SUBSEGMENTAL INTERACTIONS BETWEEN AFFRICATION AND DEVOICING IN QUÉBEC FRENCH*

Michael Dow
Université de Montréal

1. Introduction

The process of affrication in Québec French (QF) is routinely described as a fricative-like release of coronal stops /t, d/ before high front vocoids, that is, /i, j, y, ɥ/ (e.g., Dumas, 1987). The outputs of this process, transcribed as either [ts, dz] or [t^s, d^z], are understood as affricates (as the name makes evident) along the same lines as [tʃ, dʒ] in English, and so on. To my knowledge, the nature of these segments as integral and unitary (though complex) is unexplored in the literature, though some previous research on affrication and processes involving high vowels more generally may cast some doubt.

Specifically, frication (whether due to affrication or its underlying nature as a fricative) is an independent trigger for a number of processes targeting following high vowels, such as lenition, devoicing and deletion (e.g., Gendron 1966; Cedergren and Simoneau 1985). Additionally, partial or total devoicing has been noted in /d/-initial affricate sequences in QF, especially in the speech of young women (Bento, 1998).

The current paper presents experimental evidence challenging the traditional description of QF affricates, or at the very least, detailing them as multi-phased and more complex than previously noted. In particular, the fricative release of said affricates distinguishes itself from underlying fricatives by its interaction with the vowels participating in affrication. In cases involving the voiceless stop /t/, this interaction resembles a partially voiceless vowel or aspiration. Meanwhile, in sequences containing /d/, this interaction more closely resembles vowel-fricative mixing, or a *fricativized vowel* phase.

The multiple phases and the blurring of consonant-vowel boundaries in these sequences have consequences for their derivation and representation, and classic theories of the segment prove unsatisfactory in capturing their complexity. Instead, one possibility that is opened here is Q Theory, which allows us to describe affrication in terms of consonantal and vocalic subsegments which not only interact but also may cross major class lines.

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The remainder of this paper is structured as follows: Section 2 summarizes previous research on affrication in QF and other varieties of Canadian French, in addition to a discussion of the phonetic factors behind the process. The methodology of the current experiment is presented in §3. Section 4 presents results, and a discussion and conclusion finish the paper in sections 5 and 6, respectively.

2. Background

Descriptions of affrication in QF date at least back to Dunn (1880: 53, 180), who states: “On serait tenté de dire que le *d* n’existe pas dans la langue franco-canadienne, car, dans la prononciation, nous remplaçons cette lettre par une autre qui renferme un son sifflant et que l’on pourrait indiquer par *dz*. . . . Au *t* comme aux *d* les Canadiens-fr[ançais] donnent un son sifflant.” Rousseau (1935) also provides an early phonetic description, as well as a dialectal survey of the same phenomenon in Hexagonal French at the beginning of the twentieth century. Though one of the more stereotypical aspects of QF pronunciation (e.g., Friesner 2010), this process has long been and remains unstigmatized within Québec and varies little with social class, in addition to being obligatory within words (Dumas, 1987).

Similarly, affrication is present in almost all geographical areas of Québec with the exception of the Charlevoix region, where it is more variable (Poirier, 1994). With the noted exceptions of Prince Edward Island (King and Ryan, 1989) and Northeast New Brunswick (Cichocki and Perreault, 2018), where local variants of affrication include the palatalized [dʒ] and aspirated [t^h] can additionally be found, affrication is largely absent from Acadian French (Dumas, 1987).

According to an X-ray study of QF by Charbonneau and Jacques (1972), several factors distinguish the articulation of coronal stops in affrication settings from those in neutral contexts. First, both the active and passive articulators are slightly different: whereas simple stops (i.e., /t, d/ not before high front vocoids) are articulated with the tongue tip against the alveolar region, in affrication settings, these stops are articulated with the tongue predorsum further back in the postalveolar or prepalatal region. The two kinds of stops are additionally distinguished by the rapidity of tongue blade lowering after stop release, being much slower in the case of affricated stops. Finally, later portions of affricated stops are articulated with the tongue tip pointed down towards the lower teeth, whereas the tongue blade is fairly flat in the case of unaffricated stops. In both cases, the tongue body bunches almost immediately after stop release to form the gestures of the following vocalic segment; again, what distinguishes the two kinds of stops is the direction and velocity of the concurrent tongue tip movement and the resultant surface area in the anterior oral tract.

