Velar variation in French

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It is commonly noted that French velar plosives tend to take a fronted realization when followed by a front vowel. These observations are generally not accompanied by representative data, and consequently, little is known about the actual characteristics and spread of the phenomenon. This study provides a corpus analysis of velar palatalization in contemporary French, and addresses the potential linguistic and sociolinguistic factors involved. Moreover, the synchronic results are considered in the light of the palatalization processes that took place in the history of French.

Keywords: velars, palatalization, French, sociolinguistics

1. Introduction

Front vowels [i, e] and especially the palatal glide [j] are well known for triggering an anteriorization of the place of articulation of a preceding velar (see for instance Gussenhoven & Jacobs 2005). In its history, French has known two important periods of velar palatalization, where velars were fronted and turned into coronal affricates in specific contexts (see among others Pope 1934; Fouché 1958). In the third and fourth centuries, in the Late Latin period, palatalization took place before [j, i, e, ɛ], turning for instance *centum* into [kʲentu>centu>tsentu] (modern French: *cent* [sɑ̃], 'hundred'). A second phase of velar palatalization became active in the fifth and sixth centuries, and was limited to some of the Gallo-Romance dialects. This time, velars palatalized before [i, e] in Germanic and Arabic loanwords, and interestingly, the process also took place in a typologically exceptional context: Before the Latin vowel *a* and the diphthong [au̯], changing for instance *carrum* into [kʲarru>carru>tʃar] (modern French: *char* [ʃaʁ] 'cart').

In contemporary French, the coarticulatory effect of velars with a following front vowel is very strong as well. Gussenhoven & Jacobs (2005: 180) note that the velar gets fronted and changes into [k̟]. Other descriptions even report velars with

Linguistics in the Netherlands 2013, **13–27**. DOI 10.1075/avt.30.02ber
ISSN 0929–7332 / E-ISSN 1569–9919

a secondary palatal articulation [kʲ], or velars that turn into a palatal stop [c] (see among others Malmberg 1969; Walter 1977; Fónagy 2006). Although velar fronting is commonly noted as a property of modern French, its precise characteristics remain unclear, mainly because the descriptions are not backed up by representative data. We are ignorant about the strength of the fronting process as such, and it is unclear whether palatalization solely depends on the linguistic context, or whether the sociolinguistic background of the speakers is involved as well.

Furthermore, as far as the puzzling Gallo-Romance palatalization context[1] *a* is concerned, it is noted by Buckley (2003: 11) that some[2] northern varieties seem to reproduce a similar change in contemporary *ka* sequences. These sequences were still pronounced [kʷa] when the second process of velar palatalization took place, but Buckley points out that nowadays for instance *quatre* [katʁ(ə)] ('four') may be realized as [kʲatʁ(ə)]. Synchronic data of the pronunciation of *ka* could therefore be informative with respect to the diachronic developments: If palatalization of the velar takes place, does the vowel *a* have a fronted realization in this context? If so, is it a general change affecting that vowel, or is it restricted to a specific context? If not, are there some non-phonetic factors that may have caused velar fronting in this context?

This study considers the different questions related to synchronic velar palatalization by examining oral corpus data of several regions in France. Section 2 presents the design of the corpus and describes the analysis procedure. The results are presented in Section 3, and Section 4 concludes by summarizing the main results and by addressing some interesting issues for future research.

2. Methodology

2.1 Corpus data

The characteristics of velar fronting in France were examined through the analysis of spoken language data of different varieties included in the *Phonologie du français contemporain* (PFC) database. This corpus is one of the largest and most varied collections of spoken French currently available (cf. Durand, Laks & Lyche 2002), and as to date it contains recordings from about 35 French-speaking areas (in France and abroad).

On the basis of the observations made in the existing literature, our selection first of all contains surveys conducted in the northern part of France: Fronting has been reported for the standard varieties (which are virtually always equated with Parisian French), and Buckley (2003: 11) reported palatalization before *a* in "some northern varieties". For the Parisian region, three subcorpora were actually

available. The first one captures the speech of French speakers living in the centre of Paris. The second one contains recordings of a specific group of Parisian residents who moved from the Aveyron region in the south of France to Paris from the mid nineteenth century until the first decades of the twentieth century. This survey contains recordings of the later original migrants and of the younger generations who were born in Paris and have parents originating from the Aveyron. The third corpus was recorded in the suburbs Puteaux and Courbevoie, which lie to the west of Paris, near the business quarter *La Défense*. In order not to limit the "northern varieties" to Parisian French, the corpus study also considers speakers from Brunoy and Ogéviller.[3] The other regions of France are represented by Nantes (mid-west), Lyon (mid-southeast), Rodez (mid-south) and Marseille (south). This selection contains a total of 84 speakers; the geographical distribution is shown in Table 1, the distributions with respect to the sociolinguistic variables 'gender' and 'age' are given in Table 2 and Table 3.

