Vowel space of French and Inuktitut: An exploratory study of the effect of vowel density on vowel dispersion*

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Abstract: Studies in phonetics tend to show that the vowel space of a language is organized following logical principles such as contrast and stability of articulation. This study falls within the same scope and investigates the impact of a system's vowel density on the dispersion of its vowels by comparing the formant values of the cardinal vowels /a/, /i/, and /u/ in the Nunavik dialect of Inuktitut, which has only these three vowels, and Quebec French, which has 16 vowels. The data were gathered using an elicited corpus from a native speaker of each language and analyzed graphically (using Praat and Excel). Similar studies suggest that the number of phonological vowels of a language has an impact on the vowel dispersion. Our results, although limited, seem to follow the expected dispersion for each language, with a possible effect of the density of the system on the dispersion of the cardinal vowels of French.

Keywords: Inuktitut, French, vowel density, vowel space, vowel dispersion

1 Introduction

Our research's main goals are to widen the scope of acoustic studies in Inuktitut, a language on which very little phonetic literature exists, and to study the impact of the vowel density of a system on its organisation by comparing a language with a minimal vowel system to a language with many vowels. Consequently, we observed the cardinal vowels (/a/, /i/, and /u/) of Inuktitut, which only has those three vowels (Denis & Pollard 2008, Dorais 2003, Maddieson 1984) and those of Quebec French, a dialect possessing 16 vowels (four nasals) distributed over 12 place of articulation (Dumas 1987, Maddieson 1984). To do so, we observed the vowel organization of both languages through their vowel spaces and the position of those spaces. We then compared those spaces in the two languages by observing each vowel in different syllabic contexts common to both languages. This allowed us to test the premises of Lindblom's (1986, 1990) adaptive dispersion theory with actual phonetic data.

Adopting the hypothesis that vowel space density would influence the dispersion of the point of articulation and that our methodology would allow us to highlight its effect if it existed, we predicted that the vowel spaces of the cardinal vowels of Inuktitut would be more centralized than those of French and that the vowel spaces of the cardinal vowels of Inuktitut would cover a bigger area than those of French.

2 Framework

Chiba and Kajiyama (1958) proposed that the acoustic study of vowels could be achieved by modelling their production mathematically, thus establishing that the observation of the first two

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formant values would provide enough information to characterize a vowel's relative place of articulation. As a consequence of Chiba and Kajiyama's proposal, subsequent studies have been done on the relative position of phonological vowels. Liljencrant and Lindblom (1972) first used a principle of maximum contrast to try to simulate the various probable organizations of vowel spaces. Studies on the relative position of vowels in vowel systems (e.g., Maddieson 1984, Lindblom 1986), made with the use of relatively massive linguistic corpora such as the *UCLA Phonological Segment Inventory Database* (UPSID), allowed Lindblom to transform his dispersion model into what is known as the "adaptive dispersion theory". Rather than a maximal contrast axiom describing dispersion, he proposed two related notions: perceived contrast (linked to speech production and articulation) and the number of phonological vowels in a language. As a consequence, the more vowels a language has, the more contrasts its speakers must make. According to Lindblom's (1986, 1990) theory, French speakers must make more contrasts to differentiate the 16 vowels of their language than a speaker of Inuktitut, since it only has three vowels. Moreover, looking at minimum (i.e., three) vowel systems cross-linguistically, in most cases we find a vowel system with the cardinal vowels /a/, /i/ and /u/ (Maddieson 1984), which has the widest distance between vowel spaces, hence the most significant perceptual contrast. However, in Lindblom's theory, vowel contrast does not seem to be the sole element influencing the dispersion of the place of articulation. Other factors, such as the speech production context (e.g., a noisy environment or a high rate of speech) might affect the need for contrast. This is what Lindblom refers to as adaptability (Lindblom 1986, 1990). In short, a speaker must produce sufficient contrast to be understood and adapt to the speech context by hyper- or hypo-articulating. Considering this, we took into account the notions of sufficient contrast and adaptability in our methodology, as we wanted our speaker to produce a set of data with the largest possible variation.

3 Methodology

3.1 Corpus creation and data collection

In order to be able to compare the vowels of French and Inuktitut, similar contexts in both languages must be provided. Therefore, the target vowels were placed in CV type syllables and with either /p/, /t/, or /k/ as their onset, as this type of syllable affects the quality of the vowel less than others, and /p/, /t/ and /k/ are the plosive consonants shared by both languages. These choices also make it easier to segment and analyse the vowels. With the three vowels combined with these three onsets, we get the nine syllables of Table 1.