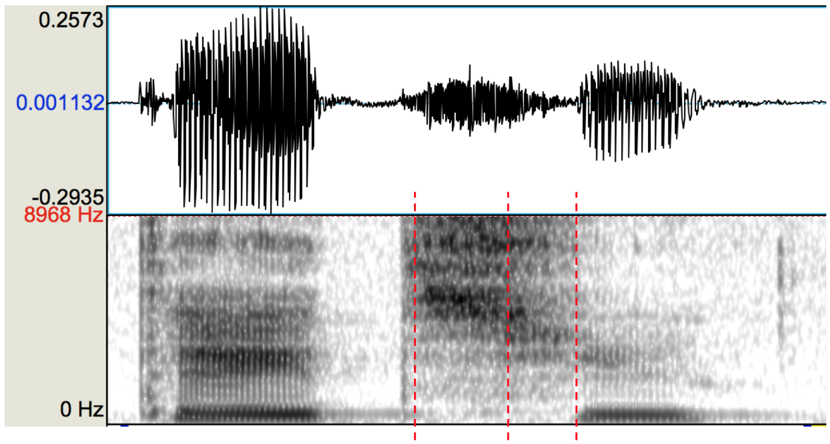
The sort of process exemplified by affrication in QF is neither rare from a typological perspective nor unnatural from a phonetic perspective. The production of an affricate from a coronal stop before a high vocoid is just one of several possible outcomes of *assibilation* more generally; others include /t/ $\longrightarrow$ [s] and [tʃ] (Hall et al., 2006). Assibilation targets are typically, but not necessarily coronal, while triggers are most often high and front vocoids (Kim, 2001). Assibilation is favoured in coronal stop + high front vocoid sequences in particular because of the similar loci of stop release and relatively high degree of closure in the vocoid, creating the requisite conditions for turbulence (Jaeger, 1978). While all released stops necessarily have some small degree of friction release before all vowels, this release is demonstrably longer before high vowels (e.g., Ohala 1983; Clements 1999).

Hall et al. (2006) distinguish two phases within affrication, namely, burst friction and aspiration. The former corresponds to the release of the plosive element and therefore shows spectral properties characteristic of its place of generation. In particular, the energy of this phase is typically in the 3500 to 7000 Hz range. This phase necessarily precedes and is shorter than the aspiration phase, which shows higher and less dispersed spectral energy. Spectral peaks resembling the formants of the adjoining vowel can also be observed, commensurate with the positioning of articulators to produce the vocoid's constriction. In order to avoid confusion surrounding the term *aspiration*, the rest of this paper will primarily refer to this phase as friction or fricative-like, in comparison with a stop release phase (not considered in the experiment).

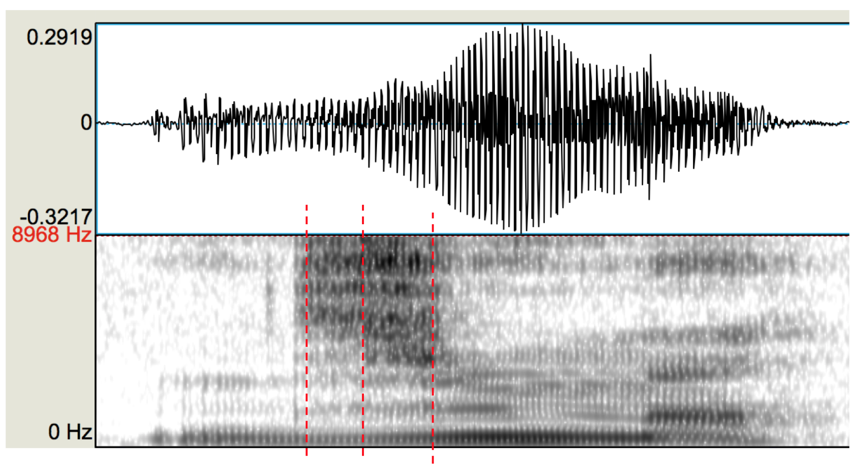
We consider here evidence from QF for the need to subdivide the fricative-like phase in two, resulting in an additional but optional phase. Such a proposal is based on the dynamic but fairly abrupt behaviour of both spectral energy and vowel-like formants between burst friction and so-called pure vowels (i.e., not mixed with any frication), as illustrated in Figures 1a and 1b. Specifically, there appears to be an abrupt lowering and/or dispersion of higher energy in the spectrum, as well as the appearance or strengthening of formants associated with the following vowel. Whether this phase or the former, much more fricative-like phase should be considered as more analogous with the aspiration phase of Hall et al. (2006) is still unclear, as are the exact criteria for identification of boundaries. This paper examines some, but certainly not all, quantifiable means of subdividing affrication, as discussed in §3. In this paper, we examine the nature of this phase in /t, d/ + /i, y/ sequences in QF and how it may be distinguished from the preceding phase as well as from underlying fricatives /s, z/.

