A Comparative Study of Word-final Laterals: General American English vs. Metropolitan French*

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The purpose of this study is to examine and compare the acoustic properties of the lateral approximant /l/ in two different languages, English and French. Among various dialects of the two languages, General American English (GA) and Metropolitan French (MF) are explored. The two dialects are most commonly found in each language and, arguably, considered as standard in both languages. Based on a production study, several acoustic properties were compared, including temporal duration, the three formants - F1, F2 and F3 -, the trajectories of laterals and darkness of the lateral by comparing the difference between the second and the first formants. The experiment showed that unlike the English one, the French lateral approximant is characterized by significant consonantal release that is consistently found at the end of the lateral articulation. English lateral itself is mostly longer than French one while the combined length of the lateral and the release is longer in French. The F2 of the French lateral was found to be significantly higher than that of the English one. Also, English laterals are darker than French ones. Time-normalized trajectories showed that each formant value varies at the onset phrase of the lateral articulation but the various formant values become merged as the lateral articulation proceeds.

Keywords: lateral approximant /l/, English, French, release, velarization

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1. Introduction

The lateral approximant /l/ is found in various languages including English and French. In this study, we examine the acoustic properties of laterals in English and French. This is a preliminary study to explore acoustic cue that may play a role in the Korean listeners' perception of the laterals. Korean listeners are known to show devious vowel epenthesis with respect to distinct acoustic properties (e.g., English *L* [el] vs. French *elle* as [elɨ]) (Kang, 2002, 2003). By examining the acoustic properties of English and French laterals in the current study, we investigate the possible factors that contribute to Korean listeners' perceptual strategy. The investigation is limited to the word-final position where the darkness and the release can be best measured. Among various dialects of the two languages, most commonly found variants, General American English (GA) and Metropolitan French (MF) are discussed. It is often the case that these two dialects are considered as the standard pronunciation of English and French, respectively.

The comparative research with respect to the two languages has tended to focus on the vowel systems (Peperkamp, 2015) or on a set of vowels that are lacking in one language (e.g., how French front-rounded vowels are borrowed in English; Bohn & Best, 2012). Little attention has been paid to lateral approximants in English and French. It would seem, therefore, that the articulatory and acoustic investigation is needed in order to understand and to compare the phonetic details of the two kinds of laterals.

It is generally known that when producing the lateral /l/, the tongue tip reaches toward the alveolar ridge and this articulatory gestures result in the center of the oral cavity being relatively closed. The terminology *'lateral'* is based on the aspects of the manner of articulation. Like any other approximants, laterals do not involve severe air obstruction but they differ from the other approximants in that the air escapes through the sides of the tongue. Depending on variants of laterals, the airstream may flow only one side of the tongue or both sides (Crystal, 1997). This kind of description implies that there may be at least more than one type of

laterals depending on the airflow and the articulatory gestures.

Traditionally, English /l/ is considered as involving at least two allophonic variations - clear [l] vs. dark [l] (Catford, 1977, 1992). In General American English, for instance, the realization of English /l/ depends on the position within a syllable - that is, where the lateral /l/ stands in a syllable. When it appears before a vowel as an onset, clear [l] is most likely found. On the other hand, dark [l] is found when the lateral comes after a vowel as a coda. The darkness of /l/ depends on the articulatory movement, i.e., the tongue gesture. While fixing the tongue tip near the alveolar ridge, one pushes down the front of the tongue, as the secondary articulation, which leads to the relative raise of the tongue body toward the velum. This tongue retraction toward the velum results in velarized or dark [l].

In terms of the place of articulation, English /l/ has been categorized as an alveolar. In an experimental study to provide linguagraphic and palatographic data, however, it was found that the point of air constriction may be either alveolar or dental, and that English laterals are largely apical (i.e., involving tongue tip) or apicolaminal (i.e., involving tongue tip and blade) (Dart, 1998). In addition, the tongue was clearly on the alveolar ridge in an electropalatographic study (Ahn, S.-W., 2006). An MRI-based study showed the articulatory difference between the clear and dark varieties of the English lateral. Zhou *et al.* (2010) found that the dark /l/ showed the short linguo-alveolar contact compared to the clear /l/. These experimental results of a production study and the clear vs. dark [l] distinction depending on the syllable structure suggest that there may be a few types of allophonic variants.

