English Language & Literature Teaching, Vol. 21, No. 4 Winter 2015

English Word-initial 's-stop' Clusters Produced by English and Korean Speakers

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Yun, Yungdo (2015). English word-initial 's-stop' clusters produced by English and Korean speakers. *English Language & Literature Teaching, 21*(4), 107-127.

The purpose of this study is to investigate how Korean speakers differ from English speakers in producing English words with initial /s/ followed by a stop and also to suggest how to teach pronunciation of those words in English classrooms. Fifteen English and twenty Korean speakers participated in a production experiment. Based on the statistical results, durations of the /s/ of all the experiment words were significantly different between the English and Korean groups. The statistical results for maximum intensities of the /s/, and durations and maximum intensities of the following vowels were complex; some of them were significantly different and others were not between the two groups. When relative durations of the /s/ to those of the following vowels were considered, those of the English speakers were significantly higher than those of the Korean speakers. In addition, relative maximum intensities of the /s/ to those of the following vowels were significantly higher in the English speakers' productions than in the Korean speakers' productions. These results reveal that Koreans have difficulty pronouncing those words. Based on these findings, English teachers should have students practice pronouncing the /s/ with longer duration and higher intensity than those of the following vowel.

[English/word-initial/voiceless alveolar fricative/consonant cluster/duration/intensity]

I. INTRODUCTION

It is well known that when foreign language learners pronounce the second language sounds, their pronunciations are affected by their mother tongue (Lado, 1957; Flege, 1995; Best, 1995). The English /s/ sound is known to be salient in that it is longer and louder than those of other languages (Stevens, 1971). In Jongman et al. (1998) the English /s/ was 148 milliseconds (ms) and 66.3 decibel (dB) in duration and average, respectively. Choi (2013) measured the /s/ produced by Korean speakers. The Koreans were divided into two groups based on their English test scores. The frication noise of /s/ of a nonsense English word /sa/

produced by high level Koreans was 152ms and that by low level Koreans was 123ms. When the nonsense Korean word /sa/ (사) was given, the high level Koreans produced 88 ms of it and the low level Koreans produced 100 ms of it. When they produced the nonsense Korean word /s*a/ (싸), the frication noise durations were 131ms and 132ms, respectively. Kim (1999) examined how Koreans produced English loanwords. She found that Koreans pronounced Korean /s*/ (ㅆ) when English /s/ were followed by a vowel (e.g., say, sea), and they pronounced Korean /s/ (ㅅ) when English /s/ was followed by other consonants within a cluster (e.g., spy, stick, skit).

Kim (2008) analyzed 's-stop' clusters using Korean-Spoken English Corpus (K-SEC). The frication noise durations of /s/ produced by English: dud male speakers were 183.11ms for /sp/, 204.20ms for /st/, and 194.83ms for /sk/. Those of /s/ by Korean male speakers were 97.82ms for /sp/, 104.62ms for /st/, and 105.33ms for /sk/. But the problem of this research was that the corpus was based on the data obtained from the English speakers who were from various English-speaking countries such as the U.S., Canada, and New Zealand, thus homogeneity of the subjects' languages was not controlled.

The aim of this study is to examine how Koreans produce the /s/ of English word-initial 's-stop' clusters. I will compare the frication noise duration and intensity of /s/ of word-initial 's-stop' clusters produced by native speakers of English and Korean. In most of the previous research the frication noise duration of /s/ produced by Koreans was obtained from nonsense words of '/s/-vowel' form. In this study I will compare the frication noise duration of /s/ of 's-stop' clusters of English words. Although the speech corpus K-SEC has the data on 's-stop' clusters, it is based on the uncontrolled experiment since the subjects participated in making the corpus were from various English-speaking countries. However, this study is based on the data from only American English speakers. Since the Koreans' production of /s/ related to its intensity has not been examined yet in the previous studies, I will compare the intensities of /s/ between American English and Korean speakers. Since the English /s/ is longer than Korean /s/ (ㅅ) and /s*/ (ㅆ), Koreans may have difficulty in pronouncing it. The unpublished previous version of this study was cited in Yun (2015), where raw data of durations and maximum intensities of /s/ of three English words (spot, stop, skit) were mentioned. This study extends it and deals with nine English words starting with /s/ followed by a stop. The analyses of the nine words include raw data of the durations and maximum intensities of /s/, the three following vowels' (/i, u, a/) durations and maximum intensities, the relationship between the /s/ and the three types of the following stops, and relative durations and relative maximum intensities of the /s/ to those of the following vowels, etc.

Since the word-initial 's-stop' cluster is not possible in Korean, I expect that Korean speakers' production of the cluster will be different from that of English speakers. When stress falls on a word, it carries high pitch, high intensity, and long duration of sounds.

English is a stressed-timed language but Korean is not. Thus, based on the previous research I expect that the duration and intensity of /s/ produced by Korean speakers will be shorter and lower, respectively, than those produced by American English speakers. Based on Kim (1999) the English /s/ in this case may be produced like the Korean /s/ (ㅅ) if it is produced like typical English loan words. Then the duration will be around 88 - 100ms as shown in Choi (2013).

II. PRODUCTION EXPERIMENT ON /s/ OF INITIAL ‘s-stop’ CLUSTERS

1. Research Methods

1) Subjects

The American English subjects were composed of eleven males and four females. When they participated in the experiment, they were professors of the A university located in Seoul. The Korean subjects were eleven males and nine females. They were the students of the A university. The Korean subjects had not stayed in English-speaking countries at the time of the experiment. Their TOEIC scores were 496 - 724 points, thus their English was middle to upper middle levels. The subjects were limited to the Seoul dialect speakers to avoid possible influence of dialects when they pronounced English words. They were all born and grew up in Seoul and Kyunggi province. All of the subjects of both language groups had not had experience of clinical treatments due to speech and hearing disorders. The American English subjects’ average age was 37.5 years and that of Korean subjects was 21.2 years.

