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Lexical Status and the Degree of /l/-darkening

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ABSTRACT

This study explores the degree of velarization of English word-final /l/ (i.e., /l/-darkness) according to the lexical status. Lexical status is defined as whether a speech stimulus is considered as a word or a non-word. We examined the temporal and spectral properties of word-final /l/ in terms of the duration and the frequency difference of *F*2-*F*1 values by varying the immediate pre-liquid vowels. The result showed that both temporal and spectral properties were contrastive across all vowel contexts in the way of real words having shorter [l] duration and low *F*2-*F*1 values, compared to non-words. That is, /l/ is more heavily velarized in words than in non-words, which suggests that lexical status whether language users encode the speech signal as a word or not is deeply involved in their speech production.

Keywords: speech production, /l/-darkness, velarization, duration, *F*2-*F*1

1. Introduction

Effect of lexical status on speech processing has been largely discussed in the context of listeners' perceptual decision. Research on this topic found that lexical knowledge about whether a speech signal is a word or non-word creates independent lexical representations during perceptual processing. Ganong (1980), for instance, examined an ambiguous acoustic stimulus token continuum and found that listeners' perception of a phoneme is deeply affected by the lexical status of the stimuli. Fox (1984) also studied the lexical effects on listeners' phonetic categorization and argued that listeners' perceptual decision is lexically biased in the way of words processed earlier and easier than non-words. These two studies suggest that the lexical knowledge of a stimulus is considered as a word or not has to do with the perceptual process of an ambiguous token. Words and non-words have separate activation process of lexical representations (Garman, 1990; McMillan & Corley, ms.). When real words are pronounced, speakers activate pre-existing phonological representation that corresponds to the speech materials, that is, the texts. Now that the phonological representation is already stored in lexical memory, speakers simply locate the best-match representation to the material. On the other hand, since non-words are not stored in the lexicon, the corresponding phonological representations of non-words do not exist. Activation of non-word representation, therefore, undergoes different process from words. Pronouncing of non-words is building up a newly encoded lexical representation in which speakers need to plan timely mannered motor movements while processing the speech signal (Krishnan *et al.*, 2013). While production of real words involves articulating appropriate phonological representation only, that of non-words requires extra stage of processing, organizing a newly developed lexical representation.

The difference according to lexical status implies variations in production in that real words may be benefited of knowing them in advance and simply locating the pre-existing representation. Since one knows the coordinated movements of real words in advance, articulatory arrangements may be rapidly processed compared to non-words during articulation (Lange-Küttner *et al.*, 2013). Non-words involve the overall process of transforming the material into motor movements, creating a novel phonological representation and the organizing articulators accordingly

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(Krishnan *et al.*, 2013). Speech production of non-words, therefore, may be distinct from that of words in acoustic and/or articulatory manners.