Table 1. Surveys

a.	Aveyronnais à Paris	12
b.	Brunoy	10
c.	Lyon	8
d.	Marseille Centre	10
e.	Nantes	10
f.	Ogéviller	10
g.	Paris Centre	12
h.	Puteaux-Courbevoie	5
i.	Rodez	7
		84

Table 2. Gender

Male	**Female**
38	46

Table 3. Age

≤ 30[4]	**31–54**	**≥ 55**
30	20	34

2.2 Analysis

The PFC participants were recorded during two conversations (an interview and a spontaneous conversation) and during two reading tasks (a one-page text and a

word list of 94 items). The place of articulation of velars was examined on the basis of these two reading tasks, as their quality was superior to the quality of the conversations. Moreover, these two tasks are identical for all the participants in the different surveys, contrary to the conversations which differ from one speaker to another.

The analysis concerned all velar plosives followed by a palatal glide or non-nasal vowel (except [ə]).[5] The identification of these contexts was primarily based on the actual recordings of the speakers, in order to control for deviant realizations or realizations that could not be predicted by relying on the orthographic transcription. In the case of the list, the digits that precede the lexical items were also taken into account,[6] as the lexical items only contained a limited number of target contexts.

The place of articulation of the velar plosives was analyzed acoustically. Changes in the configuration of the articulators entail changes in the vocal tract resonances. These changes are reflected by the formant values. As for plosives, the first formant is not informative in this respect: Its relatively low value simply reflects the stop closure and thus indicates manner of articulation. Instead, changes in the place of articulation are mainly indicated by the frequency of the second formant (F2),[7] an observation that was first made in a study carried out by Potter, Kopp & Green (1947). About a decade later, experiments with synthetic speech conducted by Delattre, Liberman & Cooper (1955) showed that the frequency values of the F2 serve as a vital parameter for the determination of the place of articulation of consonants. They also developed the concept of "locus frequency". This is the fixed frequency of a particular plosive, which is located in the closure, and from where the F2 frequencies at the offset of the vowel seem to originate. Interestingly, for velars no single abstract locus was found. Rather, "there would appear to be a single high-frequency locus for the front vowels *i*, *e*, ɛ, and the mid vowel *a*; but for the back vowels *ɔ, o* and *u* the acoustic pattern breaks sharply, and it is obvious that the same […] locus cannot serve for all vowels" (Delattre et al. 1955: 770). This observation was ascribed to the fact that the position of the occlusion of the velar shifts, depending on the following vowel.[8]

Following Harrington (2010), the F2 frequencies in the PFC files were measured at two points: At the plosive-vowel boundary and at the vowel nucleus (i.e. the steady-state of the vowel, where effects of surrounding segments are minimal). The smaller the F2 difference between these two points, the more the F2 value at the plosive release resembles the target value of the following vowel, and the more coarticulation between the plosive and the vowel. The Velar+Vowel contexts in the selected sound files were manually labelled in Praat (Boersma & Weenink 2012). The boundaries of the plosive and the vowel were indicated, and both segments were coded for quality. Moreover, the labels added to the velars contained information about the position of the Velar+Vowel sequence in the word and intonation phrase (initial, medial, final). The intervals indicating the Voice Onset Time

(VOT)[9] of the voiceless plosives were represented on a separate tier. The F2 values were extracted by means of a PRAAT script: The $F2_{onset}$ at the zero crossing of the first detectable glottal pulse of the vowel and the $F2_{nucleus}$ at 50% of the vowel. The maximum formant frequency was set at 5000 Hertz for the male speakers and at 5500 Hertz for the female speakers; the maximum number of formants to be detected was fixed at five. Outliers in the extracted values were manually checked, and corrected if necessary.

After having described the exact content of the recordings and the methodology adopted for the acoustic analyses, let us now turn to the results. First, we will consider the front and back vowels in general. Afterwards, we will have a detailed look at the impact of *a* on the place of articulation of the preceding velar.

