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Compensation for phonological assimilation: Obstruent nasalization and coronal place assimilation*

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Sung, Eunkyung. 2018. Compensation for phonological assimilation: Obstruent nasalization and coronal place assimilation. *Linguistic Research* 35(1), 145-178. This paper investigates whether native English, Korean, and Chinese listeners show language-specific compensation mechanisms for phonological assimilation processes. To this end, two different assimilation rules, obstruent nasalization and coronal place assimilation, were tested. Fourteen Korean listeners, eleven English listeners, and fourteen Chinese listeners listened to 540 items of Korean stimuli and 540 items of English stimuli prompted by the *PsychoPy* software. For each item, a target token was presented with one of three contexts (i.e. no change, unviable change, and viable change). The participants indicated whether a target token was the same as the first syllable or the first word in a compound word (e.g. "main", "mai[m] body"). The results of detection rates showed that Korean listeners compensated for nasalization in a highly context-sensitive way, and their sensitivity to context was also revealed in place assimilation. The other two listener groups did not show sensitivity to context for either nasalization or place assimilation. Overall, the results of this study were supported by language-specific compensation mechanisms. Basic processing was controlled by language experience with assimilation rules. However, language-independent mechanism such as perceptual salience of segments was also at play. In addition, it seems that the status of a phonological rule in a native language and realization of segments in native speech also played an important role in compensation for assimilation. Lexical status of words did not seem to affect compensation patterns. **(Cyber Hankuk University of Foreign Studies)**

Keywords compensation, obstruent nasalization, coronal place assimilation, discrimination, detection rate

1. Introduction

Speech sounds are distorted in continuous speech through various phonological

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processes such as assimilation, deletion, insertion, or substitution. For example, in English ‘green’ is pronounced as [grim] in the context of ‘green balls’ because [n] is changed to [m] by the influence of the following bilabial sound [b] (Dilley and Pitt 2007). A similar pattern is also shown with voicing instead of place assimilation in Dutch (e.g. pi[t] bull → pi[d] bull; Ernestus, Lahey, Verhees, and Baayen 2006). Such changes may not disrupt spoken word recognition for native speakers (Gaskell and Marslen-Wilson 1996, 1998, 2001). However, in order to recover from the variability induced by phonological rules and activate the correct word representation, assimilation processes need to be compensated for by the perceptual system. In other words, listeners have to compensate for phonological assimilation to recognize the right words.

Previous research has examined the question of what mechanisms make robust lexical access possible in spite of severe changes caused by phonological rules. It is generally accepted that assimilated word forms are only recognized as an instance of the intended word in phonological contexts in which assimilation is allowed. There are three major approaches to perceptual compensation: lexical compensation mechanisms, universal compensation mechanisms, and language-specific compensation mechanisms.

Lexical compensation mechanisms explain that the incoming phonetic signal is matched with our stored lexicon list and closest candidate available is picked. If lexical compensation mechanisms have influence on listeners’ perception, compensation effects appear only for restoring the phonological shape of actual words, not nonce words. Also, phonological contexts are not taken into account since the most appropriate lexical item is selected (Darcy et al. 2009). However, many researchers have found a compensation effect with nonce words that were parallel to those of real words, although the effect was smaller (Gaskell and Marslen-Wilson 1996, 1998; Mitterer and Blomert 2003; Mitterer et al. 2003). Mitterer and Blomert (2003) examined how Dutch listeners dealt with context sensitivity in their native language, and observed that unviable, but not viable, changes induced a significant mismatch negativity in electrophysiological measurements. They pointed out that phonological assimilations were coped with by an early prelexical mechanism. Furthermore, Mitterer et al. (2003) presented Hungarian morphologically complex words and nonce words to Hungarian and Dutch listeners, and found out similar results for both Dutch and Hungarian listeners. They noticed that compensation patterns for assimilation were not affected by the lexical status of the assimilated words.

Universal compensation mechanisms describe that listeners compensate for

phonological variation based on acoustic or phonetic processes or cues, which is not dependent on language-specific processing. Gow (2001, 2003) and Gow and Im (2004) proposed a language independent processing model, Feature Cue Parsing, to capture coarticulation and systematic phonological assimilation. A different argument about phonological underspecification was provided by Weeldon and Waksler (2004). The authors claimed that [grimbin] 'green bean' was accepted because the final coronal sound in 'green' lacked a specification for place of articulation, supporting a phonological underspecification account of listeners' tolerance of phonological mismatch in speech (Lahiri and Marslen-Wilson 1991). Further, Weeldon and Waksler (2004) found no evidence of a context effect on underspecified stimuli. Their results favored context-independent mapping (Lahiri 1999; Lahiri and Reetz 2001) over context-dependent mapping in phonological inference rules (Gaskell and Marslen-Wilson 1996, 1998).

However, these two different claims regarding universal compensation mechanisms were not able to explain the cases of complete assimilation. In most incomplete assimilation cases, the target sound contains partial cues of the original form, whereas the complete assimilation changes leave no noticeable acoustic cues of underlying phonemes, and articulatory features do not spread across adjacent segments. Some previous research (Gaskell and Marslen-Wilson 1996, 1998; Mitterer and Blomert 2003) showed that the compensation effect emerged when tokens were produced with complete assimilation of the target segment.

Language-specific compensation mechanisms were able to provide explanations for the cases of complete assimilation. Several studies have examined the perception of assimilated forms in different languages, such as English (Gaskell and Marslen-Wilson 1996, 1998; Key 2008; Darcy et al. 2009), Dutch (Otake et al. 1996; Quené et al. 1998), Hungarian (Mitterer et al. 2003), and Korean (Lee 2005; Lee and Pater 2008).

Gaskell and Marslen-Wilson (1996, 1998) investigated compensation for place assimilation in English and observed more compensation effects when the context was viable than when the context was unviable. Participants revealed longer response time when they heard the prime word in the unviable context than in the viable context. Gaskell and Marslen-Wilson (1996) examined lexical access when English coronal sounds /t, d, n/ were assimilated to either bilabials /p, b, m/ or velars /k, g, ŋ/ by using a lexical decision task. Native English speakers listened to a prime word (e.g. lean) in the unviable context (e.g. lea[m] gammon) or in the viable context (e.g.

lea[m] bacon), and they were required to decide whether the first word is a real word or nonword. The results showed that English speakers tended to recognize a word that was changed from its original form if the change is conditioned by a phonological process. The tokens in the viable context access lexical representations as strongly as unchanged control tokens. In addition, Gaskell and Marslen-Wilson (1998) investigated the context effect in assimilation by using a phoneme monitoring task. They showed surface variations in speech were perceptually tolerated when modifications occurred in phonologically viable contexts. For example, native English speakers were able to access the mental representation of 'freight' easily when it is presented in the viable context (e.g. fray[p] bearer) rather than in the unviable context (e.g. fray[k] bearer). They also found strong effects of phonological viability for words, with weaker effects for nonwords. They argued that a phonological inference process could operate on both words and nonwords.

Mitterer and Blomert (2003), and Mitterer et al. (2003) also found a strong difference in compensation effect between the viable and unviable contexts. In Mittere et al. (2003), Hungarian and Dutch listeners participated in a discrimination task, an identification task, and a passive-oddball task involving Hungarian real words and nonce words. During the tasks the ERPs were measured. Both listener groups generally showed evidence for compensation for assimilation although Dutch listeners were not familiar with the assimilation rule. However, only Hungarian listeners showed the bias towards the original form when they heard the viable assimilation in an identification task. The authors concluded that auditory process strongly contributed to compensation for assimilation, and that language experience with native assimilation rules affected the identification performance. Otake et al. (1996) tested place assimilation in nasals which was present in both Japanese and Dutch phonology although the status of the assimilation rule is not the same in two languages (i.e. obligatory in Japanese and optional in Dutch). Both groups were tested with nasal place assimilation in Japanese. The results showed that Japanese, but not Dutch speakers, were able to use nasal place assimilation. The authors argued that Dutch speakers did not show compensation because they heard nonce words and this assimilation was not obligatory in Dutch.