Unlike listener's perceptual processing, little is known about the influence of lexical status on speech production. In this study, we explore how differently speech is produced along with the lexical status of speech stimuli. Specifically, we examine the degree of velarization of English /l/ (i.e., /l/-darkness) to which the lexical status is concerned. English alveolar liquid /l/ is known to have at least two allophones of a clear [l] and a dark [ɫ]. In the literature, it is widely known that the articulation of /l/ is generally characterized as the contact between the alveolar ridge and the tip of the tongue (Brownman & Goldstein, 1992, 1995). In spite of the contact of the two articulators, the airflow is not being blocked but flows through the two (or one) sides of the tongue (Ladefoged & Maddieson, 1996). The articulatory difference between the two [l]s lies on whether or not the tongue dorsum is being retracted. Clear [l] is produced by raising the tip of the tongue towards the alveolar ridge and remains as it is until the whole articulation is completed. For dark [ɫ], extra tongue movements are involved; while the tip of the tongue remains as being contacted with the alveolar ridge, the front of the tongue is pushed down. Being lowered of the front of the tongue leads to the back to be raised towards the soft palate, resulting in the tongue dorsum is relatively retracted towards the velum. This allophone involving a secondary articulation of tongue body, or a combined gesture of two articulators (Halle & Mohanan, 1985) one with [+back] the other with [-back], is known to be velarized or dark (Ladefoged, 2001). Being known as allophones is due to their appearance being positionally determined within a syllable. Clear [l] largely appears on the onset of a syllable as in *lit* while dark [ɫ] on the coda as in *feel* (Sproat & Fujimura, 1993). However, /l/-darkening is not fully explained by syllable position because for some /l/s, the simple distinction of onset/coda does not hold. Various factors exhibit different degree of /l/ darkness such as dialectal differences, morpho-syntactic environment, inter-speaker variations, among others. For instance, in Received Pronunciation, coda /l/ as in *heal* [l] is not velarized while in American English the same coda *heal* [ɫ] is velarized (Turton, 2014). Also, in Leeds, initial /l/ in *leaf* is dark, in Scottish English, /l/ in *leaf* and /l/ in *feel* can be dark (Carter & Local, 2007). Morphological effect is also found as in *heal it* [l] vs. *heal* [ɫ] (Bermudez-Otero, 2007), and for some speakers within one dialect, both onset and coda /l/ as in *light* [ɫ] and *heal* [ɫ] may be velarized (Huffman, 1997).The reason for the /l/-darkening being so complex is that the situation cannot be a binary distinction. That is, a discrete or categorical distinction of clear vs. dark as discussed in the traditional accounts of English /l/ does not hold (Chomsky and Halle, 1968). Instead, /l/-darkening is rather continuous or gradient (Turton, 2014; Halle-Lew & Fix, 2012).

In this work, we extend the discussion of the degree of /l/-darkness to lexical status. Lexical status refers to the way in which a speech stimulus is considered as a word or a non-word. Depending on lexical status, speakers may plan their velarization more heavily or less. The study of English /l/-darkening verifies that traditional distinction of /l/ may not hold by showing the gradient properties of velarization. This paper also argues language users perform speech planning in terms of lexical status by presenting the degree of velarization of English real words differ from that of non-words.

Table 1. Stimulus materials for English word-final /l/ in words and non-words

		pre-liquid vowels				
		i_	ɛ_	ə_	o_	u_
Lexical Status	Word	*appeal*	*gazelle*	*civil*	*charcoal*	*retool*
		rehee	*hotel*	*fatal*	*Nicole*	*befool*
		lrepeal	*impel*	*legal*	*dipole*	*recool*
		reseal	*lapel*	*peril*	*cajole*	*carpool*
		reveal	*retell*	*pupil*	*parole*	*cesspool*
	Nonword	*dofill*	*bogell*	*bofel*	*boosole*	*finule*
		haseal	*chasell*	*coupall*	*hemoul*	*kinool*
		kasheal	*homell*	*lonall*	*marole*	*masool*
		poseal	*marell*	*magel*	*mirole*	*regoole*
		sanill	*pidell*	*peedil*	*pagol*	*shedool*
		vikeel	*rifell*	*teekil*	*tofole*	*tofool*

2. Methods

2.1 Speakers

Five native speakers of American English were recruited around the Seoul National University campus. All of them were born in the US and came to Korea on their 20s or 30s, and no hearing and speaking difficulties were reported from the speakers. All speakers participated voluntarily and they were paid after the recordings were completed.

2.2 Stimulus materials and recordings

The reading materials consisted of 55 disyllabic words in which 25 were English real words and 30 non-words. All the words were CV(C).CVL sequences so that [l] fell on the word-final position. The vowels of the second syllable equally varied among one of the five vowel types /i, ɛ, ə, o, u/. The stimulus materials for the experiment were illustrated in <Table 1>. Each word embedded in a carrier sentence, "*Say* _______ *clearly*", and the order of the reading was randomized. Speakers were instructed to read each sentence one by one and they repeated the whole reading task five times. Their reading was recorded with a sampling rate of 44,100 Hz. The recording process was conducted in a sound attenuated booth of the phonetics lab at the Seoul National University.