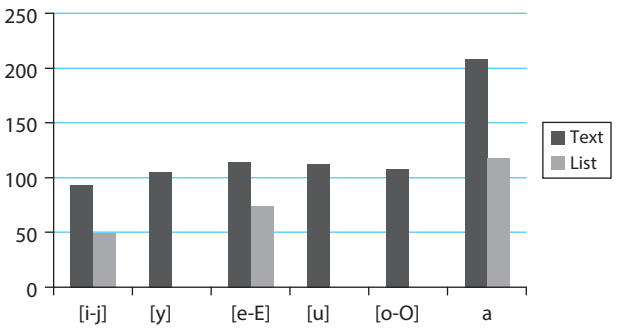
3. Results

3.1 Linguistic factors

In line with existing observations (cf. Section 1), the acoustic results first of all show that the release locus of a velar plosive is highly variable and dependent on the place of articulation of the following vowel. Roughly speaking, the velar is back when followed by a back vowel, but it strongly tends to centralize when followed by a central vowel, and to become front when followed by a front vowel. Table 4 and Graph 1 provide the average $F2_{onset}$-$F2_{nucleus}$ differences[10] (in Hz) for the different vowel contexts, generalizing over all tokens, speakers and regions.

Table 4. Average $F2_{onset}$-$F2_{nucleus}$ differences

	[i-j]	[y]	[e-ɛ]	[u]	[o-ɔ]	*a*
Text	$\bar{X}$= 93.60	$\bar{X}$= 105.11	$\bar{X}$= 114.40	$\bar{X}$= 112.87	$\bar{X}$= 107.84	$\bar{X}$= 208.91
	SD = 31.89	SD = 90.47	SD = 54.89	SD = 51.95	SD = 32.40	SD =76.61
List	$\bar{X}$= 50.10		$\bar{X}$= 74.32			$\bar{X}$= 118.06
	SD = 43.18		SD = 54.36			SD = 45.15



Graph 1. Average $F2_{onset}$-$F2_{nucleus}$ differences

To put it very generally, the mean F2 differences of the front and back vowels are relatively close together, which would not be expected if the velar only had a single place of articulation: The distance to some vowels would then be larger than the distance to vowels articulated at places closer to the velar locus. The place of articulation of the velar thus seems to move towards the following vowel, most strongly in the case of the front unrounded vowels. This effect seems virtually absent in the case of *a*, the context with the largest F2 differences, and in this case, the velar generally appears to maintain its back locus.

In order to assess the influence of the different linguistic and sociolinguistic variables on the realized F2 difference, a Repeated Measures Analysis of Variance was carried out in SPSS, taking the average $F2_{onset}$-$F2_{nucleus}$ difference per speaker for each vowel context as dependent variable. 'Vowel quality' was defined as a within-subject factor and 'regional background', 'age' and 'gender', which will be discussed in the following section, were included as between-subject variables. Two separate ANOVAs were carried out, for the read-aloud text (TG) and the list (MG) respectively, as the two tasks did not contain the same vocalic contexts.

As far as the linguistic factors are concerned, the results show a significant effect of the vowel quality (TG: $F_{5,185} = 36.640$, $p = 0.0001$, MG: $F_{2,74} = 119.128$, $p = 0.0001$).[11] Except for the contextual aspects of the Velar+Vowel sequence, speech rate might also influence the actual F2 difference between the plosive release and the vowel nucleus. That is, when speakers speak slower, and pay more attention to their articulation, it is expected that there will be less coarticulation than when they speak faster and pay less attention to their speech. In this respect, it is also worth taking into consideration how the length of the VOT (also reflecting the length of the release) of the velar relates to the degree of coarticulation. In our analysis, speech rate was expressed as the number of syllables realized per second; the VOT reflects the interval between the start of the release of the plosive closure and the first glottal pulse of the vowel, and was based on the voiceless tokens. Correlating these three variables for the text results (Pearson correlation in SPSS) shows that there is a negative relation between both speech rate and the Velar+Vowel difference, and the VOT length and this F2 difference. The faster the speech, the smaller the F2 difference, and the higher the degree of coarticulation between the velar and the vowel. A longer VOT also implies a smaller F2 difference between the vowel onset and the vowel nucleus: The articulation of the plosive takes longer and a considerable portion of the required transition can be realized already during the longer phase preceding the vowel onset. The relevant values are given in Table 5.