Lee (2005) investigated compensation for Korean obstruent nasalization by Korean and English listeners and found different perceptual patterns for two listener groups. Korean listeners revealed the compensation effect for both Korean and English stimuli in a highly context-sensitive mode although obstruent nasalization did not exist in English

phonology. Conversely, English listeners did not show sensitivity to context in either Korean or English stimuli. She suggested that compensation for phonological assimilation was induced by language-specific experience. She also pointed out that feature parsing and lexical status of words affected phonological viability. Lee and Pater (2008) conducted a cross-modal priming study with Korean listeners and showed that Korean listeners recognized an obstruent-to-nasal change on the condition under which nasalization occurs in Korean phonology. Darcy et al. (2009) also tested two groups of listeners whose native language phonologies include different assimilation processes. Whereas coronal place assimilation occurs in English, in which a syllable-final coronal segment takes the place value of the following segment (e.g. [fʊt] 'foot' vs. [fʊpbɔl] 'football'), voicing assimilation appears in French, in which an obstruent takes on the voicing of the following consonant (e.g. [fʊt] 'foot' vs. [fʊdbɔl] 'football'). The results of a word recognition task showed that tolerance for changes in the shape of words was language-specific and sensitive to phonological context although some language-independent compensation strategies were shown.

Language specificity in compensation for assimilation is not consistent across previous studies. In addition, no previous studies examining compensation for assimilation have included both Korean and English phonological assimilation rules in the stimuli. This paper addresses the issue of whether native Korean, English, Chinese listeners reveal language-specific compensation mechanisms in two phonological assimilation processes. Obstruent nasalization and coronal place assimilation are focused on. While obstruent nasalization is an obligatory rule only in Korean, coronal place assimilation is an optional rule in all three languages. In addition, the question of whether the compensation for assimilation is influenced by the lexical status of words or stimulus language will be explored.

2. Obstruent nasalization and coronal place assimilation

In Korean, syllable-final obstruent segments /p, t, k/ assimilate in nasality to a following nasal segments (e.g. /kok.mul/ [koŋ.mul] 'grain', /pɑp.næmsɛ/ [pɑm.næmsɛ] 'rice smell'). That is, syllable-final obstruents are produced as nasals due to the presence of a following nasal. This nasalization process is obligatory in Korean, but this assimilation does not occur in other languages such as English and Chinese.

In English, syllable-final coronal stops /t, d, n/ take on the place of articulation of the following noncoronal stops such as bilabials (e.g. /p/, /b/, /m/) or velars (e.g. /k/, /g/, /ŋ/) in normal connected speech (e.g. /fʊt.bɔl/ → [fʊp.bɔl] 'football', /fʌn.geɪm/ → [fuŋ. geɪm] 'fun game'). However, noncoronal segments do not assimilate to the following coronal sounds (e.g. /bæk.tɔk/ 'back talk' is not realized as [bæt.tɔk]). This coronal place assimilation process is not obligatory, but it is a very widespread in natural speech (Gaskell and Marslen-Wilson 1996; Gow 2001, 2003; Darcy et al. 2009).

The assimilation of coronal place of articulation is also shown in other languages such as Korean or Chinese. In Korean, alveolar segments /t, n/ assimilate to the following bilabial sounds /m, p/ (e.g. /k'ot.pʌt/ [k'op.pʌt] 'flower garden', /mun.pəp/ [mum.pəp] 'grammar'). Further, the alveolar segments assimilate to the following velar sounds /k, ŋ/ (e.g. /sut.kʌɾʌk/ [suk.k'ʌɾʌk] 'spoon', /tʃən.kuk/ [tʃəŋ.kuk] 'the whole country'). Korean also has another assimilation pattern that is missing in English. That is, labial segments assimilate to the following velar sounds (e.g. /ip.ku/ [ik.k'u] 'entrance', /kam.ki/ [kaŋ.ki] 'cold'). However, labial segments do not assimilate to the following alveolar sounds (e.g. /hʌp.toŋ/ [hʌp.t'oŋ] 'congruence') (Lee 2017). In Korean all these assimilation patterns of place of articulation are not obligatory, and only appear in non-standard speech (Sohn 1999).

In Chinese, only two nasal segments /n, ŋ/ can appear in the syllable-final position, and /n/ assimilates to the following bilabial or velar segment /m, ŋ/ (e.g. 人民/rénmín/ [rémmín] 'people', 辛苦/xīnkǔ/ [xīŋkǔ] 'hardship'). Like in Korean, in Chinese the assimilation of coronal place of articulation is not obligatory, and assimilated pronunciation is not considered standard pronunciation (Kang 2010). The following table presents the status of two rules in the three languages.

Table 1. The status of two rules in three languages

	Obstruent nasalization	Place assimilation
Korean	obligatory /p, t, k/ → [m, n, ŋ]	optional /t, n/ → [p, m] or [k, ŋ] /p, m/ → [k, ŋ]
English	None	optional /t, d, n/ → [p, b, m] or [k, g, ŋ]
Chinese	None	optional /n/ → [m, ŋ]

As can be seen in Table 1, obstruent nasalization is an obligatory phonological process only in Korean. Coronal place of articulation assimilation is an optional process in all three languages, but this assimilation is very widely spread in English. On the other hand, in Korean or Chinese this process is not as productive as in English, and the assimilated forms are considered non-standard speech. Thus, these two assimilation processes are not shown in the same way in the three languages. This paper investigates whether native English, Korean, and Chinese listeners show language-specific compensation mechanisms in the contexts of two phonological assimilation processes.

It is predicted that for obstruent nasalization, Korean listeners will strongly exhibit a compensation effect in a context-sensitive mode. For place assimilation, all of the three groups of listeners will show somewhat compensation effect, but English listeners' sensitivity to context will most likely be higher than the other listener groups. Furthermore, in the present study, both Korean and English stimulus items were included for each assimilation process (i.e. nasalization and place assimilation). For Chinese listeners all the items were nonnative words. That is, cross-linguistic experiments were employed to test whether three groups of listeners could compensate for the tokens with phonological variations in both native and nonnative stimuli. Moreover, not only real words but also nonce words were included in the stimuli in order to examine the effect of lexical status of words in compensation for assimilation. When a phonological change is compensated for, the original or canonical form of the word is recognized.

3. Method

3.1 Participants

Fourteen native Korean listeners, eleven native English listeners and fourteen Chinese listeners were recruited for discrimination experiments. All of them were paid for their participation. No listeners reported hearing disorders. The fourteen Korean participants were drawn from a university in the Seoul area. Their English level could be considered intermediate or low based on a self-report and a short voice recording of English sentences. Four of them took TOEIC (Test of English for

International Communication), and their scores were under 700. There were eight women and six men, and their ages ranged from 20 to 28 years old. Six of them were graduate school student who majored in Korean language and literature, and the others were undergraduate students whose majors were new material engineering, aircraft mechanical systems, Korean education, administration, German education, and Spanish. None of them had lived in an English-speaking country before.

The eleven English participants were recruited from a university and an elementary school in the Seoul area. They were from the United States, Australia, Canada, the United Kingdom, and Ireland. Their Korean level could be considered intermediate or low based on a self-report and a short interview before the experiment. Two of them had score of TOPIK (Test of Proficiency in Korean)[1], one with a score of 2 and the other with a score of 4. There were five women and six men, and their ages ranged between 21 and 40 years old. Two of them were undergraduate students whose major was Asian studies. Two of them were graduate school students whose majors were international development and TESOL. Five of them were professors who had received their degrees in various subjects such as TESOL, education, sociology, economics, and theatre history. The other two participants were English teachers at an elementary school who majored in education and linguistics. Most of the English participants had lived in Korea for less than three years, but one of them had been in Korean for ten years.

