



Geminate and singleton contrast in English affixed words

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Abstract

This paper presents two experiments examining different gemination behavior of English affixes. Experiment 1 focused on geminates through affixation with *im-*, *un-*, *-ness*, and *-ly*. The English group articulated geminates with longer absolute and relative durations than singletons for *im-*, *un-*, and *-ness*, but there was no difference for *-ly*. This suggests that *-ly* words are more likely to be perceived as whole words, and that *-ly* is less decomposable. Furthermore, *un-* geminates exhibited longer absolute and preceding vowel durations than *im-* geminates, suggesting that *im-* is more decomposable than *un-*. However, the Korean group produced geminates with longer absolute and relative durations than singletons for all *im-*, *un-*, *-ness*, and *-ly*, and produced comparable absolute durations of *im-* and *un-* geminates. Experiment 2 investigated different gemination behaviors of locative and negative *im-* prefixes. The English group showed durational contrast between geminates and singletons only for negative *im-*, indicating that locative *im-* is not easily separated from stem. However, the Korean group produced longer absolute and relative durations for geminates than for singletons for both locative and negative *im-*. According to the findings of Experiments 1 and 2, affix decomposability is less likely to influence Korean speakers' English affix gemination, and spellings may have a greater influence.

Keywords: affixation, decomposability, English geminates, durational difference

1. Introduction

Geminates are regarded as two adjacent identical sounds, particularly consonants, that co-occur in a word or at a morpheme or word boundary (Trask, 1996). In many languages with phonological gemination, the primary cue for geminates is the consonant duration (Crystal, 2008; Trask, 1996). Geminate consonants are articulated with longer durations than singleton consonants in Turkish (Lahiri & Hankamer, 1988), in Italian (Esposito & Di Benedetto, 1999), and in Japanese (Idemaru & Guion, 2008). In some languages, geminate and singleton consonants are also differentiated by the preceding

vowel duration. The preceding vowels of geminates are shorter than those of singletons in Italian (Esposito & Di Benedetto, 1999), and it is the opposite in Turkish (Lahiri & Hankamer, 1988).

There are three types of geminates: (1) lexical, (2) assimilated, and (3) concatenated geminates. A lexical geminate is found in a lexicon, such as *pappa 'mush'* and *fatto 'done'* in Italian. Assimilated and concatenated geminates are phonologically derived geminates (Lahiri & Hankamer, 1988; Ridouane, 2010). An assimilated geminate is found when one sound is affected by the adjacent sound, such as *cheon+li* → [tɛhɭi] 'the law of nature' (Oh & Redford, 2012). A concatenated geminate occurs when two adjacent consonants

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extend across the boundary of a word or morpheme, such as *good dog* or *unknown* in English. However, English lacks a true geminate-singleton contrast. Two consonants, like *happy* and *dinner*, are usually articulated as one short sound, despite being phonologically ambisyllabic in suprasegmental (Halle, 1998). Furthermore, sequences of identical consonants arise either across affixation concatenation (e.g., *unknown*, *cleanness*) or across the compound word (e.g., *pine nut*), but they are known as fake geminates because their lengths do not bring phonemic contrast, although they are phonetically long (Oh & Redford, 2012).

The current paper looked at English geminates arising from affixes in Korean speakers whose language has phonological geminates. This paper provides two experiments. The first experiment aimed to investigate the phonetic realization of English geminates with different affixes produced by Korean speakers. The second experiment looked at how Korean speakers articulated geminates with different degrees of decomposability.

2. Previous Studies

Few experimental studies on morphological gemination in English have been conducted (Ben Hedia, 2019), with the majority of them focusing on the prefixes *in-* and *un-*. Prefix *in-* has three more variants: *im-*, *ir-*, and *il-*. Kaye (2005) investigated gemination with *un-* and *in-* prefixes. He observed that the mean nasal durations of geminates in *unknown*, *unnamed*, and *immature* were longer than those of singletons in *known*, *named*, and *mature*. However, not all of his speakers produced long nasals for *immature*.

Oh & Redford (2012) looked at gemination with *im-* (a variant of *in-*) and *un-* (i.e., *immovable* and *unnoticed*) and across word boundaries (i.e., *dim morning* and *one nail*). The geminates were compared with lexical geminates assumed to be phonological singletons (i.e., *ammonia* and *annex*). The selected words were rated as singleton or geminate by Korean speakers based on their pronunciation by an English native speaker. First, Oh & Redford (2012) discovered that in careful speech, a pause was occasionally inserted after *un-* but never after *im-*. The authors explained that this pause gap exists because *un-* geminates are more represented as true geminates than *im-* geminates.

Furthermore, the authors observed that the durational differences between geminates and singletons were greater in careful speech than in normal speech. In careful and normal speech, the absolute nasal durations of *im-* and *un-* geminates were longer than the counterpart singletons. The geminates' relative nasal durations (i.e., the ratio of nasal duration to the preceding vowel duration) were also longer than those of the singletons. In addition, when comparing *im-* and *un-* geminates, the absolute durations of /n/ geminate were longer than those of /m/ geminate. Oh & Redford (2012) explained that the durational difference between the /m/ and /n/ is because *im-* is more decomposable than *un-*. It is assumed that morpheme boundary strength influences the phonetic implementation of affixed words. According to Lexical Phonology theory (Kiparsky, 1982; Mohanan, 1986), the stronger the morpheme boundary (i.e., more decomposable derivatives), the less phonological integration the affixes and stems have. However, Oh & Redford (2012) observed no relative durations between the /n/ and /m/ geminates. They explained that the lack of a difference in relative durations between /m/ and /n/ geminates indicates that the preceding vowels are longer in *un-* than in *im-*. But, at word boundary, the geminates

were longer than the singletons only in absolute durations, and the absolute durations of /m/ and /n/ geminates were not different.

A follow-up study by Oh (2013a) replicated some of the results of Oh & Redford (2012). In *un-* and *im-*, the absolute nasal and relative durations of the geminates were longer than those of the singletons. Oh (2013a) also measured durations of the preceding and following vowels, but found no evidence of a gemination effect on vowel durations. However, the vowel durations of *un-* geminates were longer than for the *im-* geminates. According to Oh (2013a), the vowel durations around the *un-* and *im-* geminates influence the nasal duration difference between them.

