PROCESSING OF WORD-INITIAL VOWELS IN FRENCH : A PRODUCTION – PERCEPTION PERSPECTIVE

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ABSTRACT

In this paper we ask whether coarticulation patterns similarly across and within lexical units in production. We hypothesize that word onsets are more resistant to coarticulation in order to preserve the canonical form of lexical entries. We look at acoustic and articulatory (EPG) cues of coarticulation in pairs of CV where vowel is either word-initial or word-internal. In addition, in a perceptual experiment, we test whether a reduction of coarticulation at word onset can preserve initial phoneme identity. Vowels of CV and C#V sequences are presented in isolation to listeners. Results do not show robust tendencies. Nevertheless, vowels in word-initial position tend to be more open than in word-internal position. This phenomena seems to be perceived by listeners.

1. INTRODUCTION

The perceptual treatment of lexical units appears particularly challenging for listeners when one consider the continuous and coarticulatory properties of speech. Listeners are confronted to the problem of finding word boundaries, identifying the segments whose production is particularly variable, and access the corresponding word stored in their lexicon. The work presented here aims to understand better the first and second processes by examining, in a comparative study, some segmental characteristics produced at word onsets and some perceptual properties of these initial segments.

Most of the studies concerned with articulatory or acoustic properties of speech segments depending on their position in word have focused on consonant production. In word-initial position (often confounded with syllable-initial position), consonants have been found to be produced differently than in word-final or -medial positions. Depending on languages and segments, one can find for initial consonants specific positional allophones (like the aspirated allophones of stops in English), lengthening, and particular articulatory characteristics (e.g. a greater linguopalatal constriction) [3].

On the contrary, little is known about the production of word-initial vowels. The most frequent particularity characterizing word-initial vowel is the presence of laryngealization or glottal stop at the onset of the vowel in languages like English, German or Finnish [6].

In a language like French, the understanding of lexical segmentation can not ignore that in running speech most of the words starting with a vowel are resyllabified with the preceding consonant if any. There are therefore not laryngealized. This is the well known "enchaînement" phenomena in which word initial vowels appears in a surface CV syllable, and where word- and syllable-boundaries are misaligned. In this study we will focus on this particularly interesting case by looking at the production of word-initial vowel in French.

From the data presented above, it appears that word initial position can be subject to a special treatment in production. It is hence tempting to consider, as other did, that the articulatory/acoustic variations observed in word initial position may contribute to make word onset an "island of perceptual recoverability" [4]. It is indeed often the case that initial segments are described as acoustically and perceptually "more salient", to account for the fact that they are usually more resistant to diachronic and synchronic variations than non-word initial segments [4, 5, 8, 10]. However little perceptual evidence are provided to validate these suggestions. One of the objective of the study presented here is to verify whether word-initial vowels can be indeed better identified than non-initial ones.

An improved recoverability in this position could be due to a difference in coarticulation pattern between the vowel and surrounding consonants depending on word position. If initial segments are known to be phonologically more robust to assimilation or lenition process (see above), it might be the case that initial segments are also less affected by coarticulation. Whereas several studies have shown that the coarticulatory influence of a word-initial segment can extend toward the preceding segments despite of a word boundary separating them (see among others [1]), little is know about the coarticulatory resistance of word-initial segments. The effect this may have on speech perception is even more puzzling. Several studies have shown that coarticulatory effects on both vowels and consonants are perceived and may be used by listeners to help identify adjacent segments (see for e.g. [7]). However, it could also be the case that contextual variation in the production of segments constitutes a perturbation to segment identification and even to lexical recognition. Indeed, if a word-initial segment is drastically modified by the articulation of the last segment of the preceding word, the matching between the surface form of the word and its underlying lexical form may be disturbed. Then observing a reduction of coarticulation at word onset could predict a better recoverability by preserving initial phoneme identity.

2. GENERAL METHOD

Acoustic and articulatory characteristics of word-initial vowels have been investigated by comparing two different kinds of CV pairs: 1) one tautosyllabic and word-internal CV sequence (e.g. in “pa<u>ssa</u>ger” *passenger*); 2) one sequence in which C#V straddles a lexical boundary, and V is word-initial, thought, in surface form, enchaînement leads to resyllabification (e.g. in “cla<u>sse â</u>gée” *old class*). Test vowels were /i, a, u/ and

preceding consonants /t, k, s, ʃ/. Test sequences have been produced by two French speakers (M & B) in carrier sentences where the test words were placed in post focus position to avoid too much difference in intonation contour on the sequences. Ten repetitions were recorded in random order with fillers. Audio recording was recorded simultaneously to electropalatographic data (the 62-electrode Reading palate) with Physiologia© [11].