The place of articulation of French lateral has been controversial. According to Passy (1899), the air constriction of the lateral consonant was made by pressing the tongue tip (i.e., apical) toward the lower teeth or the blade (i.e., laminal) toward the upper teeth (Dart 1998). Gregg (1963) also argued that the tongue tip should be placed behind the lower front teeth for the lateral articulation. Fagyal *et al.* (2006) also suggested that French lateral is the alveo-dental approximant. Dart (1998), on the other hand, experimentally showed that French lateral is mostly produced

with the tongue tip targeting alveolar ridge or further back, the postalveolar region. Unlike English, regardless of the point, French /l/ is found to be mostly apical.

According to Fagyal *et al.* (2006), there is only one type of /l/ in modern French and there is no geographic or social variation regarding the pronunciation of the lateral approximant. English-like velarized /l/ once appeared in Early Old French and it was phonetically a labialized velar. The dark /l/ has disappeared since the 11th century. The phonetic variant of the lateral found in modern French is a devoiced sound. When the lateral appears after a voiceless consonant as the second component of a consonant cluster, and the cluster is placed at the word-margin, (i.e., either word-initially or word-finally), the lateral becomes devoiced. Word-medial clusters involving a lateral are subject to be assimilated to the neighboring consonants with respect to voicing.

In terms of the phoneme categories, both English and French have a lateral approximant in their segment inventories. And, phonologically, the English lateral roughly maps on the French one, meaning that some of phonetic properties are shared in the two lateral variants. However, as discussed above, the articulatory description of English and French laterals differ from each other, which presumably causes the differences in acoustic realizations. For instance, Best (2015) pointed out that the phonetic realization of English /l/ is different from French /l/ in that English /l/ is velarized while French /l/ is not. That is, English /l/ is darker than French one. English /l/, however, is velarized limitedly and the phonetic differences may be beyond the degree of being dark, or velarized. In other words, one phonological representation of /l/ in both languages may incorporate all varieties with various phonetic details.

While the English lateral approximant has been discussed frequently in terms of its allophonic distribution and the acoustic consequences, few studies have discussed the acoustic aspects of the French lateral. Recently, Peperkamp *et al.* (2008) showed spectrograms of French nasals and explained that French nasal consonants (especially, the alveolar nasal [n]) are characterized by strong consonantal release (Tranel, 1987). It is unclear whether the French lateral approximant displays similar acoustic proper-

ties; thus, in the current experiment, we examine the acoustic realization of the release in depth.

The purpose of this study is to explore these various phonetic details of laterals in English and French. On the basis of a production experiment, the present study examines the acoustic properties of English and French laterals by varying the pre-lateral vowels. The comparative approach we employ here focuses on the word-final laterals in the two languages. We deal with the two variants of laterals based on a production study, measuring both their temporal and spectral properties. By exploring varieties of laterals, we analyze what kind of phonetic details are significantly different in the two languages.

2. Methods

2.1. Participants

In order to compare the two languages, English and French, two speaker groups, English-speaking and French-speaking participants, were recruited. Each group consisted of 6 participants and the genders were equally distributed among the participants. One of the groups, which had English-speaking participants, spoke GA English in particular. The other group had French speakers, especially Metropolitan French, a variety spoken in France. Any bilinguals or speakers from other regions, for instance, Canadian French speakers, were excluded so that the dialectal differences were minimized.

All participants were native speakers of each language and their ages ranged 20-30s. None of the participants had any difficulties in speaking or listening. They were recruited around the Seoul National University campus and they voluntarily participated in the experiment.

