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Acoustic matching and phonotactic expectations in the adaptation of English /s/ into Korean*

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Zhang, Xinyi, Yun Jung Kim, and Mira Oh. 2023. Acoustic matching and phonotactic expectations in the adaptation of English /s/ into Korean. *Linguistic Research* 40(3): 509-532. This study aims to demonstrate that the adaptation of loanwords cannot be solely explained by speech perception. Specifically, it focuses on the adaptation of the English /s/ sound into Korean. In English, a singleton /s/ is loaned as tense [s*], while a preconsonantal /s/ is adapted as lenis [s] in Korean. Kim and Curtis (2002) and Kang (2008) provided an acoustic cue-based analysis for the adaptation of English /s/, considering duration and voice quality, respectively. To investigate the perception of English /s/ by Korean listeners, we conducted a perception experiment. We examined the impact of prosodic factors, such as domain-edge position and lexical stress, on the perception of /s/. Our findings revealed diverse perception patterns depending on stress and position within a word. Specifically, /s/ in a stressed syllable and /s/ in a word-edge position were more likely to be perceived as tense [s*]. Contrary to Kim and Curtis (2002), the duration of English /s/ alone was insufficient to explain perception patterns. Based on our varied perception patterns, we argue that categorical adaptation of the singleton /s/ as tense [s*] and the preconsonantal /s/ as lenis [s] does not solely reflect speech perception. Instead, we propose that loanword adaptation is a process driven by top-down/phonotactic expectations and acoustic matching, with the goal of maximizing perceptual similarity between the source word and the loanword. This is consistent with the findings of Daland et al. (2019). (**Emory University · Chonnam National University**)

Keywords   loanword adaptation, English /s/, lenis /s/, tense /s*/, Korean, perceptual similarity

1. Introduction

Focusing on the adaptation of the English /s/ sound into Korean, this study aims to demonstrate that the adaptation of loanwords cannot be explained by speech perception alone. Borrowers are introduced to unfamiliar forms from the source language as input and they produce loanwords as output after adapting the input to fit their own sound system. Two main theories have been proposed to explain the extent to which input information is taken into consideration. The phonological account of loanword adaptation suggests that bilingual borrowers have access to the phonemic inventory of the source language, and a source phoneme should always be mapped to the same borrowing sound (Hyman 1970; Danesi 1985; Paradis and LaCharité 1997). In English and Mandarin Chinese (MC), both languages have unaspirated voiceless stops (e.g., [k]) and aspirated stops (e.g., [kʰ]). However, the status of these two sounds differs in English and Mandarin Chinese. The unaspirated [k] and aspirated [kʰ] are different allophones for the phoneme /k/ in English, while in Mandarin Chinese, they are separate phonemes. English voiceless stops are mapped to aspirated stops in Mandarin Chinese, regardless of whether they are aspirated or unaspirated. For example, English *pie* becomes MC [pʰai], and English *Scott* becomes MC [sɹ̩.kʰɤ.tʰɤ] (Miao 2005). The adaptation of English voiceless stops into Korean follows a similar pattern, where both aspirated and unaspirated stops in English are uniformly mapped to aspirated stops in Korean. For instance, English *pie* becomes Korean [pʰai], and English *spy* becomes Korean [sipʰai] (Oh 1996). The phonological perspective can explain the adaptation pattern of English voiceless stops into both Mandarin Chinese and Korean, as both languages loan both aspirated and unaspirated stops as a single stop.

The perceptual stance on loanword adaptation suggests that borrowers are sensitive to subphonemic acoustic cues of the source sound. A source sound can be adapted as more than one borrower sound (Silverman 1992; Peperkamp and Dupoux 2002). For example, the word-final voiceless stops in English are variably adapted in three different ways: as an aspirated stop followed by an epenthetic vowel, as in 'peak' [pʰikʰɨ] <피크>, 'week' [wikʰɨ] <위크>; as variable vowel epenthesis, as in 'jeep' [čip]~[čipʰɨ] <짚~지프>, 'cake' [kʰeik] ~ [kʰeikʰɨ] <케익~케이크>; or with no vowel epenthesis, as in 'kick' [kʰik] <킥>, 'back' [pek] <백>, 'pack' [pʰek] <팩>.

Kang (2003) explains these varied adaptations in terms of phonetic variation in the source words. She claims that the likelihood of an audible release burst was strongly

correlated with the presence of an epenthetic vowel in the adapted form. However, she only indirectly tested the correlation between a release burst and vowel epenthesis by comparing the TIMIT corpus and loanword corpus published by National Academy of Korean Language. On the other hand, Daland et al. (2019) clearly show that when Korean adapters hear a [+noisy] consonant, they are strongly biased to perceive a following vowel if there is not one there already by conducting a discrimination experiment. This finding is consistent with Kang's (2003) conclusions regarding the role of release bursts in the adaptation of English word-final stops. However, varied adaptation of word-final stops into Korean is not consistent with the phonological view in that English word-final stops are not consistently mapped to a single borrower sound.

The adaptation of English /s/ into Korean provides another example supporting the perceptual view. English has one alveolar voiceless fricative phoneme, /s/, while Korean has lenis /s/ (e.g., /sal/ 'skin') and tense /s*/ (e.g., /s*al/ 'rice'). A singleton /s/ is almost always adapted to Korean tense /s*/ as in 'song' [s*oŋ] <쏭>, and /s/ originating from a cluster is adapted as lenis /s/ as in 'star' [sitʰa] <스타>. Kim and Curtis (2002) argue that the adaptation of English /s/ is primarily driven by perception, as Korean listeners perceive a long singleton /s/ as tense [s*] and a short /s/ in a cluster as lenis [s]. These one-to-many mappings between English /s/ and Korean /s*/ and /s/ support the perceptual approach.