TABLE 1

Information on Subjects

Group	Gender	Number	Age	Grown-up Place	Speech and Hearing Problems
English	Male	11	33-47, M=37.2	U.S.	None
	Female	4	30-49, M=37.7	U.S.	None
Korean	Male	11	20-27, M=21.2	Seoul, Kyunggi	None
	Female	9	19-24, M=21.3	Seoul, Kyunggi	None

2) Recording and Analyses

Recording was done in a sound-attenuated room of the English Clinic of the A

university. The subjects heard how the experiment would be processed before recording. They practiced the English words used in the experiment *spot*, *speak*, *spook*, *stop*, *steep*, *stoop*, *Scot*, *skeet* and *scoot*. They wore a headset microphone around five centimeters away from their lips, thus air puffing did not occur. When I gave a signal, they read the words in the sound-attenuated room. They were supposed to put about two seconds of pause between words to avoid problems caused by connected pronunciations of adjacent words. They produced the words three times and I used the words in the middle for the acoustic analyses. I analyzed the sounds of the experiment words using Praat 5.2.28 (Boersma & Weenik, 2009).

When I analyzed the recorded sounds, I checked both waveforms and spectrograms to measure frication noise durations of the word-initial /s/ of the above English words produced by the American English and Korean speakers. The onset of the /s/ was the place where high-frequency energy found in spectrograms showed zero crossing in waveforms (for measuring frication noise durations, see Yeni-Komshian & Soli 1981; Jongman et al., 1998). The offset of the /s/ was the start of the closure of the following stops. Through the frication noise duration, the intensity of /s/ keeps changed. It starts with low intensity and becomes higher until it reaches the maximum point and then it becomes lower until the offset. Thus we had better choose one point in the intensity track. In this study the maximum intensity of the /s/ was chosen for measurements.

III. RESULTS AND DISCUSSION

1. Results from American English Speakers

The highlighted portion of Figure 1 represents the frication noise duration of the word-initial /s/ of the English word *spot* produced by a male American English speaker CM. Its frication noise duration is 214 ms. The vowel portion is shown with long vertical striations in both waveform and spectrogram. Its duration is 223 ms. As we see in Figure 1, the frication noise duration is much longer than the closure duration of the following /p/ and slightly shorter than the vowel duration. As discussed in the previous research, the frication noise of English /s/ is long in Figure 1. The maximum intensity of /s/ is 75 dB. It is found in the 72% point from the onset, which is indicated by an arrow in Figure 1.

However, if we compare the raw data of frication noise and maximum intensity of /s/, we cannot avoid problems caused by individual speakers' speech habits. For instance, an energetic speaker tends to speak loudly and an introverted speaker tends to speak quietly. A fast speaker tends to produce short consonants and vowels. A slow speaker tends to produce long consonants and vowels, and so on. To reduce or avoid these individual

speakers' speech habits in the experiment, we should normalize the frication noise duration of /s/ and its maximum intensity. Thus in this study I will use relative frication noise duration and maximum intensity to those of the following vowel. In other words the frication noise durations and maximum intensities of /s/ are represented by percents to those of the following vowels. The formula for the relative frication noise duration of /s/ in this study is [(duration of frication noise of /s/×100)÷duration of the following vowel], and the formula for the relative maximum intensity of /s/ is [(maximum intensity of /s/×100)÷maximum intensity of the following vowel]. For instance, in the American English speaker CM's production of *spot* shown in Figure 1, the duration and the maximum intensity of the following vowel /a/ are 223 ms and 89 dB, respectively. Thus the relative frication duration of /s/ and its relative maximum intensity to those of the following vowel are 95.96% and 84.26%. This means that the duration of /s/ is close to that of the vowel (95.96%, namely, almost 100%) and the intensity of /s/ is lower than that of the vowel (84.26%).

FIGURE 1

The /s/ Produced by an American English Speaker CM

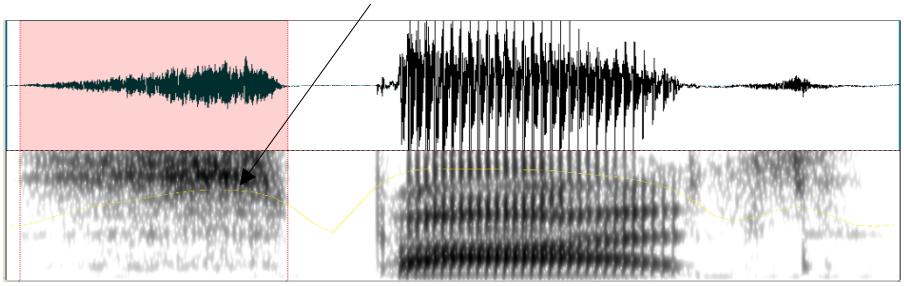


Table 2 shows the raw data of the frication noise durations and maximum intensities of /s/ obtained from the experiment words produced by the American English subjects. Table 3 shows the raw data of the durations of the following vowels and their maximum intensities. The units of duration and intensity in Table 2 and Table 3 are milliseconds (ms) and decibel (dB), respectively.