Unlike the above studies, Kotzor et al. (2016) investigated gemination with *-ness* and *-ly*, and compound boundary geminates with sonorants [l] and [n] and stops (e.g., *clown nose* and *bank card*). The geminates were compared to singletons ending in *-er*, for example, *coolly* vs. *cooler* and *meanness* vs. *meaner*. The authors observed that the absolute and relative durations of geminates were longer than those of the corresponding singletons in *-ness* and *-ly*, as well as in compound words. The geminates had no effect on the preceding vowel durations. Ben Hedia (2019), however, criticized the lack of comparison of *-ness* and *-ly* geminates. She found that geminates ending with *-ly* were not phonetically distinct from the corresponding singletons.

3. Experiment 1

Experiment 1 explored whether Korean speakers produce durational differences between geminates and singletons in English. There are not many studies on English geminates by Korean speakers. Much of the work on English geminates has focused on word-boundary geminates and compound word geminates. Shin & Hwang (2012) used minimal pairs to investigate Korean speakers' English geminates across word boundaries (e.g., *bite toys* vs. *buy toys*, *rice seed* vs. *rye seed*). For the geminates, their English and Korean speakers produced longer consonant durations than the singletons. In perception, however, while the English speakers always distinguished the singletons and geminates, the Korean speakers did not fully distinguish them. Both groups had similar perception accuracy for the geminates, but the English speakers had higher perception accuracy for the singletons than the Korean speakers. Shin & Hwang (2012) explained that the Korean phonological phenomena of coda neutralization and degemination brought about the poor perception of English geminates.

Oh (2020) looked at English and Korean geminates in words and across word boundaries. Korean assimilated geminates were always produced with longer durations than the corresponding singletons by the Korean speakers. Even the Koreans produced longer consonant durations for geminates represented as singletons by tensification like *akki* 'instrument', than their counterpart singletons. Except for geminate /l/, the English speakers produced mostly similar consonant durations for the Korean geminates and singletons. For English geminates, lexical geminates, geminates in compound words, and word-boundary geminates were examined. The English speakers produced significantly longer consonant durations for the geminates than for the singletons only at the word boundary. The Korean speakers tended to produce longer consonant durations for the three types of geminates than for the corresponding singletons, but significant durational differences were not found in all comparisons. According to Oh (2020), the geminate lengthening process was

caused by Koreans' tendency to be more conscious of spelling and more sensitive to syllable structure.

Korean phonology seems to affect English geminates, according to these studies on English geminates by Korean speakers. These studies, however, did not include gemination with affixes. While the words in compound words or in phrases can be replaced by other words, the affixes in affixed words are hardly alternatives to other affixes. This indicates that the affix and stem (or root) have a weaker boundary and are less likely to be apart than words in compound words (Hay, 2003). Consonant durations of geminates with affixes depend on the degree of decomposability (Oh & Redford, 2012). This study replicated previous studies on gemination in English affixation and investigated whether Korean speakers articulate geminates differently from the corresponding singletons in affixed words.

3.1. Method

3.1.1. Participants and Procedure

Ten native Korean speakers aged 21 to 26 took part in this experiment. They were from Seoul or Gyeonggi-do and had never lived in an English-speaking country. They all were university students. Three native English speakers from the United States also participated. To examine geminate-singleton contrast in English affixation, words with *im-*, *un-*, *-ly*, and *-ness* were selected, as shown in Table 1. Because there are so few *in-* prefixed words with a base beginning with /n/ (BenHedia & Plag, 2017), *im-* which is an allomorph of *in-* was chosen.

Table 1. Stimuli

<i>im-</i>		<i>un-</i>	
immoral	impatient	unknown	uneasy
immature	impossible	unnecessary	unable
immodest	imperfect	unnoticed	unofficial
immovable	impolite	unnatural	unoccupied
<i>-ness</i>		<i>-ly</i>	
humanness	emptiness	equally	happily
womanness	heaviness	specially	readily
commonness	easiness	finally	easily
openness	happiness	actually	heavily

Each word was presented on the computer monitor for 5s, and the participants were asked to read the word aloud in the carrier sentence of "I say again". The recording was made on a handy portable recorder (Zoom H2) using a Pyle-Pro PMHM2 Omnidirectional Head Worn Microphone. The recording was repeated three times in randomized order. A total of 1,248 tokens were recorded.

3.1.2. Measurements and Analysis

The primary distinctive feature between a geminate and a singleton is the consonant duration (Crystal, 2008; Trask, 1996), and geminate and singleton contrast also brings about difference in their preceding vowel durations in some language (Esposito & Di Benedetto, 1999; Lahiri & Hankamer, 1988). Absolute consonant duration and the preceding vowel duration were measured by using Praat (Boersma & Weenink, 2020) in this experiment.

Considering the participant's different speech rates, relative duration was calculated as a ratio of absolute consonant duration to

the preceding vowel duration. Figures 1 and 2 present affixed word examples by one Korean participant. Three tabs indicate the beginning of the first vowel, the offset of the vowel, which coincides with the target consonant's onset, and the target consonant's offset.

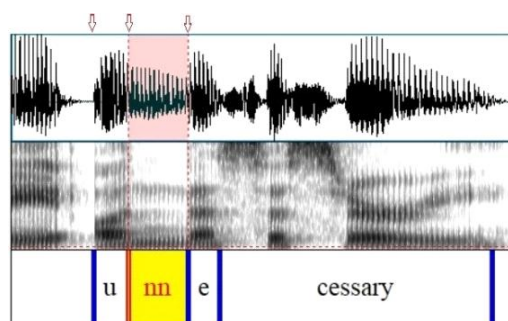


Figure 1. Waveforms and spectrograms for 'unnecessary'.

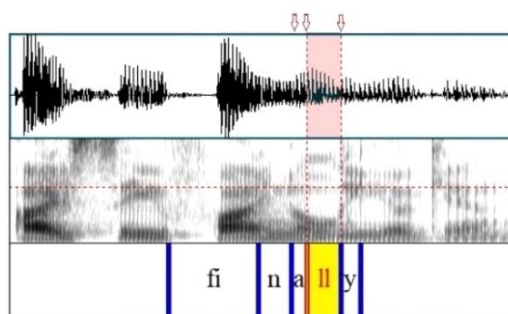


Figure 2. Waveforms and spectrograms for 'finally'.