3. Methodology

A reading list of French words was constructed for the experiment. Target sequences included tokens of /ti, ty, di, dy/ in the word-initial and word-final contexts. The list comprises of one word per sequence, per context for each of the 5 following consonant types: voiceless plosive, voiced plosive, voiceless fricative, voiced fricative and sonorant. Three additional words included the target sequences in absolute word-final position. As a suitable word-initial /ty/ + voiced fricative (other than /ʁ/) could not be found, this design in the end yielded 49 words. Finally, 50 distractor words not containing the target sequences were added to the reading list. This items included, among others, series of /p/- and /l/-initial words to distract from the /t, d/-initial words, as well as words containing intervocalic /s/ which served as voiceless controls and /z/ (intervocalic in 3 words, word-final in 2 words). This list was randomized four times and each incorporated into a slideshow presentation.



(a) *têtu*



(b) *dûment*

Figure 1: /ty/ and /dy/ sequences, speaker 1, with proposed phases

Ten native speakers of QF were recruited for the purposes of this study; the results of the first five speakers are presented here. These five speakers were all female, with an average age of approximately 24. No participants came from non-affricating areas of Québec. Each speaker read the four randomized lists aloud at a self-directed pace into a Samson Meteor microphone. Recordings were performed in Praat in mono with a sampling rate of 44.1 kHz.

Target /ti, ty, di, dy/ sequences were then divided into the following phases, where present: fricative release, the intermediate phase and vowel. Stop release was not included in measurements, though the onset of frication was defined as the end of this phase. The intermediate phase was distinguished visually from the frication phase based on abrupt changes in spectral energy and in formant structure. The reader is referred back to Figures 1a and 1b for examples of this segmentation scheme, in comparison with Figure 1 of Hall et al. (2006: 64). All in all, 877 sequences were analyzed, as two lists from speaker 2 had to be excluded due to microphone error.

Voicing of each phase was extracted automatically using information from the Praat Voice Report (pitch range: 75-500 Hz, otherwise, with standard settings) and expressed as a percentage. COG was extracted from each phase at five ms intervals based on a spectrogram with a maximum frequency of 11 kHz (standard settings, otherwise) after application of a 500 Hz high-pass filter. Mean COG was calculated for each phase for each token. Finally, timestamps were scaled within word, speaker and reading in order to allow for the COG measurements to be passed to an SSANOVA function in R using the `gss` package (Gu et al., 2014). This function was performed on an individual by individual basis.

4. Results

The results for voicing and spectral characteristics are presented in this section. In the affricate sequences, results are broken down by phase, though it bears mentioning that the maximal 4 phases were not always observed. Specific numbers on the frequency of any given combination of phases should be met with scepticism for the moment until phases can be more objectively separated. However, in both /t/- and /d/-initial sequences, this maximal type was most frequently observed (318 of 386 and 326 of 428, respectively). In /t/-initial sequences, the second most frequent type observed was equally tied between fricative release + vowel (lacking the intermediate phase) and fricative release + intermediate phase (lacking a full vowel), at 29 each. In /d/-initial sequences, this vowel-less latter type was more common than the former, at 69 forms, versus 26, respectively. Various other types comprised the remainder of tokens.

4.1 Voicing

Table 1 presents for each participant the mean percentages of voicing for the following items: the fricative release phase (F) and intermediate phase (VO) of /t, d/ before /i, y/, and the segments /s/ and /z/. True vowels were on average between 90-100% voiced, with only one exception (i.e., /i/ in speaker 2's /ti/ sequence, with a mean of 87.4%), and are excluded for this reason. The fricative release in /ti, ty/ sequences is reliably voiceless, as

Part.	/ti/		/ty/		/s/
	F	VO	F	VO	
1	2.7	37.6	1.2	21.1	3.8
2	4.0	59.1	0.6	26.9	0.0
3	1.4	50.6	0.9	47.8	0.6
4	1.5	48.2	3.4	50.9	0.0
5	1.6	47.8	2.7	59.6	0.0