TABLE 2

American English Speakers' Production of /s/

Words	Frication Noise Duration of /s/		Maximum Intensity of /s/	
	Average	Standard Deviation	Average	Standard Deviation
spot	202.13	46.27	63.27	7.51
speak	172.47	38.99	66.70	3.52

spook	172.95	40.52	69.39	4.75
<Grand Average>	182.51	41.93	66.45	5.26
stop	188.07	42.22	63.27	8.57
steep	169.64	41.17	65.95	6.06
stoop	176.27	39.36	66.83	6.22
<Grand Average>	178.00	40.92	65.35	6.95
Scot	188.42	43.34	66.68	5.22
skeet	216.54	40.81	64.95	6.07
scoot	183.87	42.61	65.22	5.99
<Grand Average>	196.28	42.25	65.61	5.76

As Table 2 shows, the /s/ is the longest when the following stop is the velar /k/ (196.28 ms in grand average (the average of the average values of 172.47, 172.95, and 202.13 ms)), and the second longest when the bilabial /p/ comes after it (182.51 ms in grand average). The /s/ is the shortest when the following stop is /t/ (178.00ms in grand average). I checked whether the relative frication noise duration of /s/ is related to the following stops using One-way ANOVA. The result is significant ($F(2, 132)=4.093$, $p=0.019$). Tukey's post-hoc test shows that /sk/ cluster is significantly different from /st/ cluster ($p=0.019$). The difference between /sp/ cluster and /sk/ cluster is not significant but marginal ($p=0.101$). But the difference between /sp/ and /st/ clusters was not significant ($p=0.777$). I also checked whether there is statistical difference among maximum intensities of /s/ with respect to the following stops. The result from One-way ANOVA is not significant ($F(2, 132)=0.358$, $p=0.699$). Thus we cannot say that the maximum intensity of /s/ is related to the following stops.

In Jongman et al.'s (1998) study, the duration of /s/ was 148 ms and its intensity was 66.3 dB. The intensity of /s/ is similar to that of the current study (65.35 - 66.45 dB). But the duration seems to be a bit different from that of the current study (169.64 - 216.54 ms). At this moment we cannot say that the duration of /s/ has been lengthened as time passed. We do not know whether the lengthening may have happened to some other consonants too. To check this phenomenon in detail we need in-depth examinations with other consonants as well as /s/. This may be done in future research.

As mentioned in the introduction, Kim (2008) analyzed the data from Korean-Spoken English Corpus (K-SEC) and found that in English male speakers' productions of /s/ in clusters, the /s/ of the /st/ cluster was the longest (204.20 ms), and the /s/ of the /sk/ cluster the second longest (194.83 ms), and the /s/ of the /sp/ cluster the shortest (183.11 ms). That finding is different from that of the current study. The /s/ in the /sk/ cluster is the longest in the current study, and the /s/ durations are similar in the /sp/ and /st/ durations. I assume that this may be because the English speakers of the K-SEC corpus were from various

English-speaking countries such as the U.S., Canada, and New Zealand whereas the subjects are only American English speakers in the current study. I assume that the results from the current study should be more reliable since the homogeneity of the subjects' languages was controlled. In addition, in the current study the vowels were chosen from the far ends of the vowel chart, namely, high front, high back, and low vowels, which also make the results in the current study reliable.

TABLE 3

American English Speakers' Production of the Vowel

Words	Duration of the Vowel		Maximum Intensity of the Vowel	
	Average	Standard Deviation	Average	Standard Deviation
spot	196.53	29.59	78.40	7.27
speak	177.20	31.17	77.53	7.06
spook	141.02	31.06	75.58	6.21
<Grand Average>	171.58	30.61	77.17	6.85
stop	164.04	17.027	74.20	5.39
steep	173.16	16.28	75.58	6.22
stoop	114.39	18.19	73.04	4.64
<Grand Average>	150.53	17.17	74.27	5.41
Scot	161.12	21.38	76.12	5.77
skeet	163.77	15.94	71.59	6.01
scoot	122.13	19.43	70.77	5.69
<Grand Average>	149.01	18.92	72.83	5.82

As Table 3 shows, the low vowel /a/ is the longest (171.58 ms in grand average), and the durations of the high vowels /u/ and /i/ are similar to each other (150.53 ms vs. 149.01 ms in grand average). The result from One-way ANOVA is significant ($F(2, 132)=6.705$, $p=0.002$). Tukey's post-hoc test says that the vowel /a/ is significantly different from /u/ ($p=0.008$) and from /i/ ($p=0.004$), and there is no significant difference between /u/ and /i/ ($p=0.972$). The maximum intensity seems to be the highest for the /a/ (77.17dB in grand average) and the second highest for /u/ (74.27dB in grand average) and the lowest for /i/ (72.83dB in grand average). Based on One-way ANOVA, the difference is significant ($F(2, 132)=5.841$, $p=0.004$). Tukey's post-hoc test says that the difference between the intensities of /a/ and /i/ is significant ($p=0.003$) and marginal between those of /a/ and /u/ ($p=0.069$) and not significant between those of /u/ and /i/ ($p=0.501$). Based on the statistical results we can say that the low vowel /a/ is the longest in duration and the highest in intensity.

To avoid problems that may be caused by individual speakers' speech habits, I provide in Table 4 the relative (namely, percent) durations of frication noise and maximum intensities of /s/ to those of the following vowels. The data in Table 4 are all percent values.

TABLE 4

English Speakers' Relative Duration and Intensity of /s/

Words	Relative Duration of /s/		Relative Intensity of /s/	
	Average	Standard Deviation	Average	Standard Deviation
spot	105.89	30.32	80.70	5.46
speak	107.87	27.19	87.93	5.77
spook	105.96	28.52	93.74	6.28
<Grand Average>	106.57	28.68	87.46	5.84
stop	109.34	32.02	81.39	4.81
steep	104.46	25.99	92.25	5.82
stoop	102.76	22.21	88.58	6.15
<Grand Average>	105.52	26.74	87.41	5.59
Scot	140.38	36.50	88.52	6.98
skeet	182.48	42.53	92.15	9.29
scoot	166.01	38.28	89.40	7.12
<Grand Average>	162.96	39.59	90.02	7.80

