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Perception of English sC Clusters Resulting from Schwa Deletion by Native and Non-Native Listeners

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Abstract

The study explored the perception of English sC onsets created by schwa deletion to investigate whether they show different perceptual patterns from other onsets with respect to predictions of onset sonority. Specifically, sC onsets of sonority falls/plateaus (*supply* [splaɪ]) and rises (*semantic* [smæntɪk]) created by schwa deletion were tested in syllable and discrimination tasks, in which English, Korean and Japanese speakers indicated the number of syllable(s) of the stimuli or judged whether the stimuli were the same or not. The results showed that onset sonority was witnessed for the schwa-deleted real and nonce words in the syllable judgment test, although Japanese speakers showed a somewhat different pattern. In the discrimination test, onset sonority was only partly confirmed for the non-identical pairs of nonce words for English and Korean speakers. The findings of the study were further discussed in terms of task effects, L1s, and English proficiency of the participants.

Studies on speech perception found that perception of word-initial onset clusters is subject to L1 phonotactic constraints. Phonotactic constraints restrict the distribution of sound sequences within the syllable. While

onset clusters are not allowed in languages like Korean and Japanese, they are allowed in English. For instance, diverse stop+liquid onset sequences are permissible in the word-initial position in English (e.g., *pl, pr, bl, br, tr, dr, kl, kr, gl, gr*). However, the sequences of *tl* and *dl* are not licit word-initial onsets. Consequently, it is frequently reported that native English speakers perceptually remedy English illicit onsets so as to make them legal ones (e.g., */tl/ as [tr], Pitt, 1998).

However, listeners' perception of onset clusters is also known to be modulated by the sonority contours of the onsets. Sonority is the energy of the pulses in air stream which is manifested as relative loudness of a sound (Giegerich, 1992). Stops are considered less sonorous than (or as sonorous as) fricatives, which are in turn less sonorous than nasals. Further, nasals are less sonorous than liquids (Clements, 1990, 2006; Vennemann, 1988). Universally, syllable structures are governed by the Sonority Sequencing Principle in which sonority contours rise from the onset to the syllable peak (i.e., nucleus) and fall or remain flat from the nucleus to the coda (Clements, 1990). Several experimental studies report that the Sonority Sequencing Principle, especially onset sonority, plays an important role in speech perception. More specifically, it was found that onsets of sonority falls create more perceptual vowel illusion (e.g., *rdif* as [rədɪf]) than onsets of sonority plateaus (e.g., *dbif* as [dəbɪf]) and rises (*dlif* as [dəlɪf]) in order (Berent, Steriade, Lennertz, & Vaknin-Nusbaun, 2007; Berent, Lennertz, Jun, Moreno, & Smolensky, 2008; Berent, Lennertz, Smolensky, & Vaknin-Nusbaun, 2009; Lee, 2011, 2012).

Besides, an unstressed schwa in English can optionally be deleted as in *support* [spɔrt][1] and *select* [slɛkt] (Patterson, LoCasto, & Connine, 2003). Because of schwa deletion, *s*C onsets of sonority falls/plateaus and rises can emerge in English (e.g., *supply* [**sp**laɪ], *semantic* [**sm**æntɪk], *select* [slɛkt]). However, *s*C onsets have been treated as an exception since /s/+stop sequences violate the Sonority Sequencing Principle in that the fricative /s/ is more sonorous than (or as sonorous as) the following stops (/p, t, k/).[1] Assuming that /s/+stop onsets are true clusters, they are expected to create much perceptual difficulty due to their falling/level sonority compared to /s/+nasal/liquid onsets with rising sonority contours.

Unlike the perception of other onset clusters, however, few studies have investigated the perception of *s*C onsets derived from schwa deletion by different L1 speakers. Thus, the study explored the perception of English

[1] Because *s*C onsets violate the Sonority Sequencing Principle, some scholars treat /s/ in the onset as an adjunct (Davis, 1990; Kenstowicz, 1994) or as an appendix (Selkirk, 1982).

