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# Dynamics of vowel-to-vowel assimilation in French.

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## Abstract

Vowel-to-vowel assimilation in French is described as an anticipatory process affecting non-final mid vowels (V1) : [e], [ɛ], [ø], [œ], [o], [ɔ] that assimilate in height to the final tonic vowel (V2). The non-final mid vowel tend to be mid-high before a high or mid-high vowel (e. g. *aimer* [eme] 'to love'), and mid-low before a low or mid-low vowel (*aimable* [ɛmabl] 'kind')[1, 4, 6]. The present study investigates the nature of vowel harmony (VH) in French. Does vowel assimilation in French represent instances of a phonological assimilation or of other types of assimilatory change ? Are the effects of this process gradient, continuous and therefore more typical of coarticulatory effects than harmony ? On the basis of the collected experimental data, we conducted a systematic study of the acoustic patterns involved in this process, i.e., V1 formants (F1, F2, F3) acoustic properties and vowel durations.

## 1 Introduction

### Starting point

The present study is a replication and extension of an earlier research conducted by Noel Nguyen and Zsuzsanna Fagyal [8]. They showed that both spectral and durational differences exist in mid vowels depending on the following word-final vowel:

- mid vowels generally tend to have a more peripheral position in the vowel space prior to a non-low vowel compared to a mid-low or low vowel, i.e. attracted by non-low word-final vowels they have more extreme F2 and F1 values.

- mid vowels have a longer duration when the word-final vowel is non low rather than low.
- informal observations made by the authors also suggest that VH effects may encompass dynamic changes in the shape of the spectrum during vowel production [9].

### Vowel quality quantification methods

1. Nguyen & Fagyal's [8] spectral analyses were performed at the acoustic midpoint of each vowel. In fact, there is agreement that vowel quality can be quantified with precision by measuring **the midpoint center frequencies of the first two or three formants**; this midpoint is supposed to be the point nearest the vowel target.
2. As reported by Lindblom & Sundberg [7], an alternative indicator of the location of the vowel target may be **the point in time where the first formant reaches its maximum frequency**. Considering that the lowest resonance of the vocal tract (F1) is an acoustic correlate of the articulatory dimension of vowel height (high vs. low vowels, or close vs. open vowels), the maximum frequency of F1 may be an alternative indicator of the temporal location of the vowel target. It may therefore be argued that the vowel target is reached when the oral tract is maximally open [7], which usually corresponds to the point of maximum frequency of the first formant.

## 2 Hypothesis and Method

### Our aim

In our study, we investigate the nature of vowel harmony (VH) in French. Does vowel assimilation in French represent instances of a phonological assimilation or of other types of assimilatory change ?

Are the effects of this process gradient, continuous and therefore more typical of coarticulatory effects than harmony ? The harmonic effects that have been evidenced by Nguyen & Fagyal [8] may, at least partly, be explained by the quantification methods that were chosen for the location of the vocalic target.

### Hypothesis

If using two methods of temporal localization of the hypothetical vowel target ( formants midpoint frequencies and F1 maximum value), produces discrepancies in the harmonic effects, then we may interpret Nguyen & Fagyal's [8] results differently. Indeed,

