The Effects of Sentential Context on the Perception of Assimilated Speech by L2 Listeners

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ABSTRACT
The aims of this study were to examine the effect of sentential context on perceptual compensation for assimilation and to compare compensation patterns between English and Korean listeners with a high proficiency level in English. To these ends, we conducted two experiments involving English coronal place assimilation. In the discrimination experiment, two types of stimuli (i.e., compound words and sentences) were presented. In the identification experiment, a target token including one of the two types of codas (i.e., coronal and non-coronal consonants) was embedded in a semantically neutral sentence. The results showed that in the discrimination experiment both listener groups demonstrated higher detection rates in sentences rather than in words. However, the Korean listeners were not as sensitive as the English listeners to phonetic differences of coda consonants in the unviable change context, and they showed more variations in detection rates than the English listeners. The results of the identification experiment presented a significant effect of coda type of target tokens on both listener groups. In sum, the L2 advanced learners were able to use sentential context to perceive assimilated speech, as were the L1 listeners.

Keywords: sentential context, assimilation, compensation, coronal place of articulation, L2 listeners, discrimination, identification

1. Introduction

Speech is inherently variable, and phonological modifications such as assimilation and deletion obscure many relevant distinctions during the production of connected speech. Assimilation is very common in many languages. For example, in English when the phrase ‘a gun battle’ is pronounced in a non-deliberate manner, the coda

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/n/ is pronounced as [m] instead of [n] due to the following sound /b/, and the resulting phrase may sound like 'a gu[$^{n}_{m}$] battle[1]'. These variations may produce lexical ambiguity, and perceptual ambiguity caused by assimilation must be resolved by the perceptual system. Thus, how listeners perceive underlying phonemes despite pervasive variations in phonetic form has been a major research question.

A number of studies of assimilated speech have focused on the distinction between regular changes triggered by normal connected speech processes and abnormal or arbitrary deviations. Phonologically legal variations are perceptually acceptable, whereas irregular changes are treated as nonce words (Gaskell and Marslen-Wilson 1996, 1998, 2002; Gow 2001, 2003; Lee 2005; Darcy et al. 2009 among others). However, debate remains over the extent to which compensation for assimilation depends on sentential contexts. In addition, the question of whether L2 listeners are able to use sentential context in the process of assimilated speech has not been addressed.

This study focuses on the assimilation of the English coronal place of articulation. Coronal place assimilation affects word-final coronal consonants such as /t/, /d/, or /n/ in connected speech, and these sounds often take on the place of articulation of the following bilabial (i.e., /p/, /b/, or /m/) or velar consonants (i.e., /k/, /g/, or /ŋ/). In terms of acoustics, coronal place assimilation is not a discrete shift from one consonant to another, but is a gradual change pattern that is characterized by alveolars, bilabials, velars, or sometimes intermediate sounds (Gow 2001, 2002).

Coronal place assimilation is shown in Korean as well as in English. In Korean, coronal coda consonants /t, n/ assimilate to the following bilabial segments /m, p/ or to the following velar segments /k, ŋ/. For example, /son/ 'hand' is pronounced as a canonical form in [son.tʃap.i] 'handle', but it is changed into [som] or [soŋ] in [som.mok] 'wrist' and [soŋ.k'a.rak] 'finger' due to coronal place assimilation. Also, in Korean bilabial coda consonants /p, m/ are assimilated to the following velar consonants /k, ŋ/, and this pattern is missing in English. For instance, [am.ki] 'memorization' is pronounced as [aŋ.ki]. In both English and Korean, these assimilation patterns of place of articulation are optional.

To date, little discussion has been provided with regard to the effect of sentential contexts in compensation for assimilation. Furthermore, few studies have addressed

1) In the compound word, the first word gu[$^{n}_{m}$] included an assimilated form in coda. Within the bracket, each phonetic alphabet refers to the original form (a superscript character) and the assimilated form (a subscript character).

comparisons of compensation patterns involving sentential contexts between L1 and L2 listeners. The aims of this study were to examine the effect of sentential contexts on compensation for assimilation and to compare compensation patterns between native English listeners and native Korean listeners with a high level of proficiency in English.

For these purposes, we performed two perception experiments (i.e., discrimination and identification). The discrimination experiment addressed two empirical questions. The first question is whether an assimilated form presented in semantically appropriate sentential contexts can trigger more perceptual compensation for English coronal place assimilation than an assimilated form presented in compound words. The second is whether perceptual compensation patterns for assimilation in compound words and sentences differ between native English listeners and Korean listeners with a high level of proficiency in English.

In order to answer these questions, two listener groups participated in a discrimination test. They listened to two kinds of stimuli (i.e., compound words and sentences). For compound words, listeners were asked to answer whether a priming word and the first syllable of a compound word were the same or different (e.g., beat, bea[$^{t}_{p}$] box). For sentences, they were asked to discriminate between a priming word and a word including an assimilated coda consonant in a sentence (e.g., beat, The bea[$^{t}_{p}$] box battle finished). In compound word structures, three phonological contexts were employed. Comparisons of three phonological contexts (i.e., no change, unviable change, and viable change) involving compound words have been made in many previous studies (Gaskell and Marslen-Wilson 1996, 1998, 2002; Darcy 2002; Mitterer and Blomert 2003; Lee 2005; Darcy 2006; Darcy et al. 2009; Sung 2018). Although the focus of this study was to compare the viable word context and the viable sentential context, the other two phonological contexts (i.e., no change and unviable change) were also included in the discrimination experiment involving compound words (e.g., bea[t] sound, bea[$^{t}_{p}$] note, bea[$^{t}_{p}$] box). If only the viable change context of words had been given without the other two contexts during the experiment, listeners could have shown a bias in their responses.

The identification experiment also examined two research questions. The first question is to what extent perceptual compensation for English coronal place assimilation occurs in lexically ambiguous sentential contexts. The second one is whether perceptual compensation patterns in identification differ between native English listeners and native Korean listeners with a high level of proficiency in

English. Lexically ambiguous sentences mean that the sentences provide semantically neutral contexts for words that end in coronal and non-coronal sounds (e.g., Jane found the cat/cap by the front door). Phonological ambiguity was caused due to the presence of the viable context for assimilation, and the word 'cat' could be perceived as 'cap' before the bilabial sound /b/. To answer these questions, two groups of listeners were asked to identify word-final sounds of words (i.e., coronal or non-coronal codas) in lexically ambiguous sentential contexts.

We tested native English listeners and advanced Korean learners of English involving English coronal place assimilation. This study is expected to provide valuable insights on understanding perceptual characteristics of compensation for assimilation by L2 listeners. If compensation is not adaptable to L2 processes, the two listener groups will behave differently. If a native-like compensation pattern is possible in L2 processes, advanced Korean learners of English will show the same pattern as native English listeners.

2. Previous Studies

2.1. Language-specific compensation for phonological assimilation

Previous research has shown that listeners compensate for phonological variations induced by L1 phonological rules. Listeners compensate only for phonological changes that correspond to existing rules in their languages (Otake et al. 1996; Gaskell and Marslen-Wilson 1996, 1998, 2002; Darcy 2002; Mitterer and Blomert 2003; Lee 2005; Darcy 2006; Darcy et al. 2009; Sung 2018). Gaskell and Marslen-Wilson (1998) presented listeners with assimilated words, and found listeners were able to detect the original form /t/ only when the words were followed by a viable context where the change is legitimated. For example, in the phrase *freight bearer*, the listeners detected /t/ although the sound was changed into [p] by the influence of the following bilabial sound /b/. However, the listeners failed to detect /t/ in the unviable context (e.g., freigh[p] bearer) where the modification violated English phonological rules. The authors indicated that listeners compensated for assimilation when the variations corresponded to any existing English rules.