*s*C onsets created by schwa deletion to investigate whether they show similar perceptual patterns to other onsets with respect to the predictions of onset sonority or whether they behave as an exception, not following the predictions of onset sonority. Namely, onset sonority would predict that *s*C onsets with a big sonority rise (i.e., /s/+liquids) should be perceived more accurately than *s*C onsets with a small sonority rise (i.e., /s/+nasals), which in turn should be perceived more accurately than onsets of a sonority fall/plateau (i.e., /s/+stops). In order to test the predictions, *s*C onsets of sonority falls/plateaus and rises resulting from schwa deletion were examined by 3 different L1 speakers (English, Korean, and Japanese) in syllable judgment and discrimination tests. Participants from the 3 language groups were recruited because Korean and Japanese do not tolerate onset or coda clusters unlike English.

EXPERIMENT 1: SYLLABLE JUDGMENT TEST

Participants

Participants were 22 English speakers, 31 Korean speakers, and 16 Japanese speakers. English speakers were either exchange students or English instructors recruited from several universities in the Seoul Metropolitan area. Their mean age was 28.2 years. Korean speakers were all undergraduate students (mean age: 22.1) who were taking *English phonetics and phonology* at the same university in Seoul when the experiments were conducted. They self-evaluated their English proficiency as being high-intermediate or advanced. In addition, the researchers assessed the participants' English skills as such through assessments in class. Japanese speakers were mostly short-term exchange students (mean age: 23) recruited from two universities in Seoul. Their self-evaluated English proficiency was at the low or low-intermediate level and the researchers also interviewed Japanese participants and assessed their English skills as such.

Stimuli

There were 28 stimuli consisted of both real and nonce words. Specifically, there were 12 real words, half of them was schwa-intact words and the other half was schwa-deleted words. Similarly, there were 16 nonce words consisted of 8 schwa-intact and schwa-deleted words each. Importantly, schwa-deleted words/nonce words, which were constructed by schwa

deletion from their schwa-intact counterparts, were made up of /s/+stop, nasal, or liquid sequences, that is, word-initial sequences of a sonority fall/level, a small sonority rise, or a big sonority rise, as given in Table 1.

Table 1. Stimuli used in the syllable judgment test

Real vs. nonce	Types	Schwa-intact	Schwa-deleted
Real words	/s/+stop	supply, support	[**sp**laɪ], [**sp**ɔ:rt]
	/s/+nasal	semantic, semester	[**sm**æntɪk], [**sm**ɛstər]
	/s/+liquid	saloon, select	[**sl**un], [**sl**ɛkt]
Nonce words	/s/+stop	sekkose [səkoʊz]	[**sk**oʊz]
		saccort [səkɔ:rt]	[**sk**ɔ:rt]
	/s/+nasal	samine [səmaɪn]	[**sm**aɪn]
		semect [səmɛkt]	[**sm**ɛkt]
		senocious [sənoʊʃəs]	[**sn**oʊʃəs]
		sonenzic [sənɛnzɪk]	[**sn**ɛnzɪk]
	/s/+liquid	selantic [səlæntɪk]	[**sl**æntɪk]
		selester [səlɛstər]	[**sl**ɛstər]

Procedure

The experiment was run with E-prime 2.0 and the participants were asked to indicate the syllable number(s) of the stimulus words they heard by stroking the keys 1, 2, or 3. Inter-stimulus intervals were 1000ms.

Results

Results of Real Words. First, let us examine the results of schwa-intact words. The differences in response accuracy among 3 language groups (English, Korean, and Japanese) were examined in terms of /sə/+stop/nasal/liquid sequence types. The mean accuracy of schwa-intact real words is summarized in Table 2.[2]

Table 2. Mean accuracy of schwa-intact real words

Type / L1	/sə/+stop	/sə/+nasal	/sə/+liquid
English	97.7%	93.2%	95.5%
Korean	88.7%	82.3%	69.4%
Japanese	65.6%	68.8%	65.6%
Total mean	84.0%	81.4%	76.8%

[2] The *sC* cluster data are part of the data presented in Lee (2011, 2012). However, the *sC* clusters were not separately analyzed in Lee (2011, 2012).

