Journal of the Korean Society of Speech Sciences Vol.7 No.3 (2015.09.30) ksss.jams.or.kr
ISSN 2005-8063, pp. 27~35 http://dx.doi.org/10.13064/KSSS.2015.7.3.027

Processing of allophonic variants from optional vs. obligatory phonological processes

Han, Jeong-Im[1)]

ABSTRACT

The purpose of this study is to examine the lexical representation of phonological variants derived from optional vs. obligatory phonological processes. Given that place assimilation is optionally processed, whereas nasal assimilation is obligatory in Korean, a long-term repetition priming experiment was conducted, using a shadowing task. Korean speakers shadowed words containing either assimilated or unassimilated consonants in three priming conditions and their shadow responses were evaluated. It was shown that in both place and nasal assimilations, shadowing latencies for unassimilated stimuli were longer than those for assimilated stimuli in the mismatched condition. These results suggest that even in the optional assimilation, assimilated variants were processed more easily and faster than the canonical variants. The present results argue against the frequency-based account of multiple lexical representation (Connine, 2004; Connine & Pinnow, 2006; Ranbom & Connine, 2007; Bürki, Ernestus, & Frauenfelder, 2010; Bürki, Alario, & Frauenfelder, 2011).

Keywords: optionality, place vs. nasal assimilations, mental lexicon, long-term repetition priming, Korean

1. Introduction

A key issue in spoken language recognition is how pronunciation variability is accommodated in the perception of speech signals and mapped to the lexical representation. One source of variability is phonological processes. For instance, the final consonant of the word *right* in English is realized as labial in the context of *right berries,* even though it is a coronal ([t]) when the word *right* appears alone (Gaskell & Marslen-Wilson, 1996, 1998; Gow, 2001, 2002, 2003; Lahiri & Marslen-Wilson, 1991; Mitterer & Blomert, 2003, among others). It may cause a mismatch between the speech signals (*righ*[p]) and a canonical lexical form (*righ*[t]). However, this variability caused by an assimilatory process may be tolerable for word recognition because retrieving a canonical form is possible.

Two primary accounts have been proposed for how pronunciation variants are recognized. In one account, only an underling form, or a lexeme, is in the lexicon; and the other assumes multiple representations in the lexicon. In Levelt, Roelofs, & Meyer (1999) and Dell (1986), the coronal nasal is assumed to be in the lexicon, and the labial nasal is derived from the coronal nasal through an assimilation process. These models assume that even though there are several phonological variants, only one phonological representation is stored in the mental lexicon, and thus, the stored form is abstract and different from the actual pronunciation.

These views have been challenged recently by some psycholinguistic studies (Patterson & Connine, 2001; LoCasto & Connine, 2002; Connine, 2004; Connine & Pinnow, 2006; Ranbom & Connine, 2007; Bürki, Ernestus, & Frauenfelder, 2010; Bürki, Alario, & Frauenfelder, 2011), where two lexemes have been proposed. For instance, Connine and her colleagues proposed multiple representations for phonological variants from a flapping process. The word-medial flapping is dominant in American English, such as the segment [t] (*pretty* [prɪɾi]). It was

1) Konkuk University, jhan@konkuk.ac.kr

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2014S1A5A2A01011147). I am grateful to three anonymous reviewers for their insightful comments.

Received: July 17, 2015
Revised: August 22, 2015
Accepted: August 25, 2015

demonstrated in a series of experiments that the most frequent form, the flap, as well as the hyperarticulated [t] form, are lexically represented (Patterson & Connine, 2001; Connine, 2004; Connine & Pinnow, 2006; Ranbom & Connine, 2007). For instance, Ranbom and Connine (2007) first conducted a corpus analysis and found that the nasal flap production is dominant in spoken American English (*gentle* -> [ʤɛɾ̃l]). In a subsequent lexical decision task, it was demonstrated that the highly frequent nasal flap was identified more quickly and accurately than the less frequent flap, whereas lexical decisions were faster and more accurate for the [nt] productions compared with the nasal flaps. Based on the results, the authors argued that both variants might be lexically represented.

Related to the issue of processing the pronunciation variants, it has been shown that the variants from obligatory vs. optional phonological processes might behave differently in processing (Cutler & Otake, 1998; Ogasawara & Warner, 2009). In across-word-boundary place assimilation in English (e.g., *garde*[m] *bench*), allophonic variants in an inappropriate environment hinders processing, but appropriately realized variants do not necessarily facilitate processing (Gaskell & Marslen-Wilson, 1998; Gow, 2001, 2002; Gow & Im, 2004). For instance, in a cross-modal priming study, *right* in a sentence *She tried to get the right berries* facilitates the recognition of visually presented RIGHT exactly as much whether it is pronounced unassimilated *righ[t]* or assimilated *righ[p]*.