Darcy et al. (2009) examined English coronal place assimilation and French voicing assimilation using a word detection task for target words embedded in sentences. They found clear differences in the way English and French listeners

compensated for the two kinds of assimilation rules. That is, while English listeners exhibited a higher compensation rate for place rather than voicing assimilation, French listeners showed a higher compensation rate for voicing rather than coronal place assimilation. Darcy et al. (2009) concluded that compensation for assimilation reflects language-specific phonological knowledge.

However, there is a language-independent account of compensation for assimilation (Gow 2001, 2002, 2003; Gow and Im 2004; Mitterer et al. 2006). Gow (2001, 2002, 2003) found that assimilated sounds often include phonetic traces or partial cues of the canonical form, and proposed feature cue parsing in order to account for coarticulatory compensation for incomplete assimilation. Gow and Im (2004) presented assimilated Hungarian and Korean stimuli (i.e., Hungarian voicing assimilation and Korean labial-to-velar place assimilation) to native Hungarian, English, and Korean listeners in order to investigate the perception of the post-assimilation context in regressive assimilation rules. They argued that the perception of assimilated utterances may be independent of native-language experience.

Mitterer et al. (2006) tested whether Dutch and Hungarian listeners compensate for Hungarian liquid assimilation, and investigated the significant phonetic details by using slightly different stimuli. The authors indicated that compensation for assimilation can occur without experience with an assimilation rule in a native language, and that compensation depends on phonetic details of assimilated segments. However, they also pointed out that these results only indicate difficulties of perceptual differences between /l/ and /r/ in front of another /r/, and that specific language experience is not required for compensation for assimilation at a prelexical level.

Previous studies have shown that the experience of L1 phonological rules strongly influences the compensation for assimilation. However, language-independent factors such as phonetic details of assimilated sounds were also at play in the process of compensation.

2.2. Semantic context effect on phonological perception

In natural language settings, speech sounds are distorted by various factors such as phonological processes, noise, or speaker differences, and some phonetic features can be degraded or lost. However, in general, degraded information does not affect speech comprehension and communication for native speakers because there is redundant information in the speech signals.

Previous research on spoken word recognition has shown that semantic context can facilitate the perception of ambiguous or perceptually degraded speech (Boothroyd and Nittrouer 1988; Sumner and Samuel 2005; Abada et al. 2008; Lukianchenko 2014; Gow and Olson 2017). When listeners were asked to make a phonemic (/t/ vs. /d/) or lexical (*tip* vs. *dip*) judgment, they showed a strong tendency to interpret ambiguous or degraded speech in a way that produced meaningful and well-formed phrases or sentences. Furthermore, it has been revealed that sentential context can help solve phonological ambiguity triggered by assimilation (Gaskell and Snoeren 2008).

Sumner and Samuel (2005) investigated the effect of semantic priming involving variants of /t/-final words (e.g., flute). He found that glottalized forms of these words enhanced recognition of semantically related words (e.g., music) as well as the citation form, whereas inviable variants involving a feature change (e.g., flu[s]) did not show a priming effect.

Lukianchenko (2014) examined how phonologically ambiguous words were interpreted by the influence of information derived from the larger linguistic context such as semantics, morphology and syntax. Russian words and nonce words were presented to two groups of listeners. The results from behavioral and electrophysiological experiments indicated that syntactic and semantic contextual constraints produced a stronger context effect than morphological constraints for both L1 (native Russian speakers) and L2 (American English speakers learning Russian) groups. The author argued that L2 listeners could take advantage of the contextual information and select the intended lexical items despite low-resolution phonological input.

Gow and Olson (2017) explored the question of how sentential context influenced post-perceptual selection (feedforward processing) or top-down effects on acoustic-phonetic representation (interactive processing). They collected simultaneous MEG and EEG data while subjects listened to meaningful sentences and performed a retrospective phoneme probe verification task. Specifically, the subjects listened to phonetically ambiguous phonemes (e.g., dusk-tusk) embedded in sentence contexts that biased interpretation towards voiced (*dusk*) or voiceless (*tusk*) interpretations. The authors found a robust sentential influence on phoneme categorization, and argued that sentential context influenced acoustic-phonetic processes.

Gaskell and Snoeren (2008) investigated whether complete assimilation was observed in casual speech and whether completely assimilated sounds triggered perceptual compensation. The results showed that the presence of following viable

context led to place assimilation. When native English listeners were asked to identify the words including assimilated sounds in sentences, strongly assimilated sounds of coronals were treated as coronals 35% of the time, which was significantly less than for the weakly assimilated sounds (75%). Strong assimilations created ambiguity, but listeners were sometimes able to make use of underlying coronal place cues after careful or repeated listening. Gaskell and Snoeren (2008) also found that compensation for assimilation depended on the following phonemic context and the semantic fit with the preceding sentence. A significant effect of semantic bias (the presence or absence of preceding biasing sentences) was revealed. Without the preceding biasing sentences, the critical consonants of target words (e.g., rum) were incorrectly categorized as coronals 36% of the time, whereas the presence of biasing sentences towards the coronal-final words, this false response rate rose to 56%. The authors indicated that the influence of semantic context was so robust that compensation for assimilation could be induced even when no assimilation occurred.

While it has been shown that contextual information plays a crucial role in the recognition of spoken words in a sentence, the question of whether L2 listeners can use sentential context effect in recognizing ambiguous speech due to assimilation as much as L1 listeners still remains unanswered.

2.3. Perceptual compensation for assimilation by L2 listeners

Previous research has shown the role of language-specific phonological knowledge in the process of compensation for assimilation. Another important question is to what extent L2 adult learners can acquire a different phonological system when they are faced with L2 phonological rules.

Darcy et al. (2007) tested native English learners of French and native French learners of English on both their native language (L1) and their second language (L2) in order to examine compensation patterns for assimilation. Each of the listener groups consisted of two parties depending on their proficiency level in L2. The results showed that beginners applied their native compensation pattern to both languages, whereas advanced learners were able to compensate for the non-native assimilation rule in their L2. Also, for advanced learners, little interference from L2 onto L1 was observed. The authors argued that learners could build a separate system for the phonological process of L2.

Choi (2015) investigated production and perception patterns involving Korean

nasalization by Chinese speakers learning Korean. Three groups of Chinese speakers based on the proficiency level in Korean (i.e., beginning, intermediate, and advanced) participated in production and identification experiments. The results showed the effects of proficiency level were significant in both production and perception. However, the effects of proficiency level were not consistent across stimulus sentences, and individual variations were also noticeable.

Previous research on the acquisition of phonological process involving assimilation by L2 speakers is sparse. In addition, the perceptual studies on the effect of L2 proficiency level have not shown consistent results. In this study we tested two listener groups (i.e., native English listeners and native Korean listeners with a high proficiency level in English) with stimuli involving English coronal place assimilation. We also investigated whether the effects of sentential context on compensation for assimilation emerged for the two listener groups.