Table 1 The nine target syllables

Vowel/Consonant	/p/	/t/	/k/
/a/	/pa/	/ta/	/ka/
/i/	/pi/	/ti/	/ki/
/u/	/pu/	/tu/	/ku/

We then located each of these nine syllables in words of both languages. We made the position of the syllable vary in the word in order to see if this would influence the articulation of the vowel. We had three positions: the beginning, middle, and end of the word. We found two words for each of these positions, which gave us six words per syllable and a total of 54 words for each language. Using our knowledge as native French speakers and an online rhyme dictionary we created the

French corpus. To establish the Inuktitut corpus, we used the online databases Tusaalanga[1] and Inuktitut Computing[2], as well as Dorais's (1978) lexicon of Quebec and Labrador dialects. We relied on our language consultant to complete the corpus and make sure the words we had found were part of his dialect.

Since reading a list of words is not very natural, we inserted the target words in frame sentences. The frame sentences make it possible to control the influence of the context, in terms of prosody, syntax, and semantics. The frame sentences, however, are needed to be as similar as possible from one language to another. The sentence in (1) is the frame sentence we used for the French corpus, and the sentence in (2) is the one we used for the Inuktitut corpus. These sentences are not only similar in meaning, but also in terms of number of syllables before and after the target word.

(1) Écrivez 'TARGET WORD' comme vous l'avez appris.
'Write TARGET WORD as you have learned it.'

(2) Allagit 'TARGET WORD' tammagunnailutit.
'Write TARGET WORD without mistakes.'

Once the words were found and the frame sentences were established, the experiment was created. It consisted of a power point presentation with the 54 words in their frame sentences; one per slide. Ten words were added at the beginning and five at the end of the test to control for the possible effects being at the beginning and end of the test could have on the speaker. Those added items were not taken into account in our analysis. There was one version for the French corpus, and one for the Inuktitut corpus. In the Inuktitut version, the sentences were written once with the Inuktitut syllabic alphabet and once with the Roman alphabet. The experimenter asked the speaker to read each sentence twice. The task was done three times: the first time, the speaker was asked to read the sentences slowly, the second time, they were asked to read them at a normal pace, and the third time, they were asked to read them quickly. The speed parameter, along with the position parameter, was intended to make the vowel space stretch as much as the language allowed them to stretch (Lindblom 1990). A break was taken between each test.

The person who took the Inuktitut experiment is our language consultant, a 44-year-old male, native speaker of the Nunavik dialect of Inuktitut. The French speaker is a 34-year-old male, native speaker of Quebec French.

During the test, the speaker was alone in a quiet room with the experimenter. A ZOOM Handy Recorder H4n was used to record the elicitations.

3.2 Data processing

Each target vowel in the recordings was then segmented and annotated with Praat. Three scripts were used to extract the formant values of the vowels; one script for the vowel /a/, one for the vowel /u/ and one for the vowel /i/. All of the data were then transferred to an Excel file, where they were sorted and coded, the outliers were eliminated, and the formant values were transformed from Hz to Bark.[3]

[1] http://www.tusaalanga.ca/fr/glossary/inuktitut
[2] http://www.inuktitutcomputing.ca/
[3] The Bark scale is a frequency scale on which equal distances correspond with perceptually equal distances.

4 Results

4.1 Graphical analysis of data

Figures 1 and 2 display the obtained data for each language. We represented our data such as the Vertical axis would correspond to the degree of aperture or height of articulation (F1) and the horizontal axis the anteriority/backness of articulation (F2).