A nasal consonant has less energy than the surrounding vowels. Nasal and vowel boundaries are identified by a marked drop in F1 and intensity in waveform and spectrogram. There is a large region above the F1 with no energy (Ladefoged, 2006). A lateral consonant is traditionally associated with non-velarized in syllable onset, so-called light lateral, and velarized in coda position, so-called dark lateral. Light laterals typically have high F2 and low F1, while dark laterals have low F2 and high F1. The higher formants are considerably diminished in intensity (Ladefoged & Maddieson, 1996). In many studies, F2-F1 has been measured to quantify lateral quality (Sproat & Fujimura, 1993). The intervocalic laterals may be ambisyllabic or non-ambisyllabic. If the lateral is ambisyllabic, it is shared between two syllables and belongs to both a coda and an onset of the syllables. According to Lee & Seo (2019), F2-F1 of the laterals are not significantly different between ambisyllabic and non-ambisyllabic positions in English.

Cases in which the boundaries of the targeted consonants were unclear were removed from the data. Pronunciation and prosodic errors were excluded from the data. For example, the Korean group occasionally pronounced *immoral* and *unnecessary* with the primary stress on the first syllable (9 tokens) and *happily* as /hæpɪli/, with the primary stress on the second syllable (4 tokens). Thus, 34 tokens were removed from the data. Furthermore, in the Korean group, elisions of the preceding vowels were occasionally found in the suffixed words. Most of the elisions occurred in *openness* (8 tokens), followed by *easiness* (4 tokens). The 20 tokens with elisions were removed from the data for the analysis of preceding

vowel and relative durations.

Data analyses were performed in R by using functions of the following libraries: “ggplot2” (R Core Team, 2021; Wickham, 2016), “lme4” (Bates et al., 2015), the lmerTest R package for *p*-values (Kuznetsova et al., 2017), and “emmeans” (Lenth et al., 2021). Linear mixed effect models (LMER) were used with geminate (geminate and singleton) and geminate by each affix (*in-*, *un-*, *-ness*, and *-ly*) as fixed factors, and speakers and speakers by items as random factors. Absolute consonant durations (hereafter absolute durations), the preceding vowel durations, and relative durations were compared between geminates and singletons in the English and Korean groups and between the English and Korean groups. In order to see differences in the phonetic implications according to different degrees of boundary strength between *im-* and *un-*, the three durational measurements of *im-* and *un-* geminates and singletons were also compared. Because the decomposability of affixes was not rated by the participants in this experiment, statistical analysis was performed regardless of prefix and suffix, assuming that all affixes have the same morphological parsing mechanisms. If degrees of decomposability for each affix vary in data, the decomposability variable may be shown in the phonetic realization of geminates through affixes.

3.1.3. Results

3.1.3.1. English Group

Table 2 presents the LMER results of absolute durations of geminates and singletons produced by the English group. The negative outcomes of Estimate (Est.) and *t* values indicate the absolute durations of singletons were shorter than those of the geminates.

Table 2. Linear mixed effect models results of the absolute durations in the English group

Classification	Est.	SE	df	<i>t</i> -value	Pr (> <i>t</i>)
(Intercept)	117.11	6.46	28	18.1	<2e-16***
<i>un-</i>	23.58	8.17	90	2.49	0.0144*
<i>-ness</i>	-14.55	8.22	92	-1.77	0.0801
<i>-ly</i>	-38.72	8.16	90	-4.74	7.90e-06***
<i>im-</i> : singleton	-41.00	8.16	90	-5.02	2.59e-06***
<i>un-</i> : singleton	-79.41	8.17	90	-9.71	1.16e-15***
<i>-ness</i> : singleton	-45.35	8.27	94	-5.48	3.59e-07***
<i>-ly</i> : singleton	-7.38	8.20	92	-0.89	0.3711

p*<.05, **p*<.001.

As shown in Table 2, the absolute durations of geminates were significantly longer than those of the singletons in the *un-*, *im-*, and *-ness* words in the English group, but in the *-ly* words, the absolute durations of the geminates and singletons were not significantly different.

Table 3 shows that the geminates and singletons were not significantly distinguished by the preceding vowel durations.

Table 3. Linear mixed effect models results of the preceding vowel durations in the English group

Classification	Est.	SE	df	<i>t</i> -value	Pr (> <i>t</i>)
(Intercept)	83.16	7.74	6	10.7	4.19e-05***
<i>un-</i>	11.36	6.33	93	1.79	0.764
<i>-ness</i>	-16.74	6.39	96	-2.61	0.0103*
<i>-ly</i>	6.13	6.32	91	0.97	0.3340
<i>im-</i> : singleton	-9.27	6.32	91	-1.46	0.1456
<i>un-</i> : singleton	-9.50	6.33	92	-1.49	0.1374
<i>-ness</i> : singleton	11.64	6.45	97	1.80	0.0742
<i>-ly</i> : singleton	-12.09	6.37	94	-1.89	0.0609

p*<.05, **p*<.001.

Table 4 shows that the relative durations of the geminates were significantly longer than those of the singletons in the *un-*, *im-*, and *-ness* words. But the relative durations were not different between the geminates and singletons in the *-ly* words.

Table 4. Linear mixed effect models results of the relative durations in the English group

Classification	Est.	SE	df	<i>t</i> -value	Pr (> <i>t</i>)
(Intercept)	1.57	0.12	19	12.4	1.53e-10***
<i>un-</i>	-0.07	0.15	89	-0.49	0.61
<i>-ness</i>	0.06	0.15	92	0.44	0.65
<i>-ly</i>	-0.57	0.15	89	-3.82	0.00024***
<i>im-</i> : singleton	-0.45	0.15	99	-3.05	0.002978**
<i>un-</i> : singleton	-0.82	0.15	90	-5.47	4.05e-07***
<i>-ness</i> : singleton	-0.89	0.15	94	-5.85	7.11e-08***
<i>-ly</i> : singleton	-0.04	0.15	91	-0.30	0.760137

p*<.01, *p*<.001.