The fourteen Chinese participants were also recruited from a university in the Seoul area. Their English and Korean level could be considered intermediate or low based on a self-report and a short voice recording of English sentences. None of them have taken TOEIC. All of them were learning Korean at the same time of the experiment. Nine of them had scores of TOPIK and their TOPIK scores ranged from 1 to 4. There were eleven women and three men whose ages were from 20 to 28 years old. Two of them were graduate school students who majored in civil engineering and Korean-Chinese business, and the others were undergraduate students whose majors were Korean, Chinese, music education, media broadcasting, economics, early childhood education, and business administration. All of them had lived in Korea for less than five years. None of them had lived in an English-speaking country before.

1 TOPIK is graded on a scale from one to six, with one being the lowest grade and six being the highest.

3.2 Stimuli

For English stimuli, 30 target tokens of real words (e.g. bad [bæd], fat [fæt], sun [sʌn]) and 30 target tokens of nonce words (e.g. glood [glʊd], sneet [snit], slun [slʌn]) were selected for coronal place of articulation assimilation. Another 30 target tokens of real words (e.g. job [ʤɑb], hat [hæt], book [bʊk]), and 30 target tokens of nonce words (e.g. sneeb [snib], slote [sloʊt], grack [græk]) were chosen for obstruent nasalization. In addition, 30 filler tokens of real words and 30 filler tokens of nonce words were included.

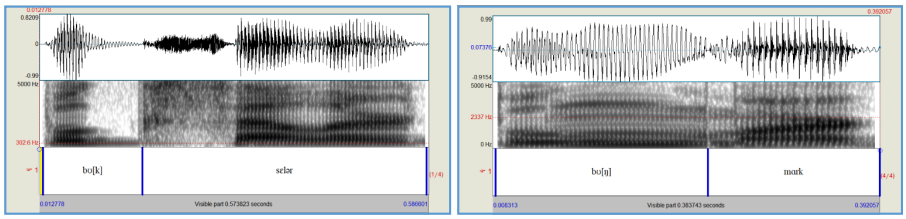
All of these target tokens were monosyllabic with a (C)CVC structure. All the target tokens of real words were nouns or adjectives, and the following context was provided by the first consonant of the second noun. For coronal place of articulation assimilation, target tokens ended in coronal segments (e.g. /d/, /t/, /n/), and for obstruent nasalization, target tokens ended in bilabial (e.g. /p/, b/), coronal (e.g. /t/, /d/), or velar (e.g. /k/, /g/) segments. Each target token was embedded into three types of contexts (i.e. no change, unviable change, viable change) using an adapted version of methodology shown in Lee (2005) and Darcy et al. (2009). The contexts including target tokens were presented in a compound structure as shown in (1):

(1)		No Change	Unviable Change	Viable Change
	Place assimilation	fa[t] dog	fa[p] sheep	fa[p] pork
	Obstruent nasalization	boo[k] seller	boo[ŋ] sales	boo[ŋ] mark

The no change context contained the original form of the target word in the first position of the compound structure. In the unviable change context, the modified form appeared in a context in which the modification is not conditioned. Thus, in both no change and unviable change contexts, the initial consonant of a context word did not trigger phonological assimilation. In the viable change context, the modified form was presented in the context in which the modification is conditioned by the phonological processes of coronal place assimilation or obstruent nasalization. The context phrases of all three types were checked for frequency, and they were excluded unless they were listed in COCA (Corpus of Contemporary American English, http://corpus.byu.edu/coca/).

Combining 30 target tokens of real words with three types of contexts provided 90 compound structures for each assimilation. Another 30 target tokens of nonce words presented with three contexts resulted in 90 compound structures for each assimilation. Also, 60 filler tokens (30 real and 30 nonce words) were embedded in three contexts. Thus, in total, There were 540 items of English stimuli, including 360 test items (30 target tokens * 3 contexts * 2 types of words * 2 types of assimilation) and 180 filler items (30 filler tokens * 3 contexts * 2 types of words). Each item consisted of a target token and context token (e.g. fat, fa[p] port). The 540 items were split into 4 blocks, each including 135 items.

The English stimuli were recorded by a native male speaker of American English who came from New York, and a native female speaker of Canadian English who came from Vancouver. All tokens were recorded in a carrier sentence of "I'm saying (a/an) _____ today" three times. The modified forms of words thus had categorically changed consonants. For example, in the target form 'boo[k]' and assimilated form 'boo[ŋ]' the two coda segments, [k] and [ŋ], are categorically different with each other. The stimuli were digitally recorded using Avantone CK-7 Large Capsule Multi-Pattern FET CK-7 microphone in a recording booth at a language lab. The recordings were digitized at a sampling rate of 44,100Hz and stored as WAV files. All the stimulus items were created by splicing the target and context words, and no compound words were made with a token from the same recording. The sound editing procedures were done manually in *Praat* (Boersma and Weenink 2012). The following figure shows the wave forms and spectrograms of 'boo[k] seller' and 'boo[ŋ] mark' in English stimuli.



(a) boo[k] seller (b) boo[ŋ] mark

Figure 1. The waveforms and spectrograms of two example tokens for nasalization in English stimuli

As can be seen in Figure 1, the target form [k] and the assimilated form [ŋ] in the coda position of the first word are acoustically very distinctive although [k] is not fully released in the token.

Korean stimuli were created with the same processes. For place of articulation assimilation, 30 target tokens which were the first syllable of real words (e.g. [tʃip] in [tʃip.t'an] 'group', [k'ot] in [k'ot.s'i] 'flower seed', [sun] in [sun.sə] 'sequence'), and 30 target tokens which were the first syllable of nonce words (e.g. [tʃip] in [tʃip.t'aŋ], [k'ot] in [k'ot.s'aŋ], [kan] in [kan.tʃam]), were selected. For obstruent nasalization, another 30 target tokens which were the first syllable of real words (e.g. [kuk] in [kuk.tʃ'a] 'ladle', [nat] in [nat.tʃ'am] 'nap', [ip] in [ip.sul] 'lip'), and 30 target tokens which were the first syllable of nonce words (e.g. [mak] in [mak.$p^huŋ$], [k'ot] in [k'ot.sum], [tʃip] in [tʃip.tʃ'am]) were chosen. In addition, 60 filler tokens were included in the stimuli. Thus, in total, there were 540 items of Korean stimuli (360 test and 180 filler items).

All these target tokens were monosyllabic with a (C)VC structure, and real words were checked for word frequency in word frequency data from The National Institute of the Korean Language (www.korean.go.kr). For place of articulation assimilation, all target tokens ended in coronal or labial segments (e.g. /t/, /n/, /p/, /m/)[2], and for obstruent nasalization, all target tokens were ended in bilabial (e.g. /p/), coronal (e.g. /t/), or velar (e.g. /k/) segments. Each target token was embedded into three types of contexts (i.e. no change, unviable change, viable change). The contexts including target tokens were presented in a structure as shown in (2):

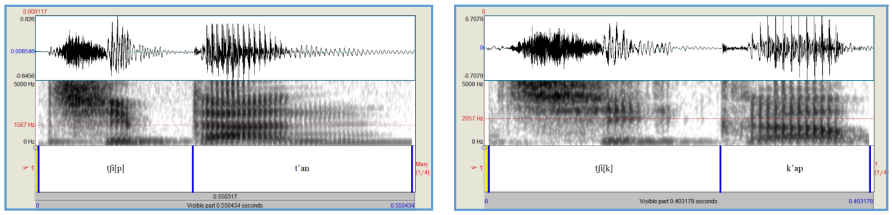
(2)

	No Change	Unviable Change	Viable Change
Place assimilation	tʃi[p] t'an	tʃi[k] $tʃ^hak$	tʃi[k] k'ap
	'group'	'obsession'	'price of a house'
Obstruent nasalization	ku[k] tʃ'a	ku[ŋ] san	ku[ŋ] mul
	'ladle'	'domestic product'	'soup'

The Korean stimuli were recorded by a native male speaker and a native female speaker of Korean, and both of the speakers were from Seoul and had a Seoul

2 Whereas in English only coronals such as /t/, /d/, /n/, are assimilated to the following bilabial or velar segments, in Korean either coronals or bilabials are assimilated to the following bilabial or velar segments.

accent. The stimuli were recorded in a carrier sentence of “Nanin onil _____ malhamnita” (‘I’m saying (a/an) _____ today’) three times. The same sound editing procedure used for the English stimuli was also employed for the Korean stimuli. The following figure shows the wave forms and spectrograms of ‘ʧi[p] t’an’ (‘group’) and ‘ʧi[k] k’ap’ (‘price of a house’) in Korean stimuli.