3. Method

3.1. Discrimination experiment

3.1.1. Participants

Twenty native English listeners (7 males and 13 females) and twenty native Korean listeners (5 males, 15 females) participated in the paid experiments. The native English listeners were English professors and teachers, and most of them were in their 20s and 30s, but one participant was in his 50s. Fourteen of them came from the United States, three from Canada and three from the United Kingdom. For the Korean listeners, the participants were asked to provide their personal information (age, occupation, major, period of foreign language learning, official foreign language test scores, and overseas residence experience) using questionnaires. In order to protect the information of all the participants, we applied to the Institutional Review Board for the review, and this research passed the examination. The following table shows the information of the Korean listeners.

Table 1. Summary of background information of native Korean listeners

Age			Gender		Mean age of 1st exposure to L2	Mean length of stay in English speaking countries	TOEIC mean score
20-25	26-30	31-35	Female	Male			
7	9	4	15	5	10	0.45 (n=18)*	908.5
Mean age 27.3							

* This value was calculated excluding two subjects, one of whom had lived in the United Kingdom for 7 years, and the other of whom had lived in South Africa for 9 years.

The Korean listeners were advanced learners of English, and they were all in their 20s and 30s. Thirteen of them majored in English education at the Graduate School of Education at Hankuk University of Foreign Studies, and all the participants received more than 850 on their TOEIC exams, except for one participant whose TOEFL score was 87[2]. Two participants had lived in English-speaking countries for a long time. One participant had lived in the Republic of South Africa for 9 years and the other in the United Kingdom for 7 years, but their first languages were Korean. One participant spent the first five years of his life in Germany, but he could not speak German. In order to check the Korean listeners' English proficiency, they were asked to read a short English text, summarize what they read, and answer three comprehension questions about the text. Their speech was recorded and evaluated by an experimenter and a native English speaker. Based on the evaluation, all Korean listeners were considered advanced learners of English. No participants had auditory deficits.

3.1.2. Stimuli

The AX discrimination experiment consisted of two types of stimuli, one involving compound words and the other involving sentences. In terms of phonological context, in compound words three contexts (i.e., no change, unviable change, and viable change) were used, and in sentences only the viable change context was utilized. Each type of stimuli are explained in detail below respectively.

2) TOEFL score 87 corresponds to TOEIC 790. However, based on the evaluation on the voice recording of a short English text and responses to comprehension questions, it was confirmed that the participant could be considered an advanced English learner.

3.1.2.1. Stimuli of compound words

In the discrimination task involving words, each of the three contexts (i.e., no change, unviable change, and viable change contexts) included 30 target tokens. The target tokens were on the first syllable of each context word (e.g., beat, bea[t] sound/ bea[$^{t}_{p}$] note/ bea[$^{t}_{p}$] box). In the no change context the original form of the target token was used. The unviable change context was the context in which the modification was not conditioned by the phonological processes, but contained the assimilated form as a target token. The viable change context was the context in which the modification was conditioned by the phonological processes and included the assimilated form. For English coronal place assimilation, the target tokens ending with coronal codas (i.e., /t/, /d/, or /n/) altered to non-coronal codas, bilabial (i.e., /p/, /b/, or /m/) or velar (i.e., /k/, /g/, or /ŋ/) sounds. In addition, 20 fillers (e.g., beach, beach sand) were selected and added to the stimuli. Thus, in total 90 test items (30 target tokens * 3 contexts) and 20 filler items were presented. The stimuli were randomized for each participant.

The target tokens were monosyllabic nouns or adjectives with a (C)CVC structure. Each target token was embedded into one of the three types of context (i.e., no change, unviable change, and viable change) on the basis of an adapted methodology shown in Lee (2005), Darcy et al. (2009), and Sung (2018). Examples of the three context words including target tokens are shown in Table 2.

Table 2. Stimulus examples used in the discrimination task involving words

Target token	Context type		
	No change	Unviable change	Viable change
fa[t]	fa[t] dog	fa[$^{t}_{p}$] sheep	fa[$^{t}_{p}$] pork
mai[n]	mai[n] shaft	mai[$^{n}_{m}$] table	mai[$^{n}_{m}$] body
re[d]	re[d] shoes	re[$^{d}_{g}$] sea	re[$^{d}_{g}$] gold

A native male speaker of American English from New York and a native female speaker of American English from Alaska recorded the stimuli. They read the stimuli in a carrier sentence, such as "I'm saying (a/an) _____ today" three times. The compound word items used in the unviable change context were nonce words since the assimilated form (e.g., fa[$^{t}_{p}$]) was not appropriate in that phonological context. Those items were made by splicing the target tokens and

context tokens, and the assimilated forms in the context tokens were from the recordings of stimuli in the viable change context. An Avantone CK-7 Large Capsule Multi-pattern FET microphone was used for recording in a sound isolation booth, and the recordings were digitized at a sampling rate of 44,100Hz in the form of waveform audio file format. In order to control the volume, the sound intensity was adjusted to 60 dB. In order to edit the speech sounds, *Praat* (version 6.0.44, Boersma and Weenink 2018) was used. The following figure shows the waveforms and spectrograms of the token words 'gu[$^{n}_{m}$] shop' in the unviable change context and 'gu[$^{n}_{m}$] battle' in the viable change context.

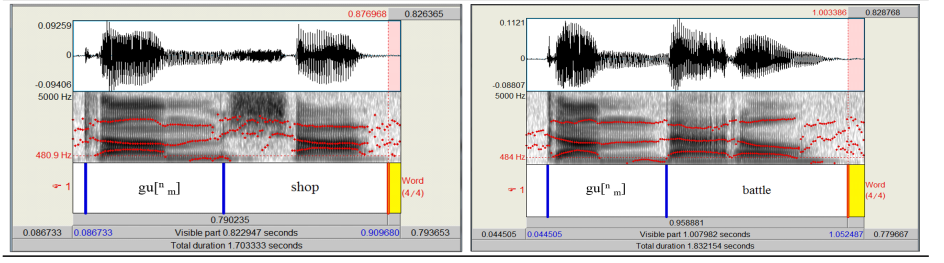

Figure 1. The waveforms and spectrograms of 'gu[$^{n}_{m}$] shop' in the unviable change context and 'gu[$^{n}_{m}$] battle' in the viable change context

As can be seen in Figure 1, the assimilated form of the target token 'gu[$^{n}_{m}$]' was used for both unviable and viable contexts. The stimulus in the unviable context was made by splicing the target token 'gu[$^{n}_{m}$]' and the context token 'shop' from different recordings.

3.1.2.2. Stimuli of sentences

In order to investigate the sentential effect in perception, the discrimination task used 30 target tokens including coronal codas (e.g., /d/, /t/, or /n/), and 30 target tokens including non-coronal codas, bilabial (e.g., /p/, /b/, or /m/) or velar (e.g., /k/, /g/, or /ŋ/) consonants. Thus, 60 target tokens was followed by sentences containing the target tokens ending in the assimilated form of coronal codas (e.g., bea[t]/bea[p], The bea[$^{t}_{p}$] box battle finished). In sentences only the viable change context were included. The other context types used in the task involving words (i.e., the no change and the unviable change context) were not employed in the task involving sentences. In addition, 20 fillers (e.g., ca[ʃ]/cat[tʃ], Kerri suddenly

decided to catch them) were added. Listeners listened to a target token ending in a coronal coda or a non-coronal coda, and a sentence. In total, 60 test items and 20 filler items were presented. The stimuli were randomly played for each participant. The examples of the sentence stimuli are shown in Table 3.