As shown in Table 2, English speakers did not show any difficulty perceiving schwa-intact words regardless of sequence types. By contrast, Korean speakers' performance on /sə/+liquid sequences was poor compared to that of English speakers. Japanese speakers also had overall difficulties perceiving /sə/+stop/nasal/liquid sequences. The different results could be due to the participants' different L1s and also due to Japanese speakers' overall low English proficiency.

Because the perception of schwa-deleted forms is our main interest, let us turn to schwa-deleted /s/+stop/nasal/liquid sequences. Unlike schwa-intact words, the participants showed much difficulty correctly indicating the syllable number(s) of schwa-deleted words, as shown in Table 3. Specifically, schwa-deleted /s/+stop sequences caused great difficulty to the English speakers (47.7%).[3] English speakers also had difficulty perceiving /s/+nasal and /s/+liquid clusters relative to schwa-intact forms: /s/+nasal (77.3%) and /s/+liquid (84.1%). The results support the predictions of onset sonority or onset markedness in which onsets of a big rising sonority (/s/+liquids) are expected to be perceived more accurately than onsets of a small rising sonority (/s/+nasals/) and onsets of a falling/level sonority (/s/+stops) in order.

Table 3. Mean accuracy of schwa-deleted real words

Type / L1	/s/+stop	/s/+nasal	/s/+liquid
English	47.7%	77.3%	84.1%
Korean	53.2%	62.9%	75.8%
Japanese	59.4%	46.9%	46.9%
Total mean	53.4%	62.4%	68.9%

As for Korean speakers, their overall performance was poor. However, /s/+stop onsets caused more trouble to the Korean speakers than /s/+nasal and /s/+liquid sequences in order, similar to the results of English speakers. In contrast, Japanese speakers had more trouble correctly indicating the syllable numbers(s) of /s/+nasal/liquid sequences than that

[3] This may partly be ascribable to the fact that native speakers of English could have been confused between *support* and *sport*, even though they are known to distinguish between the two items in terms of differences in the degree of aspiration of the stop sound [p]; the [p] in *spport* [**sp**ɔ:rt] where the schwa deleted form is aspirated while the [p] in *sport* is not or very weakly aspirated.

(those) of the /s/+stop sequences, which is not consistent with the assumptions of onset sonority.

The results were submitted to a repeated-measures ANOVA with language groups as a between-subjects factor and cluster types as a within-subjects factor. The ANOVA reveals a significant main effect of cluster types ($F(2, 132)=3.819$, $p<.05$) but no main effect of language groups ($F(2, 66)=2.540$, $p=.087$). However, there was an interaction between cluster types and language groups ($F(4, 132)=3.380$, $p<.05$). This result demonstrates that English and Korean speakers' perception of *s*C clusters supports the predictions of onset sonority while Japanese speakers showed a somewhat different pattern because they performed better on /s/+stop clusters than on /s/+nasal/liquid sequences. This could be attributed to the fact that Japanese speakers were familiar with the stimulus words *support* and *supply* so that they may have been more accurate in perceiving the stimuli (and their corresponding schwa-deleted words) than /sə/+nasal/liquid sequenced words such as *semantic* and *saloon* (and their corresponding schwa-deleted words).[4] To sum up, the predictions of onset sonority were borne out only for English and Korean speakers and L1 effect was also partly attested for schwa-deleted words.

Results of Nonce Words. Regarding the result of schwa-intact nonce words, English speakers showed a little difficulty perceiving nonce words given the lower accuracy compared to real words, as given in Table 4. Korean speakers also showed difficulty perceiving schwa-intact nonce words and their performance was overall worse than that of English speakers. As for Japanese speakers, their overall performance was comparable to that of schwa-intact real words.[5] This is different from the pattern emerged by English and Korean speakers as their mean accuracy of real words was higher than that of nonce words.

[4] A word-familiarity test was administered to Korean and Japanese speakers after the main tests. The word-familiarity test showed that the Japanese speakers overall rated *semantic* and *saloon* as being less familiar than *support* and *supply*.

[5] This might be due to the fact that Japanese participants preferred schwa-intact forms to schwa-deleted ones because of their more limited L1 syllable structures, which favor the CV forms.