(a) ʧi[p] t’an (‘group’) (b) ʧi[k] k’ap (‘price of a house’)

Figure 2. The waveforms and spectrograms of two example tokens for place assimilation in Korean stimuli

As can be seen in Figure 2, the target form [p] and the assimilated form [k] in the coda position of the first word are acoustically different. The bilabial stop [p] lowers F2 of the preceding vowel, whereas the velar stop [k] makes F2 value of the preceding vowel higher, making a velar pinch.

3.3 Procedure

Participants were tested individually in a quiet room. The experiment was run using *PsychoPy* (1.85.2) software (Peirce 2007). Each participant was tested with 540 English items split into 4 blocks, and 540 Korean items split into 4 blocks. Accordingly, each participant was tested with a total of 1080 items. There were breaks between blocks and the order of tokens was randomized across participants. Before the experiment, they were given auditory instructions about the experiment, and they had a training session to familiarize them with the task. The training session was given with feedback, and the session was repeated if a participant could not understand the experimental procedure clearly. The experimental trials consisted in the presentation of the target token in isolation, followed by a 1500ms of silence, and then the context token. In English and Korean the context tokens were either

compound words or simple words. The target tokens and context tokens were presented with different voices. Sample tokens and procedure are shown in (3) – (6).

(3) Nasalization in Korean stimuli

Target token	Silence	Context token	
ku[k] 'soup, country'	1500ms	ku[k] tʃ'a 'ladle'	(No change)
ku[k] 'soup, country'	1500ms	ku[ŋ] san 'domestic product'	(Unviable change)
ku[k] 'soup, country'	1500ms	ku[ŋ] mul 'soup drop'	(Viable change)

(4) Nasalization in English stimuli

Target token	Silence	Context token	
pea[k]	1500ms	pea[k] time	(No change)
pea[k]	1500ms	pea[ŋ] season	(Unviable change)
pea[k]	1500ms	pea[ŋ] margin	(Viable change)

(5) Place assimilation in Korean stimuli

Target token	Silence	Context token	
pa[n] 'anti-, class'	1500ms	pa[n] tʃang 'class president'	(No change)
pa[n] 'anti-, class'	1500ms	pa[m] de 'the opposite'	(Unviable change)
pa[n] 'anti-, class'	1500ms	pa[m] bal 'resist'	(Viable change)

(6) Place assimilation in English stimuli

Target token	Silence	Context token	
te[n]	1500ms	te[n] dogs	(No change)
te[n]	1500ms	te[m] shirts	(Unviable change)
te[n]	1500ms	te[m] bats	(Viable change)

Participants were required to indicate whether the target token and the first word or first syllable of the context token was the same or different. The format of the task was an AX discrimination test. Each participant was instructed to press the 'A' key on a keyboard, which was positioned under a participant's left hand when they thought the target token presented was the same with the first syllable of the context token. When a participant thought the target token was different from the first syllable of the context token, they were asked to press the 'L' key which was

positioned under a participant's right hand. The participants were allowed in total 3000ms after the context token to make their response. All auditory stimuli were presented through Sennheiser PC330 headset. The following figure is the experiment screen prompted by the *PsychoPy* program.

Figure 3. A screen shot of the experiment prompted by *PsychoPy*

The detection rates of target words in three contexts were measured to examine whether listeners could identify the target words. For example, when listeners could recognize the word ending in /k/ in the assimilated /ŋ.m/ sequence in the viable context (e.g. pea[k] in pea[ŋ] margin), they were considered to detect the right word. Also, when listeners recognized the word ending in /k/ in the wrongly assimilated /ŋ.s/ sequence in the unviable context (e.g. pea[k] in pea[ŋ] season), they were not considered to detect the right word. Thus, when the detection rates were higher in the viable context than those in the unviable context, the listeners were believed to compensate for assimilation in a context-sensitive way. Moreover, when the detection rates in the no change context were higher than those of other contexts, the listeners were considered to perform the task correctly. All participants finished the task without any failure.

4. Results

All the "same" responses in three contexts were collected to calculate the detection rates. For each participant 360 responses to target items with Korean stimuli and another 360 responses with English stimuli were analyzed. The data with no response were excluded from analyses. No participants showed error rates higher than 0.6%.

4.1 Korean listeners

The following figure shows Korean listeners' mean detection rates when they listened to Korean stimuli. Responses to real and nonce words of stimuli were combined to calculate mean detection rates.

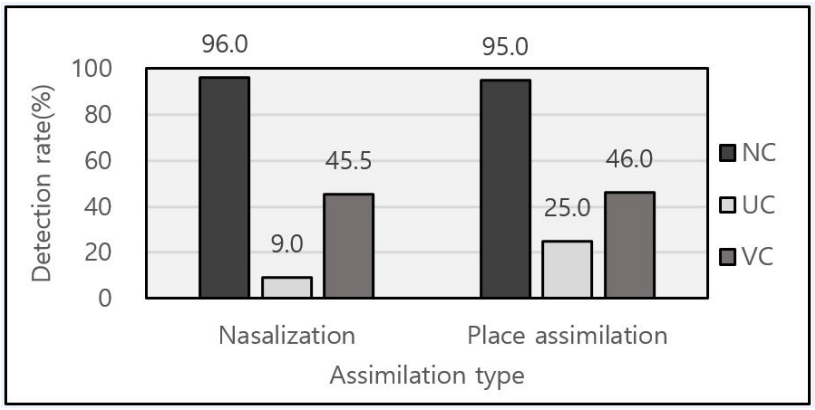


Figure 4. Korean listeners, Korean stimuli: the mean detection rate in each context, for both obstruent nasalization and place assimilation (NC=no change, UC=unviable change, VC=viable change)

Examination of Korean listeners' mean detection rates of Korean stimuli in Figure 4 indicated that the no change context behaved similarly in both nasalization and place assimilation. In other words, in both types of assimilation, Korean listeners showed a ceiling effect in the no change context (96% for nasalization and 95% for place assimilation), suggesting they performed the task correctly. However, Korean listeners revealed a big difference between the unviable and viable change contexts in nasalization (9% vs. 45.5%). On the other hand, the difference between the two contexts in place assimilation was relatively small (25% vs. 46%). Table 2 summarizes Korean listeners' mean detection rates of real words and nonce words in two contexts of Korean stimuli.

Table 2. Korean listeners' mean detection rates of real words and nonce words in Korean stimuli

Nasalization				Place assimilation			
Unviable change		Viable change		Unviable change		Viable change	
Real	Nonce	Real	Nonce	Real	Nonce	Real	Nonce
9%	9%	48%	43%	28%	22%	56%	36%

When the detection rates were compared between real words and nonce words of nasalization, in the unviable change context, the detection rate was 9% for both real words and nonce words, whereas in the viable change context, the detection rate was 48% for real words and 43% for nonce words. For place assimilation, in the unviable context, the detection rate was 28% for real words and 22% for nonce words, whereas in the viable context, the detection rate was 56% for real words, and 36% for nonce words. Thus, Korean listeners' responses were dissimilar with respect to word type (real vs. nonce words) only in the viable context of place assimilation.