Table 3. Stimulus examples used in the discrimination task involving sentences

Target token		Sentential context
Coronal coda	Non-coronal coda	
bea[t]	bea[p]	The bea[$^{t}_{p}$] box battle finished.
sa[d]	sa[b]	The sa[$^{d}_{b}$] ballet was beautiful.
gree[n]	gree[ŋ]	The gree[$^{n}_{ŋ}$] cup is on the table.

The stimuli of sentences were recorded in the same way as the stimuli of words. In order to record the target token, male and female speakers read it in a carrier sentence, for example "I'm saying (a/an) _____ today" three times. To record the sentential context, the female speaker read the sentence three times. Recordings were made with an Avantone CK-7 Large Capsule Multi-pattern FET microphone in a sound isolation booth and were digitized at a sampling rate of 44,100Hz in waveform audio file format. The sound intensity was manipulated to 60 dB. To edit the speech sounds, *Praat* was used.

3.1.3. Procedure

3.1.3.1. Procedure for words

The experiments were run by *PsychoPy* (version 1.85.2, Peirce 2007). In the discrimination task involving words, a target token in isolation (male voice) was presented, and a compound word (female voice) followed it after 1500ms of silence. The target tokens were read by the male speaker, while the compound word tokens were read by the female speaker. Training sessions consisting of 15 items were given before each instance of the actual experiment. During the training session, participants controlled the volume and they were familiarized to the task. All the participants were instructed to ignore the spellings, pitch, and duration, and focus on the sounds. The actual experimental session consisted of 110 English items in total, split into two blocks. The procedure of the discrimination task involving words is shown in Figure 2. The task took an average of 15 minutes per person.

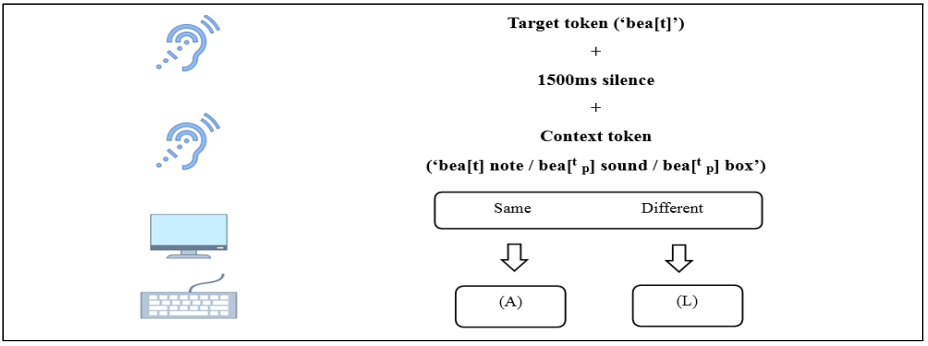

Figure 2. The procedure of the discrimination task involving words

The participants were informed to press the button 'A (same)' or 'L (different)' on the keyboard after they heard the stimuli. They were tested individually in a quiet room. The participants were allowed to have as much break time as they wanted. Response time was limited to 4,500 ms, and if a participant did not answer within that time, it was considered a failure.

3.1.3.2. Procedures for sentences

For the discrimination task involving sentences, a target token in isolation (male voice) was first presented and after 1500ms of silence, a sentence followed (female voice). The actual test session consisted of 80 English items in total (60 target items and 20 fillers), and the items were split into two blocks. Additionally, the training session consisted of 10 items. The experiment took 15 minutes per person. The instruction was the same as the task for words. The procedure for discrimination involving sentences is presented in Figure 3.

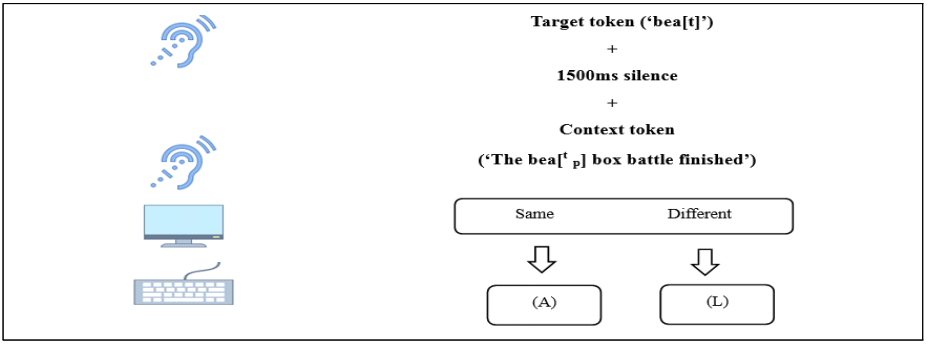

Figure 3. The procedure of the discrimination task involving sentences

Participants first listened to the target token 'bea[t]' followed by the context token 'the bea[$^{t}_{p}$] box battle finished'. The sentence provided the phonologically viable change context for coronal place assimilation. The participants were asked to choose whether 'bea[t]' in the target token and 'bea[$^{t}_{p}$]' in the sentence were the same or different.

3.2. Identification experiment

3.2.1. Participants

The participants in the previous discrimination experiment also took part in the identification experiment.

3.2.2. Stimuli

This experiment consisted of two alternative word selection tests in the semantically neutral sentential context. Thus, 40 target tokens including coronal codas and another 40 target tokens including non-coronal codas were embedded in sentences. In the sentential context, the two types of target tokens were played once at a time. In addition, 40 fillers were used. For the target tokens including coronal codas, the final consonants were coronal consonants such as /t/, /d/, or /n/, whereas for the target tokens including non-coronal codas, the final consonants were either bilabial (i.e., /p/, /b/, or /m/) or velar (i.e., /k/, /g/, or /ŋ/) sounds. Therefore, minimal pairs consisting of coronal sounds and non-coronal sounds (e.g., mat/map, line/lime, bad/bag) were embedded in semantically neutral sentential contexts. The sentences provided the phonological context in which coronal codas were assimilated to bilabial or velar segments (e.g., Jane found the cat/cap by the front door, The man's net/neck got cut by the blade). Two example sentences are shown below (See Appendix C for more example sentences).

(1) a. A sentence including a target token with a coronal coda
Jane found the cat by the front door.[3)]

3) One reviewer pointed out that in this sentence the coda [t] may not be assimilated to the following onset consonant [b] since the two consonants were across the word boundaries. When the sentence stimuli were recorded, the two native English speakers were asked to pronounce the sentences naturally so that the coda of a target token was assimilated to the following consonant. Also, three Korean speakers majoring in phonetics and one native speaker listened to all the sentences to make sure that the codas of target tokens were naturally assimilated to the following consonants.

b. A sentence including a target token with a non-coronal coda
Jane found the cap by the front door.

The underlined words were the target tokens, and a pair of target tokens were presented on the screen to let the participants identify the word they heard in the sentence.

3.2.3. Procedure

Each participant was tested in a quiet testing room individually. Before the actual test, a training session including 10 items was provided to familiarize the participants with the test procedure. The actual experiment consisted of 80 test items and 40 filler items, so there were 120 items in total. The items were split into two blocks. The participants listened to a sentence (e.g., Jane found the cat by the front door) via headphones and were instructed to choose one of the two words displayed on the computer screen (e.g., cat vs. cap) during each trial. The procedure for the identification test is shown in Figure 4.