3.1.3.2. Korean Group vs. English Group

Despite their small number, the Korean group sometimes inserted a brief pause after *un-*. The brief pause was more frequently found in singleton items (14 times) than in geminate items (5 times). It has also been found once after *un-* in the English group. The mean absolute durations between *un-* geminates and singletons were not significantly different with and without a pause (*t*=0.91, *p*=.36 and *t*=0.32, *p*=.975, respectively), as they were not in Oh's (2013a) study. Thus, *un-* geminates with and without a pause were not distinguished because a gap insertion had no effect on the main outcome.

Table 5 shows that the Korean group always produced significantly longer absolute durations for the geminates than for the singletons for all affixed words.

Table 5. Linear mixed effect models results of the absolute durations in the Korean group

Classification	Est.	SE	df	<i>t</i> -value	Pr (> <i>t</i>)
(Intercept)	156.09	5.45	26	28.6	<2e-16***
<i>un-</i>	-1.95	4.75	363	-0.4	0.68
<i>-ness</i>	-46.00	5.00	389	-9.1	<2e-16***
<i>-ly</i>	-54.25	4.81	354	-11.2	<2e-16***
<i>im-</i> : singleton	-64.67	4.80	359	-13.4	<2e-16***
<i>un-</i> : singleton	-65.12	4.70	374	-13.8	<2e-16***
<i>-ness</i> : singleton	-34.61	5.08	360	-6.8	4.19e-11***
<i>-ly</i> : singleton	-10.33	4.90	357	-2.1	0.0358*

p*<.05, **p*<.001.

Figure 3 presents the means and standard errors of the absolute

durations of geminates and singletons produced by the English and Korean groups. For each affix, from the left to the right, a white bar and a gray bar represent the absolute durations of geminates produced by English and Korean groups, and a light blue bar and a deep blue bar represent the absolute durations of singletons produced by English and Korean groups. Overall, the Korean group produced longer absolute durations than the English group, which could be attributed to the fact that the Korean groups are less fluent than the English group. A significant difference between the English and Korean groups was found in the absolute durations of the *im-*, *un-*, and *-ly* words (Est=26.51, SE=10.95, *df*=37, *t*=2.4, *p*<.05 for the *im-* words; Est=24.62, SE=10.9, *df*=36, *t*=2.25, *p*<.05 for the *un-* words; Est=22.26, SE=10.9, *df*=37, *t*=2.03, *p*<.05 for the *-ly* words).

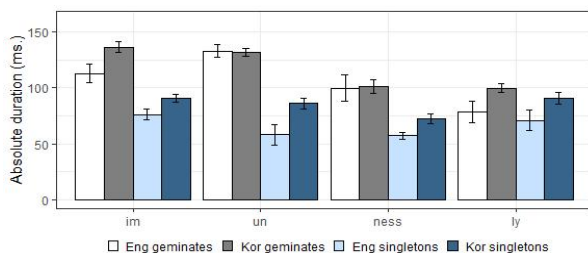


Figure 3. Absolute durations of geminates and singletons of *im-*, *un-*, *-ness*, and *-ly* words.

In the English group, the absolute durations of geminates in *un-* words were significantly longer than those in *im-* words (Est=20.38, SE=7.56, *df*=46, *t*=2.69, *p*<.001), but in the singletons between the *un-* and *im-* words, the opposite results were found (Est=-18, SE=7.55, *df*=45, *t*=-2.38, *p*<.05). These different patterns may be due to the effect of the following segments. Bilabial nasals are frequently longer than alveolar nasals in the word medial position, and nasals are typically longer before consonants than before vowels (Ben Hedia & Plag, 2017; Umeda, 1977). Both *im-* and *un-* geminates were followed by vowels, but the singleton *im-* was followed by a stop consonant while the singleton *un-* was followed by a vowel. However, absolute durational differences between *im-* and *un-* were not found in the Korean group's geminates (Est=1.89, SE=4.8, *df*=183, *t*=0.9, *p*=.69) and singletons (Est=2.4, SE=4.82, *df*=181, *t*=0.49, *p*=.61).

In Table 6, in the Korean group, the preceding vowel durations of the singletons were significantly longer than for the geminates only in the *-ly* words. But, there was no difference between the geminates and singletons in the other affixed words.

Table 6. Linear mixed effect models results of the preceding vowel durations in the Korean group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	63.0	3.71	37	16.98	<2e-16***
<i>un-</i>	19.78	3.74	358	5.302	2.22e-07***
<i>-ness</i>	-9.82	3.93	355	-2.50	0.0127*
<i>-ly</i>	-1.84	3.78	349	-0.48	0.6256
<i>im-</i> : singleton	0.11	3.77	351	0.03	0.9759
<i>un-</i> : singleton	5.36	3.69	371	1.45	0.1469
<i>-ness</i> : singleton	5.27	3.99	357	1.33	0.1871
<i>-ly</i> : singleton	7.83	3.85	353	2.03	0.0422*

p*<.05, **p*<.001.

Figure 4 shows that the preceding vowel durations in the Korean group tended to be shorter than those in the English group. The Korean group produced significantly shorter preceding vowel durations than for the English group (Est=-15.7, SE=7.17, *df*=25, *t*=-2.19, *p*<.05 for the *im-* words; Est=-16.42, SE=7.23, *df*=26, *t*=-2.27, *p*<.05 for the *-ness* words; Est=-17.97, SE=7.19). However, both group produced similar preceding vowel durations in the *un-* words (Est=-4.31, SE=7.16, *df*=25, *t*=-0.6, *p*=.55). It's interesting to note that in the English group, the preceding vowel durations for singletons were longer than for the geminates in *-ness* words. It could be related to the fact that the preceding vowels of *-ness* geminates were all schwa [ə], which is a reduced vowel.

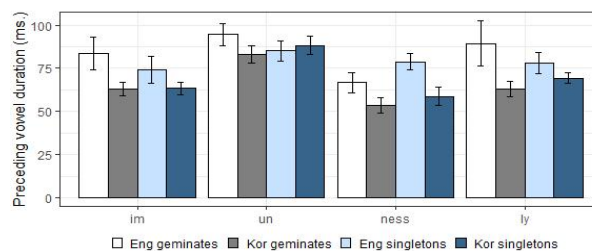


Figure 4. Preceding vowel durations of geminates and singletons of *im-*, *un-*, *-ness*, and *-ly* words.