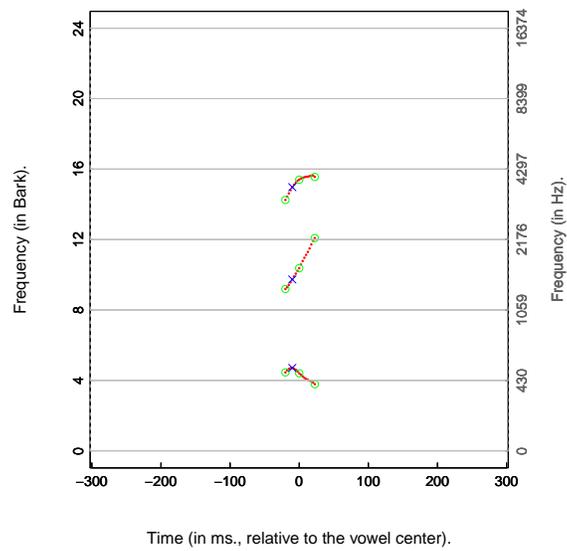


Figure 1: Spectrograph scheme of V1 in word 'Monique'; speaker 3

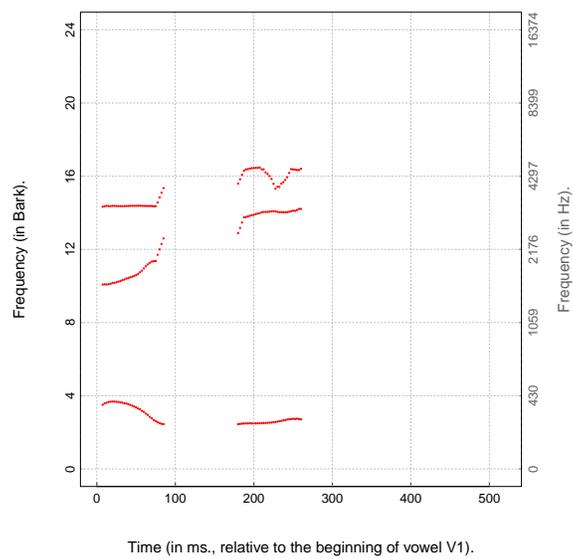


Figure 2: Spectrograph scheme of V1 & V2 in word 'bobine'; speaker 2

- if a systematic influence of word-final vowel on the preceding mid-vowel is only observed for vocalic targets taken as the acoustic midpoints and these vocalic targets are situated after the point in time where F1 reaches its maximum value, then the variation in formant frequency may simply be interpreted as the direct consequence of the formant movement that is associated with the articulatory transition from V1 to V2.
- if however, both, acoustic midpoint and F1 maximum value, lead to the observation of the same harmonic phenomena, then we may consider that there is an actual influence of V2 on V1, independently of coarticulatory transitions.
- if, looking into F1 onset values we observe the same harmonic phenomena, this fact will strongly reinforce the possibility of an actual influence of upcoming V2 on V1 independently of articulatory accommodation.

## Method

### Material

The corpus consisted of 80 pairs of disyllabic nouns ((C)V1-C-V2 (C) sequence). The first syllable always contained a mid vowel (V1) and was phonemically identical in both words of the pair. The intermediate consonant was identical in both words of the pair too. The second syllable contained a non-low vowel in one word and a low vowel in the other word of the pair (V2) e.g. /epis/ *spice* - /epat/ *impress*, /ete/ *summer* - /etεɛ/ *ether*.

### Subjects

Data from 5 adults (2 males and 3 females) were collected. Age ranged from 21 to 70 years, all were native speakers of French.

### Procedure

Every word appeared in a carrier sentence which was pronounced twice, non consecutively by every speaker at regular, relatively fast pace (one carrier sentence every 1500 ms). The recording process was controlled by a Python software that randomly presented the succession of sentences to be recorded. Each speaker read a total of 320 V-to-V word sequences.

The frequencies of the first four formants were extracted every 10 ms along with their temporal location. An R script transformed these raw data in order to compute the duration of vowels, the F1 maximum frequency and temporal position, the F1 temporal midpoint and corresponding frequency along with the corresponding F2 and F3 frequencies, both for V1 and V2. Data for 3 speakers have been extracted. All formant frequencies have been converted to Bark using Traunmüller's formula.

Word-pair	V1	V2	Words nb
ailé /Ele/ - ailette /Elet/	Front	e/ɛ	24
prêteuse /prEtøz/ - prêteur /prEtœr/	Front	ø/œ	12
dévot /dEvo/ - dévote /dEvot/	Front	o/ɔ	6
noter /nOte/ - notaire /nOtær/	Back	e/ɛ	32
donneuse /dOnøz/ - donneur /dOnœr/	Back	ø/œ	18
auto /Oto/ - automne /Otɔn/	Back	o/ɔ	8
terrine /tErin/ - terrasse /tEras/	Front	i/a	30
Rosine /rOzin/ - rosace /rOzas/	Back	i/a	28

Table 1: Word pairs type and V1/V2 type; V1 is transcribed as neutral archiphoneme E or O

Speaker	Age	Gender	Place of birth
Loc1	70	Male	Nantes (Brittany region)
Loc2	24	Female	Brest (Brittany region)
Loc3	62	Female	Orléans (Centre region)
Loc4	21	Female	Caen (Normandy region)
Loc5	45	Male	Caen (Normandy region)

Table 2: Speakers age, gender and place of birth

### 3 Results

In accordance with Nguyen’s and Fagyal’s results [8], V1 is generally higher (more closed) and has a longer duration when followed by a non-low vowel than by a mid-low or low vowel.