2.1. Production experiments

2.1.1. Acoustic measurements. Acoustic measurements of vowels depending on their position in word include vowel duration and F1/F2 frequency measurement in the beginning (¼th) and middle (½) of the vowel.

2.1.2. Articulatory measurements. Articulatory measurements consist of mean ratios of contacted electrodes in the anterior (5 front rows) and posterior (3 back rows) areas of the palate. These ratios of linguopalatal contact over time have been measured in the vowel for its beginning (from 0 to ¼th of the vowel duration) and for its middle part (from 25 to 75 %). A C-to-V distance was also approximated by a measurement of the difference in linguopalatal contact (over the whole palate) between the last frame of maximum constriction of the preceding consonant and the first frame of the vowel.

2.2. Perceptual experiment

The effect of position in word on the recoverability of initial vowels was investigated in a vowel identification experiment. Listeners have been presented the test vowels /i, a, u/ isolated from their context in one of the repetitions of the sentences of speaker M used in the production experiment. Identification of these vowels was compared depending on their position in word (word-initial vs. word-internal) in the original sentences. Subjects were first presented a vowel target visually (e.g. "a", "o", "ou"), then heard an isolated vowel and had to judge whether the vowel corresponded to the target by pressing a Yes or No key as fast as possible. Positive and negative fillers (including also "e", "eu", "o" targets) were mixed with the test stimuli. Reaction times for the Yes (identification) and No (rejection) responses were recorded from the start of the audio stimuli. Twenty French speaking subjects (both Swiss or French) participated in the experiment.

3. RESULTS

3.1. Production

3.1.1. Acoustic analysis. While the three vowels /i, a, u/ show significantly different intrinsic duration (p<.0001 for both speakers), the comparison between word-initial and word-internal position does not show an effect on vowel duration for both speakers (M, p=.7665 ; B, p=.0878) nor an interaction with vowel types (p=.463).

In the spectral analysis, we did not observe a general effect of vowel position on formant frequencies of vowels and the results follow quite heterogeneous tendencies. However, some significant differences between the two word positions could be observed (Table 1).

The first tendency we can observe is an increase of F1 when the vowel is initial in word. Even if this phenomena does not appear in every context (two contexts for /a/ only for M), the data show the same pattern. F2 differences are less easy to interpret. The most frequent tendency is an increase of F2 for vowels in initial position. Nevertheless, for /a/ in /k/ context, F2 decreases in initial position and this particular result seems quite robust (for both speakers and for both measurement points in the vowel).

Speak. M		F1		F2			
		/t/	/k/	/t/	/k/	/s/	/ʃ/
/a/	¼	ini: 781 int: 662 *p=.0194*			ini: 1962 int: 2166 *p<.0001*		ini: 2009 int: 1912 *p=.0019*
	½		ini: 837 int: 793 *p=.0179*		ini: 1962 int: 2156 *p<.0001*		ini: 1993 int: 1943 *p=.0141*
/i/	¼			ini: 2725 int: 2635 *p=.0223*			ini: 2556 int: 2475 *p=.0246*
	½			ini: 2718 int: 2587 *p=.0012*			
/u/	¼				ini: 818 int: 868 *p=.0403*	ini: 1037 int: 1161 *p=.0383*	

Speak. B		F1			F2		
		/t/	/k/	/c/	/t/	/k/	/ʃ/
/a/	¼	ini: 493 int: 428 *p=.0055*	ini: 512 int: 465 *p=.0017*			ini: 1625 int: 1737 *p=.0044*	ini: 1525 int: 1568 *p=.0430*
	½	ini: 493 int: 418 *p=.0126*	ini: 568 int: 531 *p=.0248*		ini: 1506 int: 1462 *p=.0099*	ini: 1581 int: 1725 *p=.0042*	
/i/	¼				ini: 2119 int: 2001 *p=.0189*		
	½		ini: 258 int: 220 *p=.01*				
/u/	¼			ini: 225 int: 185 *p=.0113*			

Table 1: significant differences of F1 and F2 mean values for vowel (word-initial ("ini") and word-internal ("int")) in each consonantal context (ANOVA, level of significance at 5%)

The effect of position in word on the spectral characteristics of vowels seems to depend on the nature of the preceding consonant (although the interaction position*consonant is never significant). Few significant differences between internal and initial positions appears for vowels preceded by fricatives (5 cases for /ʃV/ and only 1 for /sV/), while most differences appear when the vowel is preceded by /k/, particularly for /a/.

The effect of position in word is also dependent on the vowel type (interaction position*vowel, p=.0206 for F1 in the first part of the vowel). The spectral characteristics of /u/ are the least affected by position (only 2 cases for M, 1 for B). /i/ is more affected, but essentially for the F2 of M (F2 ini > F2 int for /ti/ and /ʃi/). /a/ seems to show the most significant differences between initial and internal position for both speakers.