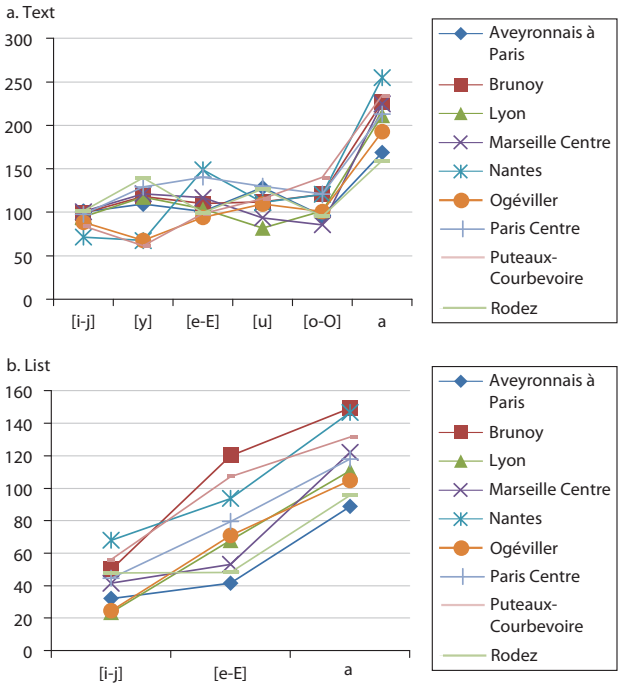
Table 5. Correlations

Speech rate – F2 difference	r = −0.156 r^2 = 0.024	p = 0.0001
VOT – F2 difference	r = −0.165 r^2 = 0.027	p = 0.0001

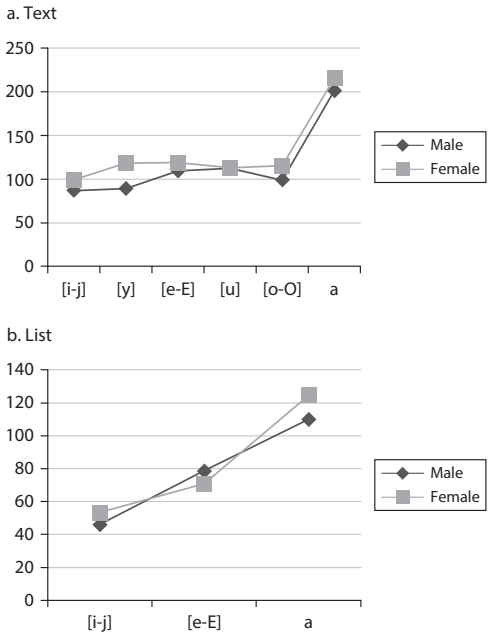
As far as the PFC data are concerned, vowel quality appears to be the strongest linguistic factor conditioning the F2 difference between the vowel onset and the vowel nucleus, and this F2 difference seems further related to the speech rate and the length of the release. Let us now consider whether next to these linguistic factors, sociolinguistic aspects also play a role in the degree of Velar+Vowel coarticulation.

3.2 Sociolinguistic factors

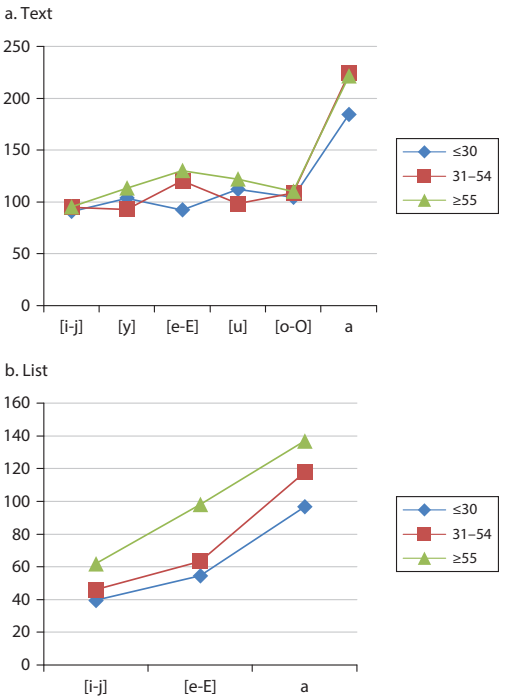
As indicated in the previous section, the extra-linguistic factors included in our study are the participants' regional background, age and gender. For each of these factors, Graphs 2–4 show the average $F2_{onset}$-$F2_{nucleus}$ differences. A full overview of the exact values and standard deviations, illustrating both the inter- and intra-group variation, can be found in Tables 6–8 in the Appendix.