Table 5 shows that the percent values of the duration of /s/ relative to the following vowels are the highest when the /s/ is followed by the velar stop /k/ (162.96% in grand average) but those followed by /p/ and /t/ seem similar to each other (106.57% vs. 105.52% in grand average). This means that the duration of /s/ of the /sk/ cluster is almost 1.6 times longer than that of the vowels, and that of /s/ of the /st/ and /sp/ clusters is slightly longer than that of the vowels. The result from One-way ANOVA is significant ($F(2, 132)=53.186$, $p=0.001$). Tukey's post-hoc test shows that the relative percent of /s/ is significant when the following stops are /p/ and /k/ ($p=0.001$) and /t/ and /k/ ($p=0.001$), and it is not significant when the following stops are /p/ and /t/ ($p=0.987$). Thus we can say that the duration of /s/ of the /sk/ cluster is longer than that of /s/ of /st/ and /sk/ clusters. In the case of relative intensities of /s/ to the following vowels, they look close regardless of the following stops (87.46 dB vs. 87.41 dB vs. 90.02dB in grand average). The result from One-way ANOVA shows that there is no statistically significant difference among them ($F(2, 132)=1.734$, $p=0.181$). Thus we cannot say that the intensities of /s/ are different when the following stops are different.

To check whether the following vowels affected the durations and intensities of /s/, I listed in Table 5 the relative durations and maximum intensities of the /s/ to those of the following vowels based on the vowels /a/, /u/ and /i/. The units in Table 5 are percents.

TABLE 5

English Speakers' Relative Duration and Intensity of /s/ with Respect to Vowels

Words	Relative Duration of /s/		Relative Intensity of /s/	
	Average	Standard Deviation	Average	Standard Deviation
spot (/a/)	105.89	30.32	80.70	5.46
stop (/a/)	109.34	32.02	81.39	4.81
Scot (/a/)	140.38	36.50	88.52	6.98
<Grand Average>	118.54	32.95	83.54	5.75
spook (/u/)	105.96	28.52	93.74	6.28
stoop (/u/)	102.76	22.21	88.58	6.15
scoot (/u/)	166.01	38.28	89.40	7.12
<Grand Average>	124.91	29.67	90.57	6.52
speak (/i/)	107.87	27.19	87.93	5.77
steep (/i/)	104.46	25.99	92.25	5.82
skeet (/i/)	182.48	42.53	92.15	9.29
<Grand Average>	131.60	31.90	90.78	6.96

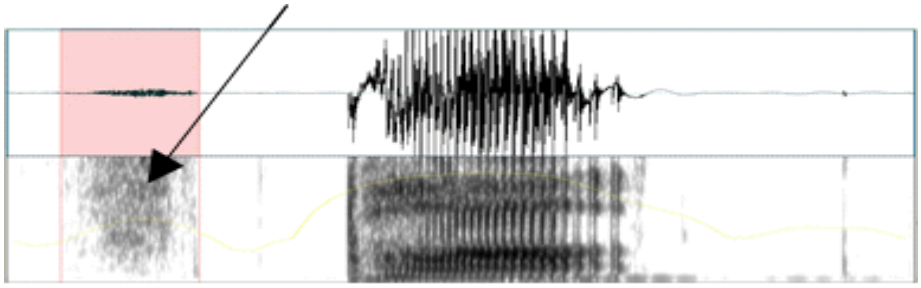
As shown in Table 5, it seems that the relative percent of /s/ duration to the following vowel duration is the highest before /i/ (131.60% in gran average) and the second highest before /u/ (124.91% in grand average) and the shortest before /a/ (118.54% in grand average). This means that the /s/ of clusters is about 1.3 times longer than the following /i/, and about 1.2 times longer than the following /u/ and /a/. However, the result from One-way ANOVA shows that the difference among them is not significant ($F(2, 132)=1.186$, $p=0.309$). Thus we cannot say that the relative durations of /s/ of clusters are different when the following vowels are different. The relative percent intensity of /s/ to that of the following vowel is the lowest before /a/ (83.54% in grand average) and similar before /u/ and /i/ (90.57% vs. 90.78% in grand average). The result from One-way ANOVA is significant ($F(2, 132)=15.639$, $p=0.001$). Tukey's post-hoc test says that it is significantly different between /a/ and /u/ ($p=0.001$), and also significantly different between /a/ and /i/ ($p=0.001$), but not significantly different between /u/ and /i/ ($p=0.979$). Thus we can say that the relative intensity of /s/ is the lowest when the following vowel is /a/ and similar when the following vowels are /u/ and /i/.

2. Results from Korean Speakers and Comparison with American English Speakers

The highlighted portion of Figure 2 shows frication noise of word-initial /s/ of an English word *spot* produced by a Korean speaker SHS.

FIGURE 2

The /s/ Produced by a Korean Speaker SHS



The frication noise duration of /s/ is 115 ms and its maximum intensity is 62 dB. As Figure 2 shows the frication noise duration of /s/ is even shorter than the closure duration of the following stop /p/ and much shorter than the duration of the following vowel /a/. The frication noise duration of /s/ in Figure 2 is very different from that of Figure 1 by the American English speaker CM. Comparing with Figure 1, the frication noise duration is much shorter (214 ms vs. 115 ms) and maximum intensity is lower (75 dB vs. 62 dB). These findings support the previous research (Stevens, 1971; among others) that the English fricative /s/ is longer in duration and higher in intensity than that of other languages. The point of the maximum intensity is found in 71% point from the onset of /s/, which is indicated by an arrow. It is similar to that of American English speaker CM (72% vs. 71%).

In the Korean speaker SHS's production of *spot* shown in Figure 2, the duration and the maximum intensity of the following vowel /a/ are 169ms and 81dB, respectively. Comparing with Figure 1 by the American English speaker CM, the vowel duration is much shorter (223 ms vs. 169 ms) and maximum intensity is lower (89 dB vs. 81 dB).