In the English group, the preceding vowel durations were significantly different between the *un-* and *im-* geminates (Est=11.31, SE=5.27, *df*=46, *t*=2.14, *p*<.05) and between the *un-* and *im-* singletons (Est=11.13, SE=5.25, *df*=45, *t*=2.12, *p*<.05). In the Korean group, the preceding vowel durations were also significantly different between the *un-* and *im-* geminates (Est=19.74, SE=3.58, *df*=183, *t*=5.5, *p*<.001) and between the *un-* and *im-* singletons (Est=24.99, SE=3.59, *df*=180, *t*=6.94, *p*<.001).

Table 7 shows that the relative durations of the geminates were significantly longer than those of the singletons in the Korean group.

Table 7. Linear mixed effect models results of the relative durations in the Korean group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	2.8649	0.18	82	15.903	<2e-16***
<i>un-</i>	-0.80	0.22	300	3.698	0.00025***
<i>-ness</i>	-0.25	0.23	298	-1.11	0.266526
<i>-ly</i>	-0.92	0.22	299	-4.18	3.74e-05***
<i>im-</i> : singleton	-1.28	0.22	286	-5.83	1.45e-08***
<i>un-</i> : singleton	-0.86	0.22	315	-3.98	8.40e-05***
<i>-ness</i> : singleton	-0.63	0.24	301	-2.72	0.006846**
<i>-ly</i> : singleton	-0.48	0.23	296	-2.17	0.030512*

p*<.05, *p*<.01, ****p*<.001.

Figure 5 shows that the ranges of relative durations were greater in the Korean group than in the English group. This was to be expected given that the Korean group produced longer absolute durations but shorter preceding vowels than the English group did. The Korean group had significantly longer relative durations than the English group in the *im-* (Est=0.87, SE=0.29, *df*=54, *t*=2.98, *p*<.01) and *-ness* (Est=1.1, SE=0.29, *df*=59, *t*=3.68, *p*<.001) and *-ly* (Est=0.74, SE=0.29, *df*=57, *t*=2.51, *p*<.05) words. But in the *un-* words, the relative durations did not significantly differ between the two groups (Est=0.54, SE=0.29, *df*=55, *t*=1.85, *p*=.069).

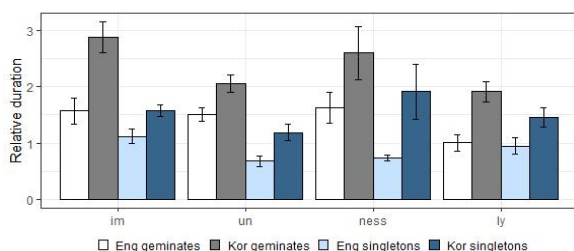


Figure 5. Relative durations of geminates and singletons of *im-*, *un-*, *-ness*, and *-ly* words.

In the English group, the relative durations were significantly different only between the *im-* and *un-* singletons ($Est=-0.44$, $SE=0.13$, $df=45$, $t=-3.31$, $p<.01$). In the Korean group, they significantly differed between the *im-* and *un-* geminates ($Est=-0.8$, $SE=12.69$, $df=183$, $t=-6.37$, $p<.001$) between the *im-* and *un-* singletons ($Est=-0.38$, $SE=0.12$, $df=177$, $t=-3.04$, $p<.01$).

3.1.3.3. Discussion

The findings of Experiment 1 support the argument that degrees of durational contrast between singletons and geminates through English affixes vary with the decomposability of affixes. However, it is more likely that the durational contrast between singletons and geminates in Korean speakers is determined by the spellings.

In the *im-* and *un-* words, the absolute and relative durations of the geminates in both English and Korean groups were longer than those of the singletons, but the preceding vowel durations did not contribute to the geminate and singleton contrast. In the English group, the absolute durations and preceding vowel durations of the *un-* geminates were longer than those of the *im-* geminates. This is consistent with the findings of Oh & Redford (2012) and Ben Hedia & Plag (2017), who claimed that *un-* affixed words have a stronger morphological boundary and are more decomposable than *im-* affixed words.

According to Lexical Phonology in Kiparsky (1982) and Mohanan (1986), affixes are divided by Level 1 and Level 2. *Un-* belongs to Level 2 and *im-* belongs to Level 1. Level 1 affixes have weak morphological boundaries and more phonological assimilation. Degemination with their stem is more expected than other affixes. But Level 2 affixes form distinct boundaries with their stem and are less phonologically integrated, so that gemination is more anticipated.

On the other hand, in comparison to English speakers, it seems that Korean speakers have a smaller gap between Level 1 and Level 2. The Korean group produced longer preceding vowels for the *un-* geminates than for the *im-* geminates but produced similar absolute durations for them. However, they sometimes inserted a brief pause after *un-* but never after *im-*. According to Oh (2013a), the brief pause indicates different morphological boundary strengths between *im-* and *un-*. Thus, it seems that the similar absolute durations of the *im-* and *un-* geminates appeared to be influenced by spellings in the Korean group, and the different decomposability between *un-* and *im-* did not have a full effect on the Korean group's English pronunciations.

Koreans usually learn English word pronunciations alongside their written forms, whereas native English speakers learn the pronunciations first. This may make Koreans more aware of how English words are spelled. Oh (2020) has proposed connecting pronunciation and spelling awareness. His Korean students clearly

preferred spelling-based pronunciation of both English and Korean words. They produced longer durations than counterpart singletons in Korean, even with phonologically degeminated consonants like *akki* and *chitssol*.

Furthermore, nasals are typically longer before consonants than before vowels, and bilabial nasals are often longer than alveolar nasals in the word medial position (Umeda, 1977). As expected, the English group in this experiment produced longer absolute durations for *im-* singletons than for *un-* singletons. However, the Korean group produced a similar duration for the *im-* and *un-* singletons. This could be thought of as the effect of the spelling. Or this could be due to the influence of a morphological boundary, if not spellings. The Korean speakers in Ahn (2014) have shown no effect of a place of articulation on durations of word final nasals.