/di/		/dy/		/z/
F	VO	F	VO	
89.2	91.2	93.1	95.6	78.1
69.3	92.0	84.7	90.5	48.3
79.5	91.3	92.2	98.8	48.1
85.6	95.3	93.4	96.6	97.9
81.6	95.4	76.2	92.5	93.8

Table 1: Mean % voiced, by participant and by segment phase and/or type

is the segment /s/. Meanwhile, the intermediate phase of /t/-initial forms is for all speakers between 21% and 60% voiced, with an apparent tendency for 50% voicing. As for the /d/-initial forms, the fricative release shows much higher degrees of voicing, though not quite ceiling rate and lower than that of the intermediate phase (to varying degrees). The voicing of /z/ shows inter-speaker variation, potentially due to devoicing of word-final tokens, as attested elsewhere in standard international varieties of French (Jatteau et al., 2019). The boxplots in Figure 2 illustrate the degree of variation of voicing by phase (including vowels) for affricate sequences.

4.2 Centre of gravity

In this section, we consider mean COG by segment type: first, /t/ and /d/ before /i, y/ and second, /s/ and /z/, in order to provide a point of comparison with previous studies. Then we look at changes in COG over time (along with dispersion), comparing intervocalic fricatives /s, z/ with the frication and intermediate phases of affricate sequences. Vowels in all contexts were necessarily excluded. Note that the discussion of COG over time does not presuppose or depend on the existence of phases. Finally, as frequency was not normalized, we consider individual trends rather than at a group level.

Table 2 presents the mean COG of /t, d/ before /i/ and /y/ separately according to phase, as in Table 1, and of /s/ and /z/. Mean COG was lower for each participant in the consonantal phases of /t/ and /d/ before /y/ than of those before /i/, though to varying degrees. In fact, for the majority of speakers, the friction release in /ti/ sequences had a mean COG similar to that of /s/. Unsurprisingly, due to voicing, mean COG was lower in /d/-initial sequences for each participant within each phase type. Most importantly, the intermediate phase of affricate sequences showed a lower (typically quite lower) mean COG than that of their corresponding fricatives.

The boxplots in figures 3a and 3b illustrate COG values by speaker according to underlying voicing. Affricate sequences are broken up into phases, as usual. Colour indicates vowel type. As evidenced before in table 2, when broken down into phases, the fricative

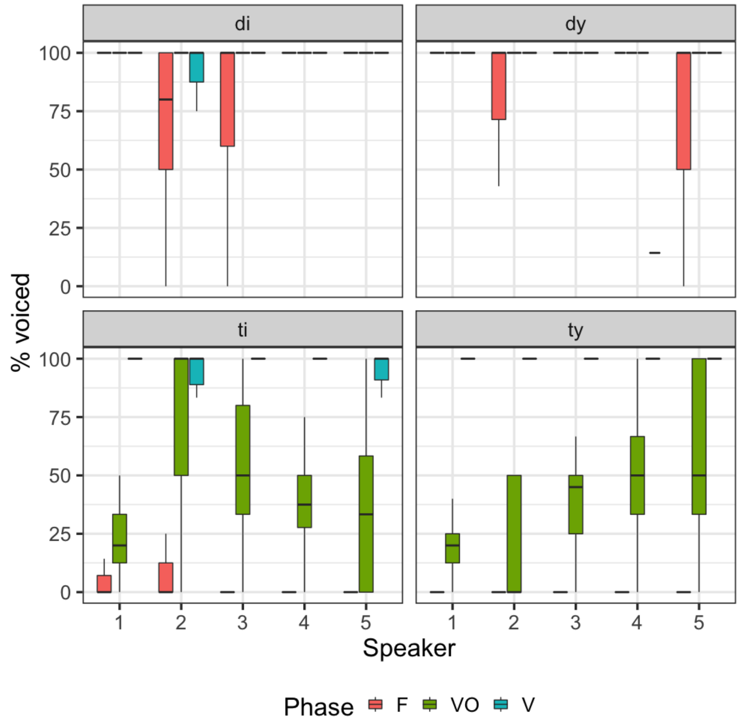
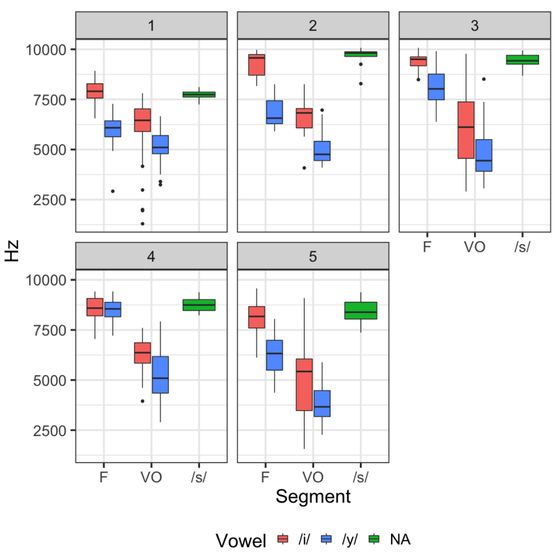
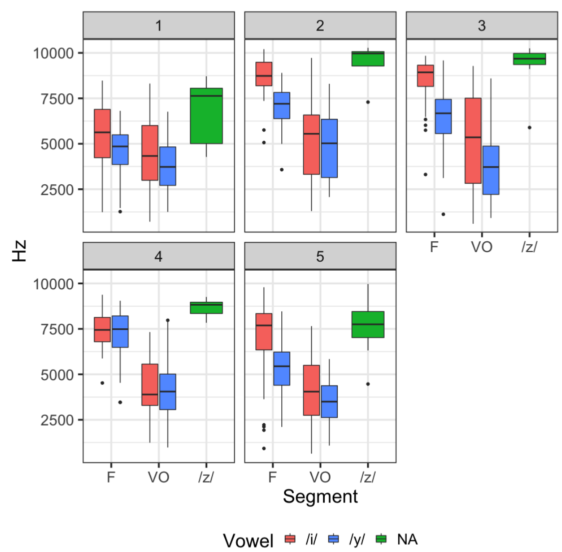