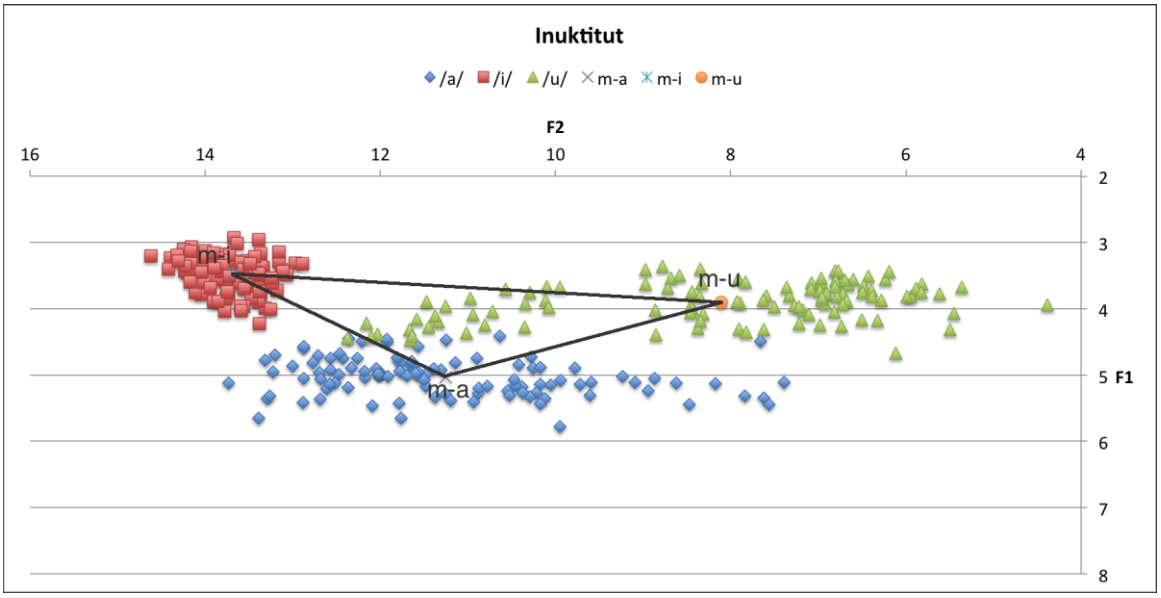

Figure 1 The three cardinal vowels in Inuktitut

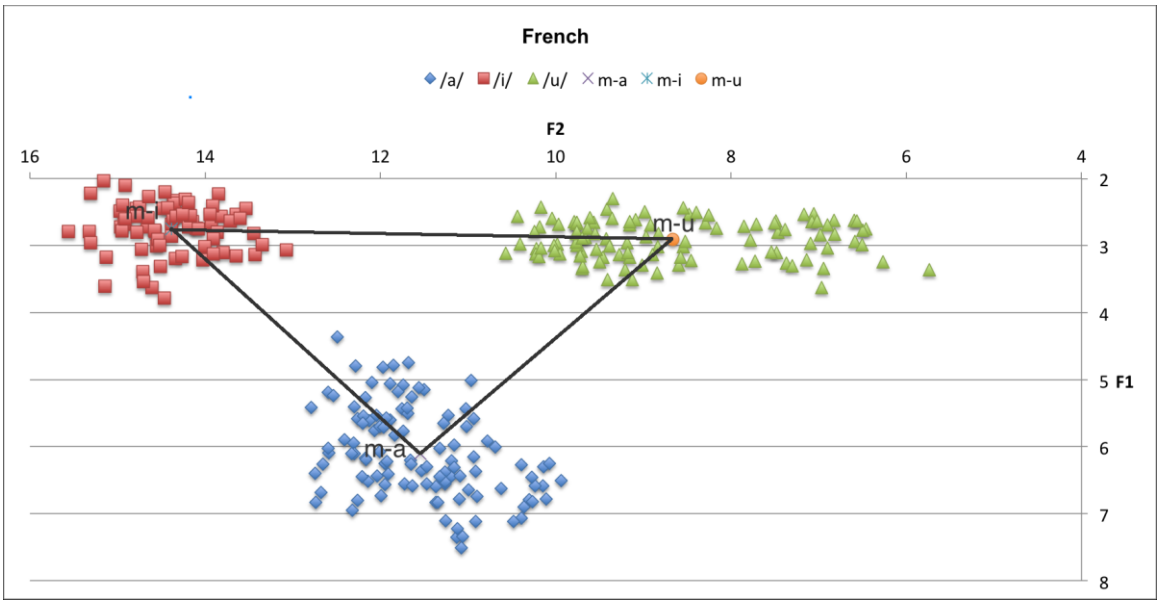

Figure 2 The three cardinal vowels in French

As expected, in both languages we found that /i/ (square dots) is articulated in a high and anterior place of articulation, /u/ (triangle dots) is mostly articulated in a high back place of articulation, as for /a/ (diamond dots), it is articulated in low mid place of articulation. In general, relative to the other two vowels, each vowel is found where it is supposed to be. Also we noticed that the French vowel space covers a vertical area (F1 axis) of four and a half Barks, whereas the Inuktitut vowel space only covers 2.5 Bark on this axis. Looking at each vowel's space of articulation in each language, we observed different patterns of variation. Looking at the French vowel /a/, we noticed that its points of articulation on the F1 axis (vertically) spread over three Barks when the same vowel in Inuktitut would vary more on the F2 axis (horizontally) over seven Barks. The /u/ vowel also had specific patterns of variation in each language: in Inuktitut it varied on the F2 axis (horizontally over 7.5 Barks), while in French it varied over only four Barks on the same axis. Finally, the /i/ vowel showed interesting stability for both languages varying comparatively less than /a/ and /u/ on the F2 axis.