The relative frication noise duration of /s/ and its relative maximum intensity to those of the following /a/ are 68.04% and 92.59%, respectively. Comparing with Figure 1 by the American English speaker CM, the relative duration is shorter (95.96% vs. 68.04%). This means that the American English speaker CM produced the /s/ (214 ms) and the vowel /a/ (223 ms) with similar durations, but the Korean speaker SHS's production of /s/ (115 ms) is only about 68% of the vowel /a/ (169 ms). Although the intensity of /s/ to the following vowel by the Korean SHS is higher (92.59%) than that by the American English speaker CM (84.26%), this is only because the Korean SHS's difference between the intensities of /s/ and the vowel is smaller than that of the American English speaker CM.

Table 6 shows the raw data of the frication noise durations of /s/ and maximum intensities obtained from the English words used in the experiment produced by the Korean subjects. Table 7 shows the raw data of the durations of the following vowels and their maximum intensities. The units of frication noise duration and maximum intensity in Table 6 and Table 7 are milliseconds (ms) and decibel (dB), respectively.

TABLE 6

Korean Speakers' Production of /s/

Words	Frication Noise Duration of /s/		Maximum Intensity of /s/	
	Average	Standard Deviation	Average	Standard Deviation
spot	112.75	28.27	64.25	5.95
speak	124.00	29.26	63.15	5.22
spook	117.30	33.52	61.15	4.75
<Grand Average>	118.02	30.35	65.60	5.31
stop	114.20	33.64	64.85	7.17
steep	105.43	37.86	65.20	4.97
stoop	112.85	36.31	60.46	4.61
<Grand Average>	110.83	35.94	63.50	5.58
Scot	94.38	22.46	67.57	5.15
skeet	93.85	29.28	68.80	4.93
scoot	95.96	29.49	61.64	4.70
<Grand Average>	94.73	27.08	66.00	4.93

As shown in Table 6, the /s/ is the longest when the following stop is the bilabial /p/ and the shortest before the velar /k/. This finding is different from that of the American English speakers where the /s/ is the longest before /k/ and shortest before /t/. To check whether the difference among the frication noise durations of /s/ is influenced by the following stops, One-way ANOVA is done. The result is significant ($F(2, 177)=17.382$, $p=0.001$). Tukey's post-hoc test shows that the /sp/ cluster is significantly different from /sk/ cluster ($p=0.001$), and /st/ cluster is also significantly different from /sk/ cluster ($p=0.001$). However, /sp/ and /st/ clusters are not significantly different ($p=0.179$). In general the duration /s/ is much shorter than that by American English speakers (169.64 - 216.54 ms vs. 93.85 - 124.00 ms in average), and the maximum intensities of /s/ seem overlapped (63.27 - 69.39 dB vs. 60.46 - 68.80 dB in average). It seems that the maximum intensities of /s/ are not very different regardless of the following stops in Korean speakers' productions. One-way ANOVA shows that the difference is not significant but marginal ($F(2, 177)=2.728$, $p=0.068$). Tukey's post-hoc test says that the difference between /sp/ and /sk/ is marginal ($p=0.066$), and the difference between /sp/ and /st/ clusters is not significant ($p=0.828$) and the difference between /st/ and /sk/ is not significant either ($p=0.222$). Thus we cannot say that the intensities of /s/ are different among clusters.

To check whether the durations of /s/ are different between the American English speakers and Koreans, I compared the two groups using t-test with alpha level of 0.05. Table 7 shows the statistical results where the durations of /s/ in all of the words are significantly different. The /s/ durations produced by the American English speakers are much longer than those by the Koreans.

TABLE 7

Statistical Results of Frication Durations of /s/ between Two Groups

Words	Average of Frication Duration of /s/		t-test		Significance
	English Speakers	Koreans	t	p	
spot	202.13	112.75	7.074	0.001	significant
speak	172.47	124.00	4.868	0.001	significant
spook	172.95	117.30	5.699	0.001	significant
stop	188.07	114.20	5.764	0.001	significant
steep	169.64	105.43	9.729	0.001	significant
stoop	176.27	112.85	13.427	0.001	significant
Scot	188.42	94.38	18.015	0.001	significant
skeet	216.54	93.85	16.870	0.001	significant
scoot	183.87	95.96	17.545	0.001	significant

I also compared the maximum intensities of /s/ produced by the American English speakers and Koreans, and checked whether their differences are statistically significant. Table 8 shows the t-test results with alpha level of 0.05. The results are complex. The intensities of /s/ are significantly different in the words *speak*, *spook*, *stoop*, *skeet*, *scoot*. However, they are not significantly different in the words *spot*, *stop*, *steep*, and *Scot*. At this moment we cannot say whether the intensities of /s/ are different between American English and Korean speakers' productions. It may be possible for individual speakers' speech habits to affect the intensities of the /s/. Energetic speakers tend to speak loudly and introverted speakers tend to speak softly. Thus, we should check this with relative intensities of /s/ to the vowels. I will discuss this later in Table 14 after I explain the results from the vowels.

In the previous study (Choi, 2013) the average frication duration of English /s/ by Koreans was 148 ms and its intensity was 66.3 db. The intensity is similar in both Choi (2013) and the current study. However the duration is different. In the current study, the duration of /s/ is 93.85 - 124.00 ms in average. I assume that this is because of the difference between experiment words. Choi used words with word-initial /s/ followed by a vowel (/sV.../) and the current study used words with word-initial /s/ of 's-stop' clusters followed by vowels. It seems that the /s/ of /sV.../ words is longer than that of 's-stop' clusters followed by vowels.