Graph 2. Region



Graph 3. Gender



Graph 4. Generation

The results first of all show quite a consistent pattern across the different regions for the text. For the list the picture is more variable, but the same basic pattern arises. Grouping the mean F2 differences according to the generation or the gender of the speaker, shows that the patterns across the vowel contexts are quite similar, but that there is nevertheless variation between the different subgroups.

The repeated measures analysis based on the results of the text shows that the regional background does not influence the realized F2 difference ($F_{8,37}$: 1.345, $p = 0.253$). Next to 'vowel quality', the factors 'age' and 'gender', however, do significantly contribute to the realized F2 differences ($F_{2,37}$: 3.706, $p = 0.034$ and $F_{1,37}$: 8.910, $p = 0.005$ respectively). Across the different vocalic contexts, women tend to produce larger F2 differences than men, and post-hoc tests (Games-Howell in SPSS) show that there is a difference between the youngest and the oldest generation, but that the group of speakers aged between 31 and 54 does not differ significantly from the other two generations. To be more precise, the F2 difference realized by the oldest generation is substantially larger in comparison with the youngest group.

More or less the same holds for the vocalic contexts in the list, although the patterns are less neat. All three between-subject factors as such, especially 'region' ($F_{8,37}$: 1.351, $p = 0.250$) and 'gender' ($F_{1,37}$: 0.114, $p = 0.738$), but also 'age' ($F_{2,37}$: 3.211, $p = 0.052$), turn out to be insignificant. The combination of the factors 'vowel quality' and 'age', however, does give a significant result ($F_{2,37}$: 4.681, $p = 0.015$): The F2 difference appears to increase with age and is smallest with the high front vowel.

Variation in the degree of Velar+Vowel coarticulation can be found in all regions in France. When compared to men, women tend to minimize this coarticulation, which might be an effect of the often recurring desire of female speakers to conform to a (prestige) norm (cf. Labov 2001: 261–293), and to produce neatly articulated forms. At the same time, substantial Velar+Vowel coarticulation is found among the generation of students and young professionals. This tendency might on the one hand simply be a characteristic of youth language, which disappears when they grow older (i.e. *age-grading*; cf. Labov 1994: 73–112) and when they (have to) start paying more attention to their articulation in their professional lives. On the other hand, it might be a speech habit adopted and internalized by this specific generation, which will be characteristic of this and younger generations for the rest of their lives.

3.3 Velars before *a*

Conservative descriptions of French distinguish two low vowels: Anterior /a/ and posterior /ɑ/. Up to the middle of the twentieth century, these two vowels were

clearly pronounced differently, and as Walter (1988:256) states, the *a* in *patte* ('paw') had a very fronted realization, close to [ɛ], and the place of articulation of the *a* in *pâte* ('pastry') was situated at the back, close to [ɔ]. The distinction gradually lost ground in favour of anterior [a].

The PFC list contains instances of *patte* and *pâte*. Both tokens figure twice in the list, once randomly listed and once in direct sequence as a minimal pair. The examination of the *a* tokens in these words, of which we cannot present the details here for a lack of space, indeed confirms that a large amount of variation exists with respect to the actual preservation of the qualitative F2 contrast. The inter- and intra-speaker variation is such that we may no longer assume the existence of two distinct types and, moreover, the variable nature of the realization of *a* is likely to have an impact on the actual realization of a preceding velar.

As a matter of fact, the place of articulation of *a* indeed turns out to influence the position of the preceding velar. If *a* is realized as a back vowel, the velar maintains a posterior locus, but the situation gets more intriguing if *a* takes a more anterior place of articulation. That is, in the large majority of cases, *a* is not realized as a back vowel but rather as a central(ized) vowel, as a vowel that is between a central and a front vowel, or even as a front vowel with F2 values in the same range as front [i].[12] In the Velar+*a* contexts, different realizations arise, but what they have in common is that the more anterior the place of articulation of the vowel, the more anterior the velar becomes. Speakers differ, however, as to the actual degree of coarticulation realized in this particular context, and hence as to the degree of fronting. In this respect, the Velar+*a* coarticulation is different from the Velar+[i] coarticulation for instance, which shows a far more uniform pattern, both within as well as between speakers (cf. Table 4 and Graph 1). A second important aspect that deserves to be mentioned is that fronting of the velar not necessarily means that it shifts to the exact same range of articulation as the vowel. That is, the velar may become between central and back before a central-back vowel, central before a central vowel, between central and front when followed by a central-front vowel or front before a front *a*, but the velar may also become (substantially) *more* anterior than the vowel. In such cases we find for instance a central vowel preceded by a velar which is rather front or between central and front, instead of a truly centralized velar.