However, these effects are specific to optional assimilation. When assimilation is obligatorily processed, potential confusions such as *right* and *ripe* do not occur (Cutler, 2012). Ogasawara and Warner (2012) explicitly showed that allophonic variants can actually facilitate processing more easily than their canonical forms. In Japanese, high vowels are devoiced between voiceless consonants (e.g., *kita* [k(i)ta] 'north'), which is closer to obligatory in Tokyo Dialect. Hence, a devoiced vowel is the only appropriate realization in this context. In a lexical decision task, Japanese listeners recognize words with a devoiced vowel more easily than words with a full vowel, even though devoiced variant has weaker acoustic cues.

In order to further examine the effect of optionality on the pronunciation variability, the present study investigated the lexical representation of the variants from place and nasal assimilations in Korean. In place assimilation, coronal consonants assimilate the place of the following labials or velars. The coronal consonants are either nasals or oral stops, but are not laterals (/mit+ko/ -> [mikko] 'believe and', /han+kaŋ/ -> [haŋkaŋ] 'the Han river') (Kim-Renaud, 1991; Ahn, 1998; Jun, 1995; Kochetov & Pouplier, 2009). In nasal assimilation, syllable-final obstruents become nasal when the following syllable begins with a nasal (Kim-Renaud, 1991; Sohn, 1999; Zsiga, 2011). The Korean obstruents /p, t, k/ become the corresponding nasals [m, n, ŋ] when they are immediately followed by nasals either within or across a word boundary (/kukmin/ -> [kuŋmin] 'people'; /pap#məkta/ -> [pam#məkta] 'eat rice'). The place assimilation in Korean is optional; thus, both coronal and labial/velar productions of the final consonant in the carrier words are legitimate and standard (Jun, 1995; Kochetov & Pouplier, 2009). In contrast, nasal assimilation is much close to obligatory and shows little variation across the different places of nasals in the trigger and the target of the assimilation. Zsiga (2011) showed that in 93% of experimental tokens which contained a stop and a nasal sequence across a word boundary, nasalization was complete, and underlying (e.g., /n#m/) and derived nasal sequences ([n#m] from /t#m/) were indistinguishable.

Following a frequency-based account of multiple lexical representation suggested by recent psycholinguistic studies, obligatorily processed nasal assimilation can be considered as a process with high frequency (93%), whereas optional place assimilation might happen less frequently. If obligatory, but not optional, assimilation process is stored in the lexicon, the response to the optional assimilation would be slower than that to the obligatory assimilation. However, if both obligatory and optional assimilations are in the lexicon, there would be no disadvantage for optional assimilation. Finally, if the processing of the optional assimilation process is greatly influenced by the lexical frequency of the words, only low-frequency words would slow down the shadowing process. Ernestus, Lahey, & Femke (2006) investigated the correlation between lexical frequency and degree of voice assimilation in Dutch. They found that regressive voice assimilation occurs more often in higher-frequency words, indicating that speakers tend to produce higher-frequency words with reduced articulatory effort. If their hypothesis is correct, both place and nasal assimilations contain canonical (unassimilated) forms in the mental lexicon, whereas assimilated forms are stored in the lexicon only for nasal assimilation. Hence the assimilated forms would be processed faster than unassimilated forms in nasal, but not in place assimilation. To test this hypothesis, a repetition priming paradigm with a shadowing task was employed (McLennan et al., 2003, 2005; Ogasawara, 2012). In this paradigm, participants are presented

with a block of spoken words to which they must respond (the study phase). After this initial exposure, they are presented with another block of words (the test phase). In the second block some of the words are repeated from the first block. It has been known that repeated words are responded to more quickly and accurately than new words, because repeated activation of form-based representation facilitates processing. In this study, participants were presented with a block of spoken words with either assimilated or unassimilated tokens, and they were asked to repeat the words in the second block with their natural pronunciation without imitating the stimuli. Repetition priming is used to determine whether two different stimuli – here assimilated vs. unassimilated stimuli - activate the same mental representation.

2. Method

2.1 Participants

Sixty (30 females, 30 males) native speakers of Korean aged 18 to 29 (mean = 22.9 years) were recruited from a university in Seoul, Korea. None of them reported speech or hearing disorders. They were paid for their participation.