Figures 3 and 4 show the effects of the onset (/p/, /t/ and /k/) on the place of articulation of the cardinal vowels.

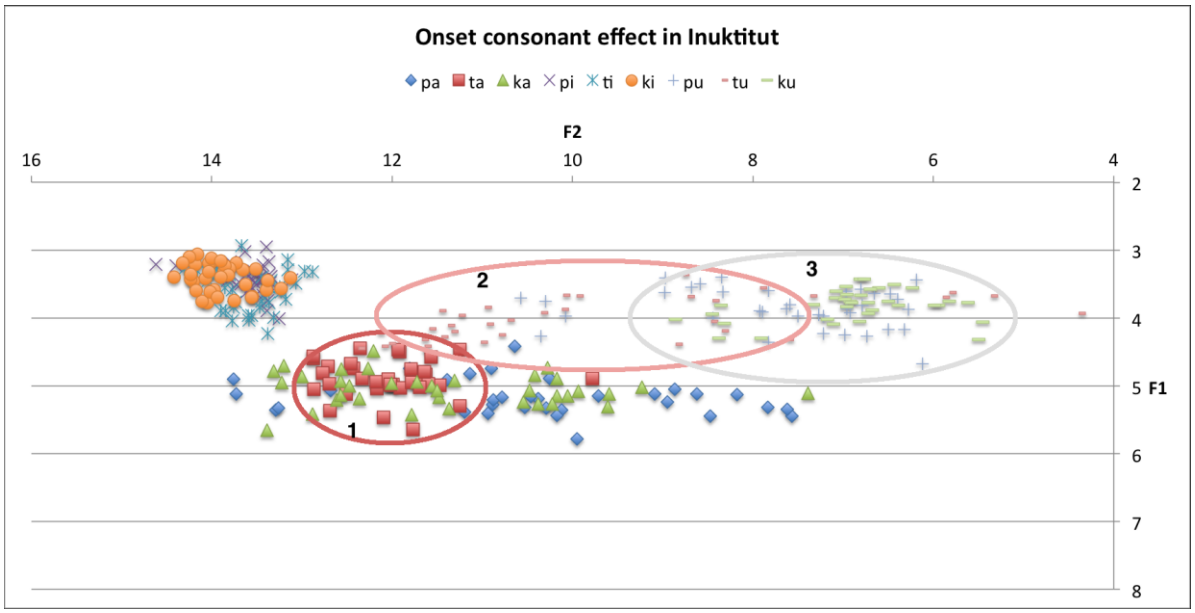

Figure 3 Onset effect in Inuktitut

We noticed that in Inuktitut, the onset /t/ seems to induce a centralization effect on the place of articulation of /a/ and /u/ (see ellipses 1 & 2 on Figure 3). When preceded by /k/, we also notice that the Inuktitut /u/ is articulated more at the back (see ellipse 3 on figure 3).