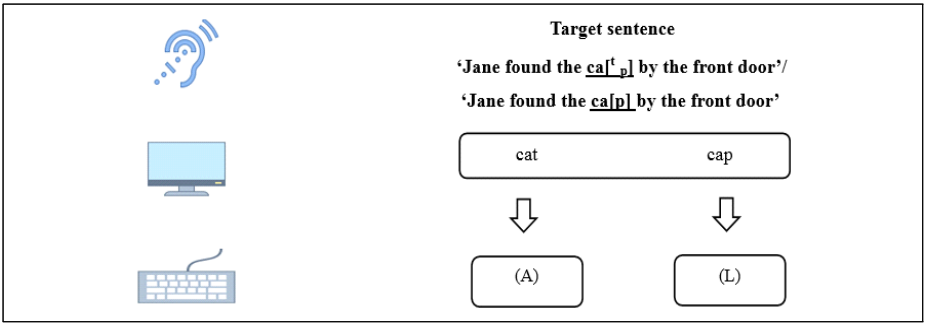

Figure 4. The procedure of the identification experiment

The participants were asked to choose the word they heard by pressing one of two buttons 'A' or 'L' on the keyboard. The participants were instructed to press the button 'A' if the word they heard in a sentence was 'cat', and press the button 'L' if it was 'cap'. Considering only the target sentences including coronal codas, if participants pressed 'A', it indicated that they detected the coronal coda in the viable change context where coronal place assimilation occurred. If they pressed 'L', it meant that they did not detect the coronal coda of the target token. The experiment lasted 20 minutes per person.

4. Results

4.1. Discrimination experiment

4.1.1. Discrimination for words

For the discrimination task for words, the target tokens were on the first syllable of each compound word (e.g., beat, bea[t] sound/ bea[$^{t}_{p}$] note/ bea[$^{t}_{p}$] box). The detection rates were calculated by collecting the 'same' responses. High rates of the 'same' response were predicted in the no change context since the target token and the first syllable of the context token were acoustically the same. On the other hand, low detection rates were expected in the unviable change context where phonological assimilation was not induced. Thus, listeners might easily perceive phonetic differences between a token with a coronal coda and a token with an assimilated form in coda in the unviable context. Conversely, in the viable change context where the phonological environment triggered assimilation, listeners were expected to compensate for assimilation, and detection rates would be high. The following table shows mean detection rates in three contexts of words by two listener groups.

Table 4. Mean detection rates in three contexts of words by two listener groups

Context type	Listener group	
	English listeners	Korean listeners
No change	93.6%	87.2%
Unviable change	11.7%	23.1%
Viable change	52.3%	66.1%

In the no change context of words, the English listeners and the Korean listeners presented high detection rates (93.6% vs. 87.2%) although the detection rate of Korean listeners was a little lower than that of the English listeners. That means that the task was correctly performed by two listener groups. In the unviable change context, the mean detection rates of English listeners were lower than those of the Korean listeners (11.7% vs. 23.1%), indicating that the English listeners were more sensitive to phonetic differences between an original form and the assimilated form of target tokens than the Korean listeners. In the viable change context for words, the mean detection rates were much higher than those in the unviable change context for both English and Korean listeners (52.3% vs. 66.1%). The

Korean listeners presented higher detection rates than the English listeners in the viable change context. However, these results may not indicate that the Korean listeners compensated for assimilation more than the English listeners because the Korean listeners also showed higher detection rates than the English listeners in the unviable change context. The following table shows the analyses of detection rates based on the coda type of target tokens.

Table 5. Mean detection rates of three coronal codas of target tokens in words

Coda type	Listener group	
	English	Korean
/t/ (e.g., fruit, hot)	66.8%	74.5%
/d/ (e.g., bead, red)	37.3%	29.4%
/n/ (e.g., green, wine)	62.2%	70.8%

When the three coronal coda consonants of target tokens were compared, the voiceless stop /t/ showed the highest detection rate for both English and Korean listeners. The detection rates of /t/ and /n/ were higher compared to the other consonant /d/ in the coda position. It meant that the participants were not able to distinguish assimilated forms [$^{t}_{p}$] and [$^{t}_{k}$] from the original form /t/, and the assimilated form [$^{n}_{m}$] and [$^{n}_{ŋ}$] from the original form /n/. These results are partially consistent with the results of previous research (Kawahara and Gravy 2014). Kawahara and Gravy (2014) compared mean similarity ratings among nasals, voiced stops, and voiceless stops in terms of place assimilation. In their study, nasals received the highest similarity ratings, which indicated that listeners had a hard time distinguishing between nasal /n/ and assimilated forms [$^{n}_{m}$] and [$^{n}_{ŋ}$]. In this study, listeners had difficulty discriminating between the original form of alveolar nasals and assimilated forms, and they also showed insensitivity to phonetic differences between the original form of voiceless alveolar stops and assimilated forms. Both listener groups were very sensitive to phonetic differences between voiced stop /d/ and related assimilated forms [$^{d}_{b}$] and [$^{d}_{g}$]. It is speculated that the reason why the listeners relatively easily distinguished between /d/ and related assimilated forms [$^{d}_{b}$] and [$^{d}_{g}$] was that /d/ was often released and less likely to be completely assimilated to the place of the following consonants.

4.1.2. Discrimination for sentences

In the discrimination experiment for sentences, the participants listened to each target token in isolation followed by a sentential context. The target tokens included two types of codas, coronal codas (e.g., /t/, /d/, or /n/) and non-coronal codas such as bilabial (e.g., /p/, /b/, or /m/) or velar (e.g., /k/, /g/, or /ŋ/) sounds. The sentential context was conditioned by coronal place assimilation. It was predicted that the sentential information would enhance the detection of the original form of the target token, and that the detection rates of the target tokens in sentences would be higher than those in words. The following table shows mean detection rates for sentence stimuli based on listener group and target token type.

Table 6. Mean detection rates in the discrimination task for sentences

Coda type	Sentential context	Listener group	
		English	Korean
Coronal coda (e.g., bea[t])	(e.g., The bea[$^{t}_{p}$] box battle finished)	80.1%	78.1%
Non-coronal coda (e.g., bee[p])		44.7%	48.6%

For the target tokens including coronal codas, similar mean detection rates were shown for both English and Korean listeners (80.1% vs. 78.1%). That means both listener groups perceived the target token 'bea[t]' and its assimilated form 'bea[$^{t}_{p}$]' in a sentence the same most of the time. The two listener groups revealed similar patterns in compensation in English stimuli regardless of different native language (L1) experiences.

Furthermore, for the target tokens including non-coronal codas, the detection rates were also similar between two listener groups (44.7% for the English listeners and 48.6% for the Korean listeners). Their detection rates for non-coronal codas were much lower than those for coronal codas. Both groups of listeners were much more sensitive to phonetic differences between 'bee[p]' and 'bea[$^{t}_{p}$]' than those between 'bea[t] and 'bea[$^{t}_{p}$]'. In addition, the sentential context was a little biased to 'bea[t]' rather than to 'bee[p]' since listeners might be more familiar with 'beat box' than to 'beep box'. Thus, it seemed that semantic context affected listeners' perception of assimilated codas. The detection rates were compared based on the consonant type of coronal codas, and the results are presented in Table 7.

Table 7. Mean detection rates of three coronal codas of target tokens for sentences

Coda type	Listener group	
	English	Korean
/t/ (e.g., fruit, hot)	73.9%	71.8%
/d/ (e.g., bead, red)	77.6%	74.2%
/n/ (e.g., green, wine)	81.8%	79.5%

As can be seen in Table 7, the mean detection rates for all three types of coda consonants were very high for both listener groups. As we expected, when the assimilation was conditioned by phonological context, the detection rates for sentences were much higher than those for words. When comparing the results in Table 5 and Table 7, a drastic increase in mean detection rates of /d/ and /n/ was observed. When mean detection rates for three types of coronal codas were compared with each other, the highest rates were revealed for nasals. These results are consistent with the results shown in Kawahara and Gravy (2014). They found that similarity ratings were highest for nasals and their assimilated forms.