2.2 Stimuli

Two assimilation environments were created: place vs. nasal assimilation. In the case of place assimilation, the onset of the second syllable was a labial (/p/) or a velar stop (/k/), and the coda of the first syllable was an alveolar nasal consonant (/n/) (e.g., /si**n.p**u/ 'bride'; /kʌ**n.k**aŋ/ 'health'). Given that place assimilation is optional in Korean, it was expected that the alveolar nasal was either assimilated to the immediately following consonant, or remained as unassimilated (or partially assimilated). As for the nasal assimilation, the onset of the second syllable was a nasal and the coda of the first syllable was an obstruent with various places of articulation (e.g., /si**k.m**ul/ 'plant'; /ca**k.n**jʌn/ 'last year'). Unlike place assimilation, nasal assimilation is obligatorily processed and thus the final obstruent of the first syllable, whatever it was, was expected to be nasalized.

Twenty real words were chosen for each type of assimilation environments. All words were bisyllabic noun words, half of which showed relatively high frequency and the other half, with low frequency. When assimilation is optionally operated, the likelihood of it being applied varies with lexical frequency. The onset of the second syllable of each word underwent the target assimilation process. In both place and nasal assimilations, no words created potential lexical competitors when they were assimilated (e.g., [sim.pu] for /sin.pu/ was a not a real word in Korean). In addition to the 40 test words, the identical number of fillers were created where not assimilation, but other phonological processes, were applied. Most of the fillers showed relatively high frequency, but all other conditions are similar to the test words. The complete list of the test words and fillers is presented in Appendix.

A male native speaker of the Seoul dialect of Korean recorded the test words and fillers in a sound-proof booth using a Tascam HD-P2 solid-state recorder and a Shure KSM44 microphone. The words were then filtered and digitized at 22,050 Hz. The stimuli were recorded multiple times to achieve a naturally sounding production. In addition to the test words, two sets of non-words were also recorded for speech synthesis. For example, in the case of place assimilation, the first set of items was non-words where the first syllables were the same as those of the test words, but the second syllable was initiated with an alveolar fricative, /s/ (e.g., [sin.sa] for /sin.pu/ 'bride'; [hon.sa] for /hon.ki/ 'marriageable age'). The second set of items was created with the same type of the first syllable, but the second syllable was a labial stop ([p]) or a velar stop ([k]) depending on the consonant the real words showed (e.g., [sin.pa] for /sin.pu/ 'bride'; [hon.ka] for /hon.ki/). With these materials, both assimilated and unassimilated tokens were synthesized using a cross-splicing procedure (Gaskell & Marslen-Wilson, 1996). For example, in the case of place assimilation, first, to obtain an unassimilated tokens, the first syllable of the target word, recorded with an alveolar fricative [s] (e.g., [sin.sa] for [sin.pu] 'bride'), was excised and attached to the second syllable of the target word (e.g., [pu]). The assimilated tokens were created with the excitation of the first syllable of the target word recorded with another labial or velar stop, and attached to the second syllable of the target word. Both assimilated and unassimilated stimuli were created with splicing, because if only unassimilated stimuli were spliced, while assimilated were not, it would create a potential for acoustic artifact and make it hard to compare the two conditions. The stimulus materials were posited in three priming conditions (match, mismatch, and control) as in Table 1. The experimental and control stimuli presented in the first block served as primes and those presented in the second block were targets. In the match condition, a prime and a target were identical. In the mismatch condition, a prime and a target were counterpart variant: a prime as an unassimilated token and a

Table 1. Experimental conditions with examples

Condition				Examples			
				Block 1: prime		Block 2: target	
				place	nasal	place	nasal
	Match						
1st set	assimilated prime	→	assimilated prime	si**mp**u	si**ŋm**ul	si**mp**u	si**ŋm**ul
2nd set	unassimilated prime	→	unassimilated prime	si**n**pu	si**km**ul	si**n**pu	si**km**ul
	Mismatch						
3rd set	assimilated prime	→	unassimilated prime	si**mp**u	si**ŋm**ul	si**n**pu	si**km**ul
4th set	unassimilated prime	→	assimilated prime	si**n**pu	si**km**ul	si**mp**u	si**ŋm**ul
	Control						
5th set	unrelated prime	→	assimilated prime	ucu	ucu	si**mp**u	si**ŋm**ul
6th set	unrelated prime	→	unassimilated prime	ucu	ucu	si**n**pu	si**km**ul

(/sin.pu/ 'bride'; /sik.mul/ 'plant'; /u.cu/ 'universe)

target as an assimilated token or a prime as an assimilated token and a target as an unassimilated token. In the control condition, a prime was an unrelated word and a target was an either assimilated or unassimilated token. Orthogonal combination of the three conditions (match, mismatch, & control) and two types of tokens (assimilated & unassimilated) resulted in six sets of stimuli (as shown in Table 1).