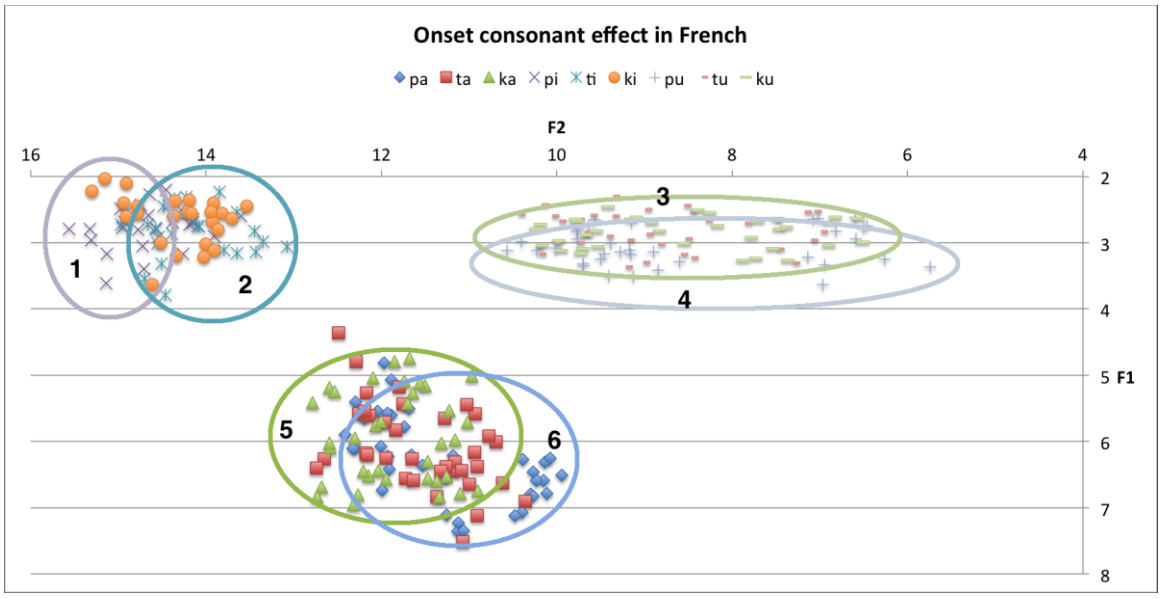

Figure 4 Onset effect in French

In French (Figure 4) we observed other kinds of effect on the place of articulation. The vowel /i/, for instance, when preceded by /p/ (ellipse 2 on Figure 4), was more posterior than when the onset was /t/ (ellipse 1 on Figure 4). When /u/ was preceded by /p/ (ellipse 4 on Figure 4), it seemed to be a little lower than when it was preceded by /t/ or /k/ (ellipse 3 on Figure 4). As for /a/, we

observed that when it was preceded by /p/ (ellipse 6 on Figure 4), it was a little lower and more at the back than the occurrences preceded by /k/ (ellipse 5 on figure 4). It is interesting to observe how the effect of the same onsets seems to be different in each language.

Figures 5 and 6 show the effect of the syllable position (*initial*, *final* and *medial*, i.e., neither initial nor final) in the target words.

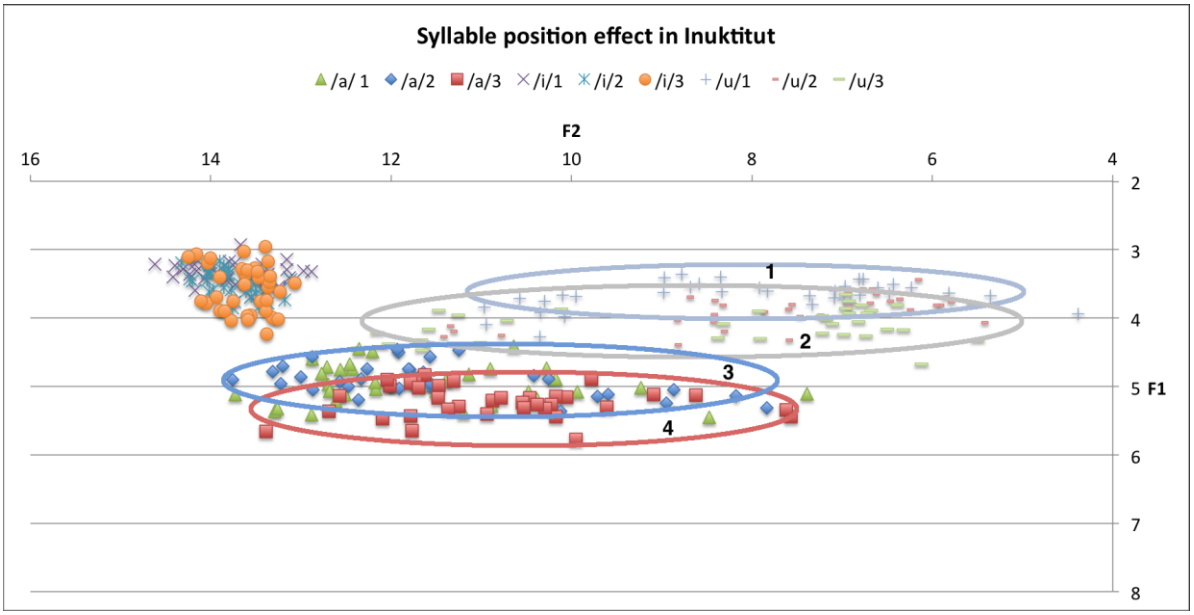

Figure 5 Syllable position effect in Inuktitut

In Inuktitut, we noticed slight effects on the vertical axis (F1) for /u/ and /a/. The vowel /u/ (ellipse 1 on Figure 5), when in the *initial* position of the word, was articulated a bit higher than in the other two positions (ellipse 2 on Figure 5). The vowel /a/ was articulated a bit lower (ellipse 4 on Figure 5) in the *final* position than in the other two positions (ellipse 3 on Figure 5).