Figure 2: Voicing by phase, sequence & participant



(a) Voiceless



(b) Voiced

Figure 3: Centre of gravity in affrication sequences fricatives, per speaker

Part.	/ti/		/ty/		/s/	/di/		/dy/		/z/
	F	VO	F	VO		F	VO	F	VO	
1	7869	6054	6046	5135	7718	5555	4506	4559	3724	6786
2	9279	6624	6838	5089	9634	8686	5375	6950	5062	9378
3	9392	6051	8096	4818	9427	8444	5156	6400	3696	9264
4	8558	6301	8478	5211	8772	7446	4315	7130	4226	8649
5	8116	4972	6305	3794	8438	6992	4066	5410	3561	7569

Table 2: Mean centre of gravity, by participant and by segment phase and/or type

release of /ti/ sequences is quite similar to /s/. In /ty/ sequences, this phase has lower COG for all speakers except speaker 4. For all speakers, the intermediate phase has lower COG than the preceding phase and /s/, regardless of the vowel. Similar effects hold within the voiced group, with the exception of speaker 1's fricative phase being lower than /z/. A vowel effect appears to hold for certain speakers, especially in the fricative release phase. Crucially, regardless of vowel, COG was lower in the intermediate phase than in the fricative phase (and also lower than that of /z/). This effect is less pronounced for speaker 1 than for the rest of the group.

Figure 4 presents the SSANOVA results for each speaker, using a three-way interaction of normalized time, segment and speaker. The y axis represents COG in Hz. Solid lines indicates COG at a given point and are surrounded by a 95% confidence interval. Colour indicates voicing (red = voiceless, blue = voiced), and transparency indicates segment type (more transparent being underlying fricatives). In all cases, affrication sequences showed a dip in COG earlier and to a more extreme degree (where relevant) than underlying fricatives. With the exception of speaker 4, /z/ showed a lower COG than /s/, particularly later in its duration.

5. Discussion

Recall that the phenomena of affricate devoicing (Bento, 1998) and post-fricative or post-affricate vowel devoicing (Cedergren and Simoneau, 1985) have been previously observed in QF, for which reason we might expect high degrees of either partial devoicing in /di, dy/ sequences, which would be evidenced here by low percentages of voicing in one or both of the initial phases (i.e., “F” and/or “VO” in Figure 2), or total devoicing of these sequences. This expectation, however, was not borne out. Some voicelessness was evidenced in the fricative release of certain /d/-initial sequences for certain speakers, but generally voicing held at ceiling rates for all phases. Similarly, many speakers had near-0 rates of voicing for the friction release of /t/-initial phases but maintained near-ceiling rates of voicing for vowels.