2.3 Procedure

Participants were tested individually in a sound-attenuated booth. The experiment was run by E-prime 2.0 (Psychology Software Tools Inc). Each participant was seated in front of a laptop computer, wearing a headphone and a microphone connected to a Serial Response Box to record responses. Participants were randomly assigned to one of the six sets as in Table 1, and thus each participant heard each target only in one condition (one set). The experiment was composed of three sessions: practice, block 1, and block 2. In each stage, participants were presented with a stimulus word binaurally over the headphone (Sennheiser HD 590). They were instructed to shadow the stimulus word as quickly and accurately as possible. However, they were asked to repeat with their natural pronunciation without imitating the recording. Reaction times (RTs) were measured from the onset of the presentation of stimulus word to the onset of the participant's shadowing response in the second block. The response window was five seconds from the onset of the presentation of the stimuli. First, in the practice stage, participants heard 10 items of real words without any assimilation, and repeated them out loud; in the first block (primes), they listened to and shadowed the 40 real word items; and finally in the second block (targets), they listened to and repeated the 40 items. There were a short pause between the two parts of the experiment (block 1 and block 2), and all experiments consisting of three sessions (practice, block 1, and block 2) lasted approximately 15 minutes. Thus the total numbers of items as they heard in each set were 90 (10 for practice, and 40 each for block 1 and block 2). Before they began the block 1, they were informed that word tokens might appear more than once. After the experiment, participants were asked to fill out a questionnaire about their biographical and language background.

3. Results and discussion

All responses were examined for mispronunciation by the experimenter, and 32 out of 2,400 responses were regarded as errors (0.13%). Any RTs outside the range from 200 to 1500 ms were treated as errors, which excluded none of the data.

Figure 1 shows the mean RTs for responses to the targets in the second block sorted by the priming conditions in the nasal assimilation.

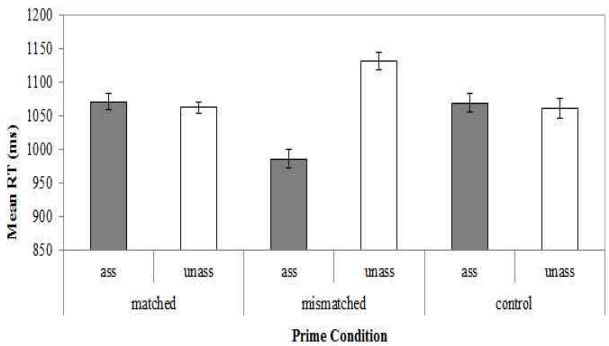

Figure 1. RTs for responses in the second block sorted by the priming condition (match, mismatch, and control) in nasal assimilation

The mean RTs were submitted to a mixed ANOVA in which prime (matching, mismatching, and control), and type (assimilated and unassimilated) were within-subject factors, and frequency (high and low) was a between-subject factor. The effect of type was significant [F(1, 18)=18.725, p=.000], but there was no main effect of prime [F(2, 36)=.469, p>.05]. The effect of frequency was marginally significant [F(1, 18)=5.018, p=.038]. The two-way interaction of prime and type was significant [F(2, 36)=51.679, p=.000], and so was the interaction of type and frequency [F(1, 18)=13.809, p<.05]. To pull apart the two-way interaction, the simple effects of the interaction between prime and stimulus, and that between stimulus and frequency were analyzed. The mean RT difference between assimilated and unassimilated tokens was significant for mismatched condition [F(1,18)=98.6, p=.000], but not for matched condition [F(1,18)=.59, p>.05]. In the matched condition, the mean RTs were similar to each other between assimilated and unassimilated tokens. This result suggests that the priming effect might neutralize the difference of the unassimilated and assimilated stimuli. It is plausible that even though participants repeated the given stimuli with their natural pronunciation and thus they repeated the words in the form stored in the lexicon, they responded quickly showing priming effect when they were presented with the repetition of the identical stimuli. However, in the mismatched condition, the mean RTs for the unassimilated tokens were longer than those for the assimilated tokens. As mentioned earlier, nasal assimilation is obligatorily processed in Korean, with a high frequency. As a result, participants took more time to respond to the unassimilated than the assimilated stimuli. The results for the interaction between frequency and stimulus, the mean RT difference between assimilated and unassimilated tokens was significant for high frequency tokens [F(1,18)=32.35, p=.000], but not for low frequency tokens [F(1,18)=.19, p>.05]. Given the effect of frequency, and the interaction effect between frequency and type, the RTs for response were further split across the frequency factor as in Figure 2. Focusing on the results for mismatched condition, the mean RT differences were shown to be clear for high frequency words, but not for low frequency words. This is against our expectation, because obligatorily processed assimilation is not expected to be influenced by lexical frequency. Though Ernestus et al. (2006) argued that only the processing of optional assimilation process is heavily influenced by the lexical frequency, even obligatorily processed assimilation shows frequency effect.