In order to investigate the effects of phonological context and assimilation type, a repeated measured ANOVA (analysis of variance) was conducted for Korean listeners with Korean stimuli, with variables of assimilation type (nasalization vs. place assimilation), and phonological context (unviable change vs. viable change), and detection rate as dependent variable. All the analyses were performed using SPSS Statistics 22, and real and nonce words were analyzed separately.

For real words of Korean stimuli, the results showed that there was a significant effect of assimilation type [$F(1, 13)=12.20$, $p<.01$] and context type [$F(1, 13)=32.627$. $p<.0001$], but there was no effect of interaction between assimilation and context type [$F(1, 13)=1.756$, $p>.05$]. Korean listeners were more likely to detect the target token in the viable context than in the unviable context, and this tendency was much more evident in nasalization than place assimilation. For nonce words of Korean stimuli, there was no significant effect of assimilation type [$F(1, 13)=.748$, $p>.05$]. However, there was significant effect of context type [$F(1, 13)=17.872$, $p<.0001$] and a marginally significant effect of interaction between assimilation and context type [$F(1, 13)=6.735$, $p<.05$].

Thus, Korean listeners showed a clear effect of context type in both real and nonce words in Korean stimuli, with much higher detection rates for the viable change context than for the unviable change context. Further, the discrepancy

between unviable and viable change contexts was more evident in nasalization than place assimilation as shown in figure 4. In other words, Korean listeners compensated for nasalization and place assimilation in a context-sensitive fashion, and their sensitivity to contexts for nasalization was higher than that for place assimilation. The following figure illustrates Korean listeners' mean detection rates of English stimuli.

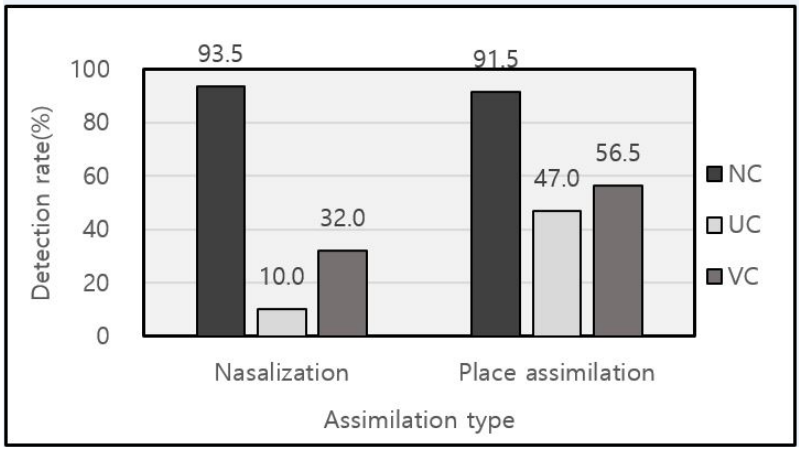


Figure 5. Korean listeners, English stimuli: the mean detection rate in each context, for both obstruent nasalization and place assimilation (NC=no change, UC=unviable change, VC=viable change)

As can be seen in Figure 5, Korean listeners showed relatively high detection rates in the no change condition for both assimilation types (93.5% for nasalization and 91.5% for place assimilation). Korean listeners revealed a discrepancy in detection rates between unviable and viable change contexts in nasalization (10% vs. 32%). The detection rate for the viable change context was much higher than for the unviable change context. However, discrepancy in detection rates for place assimilation was not obvious between the two contexts (47% vs. 56.5%). Thus, Korean listeners showed a context-sensitive mode for nasalization not only in Korean stimuli but also in English stimuli. The sensitivity to context was not clearly revealed in place assimilation. The following table shows Korean listeners' mean detection rates of real words and nonce words in two contexts of English stimuli.

Table 3. Korean listeners' mean detection rates of real words and nonce words in English stimuli

Nasalization				Place assimilation			
Unviable change		Viable change		Unviable change		Viable change	
Real	Nonce	Real	Nonce	Real	Nonce	Real	Nonce
10%	10%	36%	28%	46%	48%	59%	54%

When the detection rates of real words and nonce words were compared, in the unviable change context of nasalization, the detection rate was 10% for both real and nonce words. In the viable change context of nasalization, the detection rate was 36% for real words and 28% for nonce words. For place assimilation, while in the unviable context the detection rate was 46% for real words, and 48% for nonce words, in the viable context the detection rate was 59% for real words, and 54% for nonce words.

The data were subject to a repeated measures ANOVA in order to investigate the effects of phonological context (unviable change vs. viable change) and assimilation type (nasalization vs. place assimilation). For real words of English stimuli, the results showed that there was a significant effect of assimilation type [$F(1, 13)=69.736$, $p<.0001$] and context type [$F(1, 13)=10.548$. $p<.01$], but there was no effect of interaction between assimilation and context type [$F(1, 13)=3.779$, $p>.05$]. Like in Korean stimuli, in English stimuli Korean listeners were more likely to detect the target token in the viable context than the unviable context, and this tendency was much more evident in nasalization than place assimilation. However, Korean listeners' sensitivity to context was not revealed in English nonce words. For nonce words of English stimuli, there was significant effect of assimilation type [$F(1, 13)=87.040$, $p<.0001$]. However, there was no effect of context type [$F(1, 13)=3.833$, $p>.05$] and no effect of interaction between assimilation and context type [$F(1, 13)=3.273$, $p>.05$].

Although Korean listeners showed a clear effect of assimilation type in both real and nonce words of English stimuli, they demonstrated an effect of context type only in real words. Also, as can be seen in Figure 5, the difference of detection rates between unviable change and viable change contexts was more evident in nasalization than in place assimilation.

4.2 English listeners

The following figure illustrates English listeners' mean detection rates of Korean stimuli. Responses to real and nonce words of stimuli were combined to calculate mean detection rates.

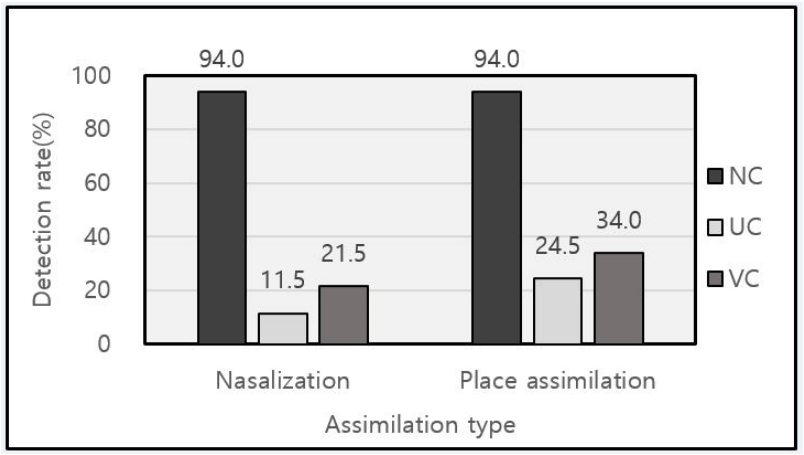


Figure 6. English listeners, Korean stimuli: the mean detection rate in each context, for both obstruent nasalization and place assimilation (NC=no change, UC=unviable change, VC=viable change)

As can be seen in Figure 6, for both nasalization and place assimilation of Korean stimuli, English listeners' detection rate of the no change context was high (94% for both assimilation types), indicating that English listeners performed the task correctly. For nasalization the detection rates between unviable change and viable change contexts were not noticeably different from each other (11.5% vs. 21.5%). The pattern of detection rates for place assimilation was similar to that for nasalization although place assimilation is a native phonological rule in English. There was a small difference between unviable change and viable change contexts (24.5% vs. 34%) for place assimilation. The following table illustrates English listeners' mean detection rates of real words and nonce words in two contexts of Korean stimuli.

