Effects of boundary strength on geminate duration in English*

Eunhae Oh
(Hyupsung University)

Oh, Eunhae. 2013. Effects of boundary strength on geminate duration in English. *Studies in Phonetics, Phonology and Morphology* 19.3. 457-478. Payne (2005) argues that fake geminates are longer than true geminates and Ridouane (2007) shows that their preceding vowel duration is also significantly longer. These effects are likely due to the boundary that distinguishes fake from true geminates. If this is correct, boundary strength is expected to affect fake geminates with different morpheme boundaries. In Experiment 1, we investigated this possibility by comparing the absolute and consonant-to-vowel durations of assimilated (Level 1) and concatenated (Level 2) word-internal and cross-word boundary fake geminates in English (e.g., *immoral* vs. *unnamed* vs. *fun name*). The results showed that both types of concatenated fake geminates were shorter than assimilated fake geminates in relative terms. A follow up experiment, comparing geminates in compound words to those emerging across words showed no differences in relative duration between the two. These results suggest that boundary strength may be less important than boundary decomposability in production. Overall, we argue that boundary decomposability impacts the phonetic implementation of geminates and likely does so whether these are true or fake. **(Hyupsung University)**

Keywords: fake and true geminates, assimilated and concatenated geminates, compounds, post-lexical geminates, consonant duration, boundary decomposability

1. Introduction

In this paper, the relationship between representation and implementation of fake geminates across different boundary types are examined. To investigate whether all fake geminates are realized in the same way, consonant-to-vowel durations of English fake geminates with different boundary types are compared. We explored the possibility that the implementational differences between true and fake geminates are not due to their phonological representations but rather motivated by the different decomposability of meaningful boundaries.

1.1 Background

Geminate consonants are phonetically long consonants that occur when consonant articulation is sustained for an audibly longer period of time than is typical for the singleton counterpart. Geminates are on average

* The current paper is an extended study (experiment 2) of my Ph.D. qualifying paper which was later published with the *Journal of Phonetics* in 2011. Responsibility for any errors of interpretation remains mine alone.

between one-and-a-half to three times longer than singletons in careful speech (Ladefoged and Maddieson 1996), but the ratio of geminate to singleton duration varies widely across languages. For example, Delattre (1968) reports from his cross-linguistic survey that the singleton-to-geminate ratio varies from 1:1.4 in English to 1:1.9 in French which indicates that the durational behavior may vary across languages. In addition to their relative duration, absolute geminate duration varies with low-level phonetic factors as well as with higher-level prosodic factors (Payne 2005, Payne and Eftychiou 2006). Geminates also often have shorter preceding vowel durations than singletons (Maddieson 1985).

There are three types of geminates in the world's languages: lexical, assimilated and concatenated. Lexical geminates (e.g., [pap:a] 'mush' in Italian) are given in the lexicon and are part of the phonemic inventory. Assimilated true geminates arise when one segment takes on the identity of the preceding or following segment at a morpheme boundary (e.g., /pul-nöŋ/ -> [pul:öŋ] 'incapability' in Korean, /kor + te/ -> [kot:e] 'do' infinitive in Bengali). Concatenated geminates arise from the accidental sequence of identical consonants that occur across a word-internal or word-peripheral morpheme boundary (e.g., un+named, fun name).

Linguists have typically considered lexical and assimilated geminates to be 'true' geminates and concatenated geminates to be 'fake' geminates. True geminates have duration as part of their lexical representation, whereas the duration of fake geminates arises during implementation (i.e., post-lexically). True geminates are distinguished from fake geminates in that, even when crossing a morpheme boundary, they are contrastive: their meaning is not reconstructed from the morphemes so much as from the phonemes. In Korean, for example, the meaning of [gammjʌn], 'exemption', with long consonants changes to [gamjʌn] 'a mask' when produced with shorter duration and neither of these meaning can be deduced from the 'morphemes,' which are archaic Chinese in origin and mean 'reduction + exemption' and 'fake + face'. Fake geminates, on the other hand, are not contrastive. In English, for example, the duration of the word-internal concatenated geminate /nn/ in 'unnamed' does not determine the meaning of the word. Rather, the meaning is deduced from the derivational morpheme 'un' and the verb morpheme 'name' to render the meaning not + name + past tense.

The phonological distinction between true and fake geminates is represented in autosegmental phonology with reference to the association between articulatory feature bundles and timing units: true geminates are represented as a single feature bundle that is linked to two timing units, whereas fake geminates are represented as a sequence of feature bundles with each bundle linked to a single timing unit. This way of representing true and fake geminates suggests that both will have the same phonetic realization (see McCarthy 1986). Such a suggestion receives mixed support from phonetic studies that have examined the absolute and relative

durations of true and fake geminates.

Studies that compared true and fake geminates in Arabic, Estonian and Bengali provide some support for the idea that true and fake geminates are realized in the same way. Lahiri and Hankamer (1988) measured preceding vowel duration, closure duration and VOT for voiceless true and fake geminates in Begali and found no difference in absolute duration between the two types. In a smaller study, Lehiste et al. (1973) measured closure duration and emg peak amplitude during the production of geminate bilabial stops that occurred either within a word (i.e., true geminates, e.g., /tappa/) or across a word boundary (i.e., fake geminates, e.g., /lap peal/) and found no significant difference between the types for one set of data, though some differences were noted in a different set of data. Similarly, Miller (1987) found some minor differences between true and fake geminates in Levantine Arabic. He compared the geminate-to-singleton duration ratio for true and fake geminates formed at word boundaries in different word positions. He further differentiated fake geminates according to their origins so that he investigated whether assimilated fake geminates behaved similarly to fake concatenated geminates. His results showed that true geminates patterned with assimilated fake geminates in word final position, but not with fake concatenated geminates in word medial position. In spite of these differences, Miller argued that they were not due to a phonemic length distinction, but rather to a syllable structure distinction.