TABLE 8

Statistical Results of Maximum Intensities of /s/ between Two Groups

Words	Average of Maximum Intensities of /s/		t-test		Significance
	English Speakers	Koreans	t	p	
spot	63.27	64.25	-0.432	0.668	not significant
speak	66.70	63.15	2.292	0.028	significant
spook	69.39	61.15	5.000	0.001	significant
stop	63.27	64.85	-0.595	0.556	not significant
steep	65.95	65.20	0.357	0.724	not significant
stoop	66.83	60.46	3.661	0.001	significant
Scot	66.68	67.57	-0.436	0.666	not significant
skeet	64.95	68.80	-2.034	0.050	significant
scoot	65.22	61.64	3.309	0.002	significant

Kim (2008) analyzed the data from Korean-Spoken English Corpus (K-SEC) and found that in Korean male speakers productions the /s/ of the /sp/ cluster was the shortest (97.82 ms), and the /s/ of the /st/ cluster and the /s/ of the /sk/ cluster were almost the same (104.62 ms and 105.33 ms). Comparing those durations with the results from the current study, they look different (97.82 ms vs. 118.02 ms for the /s/ of /sp/ clusters, and 104.62 ms vs. 110.83 ms for the /s/ of /st/ clusters, and 105.33 ms vs. 94.73 ms for the /s/ of /sk/ clusters). Especially the /s/ of /sp/ cluster was the shortest in Kim (2008) and the longest in the current study. At this moment I cannot explain why they are different. But I wonder whether there is any difference in experiment procedures between Kim's study and the current study. In the current study Koreans produced the words individually in the sound-attenuated room. Before the experiment they did not have a chance to listen to the experiment words provided by English speakers. Thus, their productions were not influenced by those of English speakers. In addition, the vowels of the experiment words in the current study are chose from the far ends of the vowel chart (high front /i/, high back /u/, and low /a/ vowels). If the words were chosen without considering the distributions of vowels in the K-SEC, it is possible to have the duration differences of the /s/ regarding the following stops between Kim's study and the current study.

Choi (2013) provided the nonsense Korean word /sa/ (사) and /s*a/ (싸) and found that the frication noise durations were 88 - 100 ms for /s/ (ㅅ) and 131 - 132ms for /s*/ (ㅆ). Kim (1999) found that Koreans pronounced Korean /s*/ (ㅆ) when English /s/ were followed by a vowel (e.g., say, sea) and they pronounced Korean /s/ (ㅅ) when English /s/ within a cluster (e.g., spy, stick, skit). Based on these studies I expected before the experiment that Koreans might pronounce the English /s/ of sC clusters like Korean /s/ (ㅅ). In the current study, the average duration of /s/ before /a/ produced by Koreans are 112.75 ms for *spot*, 114.20 ms for *stop*, and

94.38 ms for *Scot*. The average /s/ duration for *Scot* is the only one that belongs within the range of the Korean /s/ (ㅅ) duration obtained from Choi (2013). Therefore there is no evidence that Korean subjects in the current study produced the /s/ of word-initial 's-stop' clusters like Korean /s/ (ㅅ) as they did for English loan words. I assume that Korean subjects produced the experiment words as they did for English words, not for English loan words.

TABLE 9

Korean Speakers' Production of the Vowels

Words	Duration of the Vowel		Maximum Intensity of the Vowel	
	Average	Standard Deviation	Average	Standard Deviation
spot (/a/)	193.15	37.361	84.40	4.08
stop (/a/)	174.40	42.468	83.95	4.70
Scot (/a/)	156.48	31.32	82.16	4.11
<Grand Average>	174.68	37.05	83.50	4.29
spook (/u/)	210.10	34.02	79.07	3.75
stoop (/u/)	204.63	43.24	78.20	3.91
scoot (/u/)	121.40	35.58	77.21	3.86
< Grand Average >	178.71	37.61	78.16	3.84
speak (/i/)	235.95	41.38	79.40	5.77
steep (/i/)	151.80	55.94	76.05	6.01
skeet (/i/)	140.65	42.84	82.20	5.69
< Grand Average >	176.13	46.72	79.21	5.82

In Table 9, I listed the words based on the vowels to check whether durations and intensities of the vowels are different systematically. Table 9 shows that the average durations of the vowels look similar (174.68 ms for /a/ vs. 178.71 ms for /u/ vs. 176.13 ms for /i/). This finding is also different from those of the American English speakers where the /a/ is the longest (171.58 ms), and the durations of /u/ and /i/ are similar to each other (150.52 and 149.01 ms). To check whether the differences among the vowel durations produced by Koreans are statistically different, One-way ANOVA is conducted. The result says that the difference among the vowels is not significant ((F(2, 177)=0.102, p=0.903). In general the durations of the vowels between the two groups seem overlapped (114.39 - 196.53 ms vs. 121.40 - 235.95 ms in average), and the intensities of the vowels are slightly overlapped but Koreans' production of the maximum intensities of the vowels seems higher than those by American English speakers in the ranges (70.77 - 78.40 dB vs. 76.05 - 84.40 dB in average). To check whether the differences are statistically significant, I conducted t-tests with alpha level of 0.05. Table 10 and Table 11 are the statistical results for vowel duration and intensities, respectively.