Next, Figure 3 shows the mean RTs for responses to the targets in the second block sorted by the priming conditions in the place assimilation.

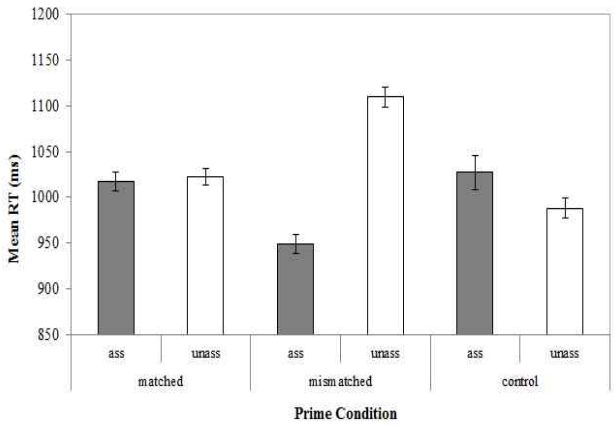

Figure 3. RTs for responses in the second block sorted by the priming condition (match, mismatch, and control) in place assimilation

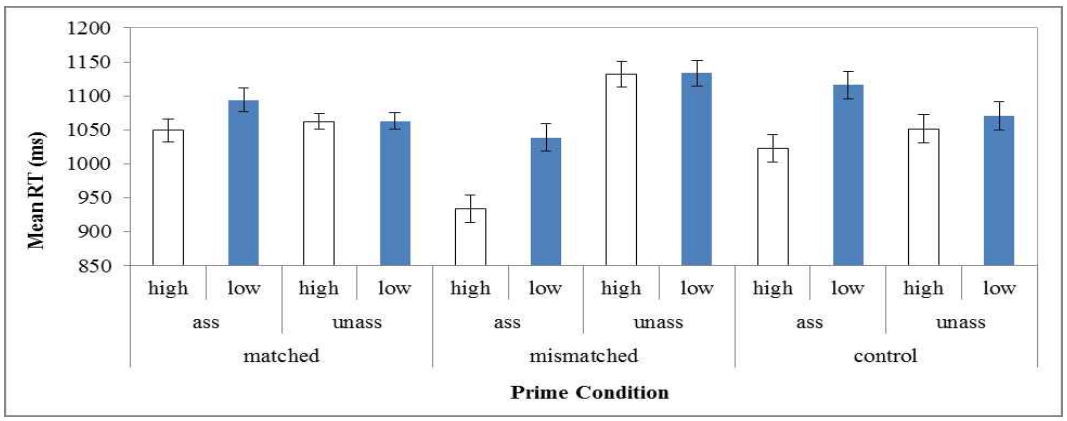

Figure 2. RTs for responses in the second block sorted by the priming condition (match, mismatch, and control) and frequency (high and low) in the nasal assimilation

The mean RTs were submitted to a mixed ANOVA with prime (matching, mismatching, and control), type (assimilated and unassimilated) as within-subject factors and frequency (high and low) as a between-subject factor. The effect of type was significant [F(1, 18)=26.159, p=.000] but no further effect was shown to be significant [F(2, 36)=2.526, p>.05 for prime; [F(1, 18)=1.444, p>.05 for frequency]. The two-way interaction of prime and type was significant [F(2, 36)=81.747, p=.000]. The simple effects of the interaction between prime and type further demonstrated that the mean RT difference between assimilated and unassimilated tokens was significant for mismatched condition [F(1,18)=247.8, p=.000], but not for matched condition [F(1,18)=.25, p>.05]. In the matched condition, the mean RTs were similar to each other between assimilated and unassimilated tokens. However, in the mismatched condition, the mean RTs for the unassimilated tokens were longer than those for the assimilated tokens. These results indicate that even in the optional assimilation, participants took more time to respond to the unassimilated than the assimilated stimuli. Following the account of multiple lexical forms for high-frequency variants, less frequent, optional assimilation would be expected to be processed similarly between assimilated and unassimilated forms. However, this hypothesis was not borne out.

4. General discussion

The aim of the study was to investigate the lexical representations of optional, place and obligatory, nasal assimilations in Korean. A long-term repetition-priming experiment was conducted with a shadowing task. Korean listeners heard the unassimilated or assimilated stimuli and repeated the words. As participants were asked to repeat the words with their natural pronunciation without imitating the stimuli, lexical access happened when the participants heard the words, and they repeated the words in the form stored in the mental lexicon (Ogasawara, 2012). The results showed that the shadowing latencies did not significantly differ between place and nasal assimilations. Crucially, in the mismatched condition, when Korean listeners heard the assimilated stimuli, they responded equally fast between the place and nasal assimilations.