In this paper, we raise a question about whether the analysis based solely on speech perception can fully explain the adaptation of English /s/ into Korean. The speech perception-only analysis assumes that loanword adaptation patterns are essentially the same as the perception results of Korean listeners. In other words, it predicts that the way Korean listeners perceive English /s/ will be the same as how English /s/ is loaned, either lenis [s] or tense [s*]. We will challenge the speech perception-only analysis by conducting a perception experiment.

The paper begins with a literature review in section 2, discussing how the adaptation of English /s/ into Korean has been analyzed within the perceptual approach. It also examines the analysis of phonotactic expectations and mere acoustic matching for loanword adaptation. In section 3, we will investigate if inter-language mapping crucially involves stress and the position of English /s/ within a word, using a perception experiment. The results will demonstrate that the adaptation of English /s/ into Korean cannot be fully explained by speech perception alone. In section 4, we propose that loanword adaptation integrates top-down phonotactic likelihood and bottom-up acoustic

matching, following Daland et al. (2019). Section 5 concludes the paper with a summary and suggestions for future research.

2. Background for the adaptation of English /s/ into Korean

English /s/ is borrowed into Korean as either lenis [s] or tense [s*]. Similar to the varied adaptation of word-final stops, the adaptation of English /s/ in Korean is not consistent with the phonological perspective. English /s/ is not uniformly borrowed as a single sound. Instead, the adaptation of English /s/ in Korean is primarily driven by perception. However, previous studies on the adaptation of English /s/ in Korean disagree on the underlying reasons behind these mappings.

Kim and Curtis (2002) and Kang (2008) argue that the presence of acoustic cues plays a significant role in the adaptation of English /s/. However, they differ in which acoustic cues are employed by Korean speakers. Kim and Curtis (2002) propose that duration of the fricative is the main factor determining the adaptation pattern. Through production and perception experiments, they suggest that the singleton /s/ is longer than /s/ in a consonant cluster in word-initial and word-final positions. They argue that the long /s/ is perceived as tense /s*/ because tense /s*/ is longer than lenis /s/ in Korean (Kagaya 1974; Cho et al. 2002).

In contrast, Kang (2008) challenges the duration-based account and argues that voice quality is the determining factor in the adaptation of English /s/. She argues that the duration of English /s/ does not significantly differ based on the following segment and therefore cannot be a reliable cue. She notes that /s/ in a stressed syllable is longer than /s/ in an unstressed syllable (e.g., s'VC vs. sVC). However, she claims that stress is not a reliable cue since prevocalic /s/ is adapted as tense /s*/ regardless of the stress pattern (e.g., 'sálary' [s*ɛllʌri] vs. 'cerámic' [s*eramik]). She proposes that the voice quality, especially the H1-H2 values, is a more stable cue for listeners. She points out that the H1-H2 values of the vowel following /s*/ in Korean are comparable to the voice quality of the post-/s/ vowel in English (Ahn 1999).

However, Kang's (2008) voice quality-based analysis fails to explain the adaptation of preconsonantal /s/ and the word-final /s/ in terms of voice quality, as they are not followed by a vowel. Specifically, it does not account for why the word-initial /s/ in 'star' is adapted as lenis [s] ([sitʰa]) since the preconsonantal /s/ lacks H1-H2 values.

Kang attributes the adaptation of the preconsonantal /s/ as lenis /s/ to the devoicing of the epenthetic vowel [ɨ] after [s] but not after [s*]. In other words, the preconsonantal /s/ in English is adapted as lenis /s/ in Korean because loanwords with lenis /s/ trigger devoicing of the epenthetic vowel [ɨ], making them more perceptually similar to the source sound without any vowel after /s/. Kang's voice quality-based analysis also fails to explain the adaptation of word-final /s/ in terms of voice quality. Instead, she relies on the duration of /s/ to account for the adaptation of the word-final /s/ as tense /s*/ (e.g., 'bus' [pʌs*ɨ]). This is based on the fact that word-final /s/ lacks H1-H2 values but is long enough to be perceived as [s*]. Therefore, while both the preconsonantal /s/ and the word-final /s/ are rescued by the same epenthetic vowel [ɨ] to satisfy the syllable structure of Korean, their adaptation is explained differently: the former by devoicing of the epenthetic vowel and the latter by the duration of /s/.

Previous analyses based on acoustic cues have only examined a limited set of stimuli. Kim and Curtis (2002) argued that duration of /s/ plays a pivotal role in perceiving English /s/ as either Korean /s/ or /s*/. However, their study only focused on singleton [s] and [s] in an [st] cluster in monosyllabic word-initial position (e.g., sack vs. stack). It is not clear if the duration of /s/ in other contexts differ as much as predicted by the duration-based account of the adaptation pattern. Kang (2008) suggested that stress and word length affect /s/ duration in English. She compared durations of stressed and unstressed word-initial /s/ in bi-syllabic words (sV′CVC and sVCV′C). Additionally, she reported that word length affects the duration of /s/, with word-initial /s/ in monosyllabic words being significantly longer than in bi-syllabic or tri-syllabic words. Both analyses only examined English /s/ in word-initial position.

Neither the duration-based nor the voice quality-based analyses considered stress as a factor in determining the loan sound for English /s/. The stimuli in Kim and Curtis (2002) consisted exclusively of mono-syllabic words, which means they were all stressed. Kang (2008) showed that both singleton /s/ and preconsonantal /s/ in a stressed syllable are significantly longer than their counterparts in an unstressed syllable. However, she refuted the stress-based account for the adaptation of /s/ since both singleton /s/ in an unstressed syllable and singleton /s/ in a stressed syllable are loaned as tense /s*/ (e.g., 'sálary' [s*ellʌri] and 'cerámic' [s*eramik]).