Table 4. Mean accuracy of schwa-intact nonce words

Type / L1	/sə/+stop	/sə/+nasal	/sə/+liquid
English	86.4%	85.2%	81.8%
Korean	61.3%	63.7%	74.2%
Japanese	78.1%	71.9%	71.9%
Total mean	75.3%	73.6%	76.0%

Regarding Korean speakers' better performance on /sə/+liquid sequences than on /sə/+stop/nasal sequences, it might be attributed to stimuli effects. That is, /sə/+liquid sequenced nonce words sounded more like English words and this could have resulted in higher accuracy of these nonce words compared to the accuracy of /sə/+stop/nasal sequenced nonce words. Further, Japanese speakers performed better than Korean speakers and this could be ascribable to the fact that Japanese speakers' overall English proficiency was low compared to that of Korean speakers and thus Japanese speakers may not have shown much difference in accuracy between real and nonce words.

As for the results of schwa-deleted nonce words, the overall mean accuracy was no less than that of schwa-intact forms, as shown in Table 5. Specifically, /s/+stop sequences caused more difficulty to English speakers than /s/+nasal sequences, which conforms the prediction of onset sonority. However, the prediction of onset markedness was not borne out when the /s/+stop sequences were compared with the /s/+liquid sequences because there was not much difference in mean accuracy between the two types of the clusters. In addition, English speakers performed better on the schwa-deleted nonce words than on the schwa-deleted real words. This can be attributed to the word effect in which nonce words behaved differently from real words.

Table 5. Mean accuracy of schwa-deleted nonce words

Type / L1	/s/+stop	/s/+nasal	/s/+liquid
English	84.1%	92.0%	81.8%
Korean	71.0%	88.7%	72.6%
Japanese	53.1%	60.9%	71.9%
Total mean	69.4%	80.6%	75.4%

Korean speakers' perceptual pattern was similar to that of English speakers. English and Korean speakers' performance pattern could partly be ascribable to the fact that schwa and its following nasal are better coarticulated than any other sequences of sounds (Peperkamp, 2007). Consequently, the deletion of schwa could have resulted in the weakening of nasal cues, thus leading to rather higher accuracy. Japanese speakers' overall performance was poor compared to that of English and Korean speakers, but their perceptual pattern was consistent with the assumptions of onset sonority.

The ANOVA on the mean accuracy revealed a marginal effect of cluster types ($F(2, 132)= 2.815$, $p=.067$) but no interaction between cluster types and language groups ($F(4, 132)= 1.664$, $p>.05$). However, there was an L1 effect ($F(2, 66)=5.403$, $p<.05$) since Japanese speakers had much difficulty perceiving schwa-deleted forms compared to English speakers. The marginal effect of cluster types was due to the higher mean accuracy of /s/+nasal sequences compared to /s/+stop sequences. Consequently, the prediction of onset sonority is partly supported for schwa-deleted nonce words in that /s/+nasal sequences with a small sonority rise were perceived better than /s/+stop sequences with a sonority fall/plateau.

EXPERIMENT 2: DISCRIMINATION TEST

Participants

Participants were 22 English speakers, 32 Korean speakers, and 20 Japanese speakers. The participants were recruited from the same university (universities) as in the syllable judgment test. Korean speakers' and Japanese speakers' English proficiency levels were comparable to those of the participants in the syllable judgment test.

Stimuli

The stimuli were the same as in the syllable judgment test. However, there were 28 identical and non-identical pairs each in the discrimination test. Sample stimuli are provided in Table 6.

Table 6. Sample stimuli used in the discrimination test

Real vs. nonce	Types	Identical	Non-identical
Real words (total 24 words)	/s/+stop	supply-supply, spply-spply	supply-spply spply-supply
	/s/+nasal	semantic-semantic smantic-smantic	semantic-smantic smantic-semantic
	/s/+liquid	saloon-saloon sloon-sloon	saloon-sloon sloon-saloon
Nonce words (total 32 words)	/s/+stop	sekkose-sekkose skkose-skkose	sekkose-skkose skkose-sekkose
	/s/+nasal	samine-samine smine-smine senocious-senocious snocious-snocious	samine-smine smine-samine senocious-snocious snocious-senocious
	/s/+liquid	selantic-selantic slantic-slantic	selantic-slantic slantic-selantic

Procedure

The discrimination test was conducted with E-prime 2.0. The participants were asked to stroke the key 1 if the stimuli they heard were the same and to press the key 2 if the stimuli were different. Inter-stimulus intervals were 1000ms as in the syllable judgment test.