Studies that compared true and fake geminates in Italian and Tashlhiyt Berber undermine the idea that different types of geminates are implemented in the same way. Payne (2005) showed that geminates arising across a word boundary are longer than tautomorphemic geminates in terms of their absolute duration. Ridouane (2007) found significant differences in the preceding vowel durations and release amplitudes of true and fake geminate stop consonants in Tashlhiyt Berber. The vowel duration finding is particularly interesting because it suggests that true and fake geminates may be better distinguished by sequential patterns (i.e., vowel-to-consonant durations) rather than by segmental articulatory differences (e.g., closure duration, VOT, peak amplitude) or by paradigmatic durational differences (i.e., singleton-to-geminate ratios).

The notion that different types of geminates may be better distinguished by sequential patterns rather than by segmental factors or paradigmatic patterns is consistent with the finding that the ratio of consonant to preceding vowel duration has been discussed as a robust higher-order cue for the singleton/geminate distinction in Italian (Pickett et al. 1999) and in English (Port and Dalby 1982). Local and Simpson (1999) argued that duration of consonants and surrounding vowels reflects differences in temporal organization better than absolute duration. Moreover, the stability of relational segment duration in varying speech rate has been discussed across different languages (Idemaru 2005 in Japanese, Pind 1999 in

Icelandic).

Leaving aside measurement differences, it is possible that when phonetic differences between true and fake geminates are found, these derive from something other than differences in contrastiveness. In particular, the Lehiste et al. (1973), Miller (1987), Payne (2005) and Ridouane (2007) studies—which all showed some differences between true and fake geminates—all used stimuli that did not control for prosodic boundary strength. So, for example, the finding that preceding vowel durations are longer before fake geminates in Tashlhiyt Berber than before true geminates might be attributable to the fact that in Ridouane's study true geminates occurred word-internally, whereas fake geminates occurred across a word boundary. Final lengthening of multiple segments before a word boundary (Klatt 1976, Boucher 1988, Turk and Shattuck-Hufnagel 2000), could account for the longer preceding vowel durations in the fake geminates. Payne's finding that fake geminates are longer than true geminates in Italian, may be explained similarly: the difference was found between those geminates that arose across a word boundary and those that did not.

1.2 Boundary effects and geminate realization

So far we have concentrated on the differences between true and fake geminates, but the possible effect of boundary strength on geminate realization suggests that further implementational differences might be expected, even within the category of true or fake geminate. In particular, fake geminates can arise both within a word and across a word boundary. Moreover, some within word boundaries are more salient than others. This situation is well illustrated in English, which is known to have both assimilated and concatenated word-internal fake geminates (e.g., immature, unnamed, Kaye 2005) as well as concatenated geminates that arise across a word boundary (e.g., I've seen Nelly, Delattre 1968).

Lexical phonology captures the different boundary types with regard to fake geminates, depending on their morphological processes. Halle and Mohanan proposed four levels of morphology in the lexicon: level 1 (class 1 derivation, irregular inflection), level 2 (class 2 derivation), level 3 (compounding), level 4 (regular inflection). Level 1 rules may only modify structure created by level 1 morphological processes and level 2 rules may only change structure created by level 2 morphological processes. For example, level 1 prefix 'in' in a word 'immoral' goes through nasal assimilation and changes to 'im' whereas level 2 prefix 'un' in 'unbalance' cannot. For these differences, Chomsky and Halle (1968) posited two different types of boundary for level 1 and 2, stipulating that they have different lexical representations. This suggests that assimilated fake geminates in level 1 and concatenated fake geminates in level 2 in English may be realized differently. If level 1 and level 2 fake geminates are

realized differently, we may expect to see durational differences between compounds in level 3 and post-lexical fake geminates.

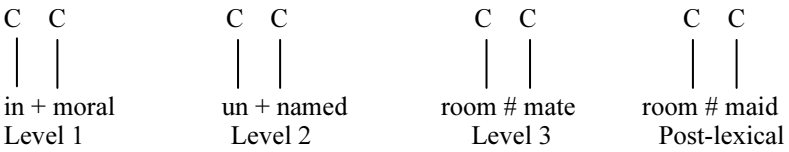

Figure 1. Underlying representation of word-internal fake geminates, compounds and word-peripheral fake geminates in English

Figure 1 illustrates different levels of lexical representations for geminates with different boundary types. With the same timing units and different boundary strength, we may expect longer geminate duration around stronger boundary strength.

1.3 The current study

The current study investigates whether boundary strength is relevant to the duration of fake geminates in English. Based on previous studies on geminates, certain methods and measurements are employed to find the appropriate ways to capture different representations. First of all, we manipulated speech style to gain insight into the speaker's representation of fake geminates with different boundaries following Johnson et al's (1993) assumption that hyperarticulated careful speech makes obvious the phonetic target, which are obscured through phonetic reduction in casual speech. Also, relative geminate duration is presented as means to distinguish word-internal geminates from word-boundary geminates in this study. More specifically, an increase in duration, namely, the duration of the vowels that immediately preceded and followed the nasal-of-interest and the duration of singleton and geminate was measured which gave us 3 dependent variables: total vowel duration (v1, v2), total nasal duration and a ratio measure (c/v), which normalized duration.

Two experiments are conducted. In experiment 1, level 1 and 2 word-internal geminates are matched to word-internal singletons and geminates across a word boundary. In experiment 2, level 3 compounds are compared with singletons and geminates across a word boundary.