In order to examine the effect of the word context and sentential context, the detection rates of four contexts (i.e., no change_word, unviable change_word, viable change_word, and viable change_sentence) were used. The following table combined Table 4 and Table 6 in order to compare mean detection rates in three contexts of words and one sentential context. For the sentential context, the detection rates for non-coronal codas were not included since the comparison between the viable change context for words and the viable change context for sentences was essential in this study. In the discrimination task involving sentences, only the target words including coronal codas were included in the comparison because the detection of coronal codas was considered compensation for assimilation.

As shown in Table 8, the two listener groups showed similar patterns of mean detection rates. They presented the highest mean detection rates in the no change context for words and the lowest detection rates in the unviable change context for words. When comparing the detection rates in the unviable change context for words and those in the viable change context for words, both listener groups clearly compensated for assimilation. However, the Korean listeners displayed higher mean detection rates than the English listeners in the unviable change context for words. These results suggested that it was more difficult for the Korean listeners than for

the English listeners to perceive phonetic differences between the original form of coronal codas and the assimilated form in the context when assimilation was not conditioned.

Table 8. Mean detection rates in the stimuli of words and sentences

Context type	Listener group	
	English listeners	Korean listeners
No change_word	93.6%	87.2%
Unviable change_word	11.7%	23.1%
Viable change_word	52.3%	66.1%
Viable change_sentence	80.1%	78.1%

Furthermore, the detection rates of the two listener groups were much higher in the viable change context for sentences than in the viable change context for words, indicating a strong effect of sentential context. However, there were differences in the degree of the effect of sentential context. That is, native English listeners showed a stronger effect of sentential context than native Korean listeners. Nonetheless, in general, the results of the present study revealed that the Korean listeners with a high level of proficiency in English were able to compensate for assimilation and use semantics in a sentential context when they heard English stimuli. The following boxplots present mean detection rates in the discrimination tasks involving words and sentences by the two listener groups.

As can be seen in Figure 5, the two listener groups showed similar patterns in four different contexts. However, some differences are noticed between the two listener groups. In the three contexts for words, the detection rates are a little more spread out and more deviations are displayed for the Korean listeners than for the English listeners.

To find the sentential effect on phonological compensation, the GLM repeated measures ANOVA (analysis of variance) were conducted using SPSS statistics version 20.0 in three contexts: the unviable change context for words, the viable change context for words, and the viable change context for sentences. The between-subject factors were the English listeners and the Korean listeners, and the within-subject factors were the three contexts. Mauchly's test of Sphericity was not significant (p>.05), which means that Sphericity can be assumed, and the result of the GLM repeated measures ANOVA can be used. For the effect of context, a

significant effect of phonological context was found [F(2,70)=294.462, p<.0001]. For the effect of listener group, there was a significant difference between the English listeners and the Korean listeners [F(1, 35)=6.845, p<.05]. For the effect of the interaction between the two listener groups and three contexts, there was also a significant difference (F[2, 70]=5.333, p<.05).

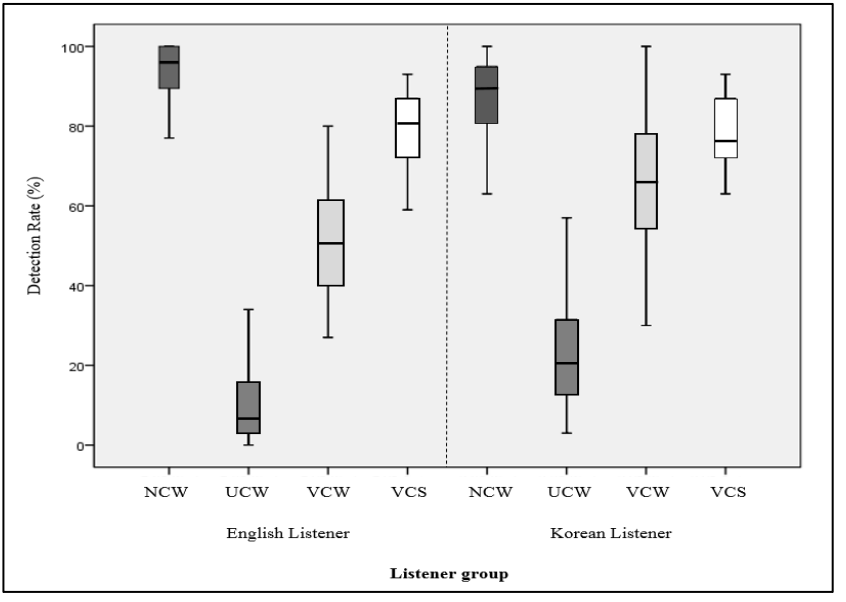

Figure 5. Mean detection rates in three contexts for words and one sentential context by two listener groups

Note. NCW=no change_word, UCW=unviable change_word, VCW=viable change_word, VCS= viable change_sentence

For English listeners separately, the GLM repeated measures ANOVA was conducted with three contexts, and the result showed that there was a significant effect of context type [F(2, 34)=206.899, p<.0001]. Fisher's Least Significant Difference (LSD) test between the contexts was performed for the comparisons between the three contexts. The unviable change word context and the viable change word context were significantly different (p<.0001). In addition, there was a significant difference between the viable word context and the viable sentence context (p<.0001). That is, a strong effect of the sentential context was observed.

For the Korean listeners, the effect of context type was found in the result [F(2, 36)=109.701, p<.0001]. The unviable change context and the viable change context

for words were significantly different in the Korean listeners' results (p<.0001). In addition, Fisher's Least Significant Difference (LSD) test revealed a significant difference between the viable context for words and the viable context for sentences (p<.01). That is, the effect of the sentential context was also observed for the Korean listeners.

4.2. Identification experiment

In the identification task, the participants were asked to select one of two types of target tokens when they heard a sentence that provided semantically neutral contexts for the two types of target tokens. One target token included coronal sounds in coda (/t/, /d/, or /n/) and the other target token included non-coronal sounds in coda (i.e., bilabial sounds /p/, /b/, or /m/, velar sounds /k/, /g/, or /ŋ/). That is, minimal pairs consisting involving coronal sounds or non-coronal sounds in coda were used (e.g., teen vs. teem). The sentences presented the viable change context for assimilation, so the alveolar codas were phonologically assimilated to the following bilabial or velar consonants in the sentences. A pair of tokens were presented on the screen and the participants were asked to choose the word they heard. We calculated mean response rates for the target tokens including a coronal coda. It was expected that when the participants heard a target token including a coronal coda in a sentence, their responses would not be biased towards the target token including a coronal coda since they heard an assimilated sound in coda. On the other hand, when the participants heard a target token including a non-coronal coda, their responses would be biased towards the target token including a non-coronal coda. The following table shows mean response rates in the identification task by the English and the Korean listeners. As stated above, the response rates for coronal coda tokens were collected.