Previous studies report that the average duration of tense /s*/ is longer than that of lenis /s/ in Korean (Cho et al. 2002). Preconsonantal /s/ is shorter than a singleton /s/ in English (Kim and Curtis 2002). Segments in the stressed syllable are usually longer

and louder (Fant et al. 1990). Based on these facts, we can hypothesize that a singleton /s/ in a stressed syllable will be perceived as tense /s*/, while /s/ in an unstressed syllable will be perceived as lenis /s/. The position of /s/ within a source word (e.g., the word-initial vs. word-medial position) can also influence the adaptation of English /s/. Perceptually or psycho-linguistically prominent positions such as the word-initial and word-final syllables may have positional privilege (Beckman 1998). In Kang's (2008) study, the stress-based account for the adaptation of /s/ was disputed because singleton /s/ in an unstressed syllable is also loaned as tense [s*], as in 'cerámic' [s*eramik]. However, the /s/ in 'cerámic' is placed in word-initial position, even though it is unstressed. Therefore, the position of /s/ within a word needs to be considered to understand the perceptual pattern. To date, there has been no investigation into how much stress and position within a word condition Koreans' perception of English /s/. The current study aims to test if inter-language mapping crucially refers to stress and the position within a word by conducting a perception experiment.

Daland et al.'s (2019) study supported that vowel epenthesis is mainly driven by perception in the adaptation of word-final stops. It also reported that Koreans' perceptual similarity judgements do not directly align with the adaptation patterns. In Korean, a sequence of stop-nasal consonants is not allowed and undergoes nasal assimilation, e.g., /kuk-min/ [kuŋmin] 'people'. However, when borrowing the English word 'picnic', the medial stop-nasal cluster, /kn/, is repaired by vowel epenthesis between the stop and the nasal sound to satisfy the phonotactic constraint in Korean: [pʰikʰinik] *[pʰiŋnik]. Daland et al. (2019) investigated if the epenthetic vowel in [pʰikʰinik] originates from speech perception. They found that Korean listeners did not identify the loanword/epenthetic repair as the most perceptually similar to the illegal source form, as determined by conducting an ABX identification experiment assessing Korean listeners' perceptual similarity. Korean listeners identified [pʰaŋna] as opposed to [pʰakʰina] as the most perceptually similar to /pakna/. Therefore, loanword adaptation cannot solely reflect speech perception. Based on the adaptation pattern for a sequence of stop-nasal consonants into Korean, Daland et al. (2019) proposed an analysis of top-down/phonotactic expectations as well as acoustic matching for loanword adaptation. The current study will investigate if the adaptation of English /s/ into Korean can be explained by speech perception alone.

In summary, the present study investigates how perceptual patterns for English /s/ vary as a function of prosodic factors (domain-edge position and lexical stress) to

understand the extent to which the perception of English /s/ by Korean listeners reflects the Korean loanword adaptation patterns. Furthermore, it will discuss the relationship between speech perception and loanword adaptation.

3. Perception experiment

3.1 Methods

Eleven people (6 female and 5 male) participated in the perception experiment. All participants are native speakers of Korean who have been living or studying in America for at least one year. Nine of them are American college students who meet the English admission requirements for top colleges. The remaining participants are working-age adults, with one speaking English at the workplace and the other having English proficiency below the conversational level.

The purpose of this perception experiment is to investigate the effects of two prosodic factors, namely lexical stress (stressed vs. unstressed) and prosodic position (word-initial, -medial and -final), on the perceptual patterns of English /s/. The stimuli consisted of 18 trisyllabic nonce English words (CV.CV.CV), with one syllable containing [s]/[sC]. The nonce words were used to eliminate any potential influence of the existing orthographic effect. These nonce words were accidental gaps in the language. They are phonotactically legal words and considered natural English words by native speakers. The lexical stress and position of this syllable within a word were varied. The test consonants, /s/ and /sC/, appeared in either stressed or unstressed syllables, which were then placed in different positions in a word (word-initial, -medial and -final). Table 1 provides an overview of how these prosodic factors (stress, position) were manipulated across the test words.

Table 1. English stimuli with target consonants /s, sC/

	stressed /s/ or /sC/	unstressed /s/ or /sC/	
sv.cv.cv	sá.la.mi	sa.lá.mi	sa.la.mí
sCv.cv.cv	stá.la.mi	sta.lá.mi	sta.la.mí
cv.sv.cv	la.sá.mi	lá.sa.mi	mi.sa.lá
cv.sCv.sv	la.stá.mi	lá.sta.mi	mi.sta.lá

| cv.cv.sv | la.mi.sá | lá.mi.sa | mi.lá.sa |
| cv.cv.sCv | la.mi.stá | lá.mi.sta | mi.lá.sta |

A female native American English speaker, who was a college junior and unaware of the purpose of the study, recorded all of the stimuli in a linguistics lab at Emory University using Praat (v5.2.16). The recording sampling frequency was 44100 Hz. She repeated each word three times, and the clearest token was chosen for the stimuli for the experiment.

Psychopy (Peirce et al. 2019) was used to associate each of the 18 stimuli with two possible Korean spellings. One spelling contained lenis /s/, while the other contained tense /s*/. Participants listened to the audio while simultaneously seeing the two possible forms on the screen. They were then asked to press on either "1" or "0" on the keyboard to indicate which form they believed was more similar. For example, when listening to lá.sa.mi, the participants would see <lasami> "라사미" and <las*ami> "라싸미" on the screen and would choose one of them.

Figure 1. An example of the displaying of choices in the experiment

To eliminate potential confounding effects from the order of the choice words, the position of the choice word was counterbalanced. Participants were randomly assigned to either condition 1 or condition 2. In condition 1, adaptations with tense /s*/ were presented on the left side, while adaptations with lenis /s/ were presented on the right side; In condition 2, adaptations with lenis /s/ were presented on the left side, while adaptations with tense /s*/ were presented on the right side. Each word was repeated three times in a random order.