2. Experiment 1

Our empirical research question is whether different boundary strength affects relative geminate duration. To be able to investigate the durational differences, word-internal geminates with different morpheme boundary

strength (level 1 vs. level 2) as well as word-internal geminates and word-boundary geminates will be compared to be able to contrast the effect of a morpheme boundary with a word boundary. We argue that the representation of word-internal geminates preserves timing information that is realized during output while boundaries of word-boundary geminate may yield to longer geminate duration. We will also consider the possibility that some word-internal boundaries may be more decomposable than others, affecting relative geminate duration.

2.1 Method

2.1.1 Participants

Six undergraduate students at University of Oregon participated. All of the participants were native speakers of English and none of them had a speech impediment. All participants were granted one credit after the experiment.

2.1.2 Procedure

We asked 6 speakers to produce 4 types of stimuli, all of which were actual English words. A randomized list of a total of 24 stimuli was presented to the speaker on a sheet of paper. All 6 speakers had approximately one minute to take a look at the paper before the production in order to make sure they know how to read all the words on the list. When the speakers finished reading the entire list of stimuli, they were asked to read the stimuli from the beginning two more times, repeating each of the stimuli 3 times in total. The speaker produced the words in a frame sentence ("I said again.") using two different speech styles: normal speech and careful speech.

The procedure was to ask the speaker to read a word in the frame sentence and after the speaker had produced the sentence, the experimenter would ask "What did you say?" which was the speaker's cue to produce the same sentence again, but in a careful speech style. Speech manipulation was expected to gain insight into different phonetic targets of word-internal and word-peripheral fake geminates in English. The recordings were made in the sound-insulated booth at the University of Oregon Linguistics Laboratory using SHURE SM10A microphone and TASCAM DA-P1 DAT.

2.1.3 Stimuli

A total of 4 types of stimuli are presented: LS, Level 1, Level 2, PG. LS refers to items with word-internal lexical singletons (ex. ammonia), Level 1 refers to items with level 1 word-internal fake geminates (ex. immoral), Level 2 refers to items with level 2 word-internal fake geminates (ex. unnamed) and PG refers to items with adjective + noun post-lexical fake

geminates (ex. dim morning). Although "lexical geminates" refer to true geminates, we will refer word-internal fake geminates as "lexical geminates" and word-boundary fake geminates as "post-lexical geminates" in this study for the argument sake. Nasal consonants were chosen for salient contrast between singletons, lexical and post-lexical geminates (Aoyama and Reid 2006). The stimuli were designed to control for spelling effects, stress and consonant type, always sonorant consonants, while varying consonantal length and word position. For example, the singleton items were words such as "ammonia" and "annoyed", that is, words with double /m/s or /n/s in their spelling. The preceding and following vowel quality are mostly matched. Especially, preceding vowels are matched by short vowels, /ɪ/, or /ə/.

Table 1. Lexical singletons and post-lexical geminates were designed to match lexical geminates of level 1 and level 2 respectively.

TYPE	Lexical Singletons	Lexical Geminates	Post-lexical Geminates
Level 1	• ammonia • immensely • immigrational • immunity	• immoral • immeasured • immemorial • immovable	• dim morning • grim magic • prim memorial • slim moviedom
Level 2	• annex • innate • annoyed • innerve	• unnail • unnamed • unnoticed • unnerve	• one nail • fun name • fun noise • one nurse

2.1.4 Data Analysis

Twenty four words repeated 3 times in two speech styles produced by 6 speakers gave us 864 items. Consonant and vowel duration measurements were obtained by segmenting the waveform, in reference to the spectrogram. Duration of consonant, preceding and following vowels (v1, v2) and gaps were measured and analyzed by SPSS. Gaps were identified only when closure duration exceeded 100 milliseconds. This criteria was chosen because it corresponded to an audible boundary. A mixed-design ANOVA was conducted with duration as the dependent variable and consonant type (singleton vs. geminate), boundary position (word-internal vs. word-boundary) and speech style (normal speech vs. careful speech) as the independent variable.

2.2 Results

It should also be noted that the nasal consonants were mostly a continuous sound within word-internal fake geminates but in careful speech a speaker inserted a gap.

Table 2. Percentage of words or word phrases spoken with a pause gap in the careful speech condition for each stimuli type

TYPE	Lexical Singletons	Lexical Geminates	Post-lexical Geminates
Level 1	0 %	0 %	96 %
Level 2	4 %	11 %	94 %

As shown in Table 2, most gaps were inserted at a word boundary and much fewer inserted word-internally at a morpheme boundary. Few more gaps occurred in stimuli with word-internal geminates than in stimuli with word-internal singletons. Level 2 geminates are produced with few more gaps than level 1 geminates, but significantly less than geminates across a word boundary.

To avoid the influence of gap insertion which would affect or be correlated with differences in the acoustic duration of the vowels and consonant measures, first the data were analyzed with and without gaps separately as shown in Figure 2.

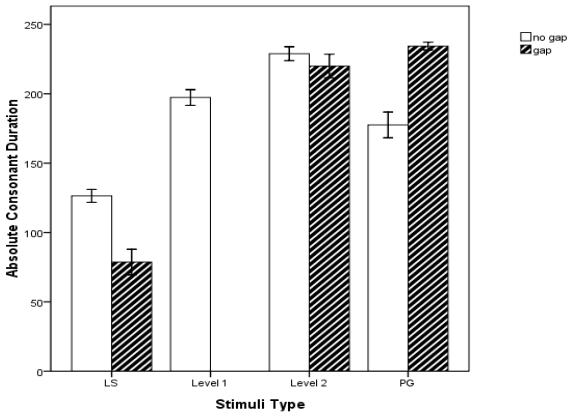

Figure 2. Absolute consonant duration by no gap/gap for each stimuli type is shown.