2.2. Stimuli and Recordings

The participants were invited to a sound attenuated booth in the phonetics lab at SNU. They were asked to read a text in which stimuli were

written in their native languages. Both English and French reading materials contained non-words in order to avoid any lexical effects (Goldinger *et al.*, 1989) such as frequency (Ganong, 1980) and neighborhood density (Bard & Shillcock, 1993; Newman *et al.*, 1997; Vitevitch and Luce, 1998). In both languages, all words were disyllabic and the syllable structure of the words were limited to $CV_1(C).CV_2L$ so that the differences between the two languages would be minimally found. The lateral was fixed on the coda of the second syllable and the immediately preceding vowel, V_2, varied; it was one of the four vowels [i_], [e_], [o_] or [u_] wherein the four are found in both English and French segment inventories. In the case of English, stress placement was not verbally instructed to the participants. However, most of the participants placed it on the second syllable, which may due to the general English stress placement rule and the syllable structure.[1)]

Considering the phonotactics of the two languages, 24 English and equal number of French non-words were generated as in Table 1. In order to obtain natural speech, the participants were instructed to read the materials as naturally as they can and all the words were embedded in a carrier sentence. The carrier sentence for English was "*Say* ____ *clearly*" and for French "*Répétez* ___ *clairement*" ('*Repeat* ____ *clearly*' in English).

Every word was randomly ordered and the speakers were asked to repeat the whole sentences five times. Each participant read each carrier sentence one by one. His/her reading was recorded in a laptop and the cardioid microphone (ATR3035) was used. The recording was made with a sampling rate of 44,100 Hz.

1) The voicing of the initial consonant was not concerned in this experiment. However, according to Port & Rotunno (1979) in which VOT for initial English stops and the vowel duration were measured, when VOT was longer, the vowels were also longer. The duration of the vowel may lead to the different realization of the following laterals.

Table 1. The reading materials: English and French non-words in which the preceding vowels of a lateral were one of the four vowels [i_], [e_], [o_] or [u_] and the lateral was placed word-finally

	Preceding vowel contexts			
	[i_]	[e_]	[o_]	[u_]
English	dofill	bogell	boosole	finule
	haseal	chasell	hemoul	kinool
	kasheal	homell	marole	masool
	poseal	marell	mirole	regoole
	sanill	pidell	pagol	shedool
	vikeel	rifell	tofole	tofool
French	béfil	çonel	dosôle	bamoule
	fapil	foutel	gatol	bésoule
	moubil	gomel	mupol	comoul
	mouvil	nétel	supole	mitoul
	nuville	patel	tunol	picoule
	tagil	radel	vocol	satoul

2.3. Analyses

For the acoustic analyses, we used a software *Praat* and measured (i) lateral duration, (ii) release duration, (iii) the frequencies of the first three formants of the laterals, (iv) the difference between the second and the first formant, and (v) the time-normalized trajectories of the laterals. All of the measure values in English and French were compared. From the carrier sentences, which were the original recordings, we extracted the target words that contained the lateral approximants. By examining both the waveforms and spectrograms, we identified an interval between the onset and the offset of the lateral and labeled the interval as the /l/ portion. The labeled interval then was sent to a *Praat* script in which the acoustic values were automatically calculated.

3. Experimental Results and Discussion

3.1. Spectrograms and waveforms

Let us first visually compare the English and French lateral approximants. Figure 1 presents the spectrograms and waveforms of the lateral containing words in which the one on the top shows English non-word *vikeel* and the one on the bottom represents French non-word *fapil*. The three portions of the second syllable - vowel, lateral and release - are marked on top of each waveform. The segmentation of the sounds was determined by visually inspecting both the waveform and the spectrogram.

The most notable difference between the two spectrograms is on the final consonant and its continuing gesture, the release. According to Nedecky (2011), the articulation of final consonants in English and French significantly differs. Unlike English, French final consonants are accompanied by a noticeable follow-through. The continuation of voicing is represented after the completion of the lateral articulation. The voicing period of the final consonant, referred to as "*la détente*, "the relaxation" of the consonant" (Nedecky, 2011:30), results from the air released out of the oral cavity wherein the air used to be encompassed. The opening of the center of the oral cavity is mandatory in French but optional in English.