The present results do not support the account of multiple lexical forms for high-frequency variants (Connine, 2004; Connine & Pinnow, 2006; Ranbom & Connine, 2007; Ogasawara, 2012). These researchers argue that if some allophonic variants happen frequently (e.g., flapping in American English), they are recognized easily because they are stored in the mental lexicon together with the canonical forms. However, they argue that less frequent variants (e.g., across-the-word place assimilation in English and other languages) do not benefit processing. If only high frequency variants are stored in the lexicon, the allophonic variants from place assimilation would not be stored. This can lead to two different behaviors between place and nasal assimilations in the mismatched condition: the shadowing latencies for the assimilated stimuli should be longer in place assimilation than in nasal assimilation, whereas the shadowing latencies for the unassimilated stimuli would be similar between place and nasal assimilations. Comparison of the results between Figure 1 and Figure 2, however, does not show such behavior.

One possible account that can be drawn from the present results is that the frequency of place assimilation might be relatively high even though it is analyzed as an optional phonological process in the phonological literature. That is, the place assimilation is optional as in the across-word-boundary assimilation in English, and thus the canonical unassimilated form is always possible pronunciation (Ogasawara & Warner, 2009). However, Korean speakers might prefer the assimilated forms of the place assimilation rather than the unassimilated forms. The actual frequency of the assimilated forms in the spontaneous speech might be high enough to lead to similar shadowing latency patterns to the obligatory phonological variants. To prove this view, however, the actual frequency of the optional phonological variants should be examined through a large scale of spontaneous speech corpora.

Another possibility is that even in the case where Korean speakers tried to produce the target token as unassimilated as in [sin.pu] from /sin.pu/, it might have both coronal and labial properties. The unassimilated token as Korean speakers normally produce might be different from [n] excised from [sin.sa] which has only coronal property. Then the completely unassimilated nasal as above could be heard as unnatural to the Korean speakers. It is therefore possible that they needed more time to shadow those unfamiliar, unnatural tokens. In the phonological analysis, rules are binary, either obligatory or optional, but phonetic realization of the rules can be more detailed with large degrees of intermediate stages. As for the across-the-word place assimilation in English, Gow (2002) showed that speakers produce the assimilated words with intermediate values. The assimilated stop in *right berries* shows spectral characteristics consistent with both labial and coronal place of articulation,

which leads speakers to use such fine phonetic details in the signal to choose the right word between *right* and *ripe*, for example.

In addition, the alveolar nasal (/n/) in the example of /sin.sa/ might be different from that in /sin/ (p.c. Hyunsook Kang). When the alveolar nasal occurs immediately before an alveolar fricative (/s/), the contact area between the tongue blade and the alveolar ridge is not large enough to increase the supraglottal air pressure. On the other hand, when /n/ is produced in the final position, there is tight blockage between the two articulators. This subtle difference between the two [n]'s might cause a delay in the shadowing response.

In this sense, it is conceivable that another unexpected result that not place, but nasal assimilation showed a frequency effect can be associated to the actual frequency of the assimilation processes. Based on earlier studies, it is expected that the frequency effect would not be shown in obligatory assimilation, because inappropriately realized variants hinder processing, regardless of the lexical frequency of the words. However, even in obligatory, nasal assimilation, high frequency words render the participants respond to the assimilated tokens faster than the unassimilated tokens. Even though place and nasal assimilations are categorically described in the phonological literature, the actual frequency or optionality of the assimilation processes might be gradiently different for different types of assimilation or even for different word forms.

In any case, it is noteworthy that listeners are likely to be sensitive to such fine-grained phonetic details when they process the allophonic variants. It is because Korean listeners responded differently to various allophonic variants of /n/ according to the degree of assimilation and the next segments in the shadowing. In fact, Darcy et al. (2013) argue that even lexical representation might be quite detailed with large degrees of intermediate stages.

With the results of the present study alone, it is not clear which model or mechanism could better explain the processing of allophonic variants. However, the results for the two types of assimilation processes in Korean can be modelled by considering more fine-grained phonetic information, rather than an abstract, categorical dichotomy such as obligatory vs. optional processes.

References

Bürki, A., Ernestus, M., & Frauenfelder, U. H. (2010). Is there only one "fenêtre" in the production lexicon? On-line evidence on the nature of phonological representations of pronunciation variants of French schwa words. *Journal of Memory and Language,* Vol. 62, 421-437.

Bürki, A., Alario, F.-X., & Frauenfelder, U. H. (2011). Lexical representation of phonological variants: Evidence from pseudohomophone effects in different regiolects. *Journal of Memory and Language*, Vol. 64, 424-442.

Connine, C. M. (2004). It's not what you hear, but how often you hear it: On the neglected role of phonological variant frequency in auditory word recognition. *Psychonomic Bulletin and Review*, Vol. 11, 1084-1089.