Each bar represents mean of absolute consonant duration without and with a pause gap respectively. There were no instances of level 1 geminates that were produced with a gap. Consonant duration was longer in tokens produced without a gap in lexical singletons and geminates. However, the mean duration between lexical geminates with and without a gap was not

significantly different [t(12.46) = 0.90, p = .39]. Also, mean differences between lexical singletons with and without a gap are not significant [t(3.15) = 4.63, p = .017]. However, the consonant duration of post-lexical geminates with a gap (N=137) is significantly different from those without gaps (N=7) [t(7.68) = -4.11, p = .004]. There appears to be an interaction between stimulus type and production with and without a gap in post-lexical geminates, but the large variance—due to the small numbers of no-gap tokens in post-lexical geminates (N=7)—means that we should not make too much of this apparent difference.

It is speculated that the difference between stimuli with lexical geminates and post-lexical geminates is due to different reasons for gap insertion in careful speech: In the word internal case, speakers appeared to be using a strategy of syllable by syllable production, where the speaker had decided on an ambisyllabic syllabification and the gap was incidental to this strategy. In the word-peripheral case, however, the gap was used to highlight the boundary itself.

Figure 2 was shown to verify the fact that the gap insertion does not change the nature of our main results. Returning to the main argument raised in the introduction, the following analyses directly address the question of whether or not lexical and post-lexical geminates behave in the same manner under different speaking conditions. Especially, lexical geminates are divided into two levels in order to convey the effect of different morpheme boundaries on overall duration. The effect of stimulus type (lexical singletons, lexical geminates(level 1, level 2), post-lexical geminates) and speech style (normal, careful) on total vowel duration, consonant duration and on normalized duration (the ratio of consonant duration to vowel duration) are presented in the result section.

Absolute vowel duration in Figure 3 and absolute consonant duration in Figure 4 are shown to present how relative consonant duration at level 1 and 2 lexical geminates are differently realized compared to one another as well as to matching lexical singletons and post-lexical geminates.

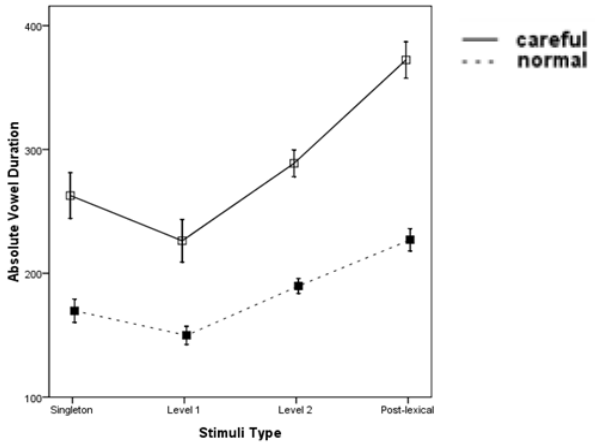

Figure 3. Absolute vowel duration for each stimuli type produced in normal and careful speech is shown

The figure shows that preceding and following vowel duration is longer overall in careful speech than in normal speech. The mean vowel duration between level 1 and level 2 lexical geminates is significantly different in both normal [$t(142) = -9.73$, $p = .00$] and careful speech [$t(142) = -7.15$, $p = .008$] . The duration is much longer in the word phrases that give rise to post-lexical geminates and this pattern is significantly exaggerated in careful speech [$F(1, 286) = 382.74$, $p = .00$]. Also, with regard to preceding vowel duration alone, the mean was significantly different between level 1 and 2 lexical geminates in normal [$t(142) = -3.44$, $p = .001$] as well as in careful speech [$t(142) = -4.79$, $p = .00$]. Preceding vowel duration was also the longest in post-lexical geminates. A similar pattern holds in absolute consonant duration.

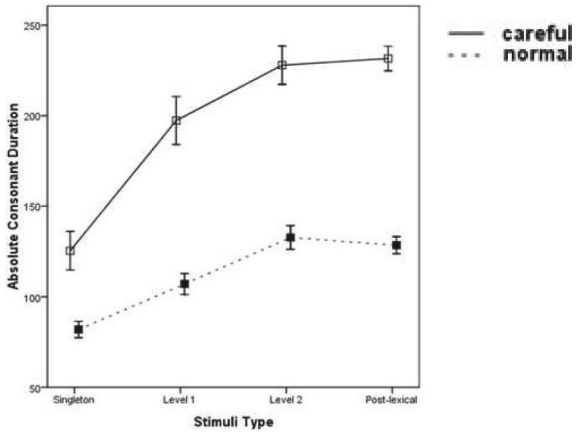

Figure 4. Absolute consonant duration of each stimuli type produced in normal and careful speech is shown.

Overall, duration is greater in careful speech than in casual speech. Lexical singletons are distinctively shorter than lexical geminates, especially in careful speech. Absolute consonant duration increases monotonically with stimulus type in careful speech styles. The mean of absolute consonant duration between level 1 and level 2 lexical geminates is significantly different in normal [$t(142) = -6.84$, $p = .00$] and careful speech [$t(142) = -4.19$, $p = .00$]. However, mean consonant duration of level 2 geminates and geminates across a word boundary was not significantly different in careful speech [$t(130.39) = -0.69$, $p = .49$]. Nevertheless, level 1 and level 2 lexical geminates show similar patterns in that absolute consonant duration disproportionately lengthened than post-lexical geminates relative to the absolute vowel duration. The difference is more evident when consonants and vowel duration is normalized using a ratio measure. A clear difference in the behavior of word-internal and post-lexical geminates is shown in Figure 5, especially in careful speech.