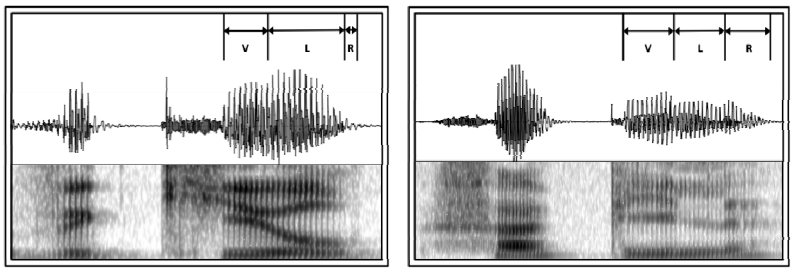

Figure 1. Spectrograms and waveforms of English non-word *vikeel* (top) and French *fapil* (bottom) with vowel, lateral and release portion marked respectively.

As presented in Figure 1, the duration of the consonantal release is different in the two languages. The consonantal release in English is absolutely op-

tional, and, consequently, although it is phonetically realized, it lasts truly short. On the other hand, the consonantal release in French is certainly necessary in the language; hence, it is much longer than that of English. Also, it is shown from the French figure that the release presents vocal formants due to the extent of the voicing transition from the previous gestures.

3.2. Duration

In order to compare the temporal properties of the lateral approximants in English and French, the lateral duration and release duration were measured. The durations were examined in terms of pre-lateral vowels so as to explore any possible influences of the preceding contexts. In general, English laterals that appear after back vowels were found to be longer than those after non-back vowels. This durational asymmetry between back vs. non-back vowels was not found in French laterals.

Table 2. The average duration of the lateral approximants in English and French as a function of the pre-lateral vowels [e_], [i_], [o_] and [u_] (*Data were expressed as mean ± standard deviation)

Duration (ms)	English		French	
	Lateral	Release	Lateral	Release
e_	122 (±45)	4 (±4)	86 (±24)	61 (±23)
i_	121 (±41)	5 (±4)	92 (±27)	66 (±25)
o_	132 (±55)	4 (±4)	86 (±25)	60 (±23)
u_	134 (±48)	4 (±3)	84 (±22)	62 (±24)

A t-test was performed to compare the duration of lateral and release of the two languages and it was found that English lateral is generally longer than that of French ($t(1426) = 20.1$, $p < 0.001$). Obviously, the French release was longer than English ($t(1426) = 66.5$, $p < 0.001$).

The short duration of French lateral presumably results from the consonantal release which, in a way, is considered as a part of the lateral. The English lateral approximant involves the tongue tip gestures through the onset to the offset of the lateral in spite of the tongue body being raised toward the velum. The tongue tip remains at the alveolar ridge

region until the whole lateral articulation is completed. Unlike the English lateral, the French one requires an extra gesture by loosening up the tongue tip contact from the region. The air stream of the center of the oral cavity is then released by means of the additional gesture of the tongue tip.

3.3. F1, F2, F3 and F2-F1

The first three formant frequencies, F1, F2 and F3, of the laterals in English and French were measured. The mean formant values of each formant in the two languages are presented in Figure 2.

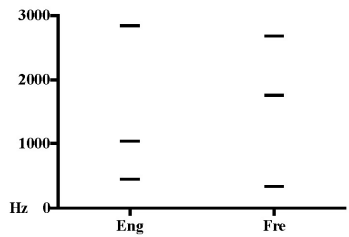

Figure 2. The average formants of the three formants of the lateral approximant in English and French.

As in the figure, the English lateral has slightly higher F1 and F3 values than the French one. The English lateral, however, has lower F2 than the French one. F2 difference was the largest among formants in that the F2 in English is very low so much that the value is closer to F1 while the French F2 is fairly high and it is closer to F3.