Connine, C. M. & Pinnow, E. (2006). Phonological variation in spoken word recognition: Episodes and abstractions. *The Linguistic Review*, Vol. 23, 235-245.

Cutler, A. (2012) *Native listening*. MIT Press.

Cutler, A. & Otake, T. (1998) Assimilation of place in Japanese and Dutch. In R. H. Mannell & J. Robert-Ribes (Eds.), *Proceedings of the 5th International Conference on Spoken Language Processing*, Sydney (Vol. 5, pp. 1751-1754). Canberra; Australian Speech Science and Technology Association.

Darcy, I., Daidon, D., & Kojima, C. (2013) Asymmetric lexical access and fuzzy lexical representations in second language learners. *The Mental Lexicon*, Vol. 8(3), 372-420.

Dell, G. S. (1986). A spreading activation theory of retrieval in sentence production. *Psychological Review*, Vol. 93, 283-321.

Ernestus, M., Lahey, M., & Femke, V. (2006) Lexical frequency and voice assimilation. *The Journal of the Acoustical Society of America*, Vol. 120(2), 1040-1051.

Gaskell, M. G., & Marslen-Wilson, W. D. (1996). Phonological variation and inference in lexical access. *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 22, 144-158.

Gaskell, M. G., & Marslen-Wilson, W. D. (1998). Mechanisms of phonological inference in speech perception. *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 24, 380-396.

Gow, D. W. (2001). Assimilation and anticipation in continuous spoken word recognition. *Journal of Memory and Language*, Vol. 45, 133-159.

Gow, D. W. (2002). Does English coronal place assimilation create lexical ambiguity? *Journal of Experimental Psychology: Human Perception and Performance*, Vol. 28, 163-179.

Gow, D. W. (2003). Feature parsing: Feature cue mapping in spoken word recognition. *Perception and Psychophysics*, Vol. 65, 575-590.

Gow, D. W., & Im, A. M. (2004). A cross-linguistic examination of assimilation context effects. *Journal of Memory and Language*, Vol. 51, 279-296.

Jun, J. (1995). *Perceptual and articulatory factors in place assimilation: An optimality theoretic approach*. Ph.D. dissertation, University of California at Los Angeles.

Kim-Renaud, Y.-K. (1991). *Korean consonantal phonology*. Seoul: Hanshin.

Kochetov, Al., & Pouplier, M. (2009). Phonetic variability and grammatical knowledge: An articulatory study of Korean place assimilation. *Phonology*, Vol. 25, 399-431.

Lahiri, A., & Marslen-Wilson, W. D. (1991). The mental representation of lexical form: A phonological approach to the recognition lexicon. *Cognition*, Vol. 38, 245-294.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences*, Vol. 22, 1-75.

LoCasto P. C. & Connine, C. M. (2002). Rule-governed missing information in spoken word recognition: Schwa vowel deletion. *Perception and Psychophysics*, Vol. 64, 208-219.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology*, Vol. 18, 1-86.

Mitterer, H., & Blomert, L. (2003). Coping with phonological assimilation in speech perception: Evidence for early compensation. *Perception and Psychophysics*, Vol. 65, 956-969.

Ogasawara, N. (2012). Lexical representation of Japanese vowel devoicing. *Language and Speech*, Vol. 56(1), 5-22.

Ogasawara, N. & Warner, N. (2009). Processing missing vowels: Allophonic processing in Japanese. *Language and Cognitive Processes*, Vol. 24, 376-411.

Patterson, D. & Connine, C. M. (2001). Variant frequency in flap production: A corpus analysis of variant frequency in American English flap production. *Phonetica*, Vol. 58, 254-275.

Ranbom, L. J. & Connine, C. M. (2007). Lexical representation of phonological variation in spoken word recognition. *Journal of Memory and Language*, Vol. 57, 273-298.

Renwick, M. E. L., Ladan B.-R., Temple, R., & Coleman, J. S. (2013). Assimilation of word-final nasals to following word-initial place of articulation in UK English, *ICA 2013 Montreal*, Montreal, Canada 2-7 Jun.

Sohn, H.-M. (1999). *The Korean language*. Cambridge: Cambridge University Press.

Zsiga, E. (2011). External sandhi in a second language: The phonetics and phonology of obstruent nasalization in Korean-accented English, *Language,* Vol. 87(2), 289-345.