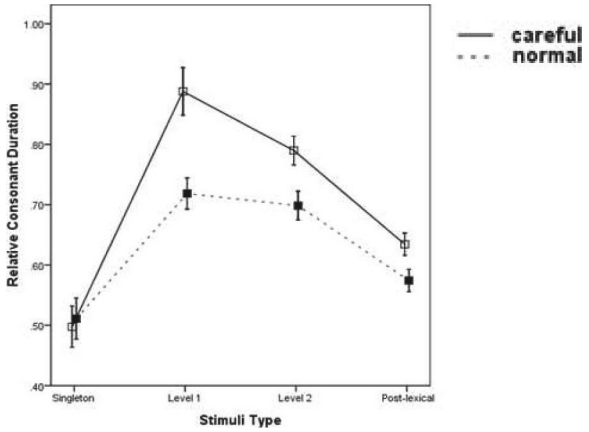

Figure 5. Relative consonant duration (absolute consonant-to-vowel duration) of each stimuli type produced in normal and careful speech is shown.

The difference between lexical geminates and post-lexical geminates are especially evident when consonant duration is normalized. The mean difference between level 1 and level 2 lexical geminates is significant in careful speech [$t(142) = 4.93$, $p = .00$], although not in casual speech [$t(142) = 1.32$, $p = .189$]. The result shows that lexical geminates were longer relative to the vowels than were the post-lexical geminates when carefully spoken. Lexical geminates stand out in that the consonants are lengthened more with respect to the surrounding vowels compared to lexical singletons and post-lexical geminates. The effect of stimuli types was significant in careful speech [$F(3, 428) = 162.16$, $p < .01$].

2.3 Discussion

The finding in Experiment 1 confirms the existence of systematic consonant length differences in English. As shown in Figure 4, the mean of absolute consonant duration was shortest for lexical singletons (125.40 msec.), longer for level 1 lexical geminates (197.32 msec.) and level 2 geminates (227.87 msec.) and longest for post-lexical geminates (231.60 msec.) in careful speech. Significant difference between leve1 and level 2 lexical geminates was also found in absolute vowel duration. When these results are put together, we get a difference in behavior. In Figure 5, we see generalized lengthening around a word boundary, which gives us our first indication that lexical and post-lexical geminates may be represented differently. Interestingly, absolute vowel and consonant duration was significantly different between level 1 and level 2 lexical geminates. Along with absolute duration, differences in the number of gap insertion and relative consonant duration between level 1 and 2 lexical geminates reflect different morpheme boundary strength. It may be due to different degrees

of decomposability between prefix and root in English geminates. That is, level 2 lexical geminates ('un-') are likely to have higher decomposability between the prefix and root than level 1 lexical geminates ('in-'). If, however, different phonetic realization is motivated by phonology, we might further ask whether compounds (level 3) would manifest phonetic evidence that is distinguished from post-lexical geminates in a similar way.

3. Experiment 2

Divided results found within lexical geminates in Experiment 1 have led us to question the relationship between levels and phonetic features reflecting different boundary types. If levels are responsible for the different representation, we expect to see the same pattern reflected on compounds and post-lexical geminates. In Experiment 2, compounds are examined in comparison to matching post-lexical geminates with regard to absolute vowel duration and consonant duration as well as relative consonant duration. Our purpose of this experiment was to investigate how two types of geminates across a word boundary, each representing different stages of phonology are realized and reflected on durational patterns.

3.1 Method

3.1.1 Participants

The same 6 participants from Experiment 1 took part in Experiment 2.

3.1.2 Procedure

Similarly to Experiment 1, 6 participants were asked to read 3 types of randomly presented stimuli 3 times in both normal and careful speech style.

3.1.3 Stimuli

Three types of stimuli – post-lexical singletons, compounds, post-lexical geminates with 5 stimuli for each type are investigated in Experiment 2. Compounds are examined with different post-lexical geminates used in Experiment 1 for two main reasons. First of all, post-lexical geminates in Experiment 1 do not match with compound with regard to the parts of speech they are composed of. Secondly, there were not enough English nasal compounds to compare with so we included liquid compounds for more data. Here, PS refers to items with post-lexical singletons (ex. dough made) and PG refers to items with post-lexical geminates (ex. room maid). Each post-lexical singleton and geminate are matched and compared to compounds which represent level 3 geminates. The stimuli were designed

to control for spelling effects, stress pattern and consonant type, while varying consonantal length and word position. The preceding and following vowel quality were matched.

Table 3. Post-lexical singletons and geminates are designed to match with compounds

Post-lexical singletons	Compounds	Post-lexical geminates
• dough made • crew mate • tray line • spa room • sofa ride	• homemade • roommate • taillight • barroom • override	• Rome made • room maid • sale line • car room • over ripe

3.2 Results

As in Experiment 1, speaker inserted a gap in careful speech style. Here, most of the geminates across a word boundary were produced with a gap.

Table 4. Percentage of phrases spoken with a pause gap in the careful speech condition

Post-lexical singletons	**Compounds**	Post-lexical geminates
48 %	**84 %**	94 %

Compounds showed more gaps than word-internal geminates (Experiment 1) but distinctively less gaps than geminates across a word boundary. This might indicate that compounds have relatively weaker boundary strength compared to geminates across a word boundary.