Table 9. Mean response rates in the identification task

Target token	Listener group	
	English	Korean
Coronal coda (e.g., The tee[$^{n}{}_{m}$] patiently awaited the arrival of the star.)	34.6%	41.8%
Non-coronal coda (e.g., The tea[m] patiently awaited the arrival of the star.)	2.7%	3.7%

As expected, the response rates of target tokens including coronal codas were distinctive from those of target tokens including non-coronal codas. When the listeners heard a target token including a coronal coda in the phonologically viable sentential context, their responses were split into two choices. The response rates of perceiving the coda as a coronal sound were 34.6% for the English listeners and 41.8% for the Korean listeners. Both listener groups showed the compensation effect for assimilation.

On the other hand, when the participants heard a target token including a non-coronal coda, their responses were predominantly biased towards the target token including a non-coronal coda. Both listener groups showed very low response rates for coronal codas (2.7% for the English listeners and 3.7% for the Korean listeners). In general, the two listener groups showed similar response patterns in the identification task as they did in the discrimination tasks. Although the coronal sounds were assimilated to bilabial or velar sounds in the viable change context in the identification task, the listeners' responses were clearly different between assimilated forms of coronal sounds and the original bilabial or velar sounds. The following boxplots present mean response rates for target tokens including coronal and those including non-coronal codas by the English and Korean listeners.

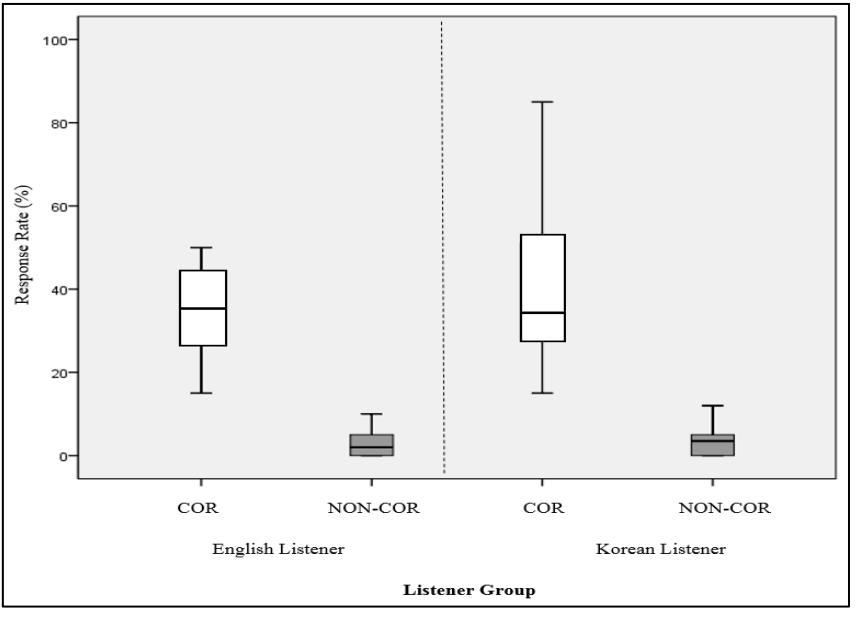

Figure 6. The boxplots for mean response rates in the identification task by two listener groups

Note: COR=Coronal codas, NON-COR=Non-coronal codas

The boxplots in Figure 6 present similar perceptual patterns for both listener groups. They perceived assimilated forms of coronal codas as coronal codas 34.6% of the time for the English listeners and 41.8% for the Korean listeners. However, there were subtle differences between the two listener groups. The Korean listeners showed noticeably wider error range of coronal codas than the English listeners. For non-coronal codas, both English and Korean listener groups showed very low response rates.

In order to examine the effects of coronal codas of target tokens and listener groups, the GLM repeated measures ANOVA was conducted. The results showed that there was a significant effect of coda type of target tokens [$F(1, 38)=205.396$, $p<.0001$]. For the effect of the listener group, there was no significant difference [$F(1, 38)=1.974$, $p>.05$]. Also, the interaction between coda type of target tokens and listener group did not present a statistically significant difference [$F(1, 38)=1.635$, $p>.05$]. It means that the English listeners and the Korean listeners did not show different response patterns in the identification task. Both groups revealed high sensitivity to phonetic differences between assimilated forms of coronal sounds and original bilabial or velar sounds in coda. Let us now summarize the statistical results from the two experiments in the present study, the discrimination task involving words and sentences and the identification task involving sentences.

Table 10. Summary of statistical results in the discrimination task

Factor type	Post-hoc comparisons		
Phonological context (UCW vs. VCW vs. VCS) $p<.0001$	English listener	UCW vs. VCW	$p<.0001$
		VCW vs. VCS	$p<.0001$
Listener group (English vs. Korean) $p<.05$	Korean listener	UCW vs. VCW	$p<.0001$
		VCW vs. VCS	$p<.05$

Note. UCW=unviable change_word, VCW=viable change_word, VCS=viable change_sentence

Table 11. Summary of statistical results in the identification task

Factor type
Coda type of target tokens (coronal vs. non-coronal consonants) $p<.0001$
Listener group (English vs. Korean) $p>.05$

As can be seen in Table 10, in the discrimination task involving words, the two listener groups revealed the compensation effect when they heard the word stimuli. Both listener groups showed significantly higher detection rates in the viable change context than in the unviable change context for words. In addition, the sentential effect was found for both listener groups. Comparing the detection rates in the viable change contexts for words and those for sentences, both listener groups showed significantly higher detection rates when they heard sentences than when they heard words. Although the English listeners and the Korean listeners presented a similar perceptual pattern in the discrimination task, differences between the two groups have also emerged. The Korean listeners' detection rates were more spread out than the English listeners. Furthermore, the Korean listeners were less sensitive to phonetic differences between the original form and the assimilated form in the unviable change context than the English listeners. On the other hand, in the identification task there was no difference between the two listener groups. The response rates for coronal codas were significantly different between the two types of target tokens. Both listener groups clearly distinguished between assimilated form of coronal codas and original bilabial or velar codas in the identification task.

5. Discussion and Conclusion

The aims of this study were to examine the effect of sentential context on compensation for assimilation and to compare compensation patterns between native English listeners and native Korean listeners with a high level of proficiency in English. To these ends, we conducted two perception experiments (i.e., discrimination and identification) on two listener groups.

In the discrimination experiment, the first research question was whether an assimilated form presented in a semantically appropriate sentential context could trigger more perceptual compensation for English coronal place assimilation than an assimilated form presented in a compound word context. The second question was whether the perceptual patterns of compensation for assimilation differed between native English listeners and native Korean listeners with a high level of proficiency in English. In order to answer these questions, two types of stimuli (i.e., compound words and sentences) were presented involving English coronal place assimilation. In the compound words, a target token was embedded in one of three phonological contexts (i.e., no change, unviable change, and viable change), and

in the sentences a target token was presented in the viable change context.

The results of the discrimination experiment showed a strong effect of the sentential context and listener group. When comparing the detection rates in the three contexts in words, the two listener groups demonstrated the highest mean detection rates in the no change context and the lowest rates in the unviable change context. Also, when the detection rates in the viable change context in words were compared with those in sentences, both listener groups demonstrated higher detection rates in sentences than in words. These results were partially consistent with those of previous research (Gaskell and Snoeren 2008; Lukianchenko 2014). Gaskell and Snoeren (2008) found a strong effect of semantic fit with the preceding sentence on compensation for assimilation. In addition, Lukianchenko (2014) showed a robust effect of semantic context on interpretation of phonologically ambiguous words. In the present study, we found significantly higher detection rates in sentences than in words when the assimilated speech were presented in the viable context where phonological modification was conditioned.