With respect to Buckley's (2003) observations, we may thus conclude that fronting of velars does occur before contemporary French *a*, but this fronting is crucially dependent on the degree of anteriority of the vowel. It is therefore very well possible that the historical process of velar palatalization before *a* was also triggered by an anteriorisation of the place of articulation of this vowel, either of all tokens of this phoneme or of only a subset. A fronted vowel yields a fronted velar, and the process of velar palatalization may gradually proceed.

As to date, velar fronting before a front or central *a* in contemporary French is not as manifest among all regions and even within a single region large differences arise, both within as well as between speakers (cf. Graphs 2–4). The developments during the coming decades, depending on the strength and the spread of fronting throughout the speech community, will tell whether the full diachronic development will indeed be reproduced in modern French, and possibly provide additional evidence for the circumstances of the historical change.

4. Discussion and conclusion

This corpus study has provided a multidimensional picture of velar fronting in contemporary French. It confirms, on the basis of representative data, that the place of articulation of the velar is highly influenced by the quality of the following vowel. The behaviour of velars before *a* appears to be particularly fascinating: Depending on its (variable) position on the horizontal dimension of the vowel space, this low vowel induces a change, and often a quite impressive one, in the place of articulation of the preceding velar. Moreover, the corpus analysis has also revealed the extent to which sociolinguistic variation is involved in fronting. Women tend to coarticulate less than male speakers, and the oldest generation shows neater realizations with larger F2 differences than the two younger generations. Time will tell whether the observed sound changes will spread throughout the lexicon and the speech community, repeating the historical developments, or whether we are just facing variation that does not give rise to a genuine sound change.

Notes

1. Roughly speaking, velar palatalization has received two different types of explanations: It is described either as articulatory-based (e.g. Jacobs 1993; Clements & Hume 1995) or it is explained in terms of perceptual confusion between fronted velars and coronal affricates in a front vowel context (e.g. Ohala 1992; Guion 1998). Both approaches cannot account for palatalization before the low vowel *a* (for a more detailed overview the reader is referred to Jacobs & Berns 2013).

2. No further specification is given as to which varieties are involved.

3. It would have been very interesting to have a survey in the Picard region, as the Picard dialect withstood the historical velar palatalization before *a*. Unfortunately, no survey in this region is available (yet).

4. Includes students and young professionals.

5. Nasal vowels preceded by a velar were excluded as the nasal venting of air highly affects the spectral characteristics of the vowel, which would introduce an undesired source of variation.

6. These 17 additional target contexts are all of the *k+a* type (i.e. *quatre* or a cognate), a context where, according to Buckley (2003), palatalization actually occurs in some modern varieties.

7. The movements of the F3 values, relative to the F2 trajectories, also mirror place of articulation, cf. Delattre et al. (1955: 773). As noted by Kent & Read (1992: 118), "the F2-F3 relationship is important for velars, for which the transitions into a following vowel are characterized by an increasing F3-F2 separation", which yields the characteristic "velar pinch".

8. Kent & Read (1992: 117) note that "[…] velar stops are not produced with a single site of contact but rather with a substantial antero-posterior (front-back) range associated with the vowel context".

9. Following Cho & Ladefoged (1999: 215), VOT was defined as the interval between the onset of the plosive release and the start of the first complete glottal pulse in the waveform. The boundaries were positioned at the zero crossing.

10. Because we are not directly comparing absolute formant values of different speakers, but only bare $F2_{onset}$-$F2_{nucleus}$ *differences* realized by the participants, no vowel normalization was applied.

11. Other linguistic variables, like syllable structure, word length and phrasal position, were not included in the statistical design because this would yield an unbalanced and insufficient number of cases. Nevertheless, considering the overall picture, the mean values are quite stable across these different contexts, and the syllabic and phrasal structures do not seem to have a noticeable influence on the realized F2 differences.