As for the proposed intermediate phase, speakers demonstrated (appropriately) intermediate rates of voicing in /t/-initial sequences. This same phase also demonstrated a

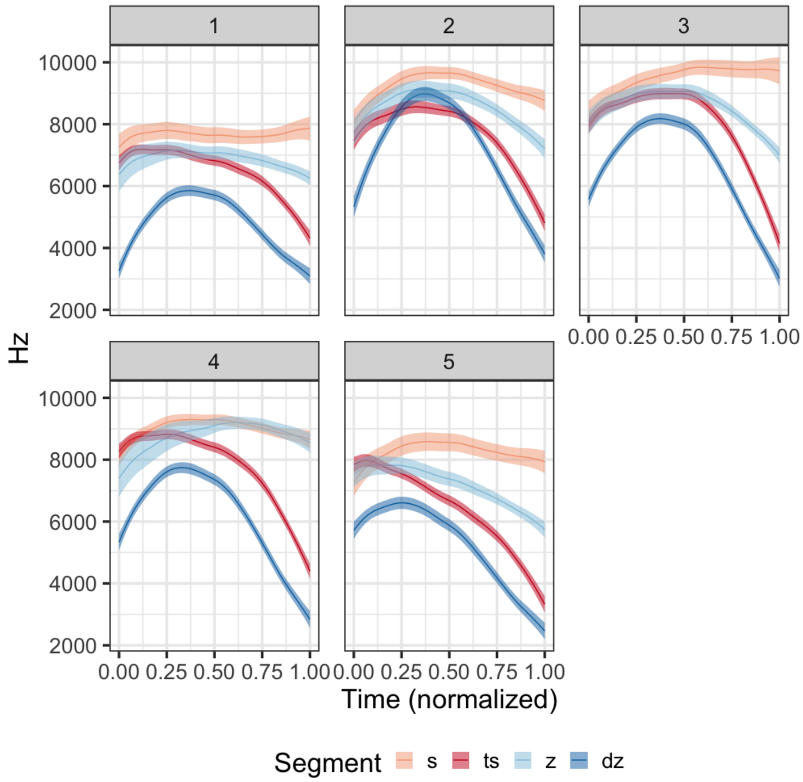


Figure 4: Centre of gravity SSANOVAs, by participant and segment type

lower (and often much lower) COG than the initial fricative release. It may be tempting to attribute this decrease in COG to the onset of voicing characteristic of this phase. However, not all speakers were similar in the percentage of voicing of this phase (and one can assume, then, the point when voicing begins), while speakers were consistent in the sharp decline in COG. Additionally, /d/-initial sequences showed the same effects while also effectively being shifted down by a constant compared to the voiceless affricates' curves. This argues against the interpretation of incipient voicing as the cause of the COG behaviour of affricates as a whole.

Instead, in keeping with the illustrations in Figures 1a and 1b, I propose that the voicelessness and decline in COG of this intermediate phase is indicative of fricative-vowel mixing.[1] In the case of the voiced affricates, this mixing resembles fricativized high vowels. These vowels,such as [z̩] in Mandarin Chinese, are articulated with simultaneous tongue tip and tongue body constriction (Zhou and Wu, 1963), resulting in strident frication and high vowel-like formant structure (Connell, 2007).[2]

[1]Of course, some degree of coarticulation is to be expected, but while this study did not control for or even consider duration, impressionistically it can be said that the fricative release and the intermediate phases showed similar durations.

[2]Compare, for instance, the second phase of Figure 1b with Figure 2 of Faytak (2014, 55).

The case of the voiceless affricates is slightly less clear. The intermediate phase of these sequences tended to resemble a voiceless vowel, though in all reality it is likely to be at the same time a fricative that is increasingly debuccalized at the same time that it necessarily increasingly gains the properties of the following target vowel. It should be noted, however, that these are hypotheses, informed in part by qualitative observation, and thus require further investigation.

Regardless of the exact nature of these intermediate phases (between the voiced and voiceless segments), it remains that, following burst friction (i.e., the plosive portion), affricates in QF are not as simple or stable as traditionally described. It is unclear, though, to what degree affricates in QF are different from those in other languages. This is primarily due to methodological differences between this study and others in the literature, which tend to employ averaging of spectra and mid-point measurements of COG. Differences in terminology also require a closer look. This study used a deliberately dynamic approach, taking spectral slices and COG at five ms intervals. In one study with a similar methodology, Butler (2012) finds a gradual rise in the COG of affricate [tʃ] in comparison with that of fricative [s] in Khmer, while the COG of both fall at similar rates at the right boundary of the segment.