2.3 Stimulus materials and recordings

In this study, we examined both temporal and spectral properties of English word-final /l/. For the temporal aspect, the duration of /l/ was measured from the onset to the offset of the vowel. Considering their independent strategies to lexical status, listeners were expected to produce relatively different duration of /l/ in words and non-words. According to Sproat & Fujimura (1993), /l/-darkness is strongly affected by duration, which suggests that the duration of English word-final /l/ in words vs. non-words may be different depending on lexical status.

In addition, for the spectral aspect, the frequency difference of *F*2-*F*1 was examined. In the literature, the frequency difference is known to be a joint indicator of typical velarization measurement to determine a clear /l/ vs. dark /l/. Dark /l/ has lower *F*2-*F*1 which ranges 650-850 Hz while clear /l/ has over 1000 Hz. Thus, if /l/ in real words are more velarized, their *F*2-*F*1 range would be lower than non-words, and vice-versa.

3. Results

The results for the temporal and spectral aspects were separately analyzed using t-tests. They investigated the significant differences of words vs. non-words conditions in terms of duration and *F*2-*F*1 differences. The results of t-tests in *F*2-*F*1 scales are presented in <Table 2>.

3.1 Durational differences

The duration of various /l/ according to the five pre-liquid vowels is described in <Figure 1>. Summing across words and non-words, the duration of /l/ was significantly longer in non-words than in words (t(1370) = 6.73, p < 0.001). Mean duration of /l/ in words was 116 ms while that in non-words 102 ms. The duration in non-word contexts was relatively uniform, which ranged around between 110 and 120 ms. In this non-word contexts, /l/ was the longest in [o_] context and the shortest in [i_]. The duration of /l/ in word contexts, on the other hand, fluctuated from 76 to 114 ms. /l/ was the longest in [i_] and [ɛ_] contexts, and the shortest in [ə_].

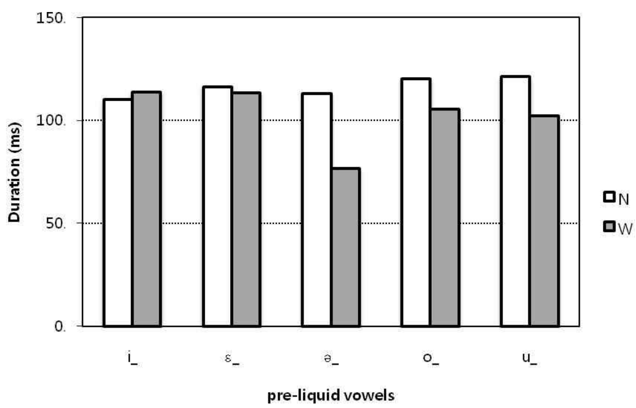

Figure 1. The duration of /l/s in [i_], [ɛ_], [ə_], [o_] and [u_] contexts

In general, the duration of /l/ varied according to the backness of pre-liquid vowels as described. In the central and back vowel contexts (i.e., [ə_], [o_] and [u_]), /l/s were found to be significantly longer in non-words than words. The significant difference of duration was not found in the front (i.e., [i_] and [ɛ_]). All-inclusive, /l/s were shortest in the after [ə_] word context and longest in the after [u_] non-word. That listeners produced /l/s differently in words and non-words contexts was encouraging because it indicates language users plan their speech differently according to lexical status.

3.2 *F*2-*F*1

The differences of *F*2-*F*1 were examined in two ways; first of all, the real time scale was measured. For each /l/ period, the means of *F*2-*F*1 at the maximum and at the minimum points were examined (Xu, 2007). The mean *F*2-*F*1 of overall /l/ period was measured as well. Secondly, the normalized time scale was examined. From the onset to the offset of each /l/, degree of velarization was time normalized in 20 points. Statistical analysis of the lexical status was conducted all conditions for real time scale. For normalized time scale, three time points of onset, midpoint and offset of /l/ were examined in terms of their average and individual vowels. The *F*2-*F*1 values and their statistical analyzes are provided in <Table 2>. The asterisks denote the statistical significance of each comparison.