Results

Results of Real Words. As for the identical pairs, English speakers identified /s/+ or /sə/+nasal/liquid sequences slightly better than /s/+ or /sə/+stop sequences. Korean and Japanese speakers also showed the same pattern in that /s/+ or /sə/+nasal/liquid sequences elicited more accurate responses than /s/+ or /sə/+stop sequences.

Table 7. Mean accuracy of identical pairs: Real words

Type / L1	/s/+ or /sə/+stop	/s/+ or /sə/+nasal	/s/+ or /sə/+liquid
English	85.2%	92.1%	87.5%
Korean	90.4%	93.0%	92.2%
Japanese	72.5%	86.3%	87.5%
Total mean	82.8%	90.4%	89.1%

However, as our main concern in the paper is the mean accuracy of non-identical pairs, let us examine the results of non-identical pairs. English speakers showed slightly higher accuracy for /s, sə/+stop sequences than /s, sə/+nasal sequences. However, /s, sə/+liquid sequences elicited slightly more accurate responses than /s, sə/+stop sequences, as shown in Table 8. Consequently, the results of /s, sə/+stop/nasal/liquid sequences were only partly supportive of onset sonority.

Table 8. Mean accuracy of non-identical pairs: Real words

Type / L1	/s, sə/+stop	/s, sə /+nasal	/s, sə/+liquid
English	77.2%	73.9%	79.6%
Korean	71.9%	67.2%	55.5%
Japanese	65.0%	25.0%	45.0%
Total mean	71.4%	55.4%	60.0%

Unlike the results of English speakers, Korean speakers' responses to /s, sə/+stop sequences were more accurate than their responses to /s, sə/+nasal sequences, which were in turn more accurate than those of /s, sə/+liquid sequences. The results of Korean speakers were not in conformity with the predictions of onset markedness. As for Japanese speakers' perceptual patterns, they perceived /s, sə/+stop sequences much better than /s, sə/+liquid and /s, sə/+nasal sequences in order, which did not support the assumptions of onset sonority.

To find out whether the mean accuracy was influenced by cluster types as well as language groups, an ANOVA was conducted. The results showed that there were main effects of cluster types ($F(2, 142)=8.369$, $p=.001$) and language groups ($F(2, 71)=15.820$, $p<.001$). The interaction between cluster types and language groups was also statistically significant ($F(4, 142)=5.476$, $p<.001$). The effect of the cluster types was due to the fact that the mean accuracy of /s, sə/+stop sequences was significantly higher than that of /s, sə/+nasal/liquid sequences. The interaction and L1 effects were due to the fact that Japanese (and Korean) speakers showed a great difference in mean accuracy between the cluster types in that /s, sə/+stop sequences were identified more accurately than /s, sə/+nasal/liquid sequences whereas English speakers showed a less degree of mean difference between the cluster types.

The result of the non-identical pairs for real words is the opposite of the result that was obtained in the syllable judgment test for real words. The different results obtained between the syllable judgment and discrimination tests may be ascribable to task effects. That is, unlike syllable judgment, discrimination test was known to be related to the low-level auditory processing (Strange & Shafer, 2008). The next question to be addressed is why /s, sə/+stop sequences were better perceived than /s, sə/+nasal and liquid sequences, especially by Korean and Japanese speakers. According to Peperkamp (2007), the perception of schwa plus nasal sequences tends to be challenging because they are more likely to be coarticulated than any other sequences, as mentioned earlier. As a result, Korean and Japanese speakers could have had more difficulty identifying /s, sə/+nasal clusters than /s, sə/+stop sequences and thus the interaction of language groups and cluster types emerged. Additionally, identical pairs elicited higher accuracy rates than non-identical pairs across cluster types and language groups.