Table 4. English listeners' mean detection rates of real words and nonce words in Korean stimuli

Nasalization				Place assimilation			
Unviable change		Viable change		Unviable change		Viable change	
Real	Nonce	Real	Nonce	Real	Nonce	Real	Nonce
9%	14%	20%	23%	24%	25%	32%	36%

For nasalization, the detection rate in the unviable change context was 9% for real words and 14% for nonce words. The detection rate in the viable context was 20% for real words and 23% for nonce words. The overall detection rate for place assimilation was higher than that for nasalization in both the unviable change and the viable change contexts. For place assimilation, the detection rate in the unviable context was 24% for real words, and 25% for nonce words, whereas in the viable context, the detection rate was 32% for real words and 36% for nonce words. Thus, with the Korean stimuli, the effect of word type (real vs. nonce words) was not noticeable for English listeners.

In order to investigate the effects of phonological context and assimilation type, English listeners' data involving Korean stimuli were subject to a repeated measures ANOVA. For real words of Korean stimuli, the results showed that there was a significant effect of assimilation type [$F(1, 10)=13.425$, $p<.01$]. However, there was no effect of context type [$F(1, 10)=2.250$. $p>.05$], and no effect of interaction between assimilation and context type [$F(1, 10)=.208$, $p>.05$]. Similar patterns were shown in nonce words of Korean stimuli. For nonce words there was a significant effect of assimilation type [$F(1, 10)=8.635$, $p<.01$]. However, there was no effect of context type [$F(1, 10)=3.468$, $p>.05$] and no effect of interaction between assimilation and context type [$F(1, 10)=.340$, $p>.05$].

English listeners did not compensate for nasalization and place assimilation in the viable change context. In other words, they showed no evidence of phonological inference for both types of assimilation. These results were very different from those of Korean listeners who showed sensitivity to contexts by revealing much higher detection rate in the viable change context than in the unviable change context. Figure 7 shows English listeners' detection rates with English stimuli.

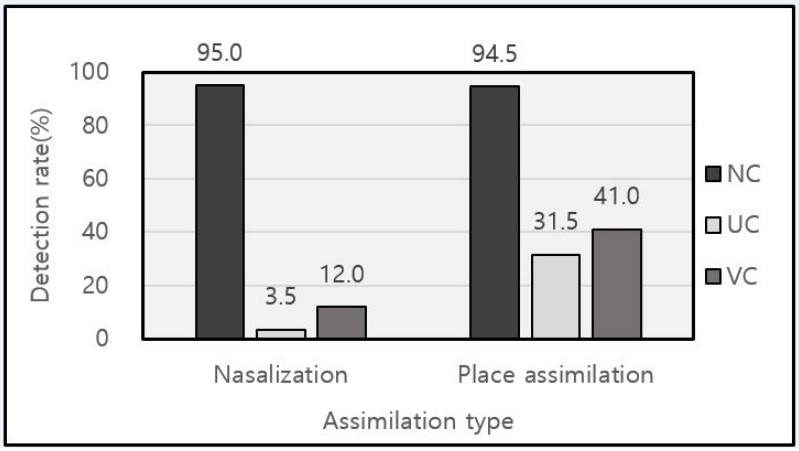


Figure 7. English listeners, English stimuli: the mean detection rate in each context, for both obstruent nasalization and place assimilation (NC=no change, UC=unviable change, VC=viable change)

For both obstruent nasalization and coronal place assimilation of English stimuli, English listeners' detection rates in the no change context showed a ceiling effect (95% for nasalization, and 94.5% for place assimilation). For nasalization the detection rates were relatively low for both unviable and viable change contexts (3.5% vs. 12%). For place assimilation which was a native phonological rule, there was a small difference of detection rate between the unviable change and viable change contexts (31.5% vs. 41%). Their detection rate in the viable context was higher than that in the unviable context although the discrepancy was not obvious. The following table shows English listeners' mean detection rates of real words and nonce words in two contexts of English stimuli.

Table 5. English listeners' mean detection rates of real words and nonce words in English stimuli

Nasalization				Place assimilation			
Unviable change		Viable change		Unviable change		Viable change	
Real	Nonce	Real	Nonce	Real	Nonce	Real	Nonce
2%	5%	16%	8%	30%	33%	41%	41%

As can be seen in Table 5, for nasalization, the detection rate in the unviable

change context was 2% for real words and 5% for nonce words. In the viable change context the detection rate was 16% for real words and 8% for nonce words. For place assimilation, in the unviable change context, the detection rate was 30% for real words, and 33% for nonce words, whereas in the viable change context, the detection rate was 41% for both real words and nonce words. It seems that English listeners did not show the effect of word type (real words vs. nonce words) for both nasalization and place assimilation, which was also consistent with the results of English listeners involving Korean stimuli.

English listeners' data involving English stimuli were subject to a repeated measures ANOVA in order to examine effects of phonological context and assimilation type. For real words of English stimuli, the results showed that there was a significant effect of assimilation type [$F(1, 10)=61.435$, $p<.0001$], and a marginally significant effect of context type $F(1, 10)=7.072$. $p<.05$]. However, there was no effect of interaction between assimilation and context type [$F(1, 10)=.307$, $p>.05$]. For nonce words there was significant effect of assimilation type [$F(1, 10)=74.913$, $p<.0001$]. However, there was no effect of context type [$F(1, 10)=1.936$, $p>.05$] and no effect of interaction between assimilation and context type [$F(1, 10)=.208$, $p>.05$].

Thus, although English listeners showed an effect of assimilation type in both real and nonce words of English stimuli, they revealed sensitivity to context type only in real words. When the results of the two listener groups (Korean and English listeners) were compared with each other, their sensitivity to context type were contrastive. Whereas Korean listeners demonstrated sensitivity to context type in all kinds of stimuli except English nonce words, English listeners showed sensitivity to context type only in English real words. Now let us move on to the results of Chinese listeners.

4.3 Chinese listeners

The following figures show Chinese listeners' mean detection rates in Korean and English stimuli, respectively.

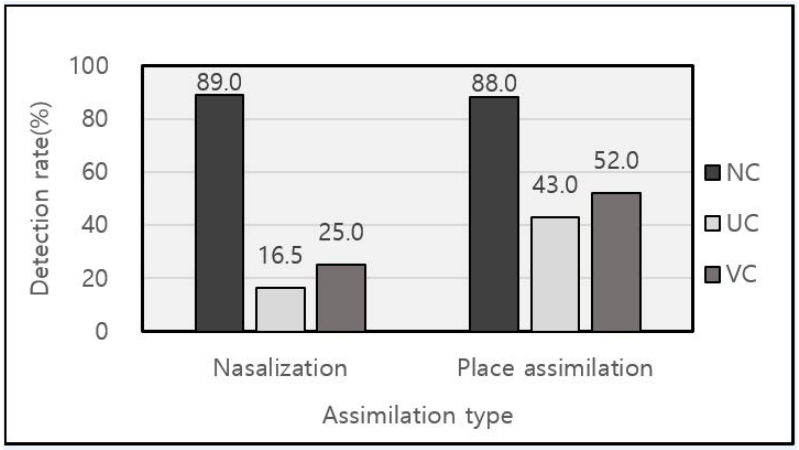


Figure 8. Chinese listeners, Korean stimuli: the mean detection rate in each context, for both obstruent nasalization and place assimilation (NC=no change, UC=unviable change, VC=viable change)

As can be seen in Figure 8, the detection rates of the no change context for both nasalization and place assimilation were much higher (89% for nasalization, and 88% for place assimilation) than those of the other two contexts. However, compared to the results of Korean listeners and English listeners, Chinese listeners' detection rate of the no change context was relatively low. For nasalization, there was a small difference between the unviable change and viable change contexts (16.5% vs. 25%). The similar pattern between the unviable change and viable change contexts was also shown for place assimilation. There was no noticeable difference between the two contexts (43% vs. 52%). Compared to Korean or English listeners, Chinese listeners revealed a high detection rate in the unviable context of Korean stimuli, which suggests that Chinese listeners did not perceive the differences between canonical form and assimilated form in the unviable context. The following table shows Chinese listeners' mean detection rates of real words and nonce words in two contexts of Korean stimuli.