Formant frequencies are deeply associated with where the constriction is introduced along the oral cavity. In terms of articulatory points, F2 has to do with the backness of oral constriction. A constriction near lips induces relatively frontal constriction of the oral cavity, which raises F2. A constriction near velum, on the other hand, results in rear constriction that results in low F2. The low F2 in English and high F2 in French suggest that the English lateral is articulated with the air constriction on the back of the oral cavity while the French one is more forward.

The mean frequencies along with minimum and maximum were presented in Table 3. In general, the formant values after the two front vowels [e_]

and [i_] and ones after the two back vowels [o_] and [u_] were similar each other. As suggested in Figure 2, F1 and F3 values were higher in English but F2 value was higher in French except F3 after [i_] context in which French was higher. With regard to the pre-lateral vowels, the formant frequencies of the lateral in English and French were significantly different in most of the contexts. Exceptionally, F3 after [e_] context was not significantly different. It may be due to the facts that the F2 and F3 values of the vowel [e_] are close to each other and that the difference between F3 and F1 is the smallest among the four vowels [i, e, o, u] in this experiment.

Table 3. Mean, minimum and maximum frequencies of the three formants of the lateral in English and French

(Hz)		English Mean (Min~Max)	French Mean (Min~Max)	Significance
F1	e_	508 (381~604)	369 (341~420)	$t(356) = 18.7$, $p < 0.001$
	i_	454 (359~503)	305 (288~337)	$t(355) = 24.2$, $p < 0.001$
	o_	432 (354~475)	368 (332~437)	$t(355) = 11.4$, $p < 0.001$
	u_	387 (336~444)	300 (282~340)	$t(354) = 19.7$, $p < 0.001$
F2	e_	1137 (1013~1340)	1817 (1727~1921)	$t(356) = 28.2$, $p < 0.001$
	i_	1214 (1026~1548)	1952 (1842~2080)	$t(355) = 41.4$, $p < 0.001$
	o_	866 (780~1044)	1690 (1575~1769)	$t(355) = 43.9$, $p < 0.001$
	u_	920 (839~1103)	1582 (1331~1736)	$t(354) = 31.2$, $p < 0.001$
F3	e_	2884 (2660~3033)	2870 (2714~2984)	$t(356) = 0.45$, $p > 0.05$
	i_	2771 (2563~2904)	3097 (2874~3226)	$t(355) = 12.4$, $p < 0.001$
	o_	2898 (2726~2995)	2397 (2237~2611)	$t(355) = 17.7$, $p < 0.001$
	u_	2812 (2640~2929)	2356 (2166~2608)	$t(354) = 16.5$, $p < 0.001$

In addition to each formant frequency, the mean formant frequency difference between the first and the second formant (i.e., F2-F1) was measured. The difference is described in Table 4.

Table 4. The formant frequency difference, F2-F1, in the lateral approximants in English and French

(Hz)	English	French
F2-F1	587	1424

Considering that F1 and F2 values are related to tongue height and backness respectively, F2-F1 values explain the degree of lateral darkness (Müller, 2011; 2015; Recasens *et al.*, 1995). As discussed in the introductory section, English laterals involve at least two allophones. Since the degree of darkness varies inversely with the F2-F1 values, English /l/ on the onset of a word is typically clear in GA and it is characterized with high F2-F1. The /l/ on the coda of a word is considered as dark and it has low F2-F1 value.

Based on the values in Table 4 that present the lower F2-F1 in English, it is implied that, word-finally, English lateral approximants are more velarized and thus darker than French ones. In other words, unlike English which heavily velarizes the word-final lateral approximant as its secondary articulation, French laterals do not require such articulatory movements.

3.3. Formants trajectories

The articulatory changes of the lateral over time, that is, the trajectories of /l/ were compared in English and French. The formant changes were measured from the onset to the offset of the lateral articulation and normalized-time measurement was adopted (Xu, 2007). The trajectories were based on 20 equidistance data points irrespective of duration.