In general, the two listener groups showed similar patterns of compensation for English coronal place assimilation. However, statistical differences in the factor of listener group were also revealed. The Korean listeners showed higher detection rates than the English listeners in the unviable context in words. This indicated that the Korean listeners were less sensitive than the English listeners to phonetic differences between the original form and assimilated form of coronal codas in the unviable context where assimilation was not conditioned. In addition, the boxplots displayed more variations in detection rates for the Korean listeners than for the English listeners.

In the identification experiment, the first research question was to what extent perceptual compensation for English coronal place assimilation occurred in lexically ambiguous sentential contexts. The second question was whether perceptual patterns of compensation in the identification were different between English listeners and Korean listeners with a high level of proficiency in English. A target token including a coronal or non-coronal consonant in coda was embedded in a sentence that provided the semantically neutral context for the two types of target tokens.

The results of the identification experiment showed a significant effect of coda type of target tokens (i.e., coronal codas vs. non-coronal codas). Both listener groups presented a strong sensitivity to phonetic differences between the assimilated form of coda consonants and original bilabial or velar consonants. When assimilated forms of the coronal codas were presented, the listeners responded that

they heard a coronal coda 34.6% of the time for English listeners and 41.8% for Korean listeners. However, when the non-coronal consonants (i.e., bilabial or velar consonants) were presented in coda, both of the listener groups rarely responded that they heard a coronal coda (2.7% for English listeners and 3.7% for Korean listeners). Thus, both groups of listeners clearly differentiate between original non-coronal consonants and assimilated forms of coronal consonants. In addition, the results of the identification experiment did not find any effect of listener group.

The general results from the two experiments indicated that the Korean listeners with a high level of proficiency in English showed similar perceptual patterns of compensation to English listeners. It might be argued that the Korean listeners in this study showed similar perceptual patterns to the English listeners since place assimilation rules exist in both English and Korean. However, the stimuli used in the present study were English and specific sounds involving coronal place assimilation were inconsistent between the two languages. In English word-final coronal consonants such as /t/, /d/, and /n/ are assimilated to the following bilabial or velar consonants, whereas in Korean the coronal consonants such as /t/ and /n/ take on the place of articulation of the following bilabial or velar consonants. Also, in Korean bilabial codas are assimilated to the following velar consonants, and this pattern is missing in English. In addition, the Korean listeners with a low level of proficiency in English did not show phonological compensation for English place assimilation in the previous study (Sung 2018). Thus, it seems that L2 listeners developed L2 phonological system as their experience of L2 increased although there were still subtle differences in perceptual patterns between L1 and L2 listeners. Furthermore, the present results were consistent with those of previous studies (Darcy et al. 2007; Choi 2015). Darcy et al. (2007) argued that while beginning L2 learners used the native compensation pattern for processing both L1 and L2 phonological rules, advanced L2 learners succeeded in compensating for L2 assimilation. Choi (2015) found a significant effect of proficiency level on the perceptual process of Korean nasalization by Chinese speakers learning Korean.

In sum, our main conclusion is that a strong effect of sentential context was found in terms of compensation for assimilation for both L1 and L2 listeners. The advanced L2 learners were able to use the sentential context in the process of assimilated speech like the L1 listeners. In order to get more insights on perceptual systems of L2 listeners involving compensation for assimilation, more research employing listeners with different proficiency levels of L2 is needed.

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Appendix A. Stimulus examples for the discrimination task involving words

Target token	Target token types		Context types		
	Original form	Assimilated form	No change	Unviable change	Viable change
beat	[bi:t]	[bi:^{t} $_{p}$]	sound	note	box
meat	[mi:t]	[mi:^{t} $_{p}$]	shop	sauce	ball
bad	[bæd]	[bæ^{d} $_{b}$]	scene	shot	beer
wide	[waɪd]	[waɪ^{d} $_{b}$]	shoulder	table	band
gun	[gʌn]	[gʌ^{n} $_{m}$]	shot	shop	battle
wine	[waɪn]	[waɪ^{n} $_{m}$]	server	shop	bar
hot	[hɑt]	[hɑ^{t} $_{k}$]	sauce	seller	cake
sweet	[swi:t]	[swi:^{t} $_{k}$]	shop	soup	corn
bead	[bi:d]	[bi:^{d} $_{g}$]	seat	test	curtain
red	[rɛd]	[rɛ^{d} $_{g}$]	shoes	sea	gold
green	[gri:n]	[gri:^{n} ŋ]	salad	shower	cup
sun	[sʌn]	[sʌ^{n} ŋ]	shield	shade	care

Appendix B. Stimulus examples for the discrimination task involving sentences

Target token	Target token types		Sentential context
	Coronal coda	Non-coronal coda	
beat	[bi:t]	[bi:p]	The bea[^{t} $_{p}$] box battle finished.
meat	[mi:t]	[mi:p]	The mea[^{t} $_{p}$] ball is yummy.
bad	[bæd]	[bæb]	The ba[^{d} $_{b}$] beer was disgusting.
wide	[waɪd]	[waɪb]	The wi[^{d} $_{b}$] band doesn't hurt.
gun	[gʌn]	[gʌm]	The gu[^{n} $_{m}$] battle was deadly.
wine	[waɪn]	[waɪm]	The wi[^{n} $_{m}$] bar serves great dishes.
hot	[hɑt]	[hɑk]	The ho[^{t} $_{k}$] cake is yummy.
sweet	[swi:t]	[swi:k]	The swee[^{t} $_{k}$] corn is delicious.
bead	[bi:d]	[bi:g]	The bea[^{d} $_{g}$] curtain is on sale.
red	[rɛd]	[rɛg]	The re[^{d} $_{g}$] gold is valuable.
green	[gri:n]	[gri:ŋ]	The gree[^{n} $_{ŋ}$] cup is on the table.
sun	[sʌn]	[sʌŋ]	The su[^{n} $_{ŋ}$] care treatment was free.

Appendix C. Stimulus examples for the identification task involving sentences

Target token		Sentential context embedding target tokens
Coronal coda	Non-coronal coda	
beat	beep	She didn't like the bea[$^{t}_{p}$] behind the lyrics of the song. She didn't like the bea[p] behind the lyrics of the song.
cat	cap	Jane found the ca[$^{t}_{p}$] by the front door. Jane found the ca[p] by the front door.
sun	sum	The su[$^{n}_{m}$] proceeded to rise at a steady pace. The su[m] proceeded to rise at a steady pace.
teen	team	The tee[$^{n}_{m}$] patiently awaited the arrival of the star. The tea[m] patiently awaited the arrival of the star.
worn	warm	There was a rather wor[$^{n}_{m}$] blanket in the hotel. There was a rather wor[m] blanket in the hotel.
fate	fake	Eventually his fa[$^{t}_{k}$] came to light. Eventually his fa[k] came to light.
late	lake	The council found the la[$^{t}_{k}$] growth surprising. The council found the la[k] growth surprising.
bad	bag	He was the ba[$^{d}_{g}$] guy on that job. He was the ba[g] guy on that job.
lad	lag	There was a small la[$^{d}_{g}$] going unnoticed. There was a small la[g] going unnoticed.
ban	bang	The ba[$^{n}_{ŋ}$] grew larger before it disappeared. The ba[ŋ] grew larger before it disappeared.
fan	fang	The fa[$^{n}_{ŋ}$] glimmered in the moonlight. The fa[ŋ] glimmered in the moonlight.