2340	3087	Extrapolated
2	270	2290	3010	[i] end point
3	290	2240	2933	Interpolated: F1 - 20 steps F2 - 50 steps F3 - 77 steps
4	310	2190	2856	
5	330	2140	2780	
6	350	2090	2703	
7	370	2040	2626	
8	390	1990	2550	[ɪ] end point
9	410	1940	2473	Extrapolated

As shown above, F1, F2, and F3 values for the end point /i/, namely the stimulus number two, are 270, 2290, and 3010 Hz, respectively. Those of the end point /ɪ/, namely the stimulus number 8, are 390, 1990, and 2550 Hz, respectively. The stimulus numbers three to seven are linearly interpolated from the end point vowels. The stimulus numbers one and nine are extrapolated from the end point vowels. The bandwidths for F1-F5 were 60, 90, 150, 200, and 200 Hz, respectively.

In the following table I provide the F1, F2, and F3 values for the /ɪ/-/ɛ/ continuum.

Table 3. F1, F2, and F3 values for the vowels in the /ɪ/-/ɛ/ (bit-bet) continuum

Stimuli	F1	F2	F3	
1	367	2015	2562	Extrapolated
2	390	1990	2550	[ɪ] end point
3	413	1965	2538	Interpolated: F1 - 23 steps F2 - 25 steps F3 - 12 steps
4	436	1940	2526	
5	460	1915	2515	
6	483	1890	2503	
7	506	1865	2491	
8	530	1840	2480	[ɛ] end point
9	553	1815	2468	Extrapolated

The end point /ɪ/'s F1, F2, and F3 values are 390, 1990, and 2550 Hz, respectively. Those of the end point /ɛ/ are 530, 1840, and 2480 Hz, respectively. Other techniques were identical to the /i/-/ɪ/ stimuli.

The word-initial /b/'s F1, F2, and F3 values were 180, 1465, and 2180 Hz. They were interpolated to the steady state values for the following vowel. The durations of the F1, F2, and F3 transitions were 25, 45, and 50 ms. The /b/'s release burst was 80 dB and 10 ms long. The duration of the VOT was 25 ms and its amplitude was interpolated from 55 to 40 dB.

The word-final /t/'s F1, F2, and F3 values were 300, 2000, and 2900 Hz, respectively. They were interpolated to the steady state values for the previous vowel. The durations of the F1, F2, and F3 transitions were 40, 40, and 60 ms. The amplitude of the vowels was interpolated from 60 to 40 dB before the /t/ closure. A silence duration of 60 ms was made for the /t/ closure. This was inserted between the formant transition of the previous vowel for the word-final /t/ and its release burst. Although English word-final stops are frequently unreleased, 30 ms of burst with amplitude of 80 dB was added for the word-final /t/ in synthesizing stimuli for perception experiments so that the stop could be perceived more easily.

One block of the stimuli contains both the /i/-/ɪ/ (beat-bit) and /ɪ/-/ɛ/ (bit-bet) continua. Each continuum contains 45 stimuli (five durations × 9 spectral steps). Since the stimuli for the /ɪ/ end point were the same in both continua, the total number of stimuli in a block was 85 (five durations × nine spectral steps × two - five). Three blocks of the stimuli were created, hence the number of the entire stimuli each subject listened to was 255. The interval between stimuli was two seconds, which was created by a commercial software Soundedit 16 (for information see [www.macromedia.com]). I randomized the stimuli and recorded them in a cassette tape (Maxell UR, normal position) using a high-quality cassette tape recorder (Tascam, model 122 MKIII).

2.2.3 Procedure

Each subject was tested in the Phonetics Lab at the Department of Linguistics at the University of Washington. Before the test began, the subjects filled out the subject information sheet. They were given a test material in which they were asked to circle one of the three choices: beat, bit, and bet. They sat in a sound-treated booth and listened to the stimuli via headphones (Audio-Technica, model ATH-M40fs). The subjects had practice trials until they completely understood the procedure. After the experiment, I debriefed the subjects. It took about 15 minutes for a subject to finish the experiment.

3. Results and Discussion

3.1 Results from the /i/-/ɪ/ Continuum

For the /i/-/ɪ/ (beat-bit) continuum, the control group, namely the native English (NE) subjects, identified 59% of the stimuli as /i/, 38% of them as /ɪ/, and 3% of them as /ɛ/. To obtain statistical results I used a factorial ANOVA ($\alpha = 0.05$). The dependent variable was the percentage of /i/ (beat) responses. The following table illustrates them.