12. Based on the individual vocalic spaces of the participants.

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Appendix. Descriptive statistics of the sociolinguistic variables

Table 6. Region
Text

	High front [i-j]	[y]	**Mid front** [e-ɛ]	**High back** [u]	**Mid back** [o-ɔ]	*a*
Aveyronnais à Paris	$\bar{X}$ = 100.22 SD = 30.18	$\bar{X}$ = 109.17 SD = 121.06	$\bar{X}$ = 100.82 SD = 25.19	$\bar{X}$ = 128.42 SD = 60.38	$\bar{X}$ = 96.21 SD = 29.65	$\bar{X}$ = 168.79 SD = 59.54
Brunoy	$\bar{X}$ = 99.29 SD = 21.70	$\bar{X}$ = 118.30 SD = 97.97	$\bar{X}$ = 109.80 SD = 45.13	$\bar{X}$ = 111.98 SD = 62.14	$\bar{X}$ = 120.47 SD = 34.48	$\bar{X}$ = 226.65 SD = 87.08
Lyon	$\bar{X}$ = 94.90 SD = 33.86	$\bar{X}$ = 117.50 SD = 112.02	$\bar{X}$ = 103.68 SD = 42.58	$\bar{X}$ = 81.94 SD = 29.22	$\bar{X}$ = 101.25 SD = 34.65	$\bar{X}$ = 211.46 SD = 53.76
Marseille Centre	$\bar{X}$ = 100.54 SD = 35.40	$\bar{X}$ = 121.30 SD = 99.15	$\bar{X}$ = 116.70 SD = 58.42	$\bar{X}$ = 93.68 SD = 46.97	$\bar{X}$ = 85.66 SD = 20.19	$\bar{X}$ = 224.68 SD = 75.87
Nantes	$\bar{X}$ = 71.49 SD = 18.35	$\bar{X}$ = 67.40 SD = 23.37	$\bar{X}$ = 148.88 SD = 49.73	$\bar{X}$ = 111.05 SD = 32.34	$\bar{X}$ = 120.73 SD = 31.56	$\bar{X}$ = 254.87 SD = 79.79
Ogéviller	$\bar{X}$ = 88.43 SD = 24.60	$\bar{X}$ = 67.60 SD = 79.04	$\bar{X}$ = 94.12 SD = 36.70	$\bar{X}$ = 109.40 SD = 54.42	$\bar{X}$ = 100.81 SD = 15.88	$\bar{X}$ = 192.73 SD = 63.41

Text (*continued*)

	High front [i-j]	**[y]**	**Mid front [e-ɛ]**	**High back [u]**	**Mid back [o-ɔ]**	***a***
Paris Centre	$\bar{X}$ = 97.73	$\bar{X}$ = 129.08	$\bar{X}$ = 140.50	$\bar{X}$ = 129.98	$\bar{X}$ = 120.87	$\bar{X}$ = 212.95
	SD = 53.04	SD = 100.19	SD = 95.32	SD = 64.35	SD = 37.20	SD = 97.00
Puteaux-Courbevoie	$\bar{X}$ = 84.25	$\bar{X}$ = 61.20	$\bar{X}$ = 98.56	$\bar{X}$ = 115.60	$\bar{X}$ = 139.96	$\bar{X}$ = 234.07
	SD = 20.67	SD = 57.78	SD = 41.06	SD = 30.80	SD = 28.97	SD = 81.07
Rodez	$\bar{X}$ = 101.32	$\bar{X}$ = 139.71	$\bar{X}$ = 99.57	$\bar{X}$ = 126.56	$\bar{X}$ = 95.29	$\bar{X}$ = 159.52
	SD = 18.81	SD = 43.79	SD = 40.70	SD = 55.68	SD = 31.50	SD = 50.57