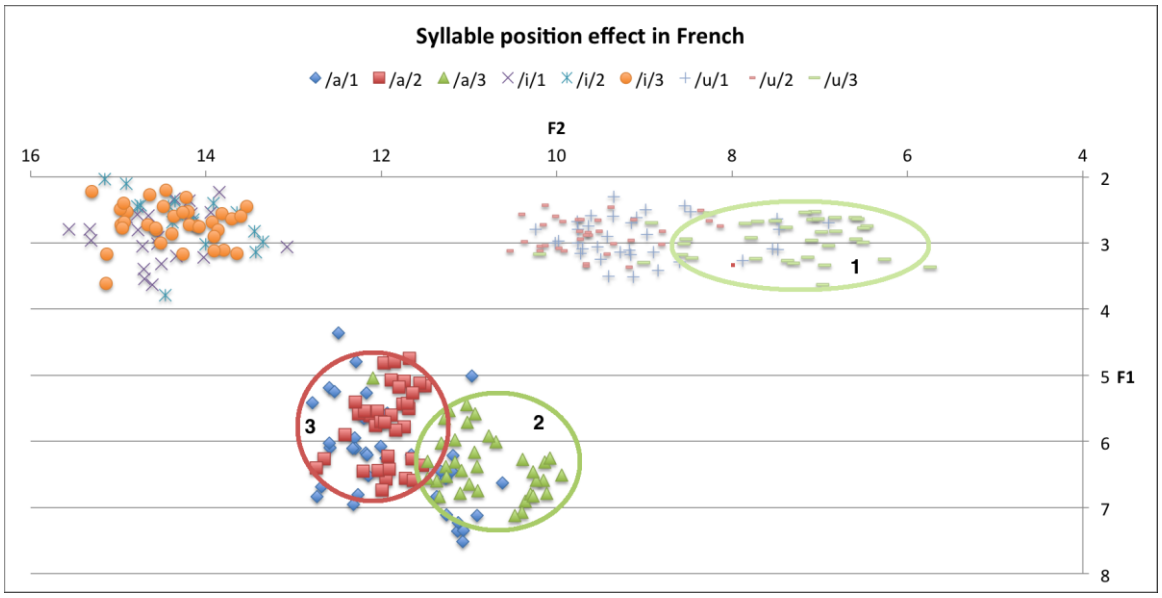

Figure 6 Syllable position effect in French

In French, the syllable position seems to affect the organisation of the vowels mainly on the horizontal axis (F2). For /u/ and /a/, the *final* position (ellipses 1 and 2 on Figure 6) is articulated further back than the other positions. For /a/ specifically, the *medial* position (ellipse 3 on Figure 6) is articulated further to the front than the other positions. Again, we observed different types of effect in each language.

Figures 7 and 8 below show the effect of the onset of the following syllable in the word.