Table 4. Statistical Results for the NE Subjects' Identification of the /i/-/ɪ/ Continuum

Factor	P-value	Significance
Individual Subjects	0.5786	Not Significant
Gender	0.9621	Not Significant
Vowel Duration	< 0.0001	Significant
Spectral Steps	< 0.0001	Significant
Vowel Duration * Spectral Steps	< 0.0001	Significant

As shown above, there was no significant variation among individual subjects' identification of the stimuli. That is, the NE subjects did not identify them randomly. Gender factor was not significant either.[1] They relied on vowel duration ($P < 0.0001$) and also spectral steps ($P < 0.0001$). The interaction between the vowel duration and the spectral steps was also significant ($P < 0.0001$). The following graph illustrates these findings.

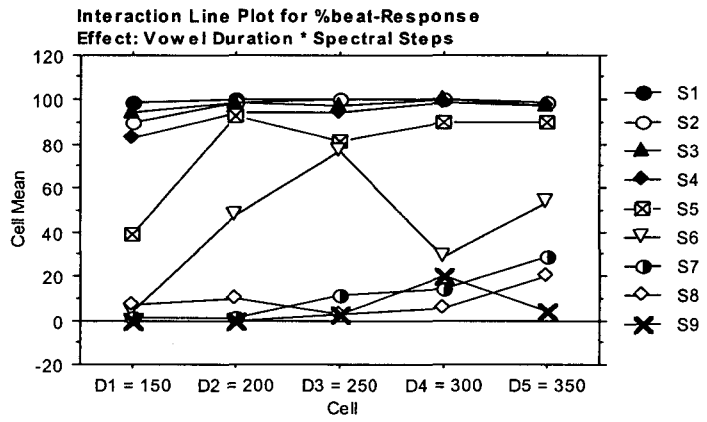

Fig. 1. The percentage of the /i/ responses for the /i/-/ɪ/ continuum based on the interaction of duration and spectral steps of vowels by the NE subjects.

1) To my knowledge, there are no L2 perception and production studies where the gender factor is statistically significant. Probably gender does not have to be considered in L2 perception studies although I did in this study.

As shown above, the NE subjects identified the spectrally /i/-like stimuli such as the S1 through S4, which are located in the higher portion of the graph, as the /i/. They identified the spectrally /ɪ/-like stimuli such as the S7 through S9, which are shown in the lower portion of the graph, as the /ɪ/. In the case of the S5 and S6, which are spectrally ambiguous in between /i/ and /ɪ/, the NE subjects relied on vowel duration. That is, the NE subjects relied heavily on spectral quality; however, when they identified spectrally ambiguous stimuli, they rely on vowel duration.[2] In general the NE subjects relied more on spectral steps than on vowel duration. This is also observed in Flege et al's (1997) study.

In the case of the native Korean subjects' identification of the /i/-/ɪ/ continuum, the English experience was not statistically significant (P = 0.6518). That is, both the experienced Korean (KE) subjects and the inexperienced Korean (KI) subjects showed the same patterns when they identified this continuum. This finding contradicts the SLM, since it assumes the 'learning effect', which expects that the KE subjects would be better than the KI subjects in the identification of the stimuli. They identified 50% of the stimuli as /i/, 39% of them as /ɪ/, and 11% of them as /ɛ/. I also used a factorial ANOVA (α = 0.05) to obtain statistical results. The dependent variable was also the percentage of /i/ (beat) responses. The following table illustrates them.

Table 5. Statistical Results for all the Korean Subjects' Identification of the /i/-/ɪ/ Continuum

Factor	P-value	Significance
English Experience	0.6518	Not Significant
Individual Subjects	0.4317	Not Significant
Gender	0.7357	Not Significant
Vowel Duration	< 0.0001	Significant
Spectral Steps	< 0.0001	Significant
Vowel Duration * Spectral Steps	< 0.0001	Significant

As shown above, the variation among the individual subjects was not significant (P = 0.4317). The gender factor was not significant either (P = 0.7357). The Korean subjects relied on vowel duration (P < 0.0001), and also spectral steps (P < 0.0001). The

2) Even though they relied on vowel duration when they identified the spectrally ambiguous S5 and S6 stimuli, the identification was not systematic. For instance, the percentage of the /i/ responses of the S6 dropped when the vowel duration was changed to 300 and 350 ms (especially in 300 ms), which were supposed to be higher than the percentages when the duration was 150, 200, and 250 ms. Obviously they were confused when they identified the S6. They just turned to vowel duration since the could not rely on spectral steps.

interaction between the vowel duration and the spectral steps was also significant ($P < 0.0001$). The following graph illustrates these findings.