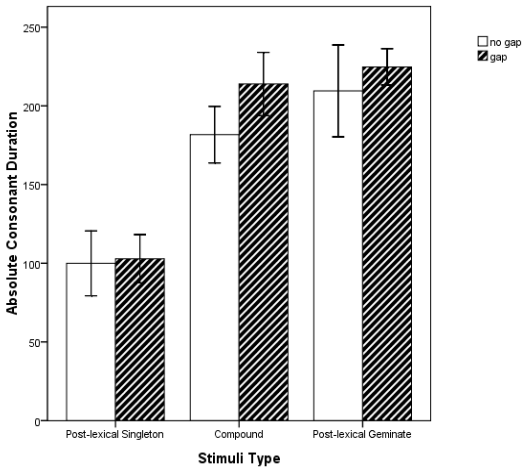

Figure 6. Absolute consonant duration by Gap/No Gap and stimulus type is shown.

The similar durational patterns between stimuli with and without a gap are compared in Figure 6. This shows that total consonant duration was slightly longer in tokens produced with a gap (mean 168.32 msec.) than in those produced without (mean 176.34 msec.) Because the effect of gap insertion was not significant [$F(1, 268) = 0.61$, $p = .44$] on all stimuli types, both gap and no gap data will be combined for further analyses.

Preceding and following vowel duration of compounds and post-lexical geminates are compared in Figure 7.

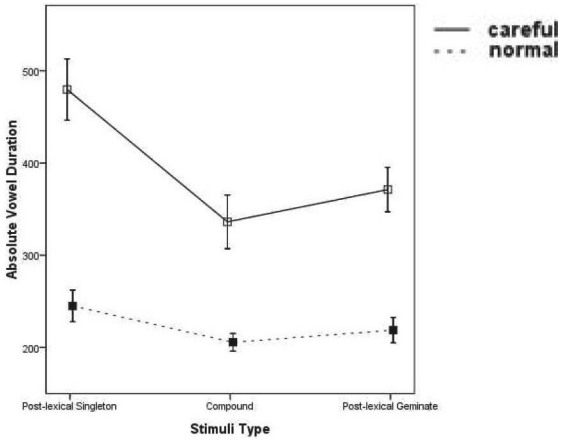

Figure 7. Absolute vowel duration of each stimuli type produced in normal and careful speech is shown.

Total vowel duration of compounds and post-lexical geminates is not significantly different in careful speech [$t(178) = -2.16$, $p = .032$]. Post-lexical singletons show much longer duration, especially in careful speech, due to final vowel lengthening at the end of the first syllable. The second indication that compounds and post-lexical geminates share a similar durational pattern comes from absolute consonant duration.

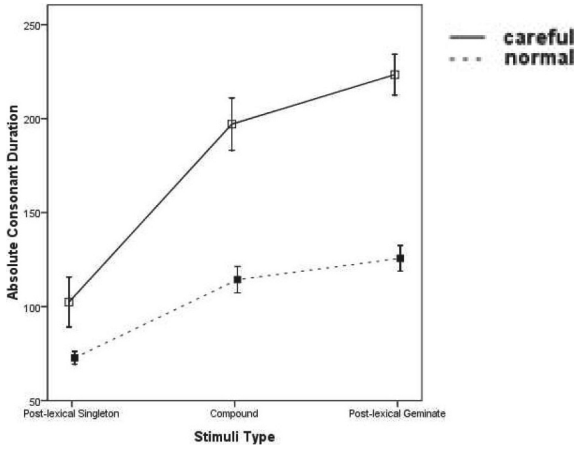

Figure 8. Absolute consonant duration of each stimuli type produced in normal and careful speech is shown.

Singletons are distinctively shorter than compounds and the differences are amplified in careful speech [$t(178) = 11.45$, $p = .00$]. Similar to the result in Experiment 1, absolute consonant duration increases monotonically with stimulus types, which indicates that singletons are distinct from geminates with regard to consonant duration. Contrary to vowel duration, the mean of consonant duration is significantly different between compounds and post-lexical geminates in careful speech [$t(178) = -3.47$, $p = .001$], but not in normal speech [$t(178) = -2.69$, $p = .008$].

When consonants and vowel duration are considered together in Figure 9, it is evident that compounds and post-lexical geminates are not distinct from each other either in normal and careful speech.

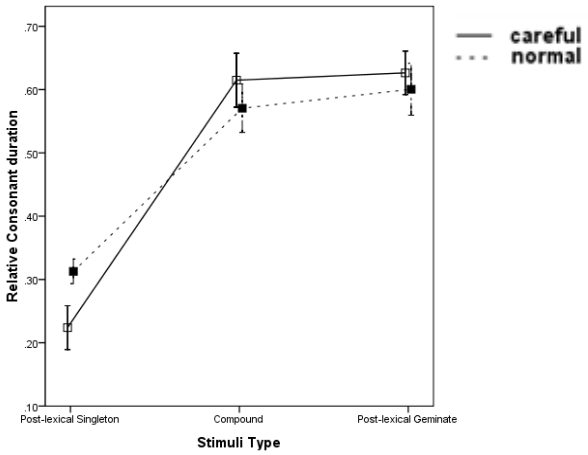

Figure 9. Relative consonant duration of each stimuli type produced in normal and careful speech is shown.

The effect of speech style was not significant across stimuli types [F(1, 538) = 0.11, p = .737]. Also, the mean of relative consonant duration between compounds and post-lexical geminates was not significant in either normal [t(178) = -1.24, p = 0.22] or careful speech [t(178) = -.49, p = .63]. Exceptionally longer preceding vowel duration due to final vowel lengthening may have led to lower ratio of singletons in careful speech.

Contrary to lexical geminates, consonant duration of compounds and post-lexical geminates did not lengthen disproportionately with respect to the surrounding vowels. Although the word boundary in compounds may not be as obvious as that in post-lexical geminates, the finding in Experiment 2 suggests that the compounds and post-lexical boundaries are marked in the same way.