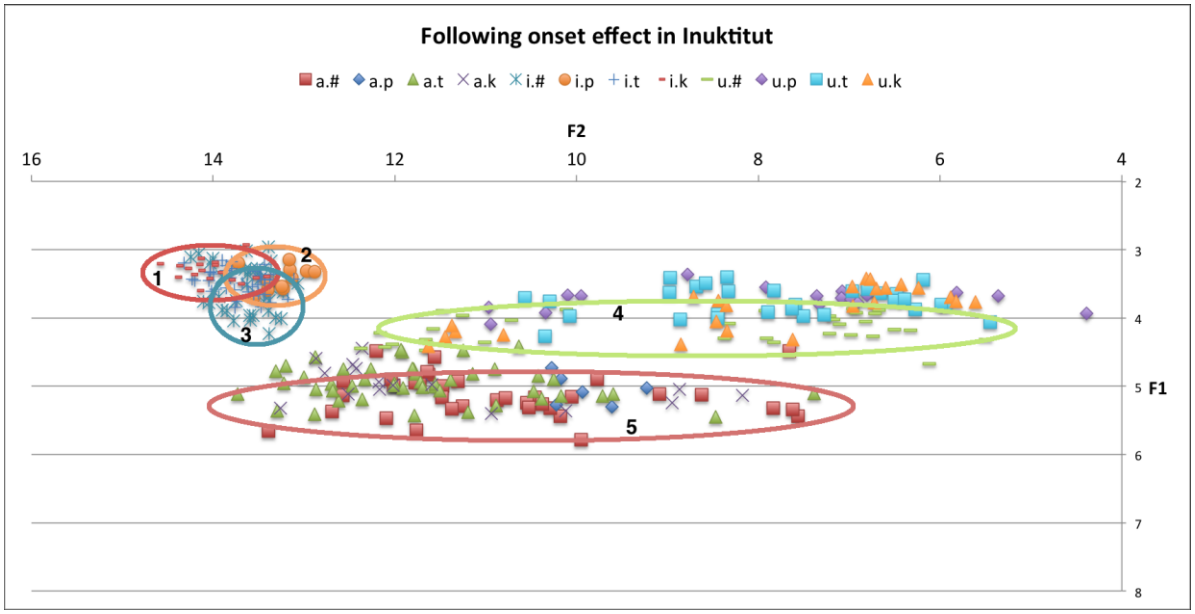

Figure 7 Following onset effect in Inuktitut

In Inuktitut we observed two types of effects, a general vertical effect (F1 axis) and a more specific horizontal effect on the vowel /i/. The vowel /i/, when followed by /p/ (ellipse 2 on Figure 7), is more posterior than when it is followed by /k/ (ellipse 1 on Figure 7). When word-final, the three vowels are articulated slightly lower than when there is a following syllable in the word (ellipses 3, 4 and 5 on Figure 7).

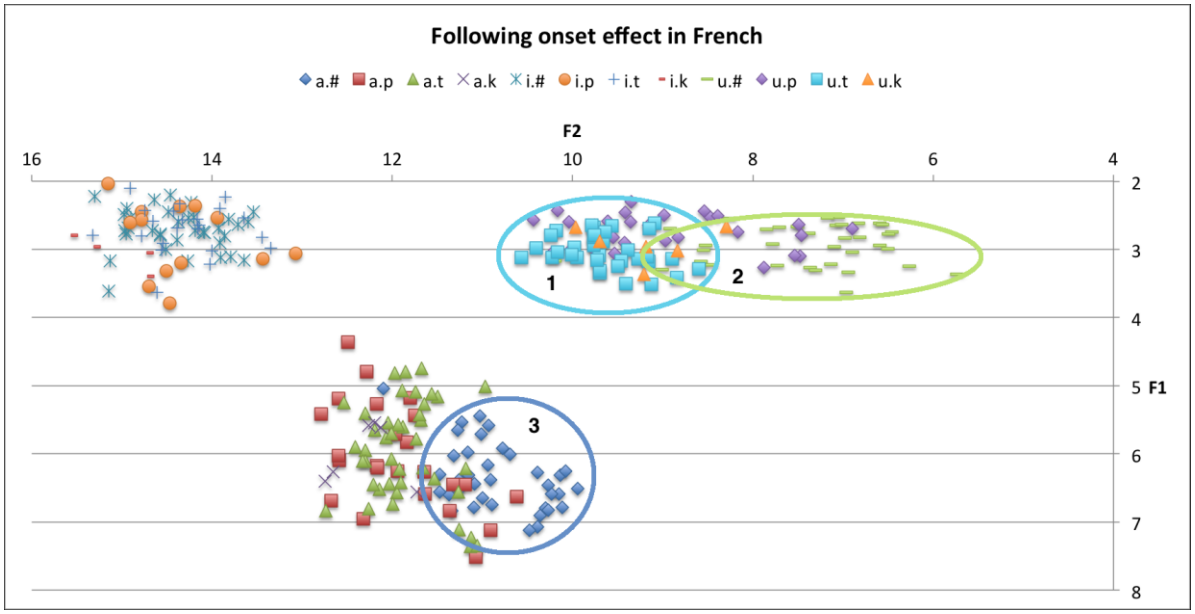

Figure 8 Following onset effect in French

In French, we observed effects on the horizontal axis (F2). The vowel /u/, when followed by /t/, was articulated more at the front (ellipse 1 on Figure 8). However, when the vowel ended the word, the articulation was more posterior (ellipse 2 on Figure 8). For the vowel /a/, we found similar effects: when the vowel /a/ ended the word, it was articulated further back (ellipse 3 on Figure 8).

To conclude this section, we would like to emphasize the language-specific differences we observed for each of the parameters which we controlled for in our methodology. Indeed, even though we looked at the same elements, we found different patterns of variation. Interestingly, this could show an effect of a system's vowel density or show language specific effects not necessarily linked to the number of vowel of the language. We will discuss this in the next section.