This experiment aims to test if the stress-based hypothesis can explain the perception patterns among Korean listeners. We hypothesize that stressed /s/ will be perceived as tense [s*] but unstressed [s] will be perceived as lenis [s]. Additionally, we will

investigate if the position of /s/ influences the responses between tense [s*] and lenis [s]. The z-score was used to compare the percentage of /s/ responses and the percentage of /s*/ responses for each experimental condition (Bobbitt 2020). If a statistically significant difference was found between the two responses, it was interpreted as an indication that participants were more likely to perceive the tokens in that condition as either /s/ or /s*/.

3.2 Results

We will report the singleton /s/ results first. The results for /sC/ will be provided in section 3.2.2.

3.2.1 Perception of singleton /s/

Stress effects
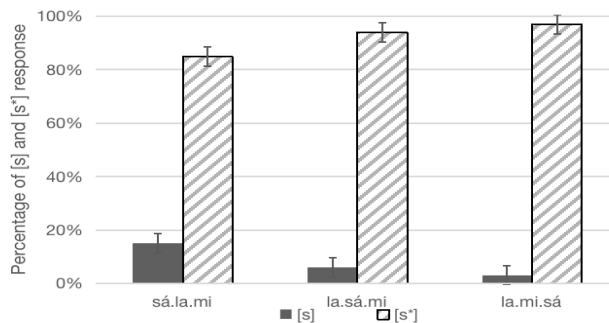We found a strong correlation between the stress and tense /s*/ mapping as shown in Figure 2.

Figure 2. Perception of stressed English [s]

Singleton /s/ in English was perceived as tense /s*/ 92% of the time when it was stressed (śa.la.mi: 85%, z= 3.28, p < 0.01; la.śa.mi: 94%, z= 4.13, p < 0.01; la.mi.śa: 97%, z= 4.41, p < 0.01). A z-score was calculated to compare tense /s*/ vs. lenis /s/ responses. Statistically significant differences were found between the tense /s*/ and lenis /s/ responses in all three positions: word-initial, word-medial, and word-final.

Figure 3 shows that the rate of the tense /s*/ response generally decreases when the
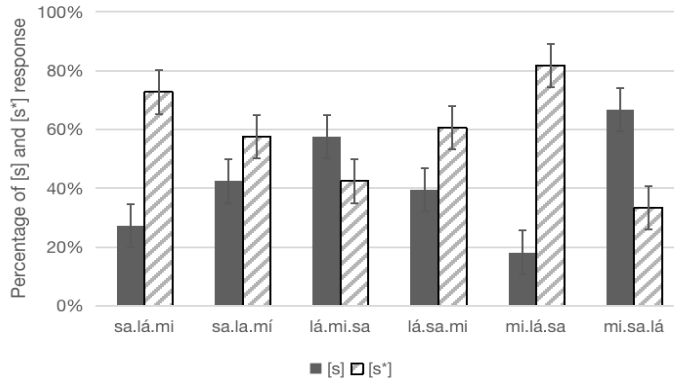
singleton [s] is in an unstressed syllable.

Figure 3. Perception of unstressed English [s]

When English [s] is in the onset of the stressed syllable, it is more likely perceived as tense [s*] (92% on average). In contrast, when English [s] is in the onset of the unstressed syllable, it is less likely to be perceived as tense [s*] (68.5% on average). The perception of [s*] at the onset of a stressed syllable is significantly higher than at the onset of an unstressed syllable (t=2.6119, p=0.0476, df=5). The previous studies by Kim and Curtis (2002) and Kang (2008) cannot explain this difference in the tense [s*] responses between the stressed [s] and the unstressed [s]. According to their predictions, the prevocalic singleton [s] would be uniformly perceived as tense [s*] regardless of stress. However, the results from the perception experiment in this study demonstrate that stress plays a crucial role in how Korean listeners perceive English [s].

On the other hand, a stress-based analysis would suggest that the singleton /s/ in English is more likely to be perceived as lenis [s] when it is unstressed. This expectation is supported by the case of *mi.sa.lá*, where the /s/ was perceived as lenis [s] 67% of the time (z= -1.59, p<0.05). However, there are two cases where the unstressed singleton /s/ is perceived as tense [s*]: *sa.lá.mi*: 73%, z= 4.13, p< 0.05; *mi.lá.sa*: 82%, z= 3, p< 0.001. It is important to note that in these cases, the syllables containing the unstressed singleton /s/ are located at word edge, either word-initial or word-final positions.

In summary, based on the perception results of the singleton /s/ and its relationship with stress, it was found that the singleton /s/ in English is mostly perceived as tense [s*] when it appears at the beginning of a stressed syllable. However, when the singleton

/s/ is in an unstressed syllable, it is not consistently perceived as lenis [s] as predicted by the stress-based analysis. Instead, Korean listeners tend to perceive it as either tense [s*] or lenis [s], depending on its position within a word.

Boundary effects

In the previous subsection, we demonstrated that /s/ in *sa.lá.mi* and *mi.lá.sa* was perceived as more tense [s*] despite being in unstressed syllables. This cannot be explained by the stress-based account, which would expect the unstressed /s/ to be perceived as lenis [s]. Both instances of unstressed /s/ occur at the word-edge position.[1] The positional effect, also known as the word-edge effect, is known to influence segmental duration, with word-initial segments typically being longer and stronger due to initial strengthening (Cho and Keating 2001). Similarly, segments in the final syllables often undergo final lengthening (Cho et al. 2002). This positional faithfulness can account for the enhanced perception of segments at the domain-edge position (Beckman 1998). Figure 4 illustrates that English /s/ in word-edge position is consistently perceived as tense [s*] by Korean listeners, except for *sa.la.mí* and *lá.mi.sa* by Korean listeners.
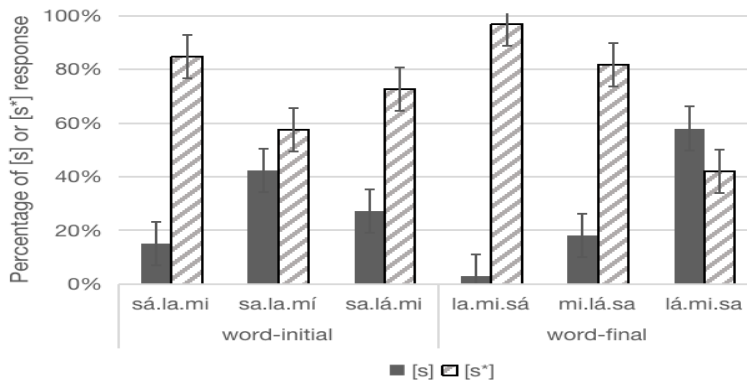