TABLE 10

Statistical Results of Vowel Durations between Two Groups

Words	Average of Duration of Vowel		t-test		Significance
	English Speakers	Koreans	t	p	
spot (/a/)	196.53	193.15	0.204	0.840	not significant
stop (/a/)	177.20	174.40	0.215	0.831	not significant
Scot (/a/)	141.02	156.48	-1.453	0.156	not significant
spook (/u/)	164.04	210.10	-4.796	0.001	significant
stoop (/u/)	173.16	204.63	-2.661	0.012	significant
scoot (/u/)	114.39	121.40	-1.207	0.236	not significant
speak (/i/)	161.12	235.95	-6.161	0.001	significant
steep (/i/)	163.77	151.80	1.319	0.196	not significant
skeet (/i/)	122.13	140.65	-3.414	0.002	significant

As shown in Table 10, when the vowel is /a/, the differences of durations are not significant for all of the words. However, the statistical results for the high vowels are complex. When the vowel is /u/, the differences are significant for the words *spook* and *stoop*, but not for *scoot*, and when the vowel is /i/, the differences are significant for the words *speak* and *skeet*, but not for *steep*. At this moment we cannot say whether the durations of the vowels are different or not between the productions of the two groups. It may be possible for individual speakers' speech habits to affect the durations of vowels rather than languages of the speakers. We should check this with relative durations to those of the /s/ sounds. We will discuss this in Table 13.

Table 11 shows the statistical results of maximum intensities of the vowels between the groups. In most of the words, the differences are significant except for the words *stoop* and *speak*. Even in these words the results are marginal (p=0.132 and p=0.051). Comparing the average values of the two groups, the maximum intensities of the vowels are higher in Koreans' productions than in American English speakers' productions. Thus, we can say that the vowels produced by the Koreans are louder than those by American English speakers. However, we should still be careful in saying so since the intensities of vowels may be due to speech habits of individual speakers. To avoid individual speakers' speech habits, we should check the relative intensities of the vowels to the /s/. This will be discussed in Table 14.

Table 12 shows the relative (namely, percent) durations of frication noise and maximum intensities of /s/ to those of the vowels. The data in Table 12 are all percent values.

TABLE 11

Statistical Results of Vowel Intensities between Two Groups

Words	Average of Intensity of Vowel		t-test		Significance
	English Speakers	Koreans	t	p	
spot (/a/)	78.40	84.40	-3.102	0.004	significant
stop (/a/)	77.53	83.95	-3.227	0.003	significant
Scot (/a/)	75.58	82.16	-3.807	0.001	significant
spook (/u/)	74.20	79.07	-3.174	0.003	significant
stoop (/u/)	75.58	78.20	-1.545	0.132	not significant
scoot (/u/)	73.04	77.21	-2.974	0.005	significant
speak (/i/)	76.12	79.40	-2.021	0.051	not significant
steep (/i/)	71.59	76.05	-2.614	0.013	significant
skeet (/i/)	70.77	82.20	-6.934	0.001	significant

TABLE 12

Korean Speakers' Relative Duration and Intensity of /s/

Words	Relative Duration of /s/		Relative Intensity of /s/	
	Average	Standard Deviation	Average	Standard Deviation
spot	60.91	20.35	76.16	6.38
speak	54.70	17.43	79.65	5.73
spook	57.72	17.55	77.41	5.97
<Grand Average>	57.78	18.44	77.41	6.03
stop	68.64	21.19	77.35	8.42
steep	71.82	15.41	85.91	5.64
stoop	57.11	11.99	77.37	5.46
<Grand Average>	65.86	16.20	80.21	6.51
Scot	62.31	12.57	82.31	5.81
skeet	67.24	8.99	83.92	7.21
scoot	80.24	12.34	77.39	6.65
<Grand Average>	69.93	11.30	81.21	6.56

As Table 12 shows, the relative percent values of the durations of /s/ to those of the vowels are the highest when the cluster has the velar /k/ (69.93 dB in grand average). This finding is the same as the case for the American English speakers. Those of the /s/ relative to the vowels are the lowest when the cluster has the bilabial /p/ (57.78 dB in grand average). I checked whether the relative frication noise duration of /s/ is related to the following stops using One-way ANOVA. The results were significant ($F(2, 177)=8.360$, $p=0.001$). Tukey's post-hoc test shows

that /sp/ cluster is significantly different from /st/ (p=0.024) and from /sk/ (p=0.001). However, the /st/ cluster is not significantly different from the /sk/ cluster. But in the results from the American English speakers, the relative duration of /s/ of /sk/ cluster to the following vowel was significantly different from the /s/ of /st/ and /sp/ clusters. Therefore we can conclude that the /s/ of 's-stop' clusters produced by Koreans is different from that by American English speakers.

I also checked whether the relative maximum intensity of /s/ is related to the following stops using One-way ANOVA. The result is significant (F(2, 177)=3.788, p=0.025). Tukey's post-hoc test shows that the /sp/ cluster is significantly different from the /sk/ cluster. However, the /sp/ cluster and /st/ cluster are not significantly different (p=0.141), and /st/ cluster and /sk/ cluster are not significantly different either (p=0.720). But in the results from the American English speakers, the relative intensities of /s/ to the following vowels was not significantly different among the clusters. These results also make us conclude that the /s/ of 's-stop' clusters produced by Koreans is different from that by American English speakers.

To avoid problems that may be caused by individual speakers' speech habits, I compared the relative frication noise durations of /s/ to those of the following vowels obtained from the English words produced by American English speakers and Korean speakers. Table 13 shows the t-test results of this with alpha level of 0.05.