To begin with, for both real time and normalized time scales, *F*2-*F*1 values were significantly higher in non-words than words. To examine the vowel contexts individually, *F*2-*F*1 values were different in the [i_] onset and midpoint environments. In the [ɛ_] context, the difference was found on the onset and midpoint but not in the offset. The [ə_] was the only context that exhibited significant difference in the onset, midpoint and offset. Oppositely, [o_] was significant in no environments and [u_] was only in the onset.

In order to examine time-wise *F*2-*F*1 changes, the trajectory of the time normalized scale was examined as in <Figure 2>.

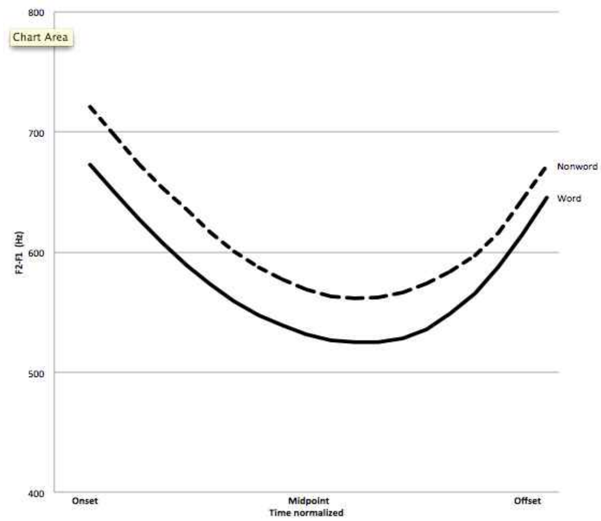

Figure 2. Time normalized trajectory of /l/-velarization in words and non-words

The dotted vs. continuous lines describe the *F*2-*F*1 changes in non-words and words, respectively. Regardless of lexical status, *F*2-*F*1 scale is high on the onset and it decreases until midpoints. The scale is the lowest between the midpoint and the

Table 2. *F*2-*F*1 scales and the significance in real time vs. normalized time

		Words	Non-words	Significance	
Real time	Max	736	782	$t(1370) = 2.4$	$p = 0.017$ *
	Min	541	576	$t(1370) = 3.4$	$p < 0.001$ *
	Mean	574	614	$t(1370) = 3.4$	$p < 0.001$ *
Normalized time	Onset	477	882	$t(1370) = 25.5$	$p < 0.001$ *
	i_	1274	1150	$t(271) = 3.6$	$p < 0.001$ *
	ɛ_	698	744	$t(271) = 2.0$	$p = 0.043$ *
	ə_	533	773	$t(271) = 6.8$	$p < 0.001$*
	o_	413	424	$t(271) = 0.7$	$p > 0.05$
	u_	450	521	$t(270) = 5.3$	$p < 0.001$*
	Midpoint	532	569	$t(1370) = 3.1$	$p = 0.002$ *
	i_	754	749	$t(271) = 0.2$	$p > 0.05$ *
	ɛ_	595	628	$t(271) = 1.1$	$p > 0.05$ *
	ə_	474	595	$t(271) = 4.5$	$p < 0.001$*
	o_	387	393	$t(271) = 0.4$	$p > 0.05$
	u_	455	480	$t(270) = 0.1$	$p > 0.05$
	Offset	646	672	$t(1370) = 1.8$	$p = 0.07$
	i_	710	724	$t(271) = 0.6$	$p > 0.05$
	ɛ_	696	702	$t(271) = 0.2$	$p > 0.05$
	ə_	583	703	$t(271) = 3.8$	$p < 0.001$*
	o_	604	586	$t(271) = 0.4$	$p > 0.05$
	u_	644	654	$t(270) = 0.8$	$p > 0.05$

offset. The decrease of the scale turns to increase after the midpoint until the offset. The difference between the non-word and word is larger on the onset than the offset. The trajectory of the $F2$-$F1$ scale indicates that the /l/-velarization changes over time.