Figure 4. Perception of /s/ at word-edge position

As shown in Figure 4, the singleton /s/ is more likely to be perceived as tense [s*] at the word-edge position irrespective of its stress. In other words, Korean listeners perceive the singleton /s/ significantly more as tense [s*] when it is placed in the

1   /s/ in *mi.lá.sa* is the onset of the word-final syllable. In this paper, "word-edge position" refers to the onset of the word-initial or word-final syllable.

word-edge position. Detailed statistical reports can be found in Table 2.

Table 2. Statistical report for [s*] response percentage at word-edge position

Example word	[s*] response percentage	z-score	p-value
sá.la.mi	85%	3.28	**0.00051
sa.la.mí	58%	0.75	0.23
sa.lá.mi	73%	2.16	*0.02
la.mi.sá	97%	4.408	***0.00001
mi.lá.sa	82%	3.002	**0.00134
lá.mi.sa	42%	-0.75	0.22

To summarize the positional effect on the perception of English /s/, the singleton /s/ is mainly perceived as tense [s*] at word-edge position regardless of whether it belongs to a stressed or unstressed syllable. However, Figure 4 and Table 2 demonstrate that /s/ in *sa.la.mí* and *lá.mi.sa* is perceived either as lenis [s] or tense [s*], even though /s/ in both stimuli belongs to the word-edge syllable. Section 3.2.3 will investigate why /s/ in *sa.la.mí* and *lá.mi.sa* is not mainly perceived as tense [s*] within the Optimality Theoretic framework.

3.2.2 Perception of [sC]

In the previous section, we demonstrated that the perception of the prevocalic /s/ in English is influenced by stress and position. Now, we will examine how Korean listeners perceive the preconsonantal /s/. Figure 5 illustrates that when /s/ is in a [sC] cluster and under stress, Korean listeners perceive it more as lenis /s/ (55.6% on average) rather than as tense [s*].
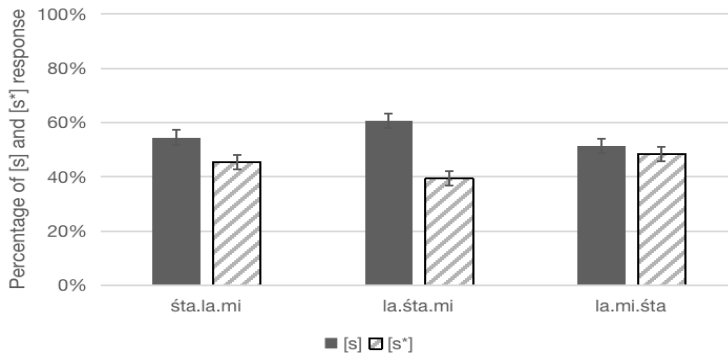
Figure 5. Perception of stressed English [sC]

Figure 5 and Table 3 demonstrate that there is no significant difference in the rates between /s/ and /s*/ responses for the stressed /sC/ in any position within a word.

Table 3. Statistical report for the perception of stressed [sC]

Example word	[s] response percentage	z-score	p-value
stá.la.mi	55%	0.47	0.32
la.stá.mi	61%	1.03	0.15
la.mi.stá	52%	0.19	0.43

Next, we will examine how the unstressed [sC] in English is perceived by Korean listeners. Figure 6 shows that the rate of the lenis [s] response is generally higher when the [sC] is part of an unstressed syllable (76% on average) compared to when it belongs to a stressed syllable (55.6% on average).
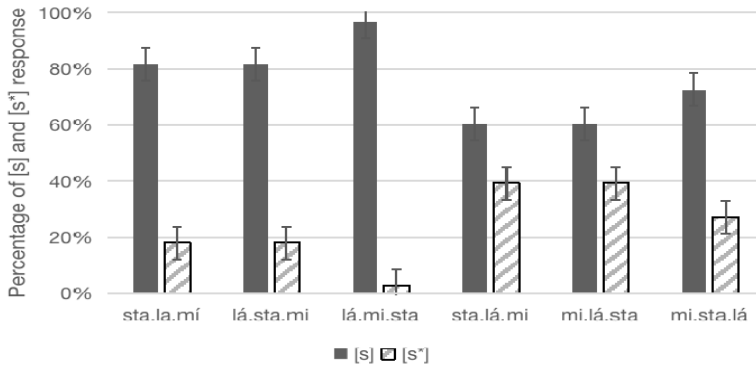
Figure 6. Perception of unstressed [sC]

Table 4 shows that the rate of [s] response for the unstressed /sC/ is significantly higher than the rate of [s*] response when the syllable containing the unstressed /sC/ is adjacent to another unstressed syllable (e.g., sta.la.mí, lá.sta.mi, lá.mi.sta mi.sta.lá).