In Lexical Phonology, both *-ness* and *-ly* belong to Level 2 (Kiparsky, 1982). However, in the English group, *-ness* geminated in terms of absolute and relative durations, while *-ly* degeminated. In the *-ness* words, the absolute and relative durations of the geminates were longer than those of the singletons, as in the *im-* and *un-* words. In the *-ly* words, the absolute and relative durations of the geminates and singletons did not differ. This absence of a durational difference supports the *-ly* degemination hypothesis. It is more likely that English speakers did not consider the stem and *-ly* to be separating. The suffix *-ly* is highly productive and transparent, and its decomposability is comparable to the prefix *un-*. Contrarily, *-ly* has unclear semantic meaning and is bound with a stem with weak boundary strength (Ben Hedia, 2019). According to Wells (2008), degemination occurs in *-ly* words because "after a stem ending in l, one l is usually lost" [as quoted in Ben Hedia (2019)], and according to Bauer (2001), there is just one /l/ when the suffix *-ly* is added to an adjective without final stress. In her corpus and experimental investigations on gemination in English affixation, Ben Hedia (2019) found evidence supporting the degemination of *-ly*, the claims of Bauer (2001) and Wells (2008). But, she also found that different factors, such as phonological environments and semantic transparency, had an impact on the degree of decomposability of *-ly* suffix.

In the Korean group, on the other hand, the absolute and relative durations of the geminates in the *-ly* words were longer than for the singletons. However, the differences in absolute and relative durations between the geminates and singletons in the *-ly* words were not much as those in the *im-*, *un-*, and *-ness* words. Actually, the mean absolute duration ratios of singleton to geminate for the *-ly* words did not substantially differ between the English and Korean groups. The ratio was 1:1.104 in the English group and 1:1.108 in the Korean group. Therefore, I compared the individual mean absolute durations of the geminate and singleton /l/ of the Korean group. Some of the Korean group produced longer durations for the geminate /l/ than for the singletons /l/, while the others produced both /l/ with similar durations.

English intervocalic consonants can only be ambisyllabic if a stressed vowel comes before them (Fallow, 1976; Rudes, 1977). However, the Korean students syllabified the intervocalic lateral /l/ as ambisyllabic regardless of vowel length or stress in Oh (2013b), who studied the relationship between syllabification and phonological factors such as stress position, vowel length, and consonant type effect. Oh (2013b) explained that ambisyllabic lateral was caused by their native language. It seems that some Korean participants in this experiment may syllabify the singleton /l/ in *-ly* words as an

ambisyllabic lateral that belongs to both coda and onset in the phonology, despite the fact that the preceding vowels were not stressed. As the Korean group articulated coda and onset /l/s in succession, the singleton /l/ in the -ly words may be lengthened as much as the geminate /l/.

On the other hand, Korean speakers who produced longer absolute and relative durations for the geminate /l/ than the singleton /l/ in this experiment may produce more -ly words depending on spelling, as they did in *im-*, *un-*, and -ness words. In general, the English proficiency of second language learners is correlated to accurate pronunciations. The various -ly patterns in absolute durations may be related to English proficiency. Unfortunately, the English proficiency of the Korean group was not examined in this experiment.

4. Experiment 2

Some studies have assumed that prefix *un-* geminates but prefix *im-* degeminates (Cohen-Goldberg, 2013; Cruttenden, 2014; Harris, 1994; Ladefoged, 2006; Mohanan, 1986). However, the findings of Experiment 1 demonstrated gemination for *im-* (a variant of *in-*), as reported by Oh & Redford (2012) and Oh (2013a). Ben Hedia & Plag (2017) noticed that prefix *in-* can mean either *not* or *inner*, but this distinction was not taken into account in previous studies on morphological geminates. Ben Hedia & Plag (2017) found that *un-* had the longest nasal duration, while locative *im-* (Loc *im-*) had a shorter nasal duration than negative *im-* (Neg *im-*). They explained that the differences in duration in Loc *im-*, Neg *im-*, and *un-* mirror morphological boundary strengths of the three prefixes, which are linked to semantic transparency. Both *im-* and *un-* had negative meanings in the words in Experiment 1. Despite the different degrees of decomposability, the Korean group did not distinguish between the Neg *im-* and *un-* geminates in terms of the absolute durations. Experiment 2 investigated how Loc *im-* and Neg *im-* are phonetically distinguished by Korean speakers.

4.1. Method

Ten Korean speakers participated in Experiment 2, and six of them took part in Experiment 1. Three English speakers who participated in Experiment 1 also took part in Experiment 2. The recording and statistical analysis were carried out as in Experiment 1. The participants were shown the Loc *im-*, Neg *im-*, and *un-* words in Table 8 at random. Loc *im-* occurs more frequently on bound bases than Neg *im-* (Ben Hedia & Plag, 2017). In this experiment, most of the words with Loc *im-* have free bases. A total of 540 tokens were obtained. One token was removed due to a prosodic error. Two tokens were removed due to brief pauses after *un-* with excessively long nasal durations. A Korean speaker seemed to have a long nasal while thinking about the next pronunciation. Because of low frequency of words with Loc *im-*, “immigration” and “immigrate” which share the same root were used.

Table 8. Stimuli

<i>un-</i>	unable	unknown
	uneven	unnoticed
	uneasy	unnatural
Neg <i>im-</i>	impatient	immature
	impossible	immutable
	imperfect	immodest
Loc <i>im-</i>	impose	immersion
	implant	immigration
	import	immigrate

4.2. Results

The absolute, preceding vowel, and relative durations of the geminates were compared to those of the singletons for each affix in each language group.

As shown in Tables 9 and 10, the LMER revealed the absolute durations of the geminates in the English group were significantly longer than for the singletons in the Neg *im-* and *un-*, but the absolute durations of the geminates and singletons in the Loc *im-* were not different. The absolute durations of the geminates, on the other hand, were always significantly longer than for the singletons in the Korean group.