Table 6. Chinese listeners' mean detection rates of real words and nonce words in Korean stimuli

Nasalization				Place assimilation			
Unviable change		Viable change		Unviable change		Viable change	
Real	Nonce	Real	Nonce	Real	Nonce	Real	Nonce
15%	18%	20%	30%	44%	42%	51%	53%

For nasalization, in the unviable change context, the detection rate was 15% for real words, and 18% for nonce words, whereas in the viable change context, the detection rate was 20% for real words and 30% for nonce words. For place assimilation, in the unviable context, the detection rate was 44% for real words, and 42% for nonce words, whereas in the viable context, the detection rate was 51% for real words, and 53% for nonce words. Thus, Chinese listeners did not show a noticeable effect of word type for both nasalization and place assimilation.

Chinese listeners' data involving Korean stimuli were subject to a repeated measures ANOVA in order to examine the effects of phonological context and assimilation type. For real words of Korean stimuli, the results showed that there was a significant effect of assimilation type [$F(1, 13)=13.127$, $p<.0001$]. However, there was no effect of context type [$F(1, 13)=1.141$. $p>.05$], and no effect of interaction between assimilation and context type [$F(1, 13)=.00$, $p>.05$]. The similar patterns appeared in nonce words of Korean stimuli. There was a significant effect of assimilation type [$F(1, 13)=33.566$, $p<.0001$], with no effect of either context type [$F(1, 13)=3.957$, $p>.05$] or interaction between assimilation and context type [$F(1, 13)=.012$, $p>.05$]. Chinese listeners' mean detection rates with English stimuli are displayed in Figure 9.

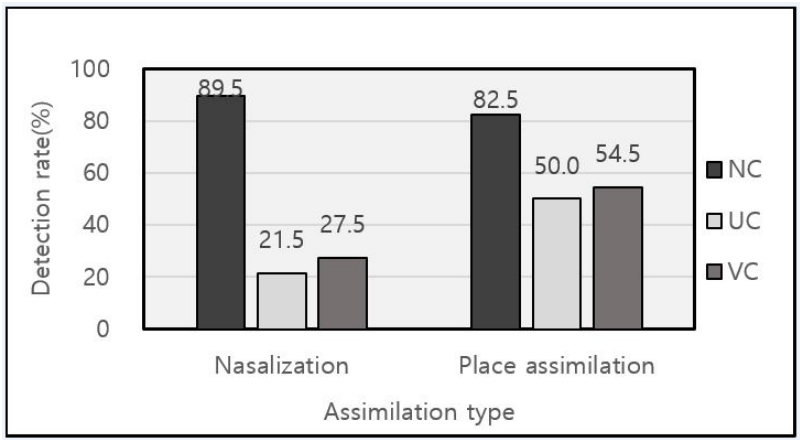


Figure 9. Chinese listeners, English stimuli: the mean detection rate in each context, for both obstruent nasalization and place assimilation (NC=no change, UC=unviable change, VC=viable change)

For both nasalization and place assimilation of English stimuli, Chinese listeners'

detection rates in the no change context were high (89.5% for nasalization, and 82.5% for place assimilation). However, these rates were relatively low considering those shown by Korean and English listeners. For both nasalization and place assimilation there no clear difference between the unviable change and viable change contexts (21.5% vs. 27.5% for nasalization, 50% vs. 54.5% for place assimilation). It seems that Chinese listeners had hard time perceiving the difference between the original form and the assimilated form involving nasalization and place assimilation. Chinese listeners' overall results in English stimuli were consistent with those in Koran stimuli. The following table shows Chinese listeners' mean detection rates of real words and nonce words in two contexts of English stimuli.

Table 7. Chinese listeners' mean detection rates of real words and nonce words in English stimuli

Nasalization				Place assimilation			
Unviable change		Viable change		Unviable change		Viable change	
Real	Nonce	Real	Nonce	Real	Nonce	Real	Nonce
21%	22%	29%	26%	47%	53%	50%	59%

For nasalization, in the unviable change context, the detection rate was 21% for real words, and 22% for nonce words, whereas in the viable change context, the detection rate was 29% for real words and 26% for nonce words. For place assimilation, in the unviable change context, the detection rate was 47% for real words, and 53% for nonce words, while in the viable change context, the detection rate was 50% for real words and 59% for nonce words. It seems that Chinese listeners did not show the effect of word type (real vs. nonce words) for both nasalization and place assimilation, which was also consistent with the results of Chinese listeners involving Korean stimuli.

The data were subject to a repeated measures ANOVA in order to investigate the effects of phonological context and assimilation type. For real words of English stimuli, the results showed that there was a significant effect of assimilation type [$F(1, 13)=117.251$, $p<.0001$]. However, there was no effect of either context type [$F(1, 13)=.628$. $p>.05$] or interaction between assimilation and context type [$F(1, 13)=2.076$, $p>.05$]. Similar results were revealed for nonce words of English stimuli. There was a significant effect of assimilation type [$F(1, 13)=232.308$, $p<.0001$].

However, there was no effect of either context type [F(1, 13)=.673, p>.05] or interaction between assimilation and context type [F(1, 13)=.348, p>.05]. Thus, Chinese listeners did not show sensitivity to phonological context in all kinds of stimuli. The following table summarizes statistical results of three listener groups.

Table 8. Summary of statistical results of detection rates by three listener groups

Listener group	Stimulus language	Word type	Variables	
			Assimilation type	Context type
Korean Listeners	Korean	Real	P<.01	P<.0001
		Nonce	p>.05	p<.0001
	English	Real	p<.0001	P<.01
		Nonce	p<.0001	p>.05
English Listeners	Korean	Real	P<.01	p>.05
		Nonce	P<.01	p>.05
	English	Real	p<.0001	P<.05
		Nonce	p<.0001	p>.05
Chinese Listeners	Korean	Real	p<.0001	p>.05
		Nonce	p<.0001	p>.05
	English	Real	p<.0001	p>.05
		Nonce	p<.0001	p>.05

This table depicts that, except Korean listeners' result in Korean nonce words, all of the listener groups revealed differences in terms of assimilation type. As shown in previous figures, all listeners demonstrated higher detection rate for place assimilation than for nasalization in both unviable change and viable change contexts. In terms of context type, Korean listeners demonstrated sensitivity to phonological context in all kinds of stimuli except English nonce words. On the contrary, Chinese listeners did not show any sensitivity to phonological context in all kinds of stimuli. Specifically, Chinese listeners' detection rates for both unviable and viable change contexts in English stimuli were on the chance level (around 50%), indicating that they were not able to distinguish between the canonical form and the assimilated form of target tokens in both contexts. English listeners' results were not quite different from those of Chinese listeners. Except for real words of English stimuli, English listeners were not sensitive to phonological context.

5. Discussion and conclusion

The results of the discrimination experiment exhibited different patterns among three listener groups. All three listener groups demonstrated perceptual difference in terms of assimilation type (nasalization vs. place assimilation), with overall higher detection rates for place assimilation than for nasalization in both the unviable change and viable change contexts. However, only Korean listeners were sensitive to context type in both Korean and English stimuli. Their detection rates in the viable change context were much higher than those in the unviable change context. Their sensitivity to phonological context was more clearly shown in obstruent nasalization than in coronal place assimilation. In other words, Korean listeners obviously compensated for obstruent nasalization in a context-sensitive way. These results were somewhat expected because obstruent nasalization is an obligatory phonological rule for Korean listeners. This sensitivity was also shown for coronal place assimilation in Korean stimuli although this process is not an obligatory rule in Korean.