Table 4. Statistical report for the perception of unstressed [sC]

Example word	/s/ response percentage	z-score	p-value
sta.la.mí	82%	2.55	**0.005
lá.sta.mi	82%	2.55	**0.005
lá.mi.sta	97%	4.41	***0.00001
sta.lá.mi	61%	1.03	0.15
mi.lá.sta	61%	1.03	0.15
mi.sta.lá	73%	2.16	*0.015

To summarize the perception of /sC/ in English by Korean listeners, the preconsonantal /s/ is perceived differently from the prevocalic /s/. In /sC/, the /s/ is more likely to be perceived as lenis [s] regardless of stress. The rate of the lenis /s/ response increases even more when the unstressed /sC/ is placed before or after an unstressed syllable.

3.2.3 A constraint-based account for English /s/ perception

Results from the perception experiment reveal that the singleton /s/ is more likely

perceived as tense [s*] when it is stressed in word-edge position, i.e., word-initially, or word-finally. In other words, the perception of English /s/ by Korean listeners is influenced by both stress and the position of /s/ within a word. The stress effect reinforces the perception of the unstressed /s/ in *lá.mi.sa* and *sa.la.mí* as lenis [s], while the positional effect triggers a perception of these instances as tense [s*]. Likewise, there is a conflict between the stress and positional effects in the case of *lá.mi.sa* and *sa.la.mí*. However, the response rates for lenis [s] and tense [s*] in the unstressed /s/ of *lá.mi.sa* and *sa.la.mí* are not significantly different. Therefore, this result suggests an interaction between the stress and positional effects, but the exact nature of this interaction requires further investigation.

Regarding the perception results of *lá.mi.sa* and *sa.la.mí*, we can investigate whether the duration of /s/ in *lá.mi.sa* and *sa.la.mí* is short enough to be perceived as lenis [s]. To determine if the duration of /s/ influences the perception results, we will examine whether the durations of the singleton /s/ and /s/ in a cluster vary based on stress and position in English. According to Kim and Curtis (2002), the duration of /s/ can play a significant role in distinguishing between the [s] and [s*] responses. However, their analysis only focused on the frication duration of /s/ in /s/- and /sC/ in monosyllabic word-initial and -final position. In contrast, the current study used trisyllabic words containing /s/ and /sC/ in various stress and position conditions. To investigate if the duration of /s/ affects the perception results, the duration of /s/ was measured under different conditions in the stimuli. The results are presented in Table 5.

Table 5. Duration of English /s/ according to stress and position

word-position	[s]/[sC]	stressness of [s]/[sC]	examples	Duration(ms)
word-initial	[s]	stressed	śa.la.mi	251
		unstressed	sa.lá.mi	224
			sa.la.mí	215
	[sC]	stressed	śta.la.mi	242
		unstressed	sta.lá.mi	232
			sta.la.mí	224
word-medial	[s]	stressed	la.śa.mi	170
		unstressed	mi.sa.lá	154

			lá.sa.mi	153
		stressed	la.śta.mi	182
	[sC]	unstressed	mi.sta.lá	123
			lá.sta.mi	143
word-final	[s]	stressed	la.mi.śa	188
		unstressed	mi.lá.sa	178
			lá.mi.sa	158
	[sC]	stressed	la.mi.śta	161
		unstressed	mi.lá.sta	157
			lá.mi.sta	158

The duration of the singleton /s/ and preconsonantal /s/ reveals four facts. Firstly, the singleton /s/ generally has a longer frication duration than the preconsonantal /s/. Secondly, stressed /s/ and /sC/ are longer than unstressed /s/ and /sC/, respectively. Thirdly, the duration of singleton /s/ is longer in the order of word-initial > word-final > word-medial. Fourthly, the /s/ duration in lá.mi.sa (158 ms) is as short as that in mi.sa.lá (154 ms). These facts suggest that the stress and position of /s/ within a word clearly influence the duration of English /s/. Similar to Kim and Curtis (2002), we can conclude that Korean listeners map long [s] in English to tense [s*] in Korean, and short [s] in English to lenis [s] in Korean. However, we still need to explain why the /s/ duration in lá.mi.sa is short even though /s/ belongs to the word-final syllable. We suggest that the unstressed /s/ following another unstressed syllable gets shortened. Based on these generalizations, we propose the following three constraints that control the duration of English /s/ as shown in (1).

(1) a. Long /s/ in Stress: /s/ is long in a stressed syllable.
   b. Sequential Unstressedness (SU): The second syllable of two consecutive unstressed syllables is short.
   c. No short /s/ at Word-Edge: English /s/ in word-edge position is not short.
   d. Constraint ranking: Long /s/ in Stress >> SU, No short /s/ at Word-Edge

We suggest that these three constraints interact to control duration of English /s/ and

Korean listeners use length difference as a perceptual cue, as evidenced in the results of this study. According to Kim and Curtis (2002), Korean listeners associate the long [s] with tense [s*] and short [s] with lenis [s]. The tableaux in (2) illustrate how the results of the perception experiment can be explained by the constraint ranking in (1d).

(2) a.

sa.lá.mi	Long /s/ in stress	Sequential Unstressedness	No short /s/ at Word-Edge
☞s*arami[2]			
sarami			*!

b.

sá.la.mi	Long /s/ in stress	Sequential Unstressedness	No short /s/ at Word-Edge
sarami	*!		*
☞s*arami			

c.

lá.mi.sa	Long /s/ in stress	Sequential Unstressedness	No short /s/ at Word-Edge
☞ramisa			*
☞ramis*a		*	

As shown in Figure 3, /s/ in *sa.lá.mi* is primarily perceived as tense [s*]. (2a) demonstrates that the first candidate with tense [s*], [s*arami], is chosen optimal since it satisfies all three constraints listed in (1). The /s/ in *sa.lá.mi* does not belong to a stressed syllable and Long /s/ in stress constraint is vacuously satisfied and it is not adjacent to an unstressed syllable. However, the second candidate with lenis [s] violates No short /s/ at Word-Edge constraint because the long /s/ in the word-initial position is mapped to lenis [s].[3] In (2b), the candidate with lenis [s], [sarami], violates both Long /s/ in stress and No short /s/ at Word-Edge constraints because the stressed long /s/ in the word-initial position is mapped to lenis [s]. The fact that /s/ in *lá.mi.sa* in (2c) is perceived as either /s/ or /s*/ by Korean listeners can be explained by the co-ranking between SU and No short /s/ at Word-Edge constraint. In (2c), /s/ in *lá.mi.sa* is not

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2   In tableaux, ☞ indicates the optimal output. In Korean, /l/ surfaces as [l] in coda but it is realized as [r] elsewhere.