The two speakers show heterogeneous variations. F1 of M is fairly not affected by position. But, both speakers show most position effect for /a/.

The acoustic results have to be interpreted with caution given the heterogeneity of tendencies. We have to note that only 22 over 96 observed comparisons on position effect were significant. And these 22 significant differences do not show the same pattern. The most meaningful effect we can observe is the increase of F1 for word-initial vowels which can be interpreted as a general opening of the vocal tract. These results validate

partially our hypothesis that a vowel should be less coarticulated when preceded by a word boundary, given that the influence of surrounding consonants could be a closing of the vowel.

3.1.2. EPG analysis. The position of vowel in a word has a main significant influence on the size of the linguopalatal contact in the anterior and posterior palatal areas for both the beginning (B, p=.0011 ; M, p=.0006) and the middle part (B, p=.0024 ; M, p<.0001) of the vowels.

Table 2 shows that the data accounting for an effect of vowel position in word represents only 27% of the 60 EPG measurements observed (all CV sequences pooled) for M and 23 % for B, and only 8 over the 12 different CV sequences for M and 6 for B.

Globally, for both speakers, the vowels preceded by a fricative (/s/ and /ʃ/) are less sensitive to position in word, in opposition to the vowels preceded by a stop (/t/ and /k/).

Among the vowels, /u/ shows generally less significant changes in amount of linguopalatal contact depending on position. This difference, in comparison to /a/ and /i/, is not due to a limitation of EPG system to capture linguopalatal articulation of /u/, because this vowel has a greater amount of contact than /a/ for both speakers (B, p<.0001 ; M, p<.0001). In the majority of the cases showing significant differences in amount of contact depending on position, vowels in word-initial position have less linguopalatal contact, even for /i/ (9/10 cases). This effect concerns particularly the sequences /ka/, /ta/ and /ti/ for M, /ka/, /ki/, /ti/ and /ʃi/ for B, and in a lesser extent /si/ and /su/ for M. Only two results weaken this trend. (1) /i/ in /k/ context shows more linguopalatal contacts in the posterior area for B, and in the anterior area for M. But, for B, this fact is concomitant with a decrease of contact in the anterior area and over the entire palate (averaged percentage of contact for each position, ini: 43.0, int: 49.5, p= .0060). (2) For M, the increase of contact are strictly localized in the anterior area and no shift of contact can be seen. Nevertheless, while /i/ of M shows more linguopalatal contacts in initial position, it appears in this case that the gap between the contact at the beginning of the vowel and that in the preceding consonant is increased when the vowel is initial in a word.

This greater difference of linguopalatal contact between C and V is another cue for the presence of a word boundary between the consonant and the vowel in number of cases, even when no variation are observed within the vowel itself (see /ʃa/ for M and, /ta/ and /su/ for B). Only 2 over 9 cases (/tu/ for M and /ka/ for B) show the inverse trend.

In sum, we notice that when being in word-initial position induces a significant influence on vowels, it can imply two main alternative or concomitant consequences for its linguopalatal articulation: 1) a greater opening of the vowel, even for the close vowel /i/ ; 2) a greater contrast in the open/close dimension between the vowel and the preceding consonant. Thus, in some degree, the presence of a word boundary could contribute strengthen the vocalic properties of the word-initial vowel either in an absolute way ([+open]) and/or in a relative way by enhancing the contrast with the preceding consonant.

3.2. Perception

3.2.1. Yes/No response distribution. The distribution of the correct identification (Yes responses) and incorrect rejection (No responses) depends on the vowel types studied. The vowels /i/ and /u/ have been correctly identified 88% of the time, while /a/ was rarely identified (22% of Yes responses). For the first two vowels, there is a trend showing a relationship between the distribution of the Yes-No responses and the position of the vowel in the word. While correct identification of /i/s and /u/s tends to be similar in the two positions (52% of Yes responses), incorrect rejection of these vowels tends to be less frequent in word-initial position (35%) than that in word-internal position (65%). However, these tendencies are only marginally significant (χ^2 = 3.8, DF 1, p=0.05). For the vowel /a/, we can observe an other tendency with the majority (60%) of the correct identification being in word initial position and 53% of the incorrect rejection being in word internal position. But these distinctions are not significant (p=.17).