4. Discussion

In this section, we discuss the implications of the results found in the experimental study. To begin with, as suggested in <Figure 1>, the duration of /l/ varied according to lexical status. The significant /l/ durational difference was found in the way of /l/s in words were shorter than those in non-words. Also, in terms of the backness of vowels, /l/s in the central and back vowel contexts were shorter than those in the front. Notably, it was found that /l/ was the shortest when it was embedded with the central vowel [ə_].

The central vowel context is typically known as no stress-bearing syllable. The unstressed vowel is characterized with the short duration of the vowel. The overall gestures of the co-occurring consonants in the unstressed vowels are reduced along with the vowel. That is, when /l/ appears in a stress-less syllable, the articulatory gesture become short; thus, the duration of /l/ becomes very short.

The shortening of /l/ gestures in the unstressed vowel contexts reflects lexical status as well. The shortening of /l/ is more severe in words than non-words. That is, the /l/s embedded in the unstressed syllable were short both in words and non-words environment but the /l/s in words were even shorter than ones in non-words.

This result suggests that the production of /l/ may be planned differently according to lexical status. Real words have pre-existing phonological representation in the lexical entry. The representation contains all the phonological information regarding, for instance, the articulatory movements and phonetic knowledge as well as stress assignments. Non-words, on the other hand, are not stored in the lexicon, suggesting that the representation of non-words do not exist. One, therefore, has to build up the phonological representation upon reading the non-words for the first time. This building up the representation holds down the time; therefore, it slows down the articulatory movements. As a result, duration of segments become longer in non-words while it is shortened in words.

The major indicator of /l/-darkness, $F2$-$F1$, also showed that the degree of velarization of words is different from that of non-words. In general, $F2$-$F1$ was lower in words than non-words, which indicate that /l/s embedded in words are heavily velarized than those in non-words. That is, language users' velarization strategies differ according to lexical status, which also infers listeners' independent speech production plan for words and non-words.

Statistical significance varies depending on the vowel contexts and the time span. As time proceeds, the /l/ becomes severely velarized from the beginning of the articulation until it reaches the midpoints. Between the midpoint and the offset, the /l/ slowly becomes less velarized. As described in the <Figure 2>, both in words and non-words, $F2$-$F1$ values are the lowest around at two-thirds of the total articulation of /l/, which is where the /l/s are most severely velarized.

The degree of /l/-darkness is also deeply affected by the preceding vowels. According to Ladefoged (2006), the first two formants have to do with the backness and openness of the vowels. $F2$-$F1$ of [i_], for instance, is around 1900-2000 Hz while those of [ə_] and [o_] are around 600-700 and 300-400 Hz, respectively. These $F2$-$F1$ values of vowels certainly affect the $F2$-$F1$ of [l] because the low $F2$-$F1$ values of the preceding vowels result in more heavily velarized [l]. $F2$-$F1$ of [l] in the [i_] context is actually high in words, (i.e., lightly velarized) while that in [ə_] context is high in non-words (i.e., heavily velarized). In summary, /l/-darkness or /l/-velarization is more severe in non-front than front vowel contexts.

5. Conclusion

In this experimental study, we examined the degree of English /l/-velarization according to lexical status by varying the preceding vowel contexts. We found that /l/-velarization severely affected by both lexical status and the preceding vowel contexts. Overall, /l/s in words are shorter in duration than those in non-words. /l/s in words also tend to be heavily velarized than those in non-words. These two durational and spectral differences seem to be due to speakers' independent speech plan for words vs. non-words. In addition, in terms of the preceding vowel contexts, /l/s are heavily velarized in the central vowel [ə_] than in the front vowel [i_] context, which is the influence of the $F2$-$F1$ values of each vowel itself.

It may be the case that the degree of velarization is affected by other factors such as genders, social classes, dialects among others. More studies on investigating the issue and compiling the relevant data would be necessary as a next step.

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