5 Discussion

As we can see in the graphic analysis of our data, there is a difference between both speakers/languages with regards to vowel dispersion. In fact, for /a/, we observed a wider range of F2 in Inuktitut than in French, but a wider range of F1 in French than in Inuktitut. As for /u/, the range was wider for F2 in Inuktitut. Regarding /i/, the vowel space is slightly bigger in French, but this vowel appears stable across both languages.

A few variables could explain the differences we observed between the two speakers, such as the frequency of each vowel in the language, the vocal apparatus of the individual, or even their personal production. However, there seems to be a very clear influence of a system's vowel density on its organisation. Indeed, since Quebec French possesses 12 places of articulation for its 16 vowels, it would be surprising to see the cardinal vowel spaces stretch so close to each other or

even overlap, as is the case for Inuktitut. This would mean that some vowels are inside the scope of others. Furthermore, the overall bigger range in F1 of French supports the hypothesis concerning the greater need for contrasts when there are more places of articulation in a language.

Considering Stevens' (1989) quantal theory of speech about the articulatory stability of frequent vowels, the stability of /i/ found in our results is expected. The post hoc tests allowed us to specify which parameters of our independent variables influenced the dependent variables F1 and F2 for each vowel in each language. These parameters have different graphical distributions in each language, which seems to support Honikman's (1964) hypothesis (cited in Bradlow 1995) concerning the specific effect of a language (type and frequency of phonemes) on the organisation of the vowel system.

6 Limits

The present study was meant to be exploratory, having as its goal to raise questions about Inuktitut and the effects of vowel density on a system by comparing two languages with different vowel densities. We are aware of the limits of our work and of the scope of our conclusions. We were only able to observe one speaker of each language and, therefore, cannot generalise our results.

A few factors, notably sociolinguistic ones, could have influenced our results. The European French accent of the experimenter probably influenced the pronunciation of the Quebec speaker. Furthermore, even though reading sentences is more natural than reading a list of words, it is still less natural than spontaneous speech. This could be even more the case when it comes to reading Inuktitut, as it is predominantly an oral language and speakers have fewer opportunities to use it in reading and writing. Since the Inuktitut speaker also speaks French and English, there is a possible influence of those languages on his pronunciation.

Note also that the Inuktitut speaker participated in the construction of the corpus and was consequently already familiar with the corpus and with certain controlled variables of the research. In addition, since our corpus was incomplete, even with the help of our informant, we used two words found in an Inuktitut lexicon that were unknown to the speaker. Also, even though we double-checked the words in our corpus with the speaker, there was an error in the syllabic version of the frame sentence. However, the version of the word written with the Roman alphabet was correct.

Regarding our data analysis, some F0 values were not extracted by the scripts. This limited the kind of analysis we could carry out on our data, such as the analysis of the distance between F2 and F1, and F1 and F0, which would have allowed us to compare different speakers more effectively.

Regarding Quebec French, coarticulation effects related to the affrication of /i/ after /t/ made some /i/ items whispered or white noise (Dumas 1987) and we had to exclude them from our analysis.

We took all of these limits into account in our analysis and wish to emphasise once again the exploratory aspect and limited scope of this work.

7 Conclusion

In this paper, we examined French and Inuktitut on an acoustic level, showing the contrast in patterning of vowel space organisation in two languages with different vowel density. We have confirmed that the high vowel density of French's system most probably influenced the dispersion of the cardinal vowels on both F1 and F2 axes. Our first hypothesis was that the vowel spaces of the cardinal vowels of Inuktitut would be more centralized than those of French. This hypothesis was confirmed: Inuktitut's cardinal vowels were more centralised than those of French. Our second

hypothesis was that the vowel spaces of the cardinal vowels of Inuktitut would cover a bigger area than those of French. This hypothesis was also confirmed insofar as we observed a wider area of production for the /u/ in Inuktitut than in French.

Moreover, we observed that, in each language, there were context-specific effects on the vowels (i.e., effects of the syllable position, the onset, etc.) and that those effects were not necessarily the same for both languages. Since the contexts were similar and controlled in both languages, our results corroborate those linked to a language-specific effect obtained by Bradlow (1995). Finally, our results are encouraging for future research because, although obtained from only two speakers, they follow the trends predicted by the theories describing the vowel dispersion (Lindblom 1990, Maddieson 1984, Stevens 1989).

All things considered, more study on this topic, and in particular experiments with a larger sample of speakers for both languages would enhance the results obtained herein.

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