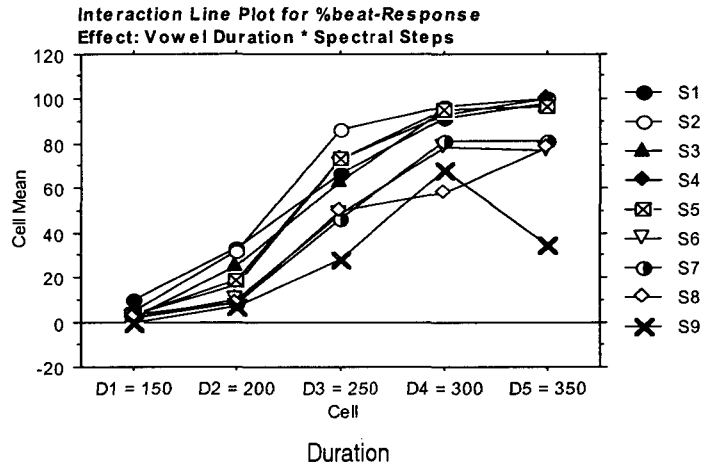

Fig. 2. The percentage of the /i/ responses for the /i/-/ɪ/ continuum based on the interaction of duration and spectral steps of vowels by Korean subjects.

As shown above, the Korean subjects heavily relied on vowel duration while they were identifying the stimuli. For instance, Koreans identified less than 5% of the S2 stimuli, which are spectrally /i/-like stimuli, as /i/ when the vowel duration was 150 ms; they identified almost 100% of the S2 stimuli as /i/ when the vowel duration was 350 ms. The same is true of the spectrally /ɪ/-like stimuli such as S8; they identified less than 5% of them as /i/ when the vowel duration was 150 ms; they identified about 80% of them as /i/ when the vowel duration was 350 ms. That is, the spectrally /i/-like stimuli are identified as /i/ better than the /ɪ/-like stimuli although the general pattern shows that vowel duration is the primary cue for identification of the /i/-/ɪ/ continuum.[3] This is exactly the opposite case of the identification of the same continuum by the NE subjects. The finding that Koreans rely on vowel duration when they rely on the /i/-/ɪ/ continuum was also observed in Ingram and Park (1997) and Flege et al. (1997). However, it was not observed in their studies that Koreans also relied on spectral quality.

3) The percentage of the /i/ responses of the S9, which is spectrally /ɪ/-like stimuli, dropped when the vowel duration was 350 ms. The percentage was supposed to be higher than that for the 300 ms of duration. I guess that 300 ms is long enough to test the vowel duration effect. This is suggestive in the above figure; in the case of S1 through S7, the percentage of the /i/ responses for 300 ms of vowel duration was not much different from that for 350 ms of vowel duration. I assume that the Korean listeners were confused when they identified S9, which is a spectrally /ɪ/-like stimuli, since the vowel duration was too long. But this does not affect the overall findings and statistical results.

3.2 Results from the /ɪ/-/ɛ/ Continuum

For the /ɪ/-/ɛ/ continuum, the NE subjects identified 40% of the stimuli as /ɪ/, 56% of them as /ɛ/, and 4% of them as /i/. I also used a factorial ANOVA ($\alpha = 0.05$) to obtain statistical results for this continuum. The dependent variable was the percentage of /ɛ/ (bet) responses. The following table illustrates them.

Table 6. Statistical Results for the NE Subjects' Identification of the /ɪ/-/ɛ/ Continuum

Factor	P-value	Significance
Individual Subjects	0.1612	Not Significant
Gender	0.3174	Not Significant
Vowel Duration	0.1685	Not Significant
Spectral Steps	< 0.0001	Significant
Vowel Duration * Spectral Steps	0.1443	Not Significant

As shown above, the variation among the individual NE subjects' identification was not significant ($P < 0.1612$). The gender and vowel duration factors were not significant either ($P < 0.3174$ and $P < 0.1685$, respectively). The NE subjects relied on spectral steps of the vowels ($P < 0.0001$). The interaction between vowel duration and spectral steps was not significant either ($p < 0.1443$). The following graph shows that the NE subjects identified the /ɛ/ based on spectral steps.

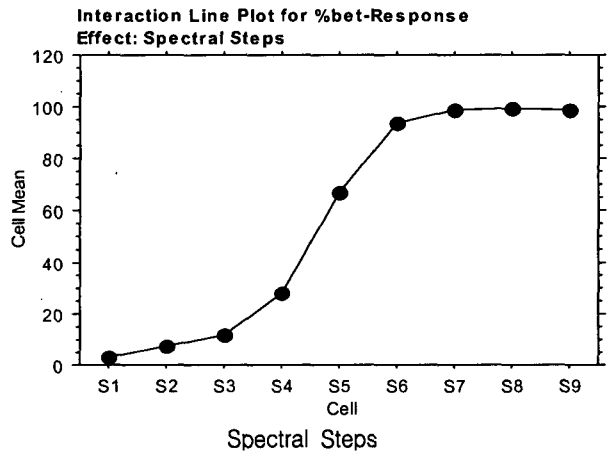

Fig. 3. The percentage of the /ɛ/ responses for the /ɪ/-/ɛ/ continuum based on spectral steps by the NE subjects. The spectral steps were varied in nine steps.