3   We note that the ranked constraints cannot fully explain the results of perception experiment within the Optimality framework (Prince and Smolensky 1993) because /s/ in sa.lá.mi is perceived as tense [s*] 72% of the time and lenis [s] 28% of the time. We can analyze the data with weighted constraints in the maximum entrophy model (Hayes and Wilson 2008) but it is beyond our scope in this paper.

stressed and both candidates, [ramisa] and [ramis*a], vacuously satisfy Long /s/ in stress constraint, which is highly ranked. The first candidate, [ramisa], violates No short /s/ at Word-Edge constraint and the second candidate, [ramis*a], violates SU constraint. Both candidates, [ramisa] and [ramis*a], can be optimal since No short /s/ at Word-Edge constraint and SU are co-ranked as given in (1d). In this way, the results from the perception experiment can largely be explained by the constraints in (1) that control the duration of /s/ in English.

We have shown that the duration of /s/ in English can be influenced by stress and position within a word. Additionally, we demonstrated that the response patterns of Korean listeners for lenis [s] and tense [s*] for singleton /s/ in English generally correlate with the duration of /s/. However, it should be noted that the results of the perception experiment cannot be fully explained by the duration provided in Table 5 and the constraint ranking in (1d). For instance, it is expected that /s/ in *stá.la.mi* would predominantly be perceived as tense [s*], contrary to the actual findings. In Table 5, the duration of /s/ in *stá.la.mi* is longer than the unstressed /s/ in *sa.lá.mi* which is mainly perceived as tense [s*]. According to the constraint ranking, it would predict that /s/ in *stá.la.mi* would be mapped to tense [s*], as this mapping would not violate any constraints, whereas the lenis [s] mapping would violate No short /s/ at Word-Edge constraint. However, this expectation is not met, as /s/ in a cluster is predominantly perceived as lenis [s] regardless of stress. Therefore, the perception patterns cannot be fully explained by the duration of /s/ in English alone.

4. Speech perception and loanword adaptation: Interplay between acoustic details and phonotactic expectations

In the previous section, we reported how the perception of /s, sC/ in English is influenced by the two prosodic factors: stress and position within a word. In this section, we will examine the results in relation to the adaptation patterns of English /s/ in Korean.

Kim and Curtis (2002) claimed that the adaptation pattern of loanwords is essentially the same as the perception results of Korean listeners. They suggested that the singleton /s/ is perceived as tense [s*] because it is long, while the short /s/ in a cluster is perceived as lenis [s] because it is short. In other words, they explained the different adaptations of the singleton /s/ and the cluster /sC/ based on the duration of [s]; for

example, 'sign' [s*ain] vs. 'story' [sit^{h}ori]. However, we have shown that the preconsonantal /s/ in a stressed syllable is as long as the stressed singleton /s/ in the word-initial position, as demonstrated by Kang (2008), but it is more commonly perceived as lenis [s] rather than tense [s*]. Furthermore, we found that preconsonantal /s/ in a stressed syllable is longer than the stressed singleton /s/ in word-medial position. Therefore, Kim and Curtis' (2002) argument that the duration of /s/ is directly related to the perception of /s/ by Korean listeners is not tenable.

Speech perception is influenced by both top-down phonotactic likelihood and bottom-up acoustic match. Dupoux et al.'s (1999) study demonstrated that when French and Japanese listeners were presented with stimuli without any vowel between consonants (e.g., [ebzo]), Japanese listeners were unable to differentiate between tokens with and without vowels, unlike French listeners. This suggests that speech perception is significantly influenced by the listeners' phonotactic knowledge as a consonant sequence is phonotactically legal in French but not in Japanese.

Contrary to what one might expect based on perception patterns, the singleton /s/ and the cluster /sC/ are predominantly borrowed as tense [s*] and lenis [s] in Korean, respectively. This means that Koreans' judgments of perceptual similarity do not directly align with the pattern of loanword adaptation. It suggests that speech perception can only partially explain loanword adaptation patterns.

The adaptation of English /s/ in the binary mode supports Kang's (2010) regularization view on loanword adaptation. Kang (2010) argues that the adaptation of the English posterior coronal obstruents /ʃ, tʃ, dʒ/ has changed over time. These consonants were initially variably adapted with a glide (/j/ or /w/) in earlier stages, but this variable phonetic detail is no longer present in Present-day Korean. For example, the spelling <w> was observed more frequently when adapting English /ʃ, tʃ, dʒ/ in the 1930s, but its occurrence has decreased in Present-day Korean, as seen in 'leadership' [li.tʌ.swip] <리더쉽>~[li.tʌ.sip] <리더십>. In other words, the diachronic shift in adaptation patterns has moved towards standardization and regularization.

Regarding the adaptation of English /s/, the singleton /s/ in unstressed syllables can variably be loaned as lenis [s], while the preconsonantal /s/ in stressed syllables is loaned as tense [s*] if the duration of /s/ strictly influences the adaptation. However, the singleton /s/ is almost always loaned as tense [s*], while the preconsonantal /s/ is consistently adapted as lenis [s]. This suggests that the singleton /s/ and the preconsonantal /s/ in English are loaned as categorically different phonemes in Korean,

specifically lenis /s/ and tense /s*/.