Results of Nonce Words. Concerning the results of identical pairs, English speakers did not show any difference in mean accuracy among the cluster types. Korean speakers also seemed not to have much difficulty perceiving the target sequences. Japanese speakers, however, showed a little different pattern from English and Korean speakers because their mean accuracy of /s/+ or /sə/+nasal/liquid sequences was higher than that of /s/+ or /sə/+stop sequences, as given in Table 9.

Table 9. Mean accuracy of identical pairs: Nonce words

Type / L1	/s/+ or /sə/+stop	/s/+ or /sə/+nasal	/s/+ or /sə/+liquid
English	88.6%	87.5%	88.6%
Korean	94.5%	87.1%	96.9%
Japanese	76.3%	85.0%	87.5%
Total mean	86.5%	86.5%	91.0%

Similar to real words, our main interest in the paper is the perception of non-identical pairs. Thus, let us turn to the results of non-identical pairs. English speakers perceived /s, sə/+nasal sequences more accurately than /s, sə/+stop sequences. However, their mean accuracy of /s, sə/+liquid sequences was lower than /s, sə/+stop sequences. Korean speakers showed a similar pattern to English speakers. Accordingly, English speakers' and

Korean speakers' patterns follow sonority preferences for onsets only for /s, sə/+stop and /s, sə/+nasal sequences. Interestingly, however, Japanese speakers showed a reverse pattern since their mean accuracy of /s, sə/+stop sequences was higher than that of /s, sə/+nasal sequences, even though /s, sə/+liquid sequences were perceived better than /s, sə/+nasal sequences, as shown in Table 10. Consequently, Japanese speakers' pattern did not support sonority preferences for onset clusters, especially with respect to /s, sə/+stop/nasal sequences and /s, sə/+stop/liquid sequences, but their patterns are similar to those of real words.

Table 10. Mean accuracy of non-identical pairs: Nonce words

Type / L1	/s, sə/+stop	/s, sə /+nasal	/s, sə/+liquid
English	79.6%	88.1%	73.9%
Korean	66.4%	73.8%	51.6%
Japanese	61.3%	36.3%	45.0%
Total mean	69.1%	66.0%	56.8%

The ANOVA revealed a significant main effect of cluster types ($F(1.79, 126.85)=6.522$, $p<.05$) because the participants' perception of /s, sə/+liquid sequences was relatively poor compared to that of other sequences. The effect of language groups was also significant ($F(2, 71)=13.472$, $p<.001$) as well as the interaction between the cluster types and language groups ($F(3.57, 126.85)=5.502$, $p=.001$). The interaction was due to the fact that Korean speakers' perception of /s, sə/+ liquid sequences was rather poor whereas Japanese speakers showed the most difficulty perceiving /s, sə/+nasal sequences. Further, similar to the results of real words, identical pairs elicited higher mean accuracy than non-identical pairs.

CONCLUSION

To summarize the results, in the syllable judgment test, the effect of onset sonority tended to be witnessed for the schwa-deleted real and nonce words. This supports the predictions of onset sonority, even though Japanese speakers performed better on the /s/+stop sequences for real words. Also, in the discrimination test, the predictions of onset sonority were only partly confirmed for the non-identical pairs of nonce words for English and Korean speakers. Therefore, the results from the syllable judgment and discrimination tests indicate that the onset sonority

principle seems to be at least partly at work, although the results were affected by several other factors. That is, the fact that onset markendness tended to be supported in the syllable judgment test, especially by English and Korean speakers, but that it was only partly supported in the discrimination test seems to suggest that the overall results should in part be ascribable to task effects in addition to onset sonority. Further, the results indicated that the perceptual patterns were influenced by the participants' L1s given that English speakers performed better than Korean or Japanese speakers. In addition, the better performance of Korean speakers relative to Japanese speakers seems to suggest that the participants' English proficiency plays a role to some degree in accounting for the emerged perceptual patterns, given that Japanese speakers' overall English proficiency was low compared to Korean speakers' English proficiency.

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