TABLE 13

Statistical Results of Relative Frication Noise Durations of /s/ between Two Groups

Words	Average of Relative Duration of /s/		t-test		Significance
	English Speakers	Koreans	t	p	
spot	105.89	60.91	5.251	0.001	significant
speak	107.87	54.70	8.965	0.001	significant
spook	105.96	57.72	7.845	0.001	significant
stop	109.34	68.64	4.531	0.001	significant
steep	104.46	71.82	6.093	0.001	significant
stoop	102.76	57.11	11.102	0.001	significant
Scot	140.38	62.31	8.902	0.001	significant
skeet	182.48	67.24	11.812	0.001	significant
scoot	166.01	80.24	9.418	0.001	significant

For instance, as shown in Table 13, the percent of the frication noise duration of /s/ relative to that of the following vowel of the English word *spot* is 105.89% by American English speakers and 60.91% by Korean speakers. The t-test results for this are t=5.251, p=0.001. Thus the difference between the two groups is significant. Likewise the relative durations of /s/ to those of the following vowels for all of the words used in the experiment are all significantly different

between the two groups. Thus, we can conclude that the relative durations of /s/ to those of the following vowels produced by American English speakers are higher than those by Korean speakers. Based on Table 13, American English speakers produced the word-initial /s/ of 's-stop' clusters longer than the following vowels. However, Koreans produced the /s/ shorter than the following vowels. Before the experiment I expected that the Koreans' frication noise duration of /s/ would be shorter than that of the American English speakers. This expectation was based on the fact that the 's-stop' cluster is not allowed in Korean and the English /s/ is known to be longer in duration than that of other languages. This expectation has been proved in the current study in that Koreans' production of the relative durations of /s/ to those of the following vowels was much lower than those by the American English speakers.

I compared the relative maximum intensities of /s/ to those of the following vowels obtained from the English words produced by American English speakers and Korean speakers. Table 14 shows the t-test results of this with alpha level of 0.05.

TABLE 14

Statistical Results of Relative Maximum Intensities of /s/ between Two Groups

Words	Average of Relative Maximum Intensity of /s/		t-test		Significance
	English Speakers	Koreans	t	p	
spot	80.70	76.16	2.154	0.039	significant
speak	87.93	79.65	4.210	0.001	significant
spook	93.74	77.41	7.705	0.001	significant
stop	81.39	77.35	1.660	0.106	not significant
steep	92.25	85.91	3.318	0.002	significant
stoop	88.58	77.37	5.629	0.001	significant
Scot	88.52	82.31	2.848	0.008	significant
skeet	92.15	83.92	2.980	0.005	significant
scoot	89.40	77.39	5.163	0.001	significant

For instance, in the case of the word *spot*, the average relative intensity of /s/ to that of the following vowel is 80.70% for American English speakers and 76.16% for Korean speakers, and its t-test results are t=2.154 and p=0.039, which show significant difference. As Table 14 shows, the average relative maximum intensities of /s/ of all of the words by American English speakers are higher than those by Korean speakers, and these differences are also statistically significant except for *stop*. In the case the word *stop*, it is marginal (p=0.106), though. Therefore we can conclude that the relative intensities of /s/ to those of the following vowels by the American English speakers are lower than those by the Koreans. Comparing this with the results shown in Table 8 for average maximum intensities of /s/ and Table 11 for average

maximum intensities for vowels, it seems that there are not much differences of maximum intensities of the /s/ between American English and Korean speakers’ productions. However, the average maximum intensities of vowels are different. Those produced by American English speakers are lower than those by Koreans. These results make the relative maximum intensities of /s/ to those of the vowels higher in American English speakers’ productions than in Koreans’ productions. In other words, the intensity difference between the /s/ and the following vowels is less in American English speakers’ productions than in Koreans’ productions, which makes the /s/ sounds more loudly in American English speakers’ productions than in Koreans’ productions from the perceptual point of view.

Before the experiment I expected that the intensity of /s/ produced by Koreans would be lower than that of American English speakers. However, this expectation has been turned out to be false. The intensity of /s/ produced by Koreans is not much different from that by American English speakers. Instead, the intensity of the following vowel is higher in the Koreans’ production than in the American English speakers. From the perceptual point of view, the relative low intensity of the /s/ and high intensity of the following vowel makes the /s/ sound less loudly in Koreans’ productions than in American English speakers’ productions.

As I mentioned before the unpublished previous study was cited in Yun (2015). The two English words *spot* and *stop* were used in both the unpublished study and the current study. The raw data of the duration and maximum intensity of the /s/ were similar to each other. In the English speakers' productions they were 201.36ms vs. 202.13ms and 62.07dB vs. 63.27dB for *spot*; 191.00ms vs. 188.07ms and 62.00dB vs. 63.27dB for *stop*. In the Korean speakers' productions they were 113.84ms vs. 112.75ms and 64.68dB vs. 64.25 dB for *spot* and 116.53ms vs. 114.20ms and 65.84dB vs. 64.85dB for *stop*. The statistical results between the two native speaker groups were also the same. The relative maximum intensities of the /s/ to the following vowels for the two words were not significant. However, the seven words added to the current study (*speak*, *spook*, *steep*, *stoop*, *Scot*, *skeet* and *scoot*) show mixed results. In the relative maximum intensities of the /s/ to the following vowels were significantly different in five words and were not significantly different in the remaining two words.

IV. CONCLUSION

This study has examined frication noise duration and maximum intensity of the /s/ of English word-initial ‘s-stop’ clusters produced by American English and Korean speakers. The previous research shows that English /s/ is longer in duration and high in intensity comparing with the /s/ in other languages, and Koreans typically pronounce Korean /s/ (ㅅ) for the /s/ of word-initial ‘s-stop’ clusters of English loan words. Based on these, I expected before the experiment that Koreans would produce shorter frication noise duration with lower intensityBased on the results

we have seen in this study, English teachers should consider the fact that word-initial 's-stop' clusters are not allowed in Korean, and the English /s/ of a cluster is longer in duration. When teachers correct Korean students' pronunciations of English words that contain 's-stop' clusters, they should focus on the duration of the initial /s/. The frication noise durations of /s/ produced by American English speakers are longer than the following vowels whereas those of /s/ by Korean speakers are usually shorter than the following vowels. Thus, the students need to practice pronouncing the words with a longer and louder /s/ and a relatively less loud vowel (see Han (2010) and Yun (2014) for the ways to do this).

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Examples in: English
Applicable Language: English
Applicable Level: Secondary

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Received in October 15, 2015
Reviewed in November 26, 2015
Revised version received in December 5, 2015