On the contrary, English listeners' overall results did not reveal sensitivity to context for both nasalization and place assimilation. Although coronal place assimilation is their native phonological rule, English listeners did not show a strong compensation for place assimilation. These results are not in accord with those of previous research (Gaskell and Marslen-Wilson 1996, 1998; Darcy et al. 2009) in which native English listeners' compensation effect was observed for English place assimilation. Furthermore, Chinese listeners did not show any sensitivity to phonological context at all. Their detection rates did not distinguish between the unviable change context and the viable change context in all kinds of stimuli.[3]

As mentioned above, Korean listeners showed the strong effect of phonological context in obstruent nasalization. However, the context effect appeared much less robust in coronal place assimilation by both Korean and English listeners. Korean listeners' strong sensitivity to phonological context for nasalization can be explained by language-specific phonological knowledge. However, English listeners' lack of

3 A reviewer raised a question of whether a listener's proficiency level of a foreign language might affect the results of detection rates. In the present study the proficiency level of Korean or English did not seem to affect the results of detection rates. When the results of Chinese listeners with an intermediate English or Korean proficiency level were compared with those of Chinese listeners with a low English or Korean proficiency level, there was no difference between the results of the two proficiency groups.

context effect for both nasalization and place assimilation cannot be explained by language-specific phonological knowledge because coronal place assimilation is a widespread process in English. Furthermore, language-specific phonological knowledge cannot provide explanation for Korean listeners' context effect for place assimilation in Korean stimuli although their sensitivity for place assimilation is weaker than that for nasalization.

There may be differences between obstruent nasalization and coronal place assimilation in terms of status of the rules in a native language and acoustic properties of related sounds. Obstruent nasalization is a categorical and obligatory rule in Korean phonology, whereas coronal place assimilation is a gradient and optional rule in both Korean and English. Furthermore, in Chinese this rule exists in a more restricted way because only /n/ assimilates to the following bilabial or velar segment /m, ŋ/. Therefore, Chinese listeners were highly insensitive to phonological context for place assimilation.

In addition, obstruent sounds and related nasalized ones are acoustically and perceptually very different. It is likely that obstruent nasalization is perceptually more salient than coronal place assimilation. That is, differences between obstruents and nasals are perceptually more salient than differences involving place of articulation assimilation. In Key (2008) English listeners were not able to differentiate coronals from labials in pre-labial position, or coronals from velars in pre-velar position in a discrimination task. As Jun (2004) suggests, the weakness of perceptual cues may be the source of the assimilation process

Thus, English listeners' lack of sensitivity to phonological context effect for place assimilation can be explained by the weakness of perceptual salience. Interestingly, despite of the perceptual robustness of the contrast between obstruents and nasals, Korean listeners' detection rates in the viable change context were much higher than those in the unviable change context. It seems that native phonological knowledge strongly affect perception, and use the knowledge to infer that the nasals are derived from underlying obstruents in the viable change context in which assimilation occurs, but not in unviable change context.

Nevertheless, Korean listeners' higher sensitivity to context for place assimilation than English listeners still remains unexplained. Presumably, English listeners are not sensitive to phonetic form of syllable-final consonants because in English speech syllable-final consonants are often unreleased. On the contrary, Korean listeners are

keen on phonetic form of syllable-final consonants because in Korean syllable-final consonants are always released although a coda neutralization process exists in Korean phonology. Thus, the difference between canonical form and assimilated form of syllable-final consonants in phonological contexts is more noticeable to Korean listeners than to English listeners.

In terms of word type (real words vs. nonce words) all three groups generally showed a parallel compensation effect between real words and nonce words although the effect was smaller in nonce words. Korean listeners revealed significant compensation effect in all kinds of stimuli except English nonce words, whereas English listeners' sensitivity to context was shown only in English real words. Although the compensation effect was weaker in nonce words than in real words, the compensation effect was found in both real and nonce words. These results were consistent with those of previous studies (Gaskell and Marslen-Wilson 1996, 1998; Mitterer et al. 2003). Thus, it is likely that the lexical status of words does not strongly affect compensation patterns for assimilation.

In sum, the overall results of this study are supported by language-specific compensation mechanisms. The phonological processing is moderated by language experience with native assimilation rules. Thus, context effects and compensation are found when the target assimilation process is present in a native language. Furthermore, the status of phonological rules in a native language, perceptual salience of segments, and realization of segments in native speech also play an important role in compensation for assimilation. In addition, lexical status of words does not seem to affect the compensation mechanism for assimilation. The results in the present study were drawn with the stimuli involving categorical changes in assimilation processes. (i.e. categorical changes between target form and assimilated form). Thus, the question of whether stimuli involving gradient changes induce similar results still remains unanswered. Moreover, in order to explain different compensation patterns for coronal place assimilation between Korean listeners and English listeners, it is worth examining acoustic properties of assimilated form of coronal consonants in Korean and English.

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Appendix I. Examples of stimuli for Korean nasalization

(1) Real words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
국	[국] [kuk]	[궁] [kuŋ]	자	산	물
복	[복] [pok]	[봉] [poŋ]	사	습	날
꽃	[꼳] [k'ot]	[꼰] [k'on]	씨	집	말
앞	[압] [ap]	[암] [am]	산	뒤	날
집	[집] [tʃip]	[짐] [tʃim]	중	단	념

(2) Nonce words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
먹	[먹] [mək]	[멍] [məŋ]	송	첨	문
색	[색] [sɛk]	[생] [sɛŋ]	찬	작	망
콧	[콛] [k^{h}ot]	[콘] [k^{h}on]	신	삼	문
입	[입] [ip]	[임] [im]	숨	삼	망
업	[업] [əp]	[엄] [əm]	정	충	물

Appendix II. Examples of stimuli for Korean place assimilation

(1) Real words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
눈	[눈] [nun]	[눙] [nuŋ]	치	썹	금
법	[법] [bəp]	[벅] [bək]	정	칙	규
암	[암] [am]	[앙] [aŋ]	시	석	기
논	[논] [non]	[놈] [nom]	술	쟁	문
꽃	[꼳] [k'ot]	[꼽] [k'op]	씨	집	밭

(2) Nonce words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
만	[만] [man]	[망] [maŋ]	좀	낙	격
입	[입] [ip]	[익] [ik]	잠	밤	간
몸	[몸] [mom]	[뭉] [moŋ]	망	산	간
본	[본] [pon]	[봄] [pom]	석	삼	발
꽃	[꼳] [k'ot]	[꼽] [k'op]	쌍	짐	밤

Appendix III. Examples of stimuli for English nasalization

(1) Real words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
cube	[kyub]	[kyum]	sugar	root	meter
stock	[stɑk]	[stɑŋ]	share	sale	market
root	[rut]	[run]	shape	sign	node
good	[gʊd]	[gʊn]	time	sense	night
sheep	[ʃip]	[ʃim]	dip	dog	milk

(2) Nonce words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
plobe	[ploʊb]	[ploʊm]	geem	dospe	maspe
guick	[gwɪk]	[gwɪŋ]	teft	saper	modone
klote	[kloʊt]	[kloʊn]	silm	sount	modone
sleed	[slid]	[slin]	soat	seesk	nige
kroop	[krup]	[krum]	daff	tibe	moof

Appendix IV. Examples of stimuli for English place assimilation

(1) Real words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
fat	[fæt]	[fæp]	dog	sheep	pork
red	[rɛd]	[rɛg]	shoes	sea	gold
clean	[klin]	[klim]	sheet	surface	pan
skin	[skɪn]	[skɪŋ]	test	suit	color
wide	[waɪd]	[waɪb]	shoulder	table	band

(2) Nonce words

Target token	Target form		Context type		
	Original form	Changed form	No change	Unviable change	Viable change
broot	[brut]	[brup]	doog	sheem	polge
smed	[smɛd]	[smɛg]	sheed	seart	goolt
slean	[slin]	[slim]	shoob	soog	peesk
shreen	[ʃrin]	[ʃriŋ]	sades	sheed	gade
glood	[glʊd]	[glʊb]	sheed	soosk	bemp

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