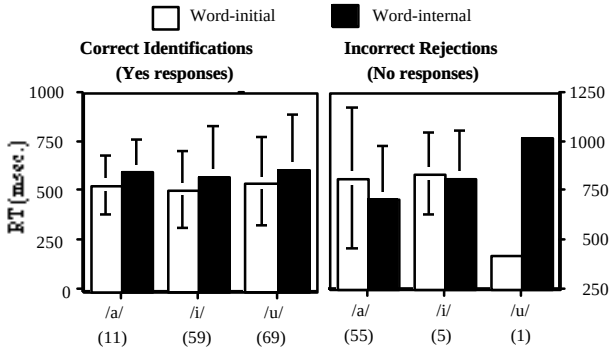

Figure 1: Reaction times for Yes and No responses depending on position in the word and vowel types. Below each vowels is indicated the number of pairs compared

3.2.2. Reaction time analysis. Since identification rates appeared to be different depending on the three vowels cases, we compared the reaction times for each vowel separately. Also, since the distribution of the Yes and No responses is different for /a/ we analyzed the reaction time for both response types. The comparison between word-initial and word-internal vowels is done with a repeated measure ANOVA based only on the cases where the responses are of the same type (Yes for both or No for both). This sample represents 84% of the data.

Results, summarized in Figure 1, shows that all the vowels are identified faster in word initial position than word internal position (for /a/, p<.0001 ; for /i/, p=.02 ; for /u/, p=.02).

Moreover, the analysis of reaction time for the rejections shows that /a/s are rejected slower when there are word-initial than word-internal (p=.03). For the other vowels, the number of rejection cases is not sufficient to do such an analysis.

DISCUSSION AND CONCLUSION

Summarizing the perception experiment, it seems that a vowel is rather more accurately and faster identified when it is in word-initial position. We had hypothesized that an increased recoverability may be the consequence of a reduction of coarticulation. Thus, we have to explain first the particular results observed for the vowel /a/ which is rarely identified in our experiment.

The vowel /a/ is known to be quite sensitive, compared to other vowels, to the influence of contiguous segments mainly because of its central and open articulation. The smaller resistance to contextual variations suggests that /a/ carries a lot of contextual information. Other perceptual studies in French [9] have shown that the identification of /a/ is much more affected by contextual variations than that of the vowel /i/. Then, the fact that /a/ is usually not recognized by the listeners may be due to

its large variability. Therefore, even if the vowel /a/ seems to be quite affected by its position within a word in the production experiment, it could be the case that this additional variability make it even harder to identify and/or that its positional variability is overruled by its large contextual variability.

More globally, the results observed in the acoustic experiment can account for the general trend of a rather better perceptual recognition of vowels in word-initial position because of a general "vocalic" effect. If the vowel is less influenced by the preceding consonant it should be more open, in other word, more vocalic. This opening is characterized by a lowering of the tongue and an increase of F1 values. In this way, our hypothesis of less coarticulation across word boundaries is confirmed.

The EPG data also validate this hypothesis. When a word boundary occurs between C and V (hence when V is word-initial), the position of the tongue in the vowel is lower relative to the hard palate. This articulatory behavior holds not only for the open vowels but also for the closed ones. As a consequence, being in a word-initial position may not enhance the distinctive features of the vowel (as suggested by [6]'s results in Finnish), but tends toward an enhancing of the open quality of the vowel either relatively to the constriction of the consonant or in absolute term (see [2] for a discussion).

To conclude, we show in this study that word-initial vowels in French may present subtle acoustic and articulatory variations that concur to increase their vocalic property, and could help the listener to recognize them more accurately and faster. However, this study has been restricted to the observation of the vowels only. A complementary observation of the production and the perceptual treatment of other kinds of coarticulatory information (such as those related to C, and CV timing...) appears necessary to validate our hypothesis of a particular treatment of initial-vowels.

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		Speaker M						**Speaker B**			
		/ʃ/	/s/		/k/		/t/	/s/	/k/		/t/
			anterior	posterior	anterior	posterior	anterior	anterior	anterior	posterior	anterior
/a/	mc 0-25				ini < int	ini < int	ini < int		ini < int	ini < int	
	mc 25-75				ini < int	ini < int	ini < int			ini < int	
	cd C-V	ini > int					ini > int		ini < int		ini > int
/i/	mc 0-25				ini > int		ini < int	ini < int	ini < int	ini > int	ini < int
	mc 25-75		ini < int				ini < int	ini < int	ini < int		ini < int
	cd C-V				ini > int		ini > int				ini > int
/u/	mc 25-75			ini < int							
	cd C-V						ini < int	ini > int			

Table 3: significant differences of mean ratios of EPG contacts in the anterior and the posterior EPG areas for the beginning (mc 0-25) and the middle part (mc 25-75) of the vowel and significant differences of EPG contact ratios between consonant and vowel (cd C-V), between the word-initial ("ini") and word-internal ("int") vowels in each consonant context for both speakers. "<" and ">" respectively indicate which condition increases or decreases the values of observed measurements (ANOVA, level of significance at 5%)