Then, how can we explain the mappings between the singleton /s/ and tense [s*], and the preconsonantal /s/ and lenis [s]? We have shown that these mappings cannot be explained solely by speech perception. We argue that loanword adaptation is a process that aims to maximize the perceptual similarity between a source word and a loanword. It is a non-local process, considering both a sequence of source language sounds and a single source language sound. Specifically, English /st/ is adapted as a sequence of lenis [s], an epenthetic vowel and an aspirated stop, resulting in 'story' [sitʰori]. In Korean and Japanese, high vowels are devoiced after an aspirated obstruent (Jun and Beckman l994).[4] By adapting English /s/ in a cluster as lenis [s], which is phonetically aspirated, the loanword becomes maximally similar to the source word containing the preconsonantal /s/ after devoicing an epenthetic vowel.[5]

On the other hand, the prevocalic /s/ in English is loaned as tense [s*] because tense [s*] does not trigger devoicing of the following vowel. However, why is the word-final /s/ in English not loaned as lenis [s] even though it is not followed by any vowel? In Korean, vowel devoicing of high vowels occurs more frequently when they are flanked by two voiceless obstruents (Jun and Beckman l994). Moreover, the word-final /s/ is long enough to be perceived as tense [s*]. We propose that the process of maximizing perceptual similarity between a source word and a loanword is selective, depending on the prosodic position of the sound in question. Specifically, English /s/ is long in word-final position and the frication duration is considered as a cue for adaptation, resulting in its loaning as tense [s*].

It is important to note that we are not suggesting that the phonetic details of the input are irrelevant in loanword adaptation. On the contrary, we propose that borrowers utilize their phonological knowledge of the borrowing language to optimize the input and output in loanword adaptation. Therefore, the preconsonantal /s/ is loaned as lenis [s] because the lenis [s] triggers the devoicing of an epenthetic vowel, resulting in a loanword that is most perceptually similar to the source word.

To summarize the adaptation patterns of English /s/, the prevocalic and word-final /s/ is loaned as tense [s*], but the preconsonantal /s/ is borrowed as lenis [s] in Korean. These adaptation patterns cannot be explained solely by speech perception. Instead,

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4   Vowel devoicing also occurs in Japanese (Whang and Yazawa 2023).
5   Kang (2008) also suggested a similar account.

loanword adaptation should consider both acoustic details in the signal from the source word and the phonotactic expectations derived from the borrower's previous language experience.

5. Conclusion

This study examined two previous studies on the adaptation of English /s/ from a perceptual perspective in loanword adaptation. Kim and Curtis (2002) and Kang (2008) argue that the presence of acoustic cues is a significant factor in the adaptation of English /s/. Kim and Curtis (2002) suggest that the duration of English /s/ determines its adaptation; the long singleton /s/ loaned as tense [s*], while the short preconsonantal /s/ is adapted as lenis [s] in Korean. On the other hand, Kang (2008) claims that voice quality determines the adaptation of English /s/; the singleton /s/ is followed by low H1-H2 values and is loaned as tense [s*]. However, her analysis only partially explains the adaptation of English /s/ in terms of voice quality, as the preconsonantal and word-final /s/ is not followed by a vowel. Both studies have not taken stress and the position of /s/ within a word into consideration.

To address these gaps, we conducted a perception experiment to investigate whether stress and the position of /s/ within a word can influence the perception of English /s/ by Korean listeners. The experiment yielded three key results. Firstly, stress and the position of /s/ within a word largely influence the perception patterns of Korean listeners. Stressed /s/ and /s/ in the word-edge position are more likely to be perceived as tense [s*]. Secondly, the preconsonantal /s/ in a stressed syllable has a similar duration to the prevocalic /s/ in a stressed syllable, but it is more often perceived as lenis [s] than tense [s*]. This suggests that the duration of English /s/ cannot fully explain perception patterns, contrary to the argument made by Kim and Curtis (2002). Lastly, stress and the position of /s/ in general have an impact on the duration of /s/. Based on these findings, perception patterns are analyzed within the framework of Optimality theory.

Despite the variable perception patterns, English /s/ is categorically adapted in two ways; singleton /s/ is loaned as tense [s*], but preconsonantal /s/ is adapted as lenis [s]. We therefore concluded that loanword adaptation cannot be solely explained by speech perception. Instead, we proposed that loanword adaptation, as a process of maximizing perceptual similarity between the input and the output, is driven by top-down/phonotactic

expectations and acoustic matching.

In Korean, the preconsonantal /s/ in English is always loaned as lenis [s], regardless of stress or position within a word. On the other hand, the singleton /s/ is mostly borrowed as tense [s*] in the onset of the stressed syllable and in word-final position. However, the singleton /s/ can be adapted as lenis [s] when it is part of an unstressed syllable, such as in 'parasol' [pʰarasol] and 'Robinson' [robinsin]. Specifically, it is more likely to be borrowed as lenis [s] when it is placed in an unstressed syllable following another unstressed syllable. For example, /s/ in 'lesson' is borrowed as tense [s*], [res*in], but /s/ in 'Robinson' is likely adapted as lenis [s]. Our study demonstrated that the duration of /s/ in unstressed syllables following another unstressed syllable is short and is perceived more as lenis [s]. This suggests that stress information from the source word can influence the adaptation of English /s/ into Korean. However, the extent to which the degree of stress affects the adaptation of English /s has not been comprehensively investigated in the literature. Therefore, a more systematic study is needed to examine how the adaptation of English /s/ can vary depending on acoustic realizations constrained by stress.

In this study, all participants resided in the US at the time of the perception experiment. It may be necessary to conduct the same perception experiment for Korean listeners living in Korea to determine if English proficiency might influence their perception of English /s/. We leave this type of experiment for future research.

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