3.3 Discussion

In Experiment 2, difference in behavior between compounds and post-lexical geminates was not significant as in relative durational differences observed between word-internal fake geminates across a morpheme boundary and post-lexical geminates across a word boundary in Experiment 1. While word-internal fake geminates with different Levels showed disproportional lengthening of consonant duration with respect to the surrounding vowels, compounds patterned with post-lexical geminates. Exceptionally longer preceding vowel duration due to final vowel lengthening may have led to lower ratio of post-lexical singletons in careful speech. Although a word boundary in compounds may not be as obvious as that in post-lexical geminates, the finding in Experiment 2 suggests that the compounds and post-lexical boundaries are marked and

possibly represented in the same way. In other words, the results indicate that the way native speakers of English mark the boundary is the same for compounds and post-lexical geminates, which is highlighting the word boundary itself to convey the independent meanings of each word, whereas lexical geminates is underscored as a unit in a way that such boundaries do not seem to be encoded in the representations themselves.

4. General Discussion

Despite many phonological discussions on geminates, there have been few empirical studies on the phonetic realization of fake geminates across different boundary types. The aim of this study was to investigate whether English fake geminates across a morpheme and a word boundary, which are formed on different phonological levels, are realized in the same way and if not, how they differ from one another, especially in their relative consonant duration.

Whether word-internal or across a word boundary, long consonants in English are considered to be 'fake' geminates because they are heteromorphemic and noncontrastive with their short counterparts. The phonological literature typically represents fake geminates differently from true geminates (Hayes 1989), but all fake geminates are represented in the same way no matter where they arise. In contrast, phonetically-based emergentist theories of phonology (e.g., Lindblom et al. 1984, Browman and Goldstein 1990, 1992, Lindblom 1992, Beckman and Edwards 2000, Bybee 2001) might predict that word-internal fake geminates are different from those that arise across a word boundary. In these theories, linguistic units such as the morpheme emerge from lexical representations, suggesting that such boundaries are not encoded in the representations themselves. If word-internal boundaries are not encoded, then word-internal fake geminates may well be represented as long consonants rather than as consonant sequences, which is the underlying representation for fake geminates that arise across a word boundary.

The results of Experiment 1 provide evidence to two issues of interest. Although English has only one phoneme category on the consonant duration continuum and length is not contrastive in English, it shows that native speakers of English produce fake geminate consonants much longer than singletons (see Delattre 1971, Kaye 2005). Especially, the absolute consonant duration confirms the existence of systematic length differences in English. Total consonant duration was shortest for word-internal singleton nasals, longer for word-internal fake geminate consonants (including both geminates with Level 1 and Level 2 affixation) and longest for post-lexical geminates. It should be noted that the difference in length does not, by itself, suggest a difference in the representation of word-internal and post-lexical geminates, because absolute consonant duration may be susceptible to many other suprasegmental and situational

factors such as juncture. For instance, segmental duration is usually longer at stronger prosodic boundaries. This type of lengthening may be attributed to the global slowing of a motor clock or local lengthening around stronger boundaries (Beckman et al. 1992, Byrd and Saltzman 1998, 2003). Especially, the results on absolute consonant duration were consistent with the global slowing that is known to occur in clear speech (e.g., Picheny et al. 1986).

The finding, however, that absolute vowel duration for singletons and word-internal fake geminates patterned together must be explained differently. Interestingly, similar to Ridouane's (2007) study on true and fake geminates, our study showed no significant difference in absolute consonant duration but there was a significant difference in the absolute vowel duration between fake geminates across a morpheme and a word boundary. Moreover, the distinctively longer relative consonant duration in word-internal fake geminates than in post-lexical geminates in clear speech (see Figure 5) indicates that fake geminates across a morpheme and a word boundary may be represented differently. It is assumed that the length of post-lexical geminates arises differently, namely from the concatenation of two identical consonants, which—along with the surrounding segments—can be expanded in time around the word boundary, whereas substantial increase in relative consonant duration of word-internal geminates suggests that the phonetic target of word-internal geminates may be different from that of post-lexical geminates.

Secondly, the results from Experiment 1 showed that geminates with Level 1 affixation showed significantly longer relative consonant duration from those with Level 2 affixation and the differences were significantly larger in careful speech. This supports the assumption that geminates with less productive and decomposable Level 1 affixes may have different representation to those with Level 2 affixes. The possibility of the relationship between phonological levels and their distinctive boundary effect on lexical and post-lexical geminates led to Experiment 2. It was assumed that if different phonetic realization is motivated by phonology, compounds in level 3 are expected to be realized differently from post-lexical geminates in a similar manner. Contrary to experiment 1, however, no difference was found between compounds and post-lexical geminates. These results indicate that boundary strength may be less important than boundary decomposability in production. Overall, we argue that boundary decomposability impacts the phonetic implementation of geminates and likely does so whether these are true or fake.

REFERENCES

AOYAMA, KATSURA and LAWRENCE A. REID. 2006. Cross-linguistic tendencies and durational contrasts in geminate consonants: An

examination of Guinaang Bontok geminates. *Journal of the International Phonetic Association* 36.2, 145-157.

BECKMAN, MARY E., JAN EDWARDS and JANET J. FLETCHER. 1992. Prosodic structure and tempo in a sonority model of articulatory dynamics. In G. J. Docherty and D. R. Ladd (eds.). *Papers in Laboratory Phonology II: Gesture, Segment, Prosody*, 68-86. Cambridge: Cambridge UniversityPress.

BECKMAN, MARY E. and JAN EDWARDS. 2000. The ontogeny of phonological categories and the primacy of lexical learning in linguistic development. *Child Development* 71, 240-249.