• **Han, Jeong-Im**
Department of English
Konkuk University
120 Neungdong-ro, Gwangjin-gu
Seoul, 143-701, Korea
Email: jhan@konkuk.ac.kr

Appendix

Test items

	type	test words	frequency
1	nasal	/hjʌk.mʌŋ/ ‘revolution’	163
2	nasal	/ʌp.mu/ ‘work, business’	207
3	nasal	/sik.mul/ ‘plant’	158
4	nasal	/ak.ma/ ‘devil’	24
5	nasal	/pit.mul/ ‘rainwater’	40
6	nasal	/mak.næ/ ‘the youngest’	45
7	nasal	/hak.njʌn/ ‘grade’	413
8	nasal	/ap^{h}.nal/ ‘future’	31
9	nasal	/cak. njʌn/ ‘last year’	216
10	nasal	/c^{h}ʌt.nal/ ‘thefirstday’	55
11	nasal	/kak.mak/ ‘cornea’	2
12	nasal	/sæk.mæŋ/ ‘color blindness’	1
13	nasal	/c^{h}ok.mæ/ ‘catalyst’	4
14	nasal	/pok.mjʌn/ ‘mask’	1
15	nasal	/cak.mjʌŋ/ ‘naming’	3
16	nasal	/muk.njʌm/ ‘silent tribute’	4
17	nasal	/pok.nal/ ‘canicular days’	2
18	nasal	/ip^{h}.nun/ ‘leafbud’	1
19	nasal	/cik.niŋ/ ‘function’	4
20	nasal	/tɨk.nam/ ‘begetting a son’	1
mean frequency			63.6
21	place	/sin.pu/ ‘bride’	94
22	place	/nun.mul/ ‘tear’	271
23	place	/un.pan/ ‘transportation’	18
24	place	/cun.pi/ ‘preparation’	211
25	place	/pjʌn.mjʌŋ/ ‘excuse’	34
26	place	/kʌn.kaŋ/ ‘health’	337
27	place	/pʌn.kæ/ ‘lightening’	32
28	place	/hjʌn.kɨm/ ‘cash’	94
29	place	/an.kjʌŋ/ ‘glasses’	80
30	place	/han.kɨl/ ‘Korean alphabet’	182
31	place	/kan.pjʌŋ/ ‘nursing’	1
32	place	/pun.pæ/ ‘distribution’	3
33	place	/cʌn.pʌm/ ‘war criminal’	1
34	place	/c^{h}un.pun/ ‘vernal equinox’	8
35	place	/hwan.pu/ ‘affected area’	7
36	place	/tun.kap/ ‘transforming’	3
37	place	/san.ko/ ‘labor pains’	1
38	place	/c^{h}on.kɨk/ ‘skit’	2
39	place	/hon.ki/ ‘marriageable age’	2
40	place	/wan.ku/ ‘toy’	2
mean frequency			64.2

Control items

	control words		frequency
1	/so.maŋ/	‘hope’	5507
2	/ci.kap/	‘purse’	3888
3	/coŋ.i/	‘paper’	1423
4	/tæ.sa/	‘ambassador’	5471
5	/toŋ.sæŋ/	‘younger brother/sister’	602
6	/mʌ.li/	‘head’	288
7	/mo.ki/	‘mosquito’	6582
8	/pæ.u/	‘actor’	2197
9	/ho.pak/	‘pumpkin’	3617
10	/pi.nu/	‘soap’	6608
11	/sa.mak/	‘dessert’	4801
12	/ʌl.kul/	‘face’	157
13	/jʌ.ca/	‘woman’	84
14	/o.li/	‘duck’	6846
15	/jo.cʌŋ/	‘fairy’	10172
16	/u.pjo/	‘stamp’	12746
17	/u.cu/	‘universe’	578
18	/kɨ.lim/	‘picture’	362
19	/sa.kwa/	‘apple’	3237
20	/hʌ.li/	‘waist’	1082
21	/sil.hʌm/	‘experiment’	639
22	/kuk.hwa/	‘chrysanthemum’	18116
23	/jʌn.ljo/	‘fuel’	4222
24	/pjʌn.ho/	‘justification’	18620
25	/ʌn.ʌ/	‘language’	667
26	/kuk.ʌ/	‘native language’	3108
27	/cip^{h}.sin/	‘straw shoes’	24880
28	/sæŋ.hwal/	‘life’	174
29	/jak.cin/	‘great advance’	24117
30	/ʌl.ɨm/	‘ice’	3593
31	/hak.kjo/	‘school’	125
32	/mat.i/	‘eldest’	16778
33	/k^{h}al.nal/	‘blade’	7938
34	/hap.kjʌk/	‘pass’	6725
35	/c^{h}uk.ku/	‘soccer’	1317
36	/kkoc^{h}.cip/	‘flower shop’	18206
37	/jʌp.sʌ/	‘postcard’	7581
38	/c^{h}æk.saŋ/	‘desk’	1653
39	/mun.hak/	‘literature’	272
40	/mun.hwa/	‘culture’	73