#### Vowel durations

Our statistics (t-test) show that V1 has a longer duration when following V2 is close. The mean duration of V1 followed by close V2 is 60.88 ms. vs. open V2 56.47 ms ( $t = 3.5637$ ,  $df = 955.596$ ,  $p\text{-value} = 0.0003838$ ).

#### Formant frequencies

- V1: front vowel E  
F1 is significantly lower before front close vowels /i/ and /e/ than before open vowels /ɛ/ and /a/ at formants midpoint, at F1max and at formants onset point.  
F2 is significantly higher before vowels /i/ and /e/ at the three measurement points.  
F3 is significantly higher before /i/ and /e/ at F midpoint and F1max point.
- V1: back vowel O  
F1 is lower before /i/ and /e/ than before /ɛ/ and /a/ at formant onset

point only.

F1 is lower before /ø/ than before /œ/, especially at F mid and F onset point.

Our data show that front V1 E is systematically higher before /i/, /e/ V2 vowels (a lower F1 frequency and a higher F2 frequency). Back V1 O is higher before /ø/ vs. /œ/ (both a lower F1 and F2 frequency), but the difference in F2 height is not statistically significant. We can observe the same 'harmonic' phenomena at different points of vowel duration; thus we may not reject the hypothesis that there is an actual influence of upcoming V2 on V1 independently of articulatory accommodation.

V1	Formant	V2			Δ F1 max in Bark		
		Δ F mid in Bark					
		i,e/ε,a	ø/œ	o/ɔ	i,e/ε,a	ø/œ	o/ɔ
E	F1	<b>-0.19</b>	-0.04	-0.11	<b>-0.21</b>	-0.04	-0.09
	F2	<b>+0.17</b>	+0.02	+0.04	<b>+0.19</b>	-0.04	+0.06
	F3	<b>+0.14</b>	+0.09	+0.05	<b>+0.17</b>	+0.12	+0.10
O	F1	-0.07	<b>-0.12</b>	+0.04	-0.09	-0.09	+0.04
	F2	-0.01	-0.13	-0.51	+0.02	-0.25	-0.35
	F3	-0.01	-0.09	+0.15	-0.01	-0.16	+0.09

Table 3: Mean difference in F1, F2 and F3 at F mid, F1max and F onset position depending on V2; statistically significant differences ( $p < 0.05$ ) are in bold.

#### F1 max as vowel target

The point in time where the first formant reaches its maximum frequency is situated not very far from vowel midpoint. The mean distance is of 0.31ms. However, F1max point is situated sometimes before and sometimes after the midpoint. If the F1max point is situated before the formant midpoint and the harmonic phenomena is only observed at this formant midpoint than we can assume that V-to-V assimilation in this case is rather an articulatory mechanism of coarticulation. Detailed statistical analysis have to be carried out so as to examine these cases and identify causes of this variation (V1/V2 nature, vowel duration).

#### 4 Development axis

It was expected that coarticulation effects would be greater at the edge of the vowel closest to the influencing vowel. However, the anticipatory effects were observed at V1 midpoint and even at F onset position. This result rather suggests an actual influence of word-final vowel V2 on V1 and call for a more sophisticated model of phonetic/phonological behaviour.

Experimental findings in speech perception show that listeners are more sensitive to changing stimulus patterns than to purely static ones. It's possible that vowel harmony phenomena in French may best be investigated in terms of dynamic patterns and formant velocity behaviour [3, 9, 5, 2]. According to a dynamic specification account, coarticulated vowels are identified on the basis of time-varying acoustic information. So, the direction and/or slope of formant movement may differentiate vowels with spectrally similar formant maxima. Following findings of Di Benedetto ([2], vowel identity (at least for mid to high front vowels) may be measured as a function of the temporal location of F1 maxima as well as their spectral location. In this respect, we will soon analyse VH phenomena in terms of formant velocity vs. formant frequency on the same speech data.

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