Table 9. Linear mixed effect models results of the absolute durations in the English group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	95.07	11.59	7	8.19	9.25e-05***
Loc <i>im-</i>	31.81	10.45	52	3.04	0.00367**
<i>un-</i>	74.22	10.45	52	7.10	3.44e-09***
Loc <i>im-</i> : singleton	-3.78	10.22	53	-0.37	0.71265
Neg <i>im-</i> : singleton	-59.92	10.45	52	-5.73	5.09e-07***
<i>un-</i> : singleton	-103.59	10.45	52	-9.90	1.43e-13***

** $p < .01$, *** $p < .001$.

Table 10. Linear mixed effect models results of the absolute durations in the Korean group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	133.176	12.19	14	10.96	2.65e-08***
Loc <i>im-</i>	20.98	7.35	195	2.85	0.0048**
<i>un-</i>	17.28	7.41	196	2.47	0.01423*
Loc <i>im-</i> : singleton	-35.39	7.72	173	-5.18	5.53e-07***
Neg <i>im-</i> : singleton	-54.09	7.41	194	-7.81	2.52e-13***
<i>un-</i> : singleton	-45.89	7.38	201	-6.74	1.34e-10***

* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 6 shows the means and standard errors of the absolute durations of the geminates and singletons. The Korean group produced longer absolute durations than the English group. The absolute durations of Loc *im-* words (Est=46.85, SE=22.03, df=17, $t=2.12$, $p < .05$) and Neg *im-* words (Est=55.28, SE=22.03, df=17, $t=2.5$, $p < .05$) significantly differed between the two groups.

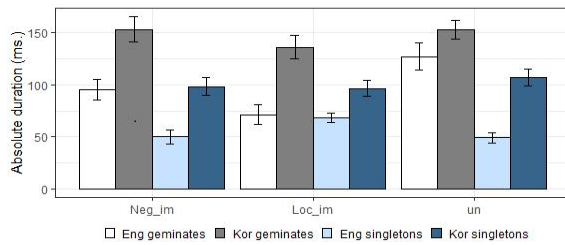


Figure 6. Absolute durations of geminates and singletons in Loc *im*-, Neg *im*-, and *un*- words.

The absolute durations in the English group differed significantly between the Neg *im*- and Loc *im*- geminates ($Est=31.81$, $SE=14.05$, $df=24$, $t=-2.26$, $p<.05$) and between the *un*- and Loc *im*- geminates ($Est=74.22$, $SE=14.05$, $df=24$, $t=5.28$, $p<.001$). The absolute durations of the Neg and Loc *im*- singletons ($Est=24.62$, $SE=5.49$, $df=26$, $t=4.5$, $p<.001$), as well as the Loc *im*- and *un*- singletons ($Est=25.87$, $SE=5.45$, $df=26$, $t=4.74$, $p<.001$), differed significantly. In the Korean group, the absolute durations significantly differed between the Neg and Loc *im*- geminates ($Est=21.5$, $SE=7.45$, $df=90$, $t=2.89$, $p<.01$) and between the *un*- and Loc *im*- geminates ($Est=18.24$, $SE=7.51$, $df=91$, $t=2.42$, $p<.05$). But the absolute durations of singletons were not different at all affixes.

The preceding vowel durations of the geminates and singletons were not significantly different in the English group, as seen in Table 11. However, only in Loc *im*- words did the preceding vowel durations of the geminates in the Korean group differ significantly from those of singletons as shown in Table 12.

Table 11. Linear mixed effect models results of the preceding vowel durations in the English group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	54.92	3.57	17	15.35	2.26e-11***
Loc <i>im</i> -	4.66	4.31	51	1.08	0.284
<i>un</i> -	21.81	4.31	51	5.06	5.93e-06***
Loc <i>im</i> -: singleton	5.80	4.26	53	-1.36	0.180
Neg <i>im</i> -: singleton	-5.66	4.31	51	-1.31	0.195
<i>un</i> -: singleton	-6.81	4.31	51	-1.58	0.120

*** $p<.001$.

Table 12. Linear mixed effect models results of the preceding vowel durations in the Korean group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	47.21	3.26	36	14.44	<2e-16***
Loc <i>im</i> -	5.42	3.53	184	1.53	0.1258
<i>un</i> -	8.02	3.56	185	2.53	0.0255*
Loc <i>im</i> -: singleton	8.85	3.64	173	2.43	0.0160*
Neg <i>im</i> -: singleton	-1.28	3.55	183	0.03	0.99793
<i>un</i> -: singleton	4.55	3.52	191	1.13	0.25967

* $p<.05$, *** $p<.001$.

As shown in Figure 7, the Korean group produced longer preceding vowels than the English group, but a significant difference was not found between the two groups for the three prefixes.

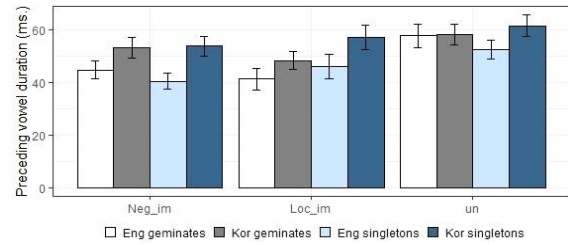


Figure 7. Preceding vowel durations of geminates and singletons in Loc *im*-, Neg *im*-, and *un*- words.

Significant differences in preceding vowel durations were found in the English group between Neg *im*- and *un*- geminates ($Est=-17.14$, $SE=4.0$, $df=24$, $t=-4.28$, $p<.001$) and between the Loc *im*- and *un*- geminates ($Est=-21.81$, $SE=4.0$, $df=24$, $t=-5.44$, $p<.001$). They were also found between the Neg *im*- and *un*- singletons ($Est=-16$, $SE=4.49$, $df=25$, $t=-3.56$, $p<.01$) and between the Loc *im*- and *un*- singletons ($Est=-9.24$, $SE=4.43$, $df=26$, $t=-2.08$, $p<.05$). In the Korean group, significant difference in preceding vowel durations were found only between the Loc *im*- and *un*- geminates ($Est=-7.93$, $SE=3.36$, $df=88$, $t=-2.35$, $p<.05$).

Tables 13 and 14 show the LMER results for relative durations in the English and Korean groups. While the relative durations of the geminates in the English group were significantly longer than for the singletons only in the Neg *im*- and *un*- words, the relative durations of the geminates in the Korean group were always significantly longer than for the singletons.

Table 13. Linear mixed effect models results of the relative durations in the English group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	1.84	0.22	7	8.23	8.63e-05***
Loc <i>im</i> -	0.35	0.20	51	1.75	0.0858
<i>un</i> -	0.43	0.20	51	2.12	0.0384*
Loc <i>im</i> -: singleton	-0.21	0.20	53	-1.06	0.2898
Neg <i>im</i> -: singleton	-0.91	0.20	51	-4.49	3.98e-05***
<i>un</i> -: singleton	-1.30	0.20	51	-6.39	4.87e-08***

* $p<.05$, *** $p<.001$.