BOUCHER, VICTOR. 1988. A parameter of syllabification for V stopV and relative timing invariance. *Journal of Phonetics* 16, 299-326.

BROWMAN, CATHERINE P. and LOUIS, M. GOLDSTEIN. 1990. Gestural specification using dynamically-defined articulatory structures. *Journal of Phonetics* 18, 299-320.

_____. 1992. Articulatory phonology: An overview. *Phonetica* 49, 155-180.

BYBEE, JOAN. 2001. *Phonology and Language Use*. Cambridge: CUP.

BYRD, DANI and ELLIOT SALTZMAN. 1998. Intergestural dynamics of multiple phrasal boundaries. *Journal of Phonetics*, 26, 173-199.

_____. 2003. The elastic phrase: Modeling the dynamics of boundary-adjacent lengthening. *Journal of Phonetics* 31.2, 149-180.

CHOMSKY, NOAM and MORRIS HALLE. 1968. *The Sound Pattern of English*. New York: Harper and Row.

DELATTRE, PIERRE. 1968. *The General Phonetic Characteristics of Languages* (final report, 1967-1968). Santa Barbara: US Office of Education and the University of California, Santa Barbara.

_____. 1971. Pharyngeal features in consonants of Arabic, German, Spanish, French and American English. *Phonetica* 23, 129-155

HAYES, BRUCE. 1989. Compensatory Lengthening in Moraic Phonology. *Linguistic Inquiry* 20, 253-306.

IDEMARU, KAORI. 2005. *An Acoustic and Perceptual Investigation of the Geminate and Singleton Stop Contrast in Japanese*. PhD Dissertation. University of Oregon.

JOHNSON, KEITH, EDWARD FLEMING and RICHARD WRIGHT. 1993. The hyperspace effect: Phonetic targets are hyperarticulated. *Language* 69, 505-528.

KAYE, ALAN S. 2005. Gemination in English. *English Today* 21, 43-55.

KLATT, DENNITH. H. 1976. Linguistic uses of segmental duration in English: Acoustic and perceptual evidence. *Journal of the Acoustical Society of America* 59, 1208-1221.

LADEFOGED, PETER and IAN MADDIESON. 1996. *The Sounds of the World's Languages*. Oxford: Blackwell.

LAHIRI, ADITI and JORGE HANKAMER. 1988. The timing of geminate consonants. *Journal of Phonetics* 16, 327-338.

LEHISTE, ILSE, KATHERINE MORTON and MARK TATHAM. 1973. An instrumental study of consonant gemination. *Journal of Phonetics* 1, 131–148.

LINDBLOM, BJORN. 1992. Phonological units as adaptive emergents of lexical development. In Ferguson, C.A., Menn, L. and Stoel-Gammon, C. (eds.). *Phonological Development*, 131-163. York Press.

LINDBLOM, BJORN, PETER MACNEILAGE and MICHAEL STUDDERT-KENNEDY. 1984. Self-organizing processes and the explanation of language universals. In Butterworth, B. and Bernard, C. and Dahl, O. (eds.). *Explanations for Language Universals*, 181-203.

LOCAL, JOHN and ADRIAN P. SIMPSON. 1999. The phonetic implementation of gemination in Malayalam. *Proceedings of the XIVth ICPhS* 1, 595-598. San Francisco.

MADDIESON, IAN. 1985. Phonetic cues to syllabification. In V.A Fromkin (ed.). *Phonetic Linguistics.* New York: Academic Press.

MCCARTHY, JOHN J. 1986. OCP Effects: Gemination and antigemination. *Linguistic Inquiry* 17, 207-263.

MILLER, ANN. 1987. Phonetic characteristics of Levantine Arabic geminates with differing morpheme and syllable structures. *Ohio State Papers from the Linguistics Laboratory* 36, 120-140.

PAYNE, ELINOR. 2005. Phonetic variation in Italian consonant gemination. *Journal of the International Phonetic Association* 35.2, 153-189.

PAYNE, ELINOR and EFTYCHIA EFTYCHIOU. 2006. Prosodic shaping of consonant gemination in Cypriot Greek. *Phonetica* 63, 175-198.

PICHENY, MICHAEL A., NATHANIEL I. DURLACH and LOUIS D. BRAIDA. 1986. Speaking clearly for the hard of hearing II: Acoustic characteristics of clear and conversational speech. *Journal of Speech & Hearing Research* 29, 434-446.

PICKETT, EMILY R., SHEILA E. BLUMSTEIN and MARTHA W. BURTON. 1999. Effects of speaking rate on the singleton/geminate contrast in Italian. *Phonetica* 56.3-4, 135-157.

PIND, JORGAN. 1999. Speech segment durations and quantity in Icelandic. *Journal of Acoustic Society of America* 106.2, 1045-1053.

PORT, ROBERT and JONATHAN DALBY. 1982. C/V ratio as a cue for voicing in English. *Journal of the Acoustical Society of America* 69, 262-274.

RIDOUANE, RACHID. 2007. Gemination in Tashlhiyt Berber: an acoustic and articulatory study. *Journal of the International Phonetic Association* 37.2, 119-142.

TURK, ALICE E. and STEFANIE SHATTUCK-HUFNAGEL. 2000. Word-boundary-related duration patterns in English. *Journal of Phonetics* 28, 397-440.

Eunhae Oh
Department of English Language & Literature
Hyupsung University
72, Choerubaek-Ro, Bongdam-Eup, Hwaseong-Si, Gyeonggi-Do
Korea 445-745
e-mail: gracey1980@yahoo.com

received : November 2, 2013
revised : December 4, 2013
accepted : December 9, 2013