The lower-numbered stimuli such as the S1 and S2 are spectrally /ɪ/-like stimuli, and the higher-numbered stimuli such as the S8 and S9 are spectrally /ɛ/-like stimuli. In the above graph, for instance, less than 5% of the S1 stimuli were identified as the /ɛ/, and

almost 100% of the S9 stimuli were identified as the /ɛ/.

In the case of the Korean listeners, English experience factor was not statistically significant (P = 0.1442). Again, this contradicts the SLM since its 'learning effect' does not work. That is, the variation between the KE and KI subjects' identification was not statistically different. Again, this contradicts the SLM since its 'learning effect' does not work. They identified 69% of the stimuli as /ɛ/, 16% of them as /i/, and 15% of them as /ɪ/. The following table shows the statistical results from a factorial ANOVA.

Table 7. Statistical Results for all the Korean Subjects' Identification of the /ɪ/-/ɛ/ Continuum

Factor	P-value	Significance
English Experience	0.1442	Not significant
Individual Subjects	0.1526	Not Significant
Gender	0.3017	Not Significant
Vowel Duration	0.2271	Not Significant
Spectral Steps	< 0.0001	Significant
Vowel Duration * Spectral Steps	0.4243	Not Significant

As shown above, the variation among the individual subjects was not significant (P = 0.1526). The gender factor and vowel duration were not significant either (P = 0.3017 and P = 0.2271, respectively). The spectral steps were statistically significant (P < 0.0001). The interaction between vowel duration and spectral steps was not significant. The following graph shows that the Koreans relied on spectral steps when they identified the /ɪ/-/ɛ/ continuum.

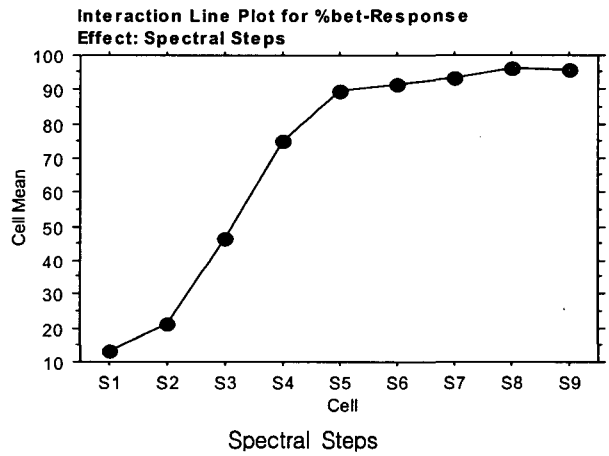

Fig. 4. The percentage of the /ɛ/ responses for the /ɪ/-/ɛ/ continuum based on spectral steps by the Korean subjects.

For instance, less than 15% of the S1 stimuli, which are spectrally /ɪ/-like stimuli, are identified as /ɛ/, and about 95% of the S9 stimuli, which are spectrally /ɛ/-like stimuli, are identified as /ɛ/. In this sense, Koreans' identification of this continuum shows the same pattern as that of the NE subjects. This supports the SLM in that Koreans identified the /ɛ/ categorically since Korean has the equivalent vowel. However, based on the statistical results and the above graph, it appears that Koreans identified the spectrally /ɪ/-like stimuli as either /i/ or /ɪ/, which is not found in the NE subjects' identification of the this continuum.

4. Conclusion

In general most of the hypotheses were proved to be true; in the case of the /i/-/ɪ/ continuum, Koreans relied more on vowel duration and on spectral quality while they were identifying the stimuli; most of the stimuli were not identified as /ɛ/. In the case of the /ɪ /-/ɛ/ continuum, Koreans relied more on spectral quality than on vowel duration when they identified the /ɛ/; they identified the /ɛ/-like stimuli as /ɛ/, and the /ɪ/-like stimuli as both /i/ and /ɪ/. This supports the SLM. That is, Koreans identified the /ɛ/ categorically since Korean has the equivalent vowel.

However, the hypothesis that the KE subjects would do better than the KI subjects for both continua were proved to be not true. That is, the English experience factor was not statistically significant in the identification of both continua. This contradicts the SLM, which posits that there is a learning effect; speakers with more L2 experience are better than those with less L2 experience. The exact nature of this should be investigated further in the SLM.

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