Table 14. Linear mixed effect models results of the relative durations in the Korean group

Classification	Est.	SE	df	t-value	Pr (> t)
(Intercept)	3.64	0.44	20	8.17	8.86e-08
Loc <i>im</i> -	0.07	0.35	197	0.21	0.82963
<i>un</i> -	-0.55	0.35	198	-1.56	0.12005
Loc <i>im</i> -: singleton	-1.57	0.35	189	-4.41	1.73e-05***
Neg <i>im</i> -: singleton	-1.56	0.35	196	-4.42	1.61e-05***
<i>un</i> -: singleton	-1.03	0.35	205	-2.92	0.00383**

** $p<.01$, *** $p<.001$.

Figure 8 shows that the Korean group had greater ranges of relative durations than the English group, but a significant difference was not found between the two groups. The relative durations in the English group were significantly different only in the singletons between Neg *im*- and Loc *im*- ($Est=0.34$, $SE=0.15$, $df=25$, $t=2.24$, $p<.05$) and between Loc *im*- and *un*- ($Est=0.35$, $SE=0.15$, $df=25$, $t=4.24$, $p<.001$). In the Korean group, any significant difference was not found.

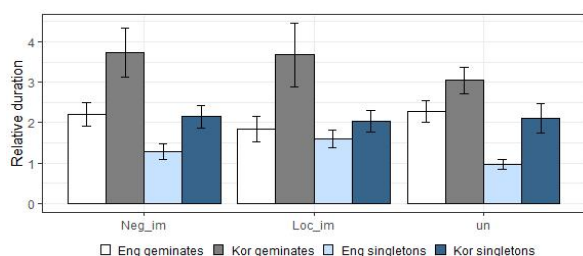


Figure 8. Relative durations of geminates and singletons in Loc *im-*, Neg *im-*, and *un-* words.

4.3. Discussion

Experiment 2 confirmed the findings in Experiment 1 for geminate-singleton contrast in *un-* and Neg *im-* words. The *un-* and Neg *im-* geminates had significantly longer absolute and relative durations than the counterpart singletons in both English and Korean groups. However, when it came to the Loc *im-* words, the English and Korean groups exhibited different results.

In the English group, in Loc *im-* words, the absolute and relative durations of geminates and singletons did not significantly differ. This means that unlike *un-* and Neg *im-*, the double spelled <mm> in Loc *im-* words were not geminated. In this experiment, because Loc *im-* degeminate in the English speakers, hereafter, double <mm> and single <m> will be used instead of geminates and singletons for Loc *im-*. Furthermore, the mean absolute durations of double <mm> of Loc *im-* were the shortest, followed by Neg *im-* geminates and *un-* geminates in the English group. This may imply that the boundary strengths of three prefixes with stem vary and that Loc *im-* is a less decomposable prefix and *un-* is a more decomposable prefix based on Lexical Phonology theory, which proposes that affixes have different degrees of morphological boundary strength (Kiparsky, 1982; Mohanan, 1986). That is, the Loc *im-* words were more likely to be regarded as whole words by the English speakers.

Furthermore, as shown in Figure 7, the mean absolute duration of single <m> of Loc *im-* was longer than that of Neg *im-* singletons in the English group. Some studies have shown that non-morphemic /s/ and /z/ in English have longer fricative durations than /s/ and /z/ in the plural and verb past (Plag et al., 2017; Tomaschek et al., 2019; Zimmermann, 2016). The non-morphemic /s/ and /z/ are unquestionably less decomposable than the plural and verb past /s/ and /z/. Therefore, given that the mean absolute duration of single <m> in Loc *im-* was longer than that of Neg *im-* singletons, it may be reasonable to conclude that Loc *im-* is less separable from stems compared to Neg *im-*.

In the Korean group, the mean absolute and relative durations of double <mm> were longer than for single <m> in the Loc *im-* words. This may suggest that the orthographic effect resulted in the durational contrast between double and single nasal consonants through Loc *im-*, Neg *im-*, and *un-* in the Korean group. Nevertheless, the durational differences between the double <mm> and single <m> in Loc *im-* words were not as much as those in Neg *im-* and *un-* words in the Korean group, as shown in Figure 7. This could explain the different degrees of decomposability of Neg and Loc *im-*. However, it cannot be ignored that the low frequency of words starting Loc *im-* could affect absolute durations of Loc *im-* words in the Korean group.

In addition, unlike Neg *im-* and *un-* words, the preceding vowel

durations of the double <mm> in the Loc *im-* words were significantly shorter than for the single <m> in the Korean group. The preceding vowel durations of the double <ll> in the *ly* words in Experiment 1 were also significantly shorter than for the single <l>. The levels of decomposability of Loc *im-* and *-ly* affixes have been similarly lower in Ben Hedia (2019). Thus, further study is needed to determine whether there is a link between lower decomposability of affixes and preceding vowel durations in Korean speakers.

5. Summary and Conclusion

This paper investigated gemination with five different types of affixes, Neg *im-*, Loc *im-*, *un-*, *-ness*, and *-ly*. In the English group, Neg *im-*, *un-*, and *-ness* affixes geminated in terms of their absolute and relative durations, but Loc *im-* and *-ly* affixes degeminated. These findings may support the assumption that gemination in affixation is dependent on the degrees of morphological decomposability of the affix and root (Hay, 2003). However, in the Korean group, all Neg *im-*, Loc *im-*, *un-*, *-ness*, and *-ly* affixes geminated in terms of absolute and relative durations. This may be evidence of the effects of orthographic representation on Korean speakers' English pronunciations. Compared to Neg *im-*, *un-*, and *-ness* words, on the other hand, the relatively small duration differences between double and single consonants in Loc *im-* and *-ly* words, may demonstrate that the degrees of morphological decomposability of the affixed words were not totally disregarded by the Korean speakers. But, this paper has drawbacks. As one reviewer pointed out, the syllable numbers and phonological environments such as types of surrounding vowels and stress are not the same for the geminates and singletons in the words. Since these variables cannot be said to be independent of consonant length, geminates and singleton consonants in affixed words should be examined within a more controlled phonological environment in further studies.

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