Otherwise, we can at least infer that, even if some differences are documented between the COG of /s/ and /ts/, their ranges or variation are not as extremely different as seen here. The closest evidence found for another instance of similarly multi-phased affricates comes from Nyagrong Minyag (Van Way, 2018), in which the interquartile range of COG values for /ts/ appear to be 5000 and 8750 Hz (p. 80), versus that of the fricative portion of /sh/ at 7500 and 8750 Hz (p. 87), as estimated from boxplots. The larger range of COG in /ts/, measured at its “stable portion of frication” (p. 78) without periodic energy, may point to a late decline similar to that noted here. Meanwhile, in both Eastern and Western Catalan (Recasens and Mira 2018: 153), /s/ and /ts/ showed both similar COG means and ranges. Taking Eastern Catalan as an indicative example, /s/ had a mean and range of 3960.6 and 591 Hz, respectively, while /ts/ had a mean and range of 4095.9 and 611.3 Hz. In sum, the evidence suggests that QF affricates are distinct from simple affricates in the literature.

However this difference is eventually defined, we have seen evidence for an additional phase between the fricative release and vowels of coronal stop + high front vocoid sequences in QF. Even in the absence of such an intervening phase, but especially so now with its argued presence, affrication in QF regularly creates complex segments with identifiable internal structure, and it may do so within both the consonantal and vocalic elements of these sequences, depending on how one classifies this additional phase.

In this sense, Q Theory (e.g., Inkelas and Shih 2016) is particularly well advantaged to model this process. In this theory, the traditional segment (here, Q) is maintained but divided into subsegments (represented by q) which frequently, but not necessarily, number maximally three per segment. When combined with Agreement by Correspondence (ABC) Theory (e.g., Walker 2000) to give ABC+Q Theory (Inkelas and Shih, 2016), we can model phonetically-motivated interactions between subsegments. This is particularly desirable if we consider the intermediate phase as evidenced here to be a partial assimilation which, unless relegated to phonetics, proves problematic in optimality theoretic frameworks, if not the majority of bimodal frameworks.

In the case of underlying /ti/, if we assume an output of [tsi̥i], we may consider assibilation of the stop, due to aerodynamic constraints linking /t/ and /i/, as feeding vowel devoicing, due to the affinity of fricatives with voicelessness (Ohala 1997) and their well-documented likelihood of leading to vowel devoicing in QF (Cedergren and Simoneau 1985; Bayles 2016). In Q-theoretic terms, this would correspond to a derivation along the following lines: $C(t_1t_2t_3)V(i_1i_2i_3) \longrightarrow C(t_1s_2s_3)V(i_1i_2i_3) \longrightarrow C(t_1s_2s_3)V(\underset{\circ}{i}_1i_2i_3)$. Under an analysis of vowel-fricative mixing, a consonantal (fricative) gesture may spread to a vocalic subsegment, for instance, $C(t_1s_2s_3)V(s_1i_2i_3)$.

6. Conclusion

This paper examined the prevalence and ramifications of a proposed additional phase of affrication in QF. This phase was visually identified by abrupt changes in higher spectral energy and the appearance or strengthening of vowel-like formants. It was found in a reading task experiment that such a phase was more often present than not. Additionally, the non-vocalic portions of affricates demonstrated a significant decline in centre of gravity, in comparison with the relatively stable profiles of /s/ and /z/. Finally, this phase demonstrated middling rates of voicing for voiceless affricates, while their friction phases showed next to zero percent voicing and the pure vocalic phases near-ceiling rates of voicing. In comparison with other languages, it may be that the behaviour of these affricates differs from that of (unaspirated) affricates in other languages. More studies, especially ones with a dynamic approach to centre of gravity, need to be consulted in the future.

At this stage, it is difficult to take a firm stance on what this phase must be, or whether or not it constitutes a real target in QF. However, affricate sequences strongly show evidence that either such a phase exists as a target, or that some aspect of these sequences allow for, if not prefer loose interpolation. Looking to the future, this paper argues that such affricates can be elegantly captured in Q Theory, thanks to its ability to formalize partial assimilations.

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