List

	High front [i-j]	**Mid front [e-ɛ]**	***a***
Aveyronnais à Paris	$\bar{X}$ = 32.08	$\bar{X}$ = 41.44	$\bar{X}$ = 88.74
	SD = 22.59	SD = 16.90	SD = 19.87
Brunoy	$\bar{X}$ = 49.88	$\bar{X}$ = 120.08	$\bar{X}$ = 149.38
	SD = 44.76	SD = 66.86	SD = 47.29
Lyon	$\bar{X}$ = 23.50	$\bar{X}$ = 67.81	$\bar{X}$ = 110.63
	SD = 19.24	SD = 28.45	SD = 21.95
Marseille Centre	$\bar{X}$ = 41.40	$\bar{X}$ = 53.10	$\bar{X}$ = 122.00
	SD = 35.97	SD = 20.11	SD = 32.55
Nantes	$\bar{X}$ = 67.90	$\bar{X}$ = 93.65	$\bar{X}$ = 146.57
	SD = 67.14	SD = 42.76	SD = 57.89
Ogéviller	$\bar{X}$ = 24.50	$\bar{X}$ = 70.84	$\bar{X}$ = 104.66
	SD = 46.13	SD = 49.37	SD = 41.22
Paris Centre	$\bar{X}$ = 44.50	$\bar{X}$ = 79.48	$\bar{X}$ = 117.87
	SD = 43.85	SD = 81.47	SD = 59.96
Puteaux- Courbevoie	$\bar{X}$ = 55.95	$\bar{X}$ = 107.05	$\bar{X}$ = 131.37
	SD = 45.19	SD = 74.66	SD = 43.75
Rodez	$\bar{X}$ = 47.86	$\bar{X}$ = 48.18	$\bar{X}$ = 95.68
	SD = 22.70	SD = 31.05	SD = 26.30

Table 7. Gender
Text

	High front [i-j]	**[y]**	**Mid front [e-ɛ]**	**High back [u]**	**Mid back [o-ɔ]**	***a***
Male	$\bar{X}$ = 86.92	$\bar{X}$ = 89.03	$\bar{X}$ = 109.24	$\bar{X}$ = 112.63	$\bar{X}$ = 98.95	$\bar{X}$ = 201.08
	SD = 29.41	SD = 77.22	SD = 47.06	SD = 60.31	SD = 30.36	SD = 76.85
Female	$\bar{X}$ = 99.12	$\bar{X}$ = 118.39	$\bar{X}$ = 118.67	$\bar{X}$ = 113.08	$\bar{X}$ = 115.18	$\bar{X}$ = 215.38
	SD = 33.09	SD = 98.97	SD = 60.79	SD = 44.57	SD = 32.51	SD = 76.64

List

	High front [i-j]	**Mid front [e-ɛ]**	***a***
Male	$\bar{X}$ = 46.08	$\bar{X}$ = 78.67	$\bar{X}$ = 110.06
	SD = 41.99	SD = 52.64	SD = 41.49
Female	$\bar{X}$ = 53.43	$\bar{X}$ = 70.72	$\bar{X}$ = 124.67
	SD = 44.31	SD = 56.05	SD = 47.40

Table 8. Generation
Text

	High front [i-j]	**[y]**	**Mid front [e-ɛ]**	**High back [u]**	**Mid back [o-ɔ]**	***a***
≤30	$\bar{X}$ = 90.81	$\bar{X}$ = 103.77	$\bar{X}$ = 92.29	$\bar{X}$ = 112.08	$\bar{X}$ = 104.37	$\bar{X}$ = 184.37
	SD = 26.36	SD = 91.64	SD = 38.89	SD = 44.29	SD = 32.37	SD = 50.33
31–54	$\bar{X}$ = 94.97	$\bar{X}$ = 92.85	$\bar{X}$ = 120.46	$\bar{X}$ = 98.24	$\bar{X}$ = 108.79	$\bar{X}$ = 224.06
	SD = 38.01	SD = 93.24	SD = 63.38	SD = 51.18	SD = 33.70	SD = 94.03
≥55	$\bar{X}$ = 95.26	$\bar{X}$ = 113.50	$\bar{X}$ = 130.36	$\bar{X}$ = 122.18	$\bar{X}$ = 110.34	$\bar{X}$ = 221.67
	SD = 33.22	SD = 89.64	SD = 56.63	SD = 57.76	SD = 32.37	SD = 81.17

List

	High front [i-j]	**Mid front [e-ɛ]**	***a***
≤30	$\bar{X}$ = 39.46	$\bar{X}$ = 54.53	$\bar{X}$ = 96.81
	SD = 32.30	SD = 38.92	SD = 29.49
31–54	$\bar{X}$ = 46.00	$\bar{X}$ = 63.39	$\bar{X}$ = 117.78
	SD = 41.46	SD = 38.99	SD = 38.23
≥55	$\bar{X}$ = 61.91	$\bar{X}$ = 98.21	$\bar{X}$ = 136.97
	SD = 50.26	SD = 64.87	SD = 52.38

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