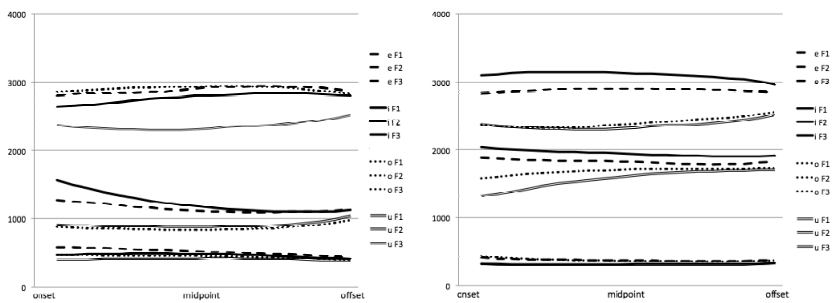

Figure 4. The trajectories of the three formants of the lateral approximant in English (top) and French (bottom).

Figure 4 shows the changes of three formants of the laterals in English and French depending on the pre-lateral vowels. In both of the languages,

it is equally found that, near the onset of the lateral, the frequencies of the three formants were virtually distinctive. This distinctiveness is particularly noticeable in F2 and F3. Toward the offset, however, the distinctive values of the formants converged upon one data point.

These formant changes suggest that the onset of the lateral has carryover effect from the pre-lateral vowels due to coarticulated gestures of vowels and the lateral. For instance, the vowel [i] has the highest F2 among the four vowels [i], [e], [o] and [u]. This high F2 of [i] influences F2 of the following lateral /l/; thus, the onset of the lateral has relatively high F2. As the lateral gestures proceed, the coarticulated effects fade away and properties intrinsic to laterals are found.

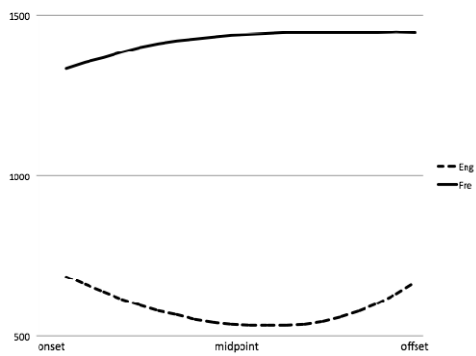

Figure 5. The trajectories of the average difference of the first two formants in English and French.

Figure 5 displays the F2-F1 changes over time. English F2-F1 is lowest around the midpoint and increases toward the offset. The lowest F2-F1 in French is found on the onset. These trajectories of F2-F1 in Figure 5 represent that the English lateral approximant is most severely velarized immediately after the midpoint and less so when completing the lateral gestures. On the contrary, this dynamic change is not found in French because, as discussed above, French laterals are clear. Except the onset of the lateral in which the lateral is influenced by the pre-lateral vowels, the French lateral has a fairly high F2-F1 value difference and the high value retains constant until the lateral gestures are completed.

4. Conclusion

In this experimental research, we examined the acoustic properties of lateral approximants in English and French. We focused on the temporal duration, the frequencies of the first three formants, the difference between the first two formants and the trajectories of lateral gestures. It was found that, word-finally, English laterals were to be longer than French ones but mostly the difference was due to the release period of French lateral, which significantly differentiates French consonants from English ones. French laterals were characterized with the follow-through of vocalic release immediately after the lateral and the release is noticeably intense and lasts fairly long. With respect to the formant frequencies, F2 showed the largest difference. The F2 of English lateral was closer to its F1 while that of French lateral was to its F3. Additionally, the trajectories of F2-F1 in English showed that English laterals are velarized over time and the degree of velarization may become severe or less. Compared to the arguably dramatic changes in English, F2-F1 in French is relatively static. French laterals were found to be clear throughout the whole lateral gestures.

On the basis of the production study, we found that English and French laterals are different from each other in terms of (i) whether the lateral is released or not and (ii) whether it is velarized or not. English results comply with the literature that English word-final laterals are velarized. In the literature, French laterals are known not to have the clear vs. dark variations. However, the characteristics of French laterals whether they are clear or dark has been unknown (Ball, 2009). The current paper possibly answers to the question whether French laterals are still clearer than English ones and they may be clear thoroughly regardless of their stance within words.

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