MARKING THE BOUNDARY: UTTERANCE-FINAL PROSODY IN FRENCH QUESTIONS AND STATEMENTS

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ABSTRACT

The use of two markers of prosodic finality in French, vowel lengthening and high vowel breathiness/devoicing, were compared among statements and questions of various types (echo-questions, Wh-questions, questions with inverted subject and verb). The comparison focuses on the relation between sentence-final intonation and the other markers of finality. The intonation pattern of statements and Wh-questions ends with a L% boundary tone; echo questions and inverted questions end with a H% boundary tone, like non-final stress groups. It was hypothesized that because the H% boundary tone of these questions is not unambiguously phrase-final, there would be greater use of other markers of finality. The hypothesis was contradicted by the data: statement-final vowels were more breathy and more likely to be devoiced than question-final vowels. The vowel duration results also suggest that statement-final vowels were different from question-final vowels regardless of intonation pattern.

1. INTRODUCTION

The boundaries of prosodic units are demarcated in speech in a number of different ways, involving both segmental and suprasegmental properties. These boundaries may be signaled by changes in duration or intensity, specific tonal patterns, pauses, or other modifications. Listeners are capable of using at least some of these modifications in detecting the end of a prosodic unit [10], supporting the argument that such prosodic modifications help to organize continuous speech into coherent units.

Although numerous studies have investigated the modifications that indicate prosodic boundaries in speech, fewer have considered the interactions among different ways of marking boundaries. In this study, the focus is on the relation between F0 pattern, known to be a crucial indicator of the location and type of boundary, and segmental modifications, specifically vowel lengthening and devoicing.

1.1. Intonation of statements and questions

There are numerous studies of French intonation; this account follows [3] and [9].

The smallest unit that is significant for intonation is the stress group, or tonal unit, whose basic intonation pattern is a rise (LH). An Intonation Unit is composed of one or more stress groups; an Intonation Unit that is a neutral statement ends with a low tone, which will be indicated here as L%. A statement composed of several stress groups will thus have a series of pitch peaks at the end of each stress group and a final low pitch at the end of the last stress group in the sentence.

Questions of different syntactic structures have different intonation patterns. As in many other languages, Wh-questions (those introduced by a question word such as "qui" (who) or "quel" (which)) have an intonation pattern similar to that of statements, in that they also end with a pitch fall. But their intonation is not identical to that of statements. There is usually a high pitch associated with the question word itself, but then "the pitch drops regularly until the final syllable" [3 p.205]. In other words, an Intonation Unit that is a Wh-question will usually not have multiple high pitches, as is found in statements.

Other types of questions are usually characterized by a rising pitch (H%) at the end of the Intonation Unit. These include the type of question that will be referred to here as Echo-questions, which [3] refers to as syntactically unmarked. In these questions, there is no syntactic difference from a statement; intonation is the sole indicator that the sentence is a question. The sentence-final intonation of Echo questions is very similar to that of questions with inverted subject and verb, which will be referred to here as Inverted questions.

The rises that occur at the end of Echo and Inverted questions may be poorly distinguished from the rises that mark the end of each stress group in a sentence. Various researchers have suggested that the rises at the ends of questions have greater range, steeper slope or higher final pitch [3]. However, [3 p.202] states that "there is a single overall intonation pattern for both continuative and interrogative utterances in French." This suggests that unlike statements and Wh-questions, which end with a L%, questions ending with a H% have less intonational marking of sentence-end. This lack may be perceptually important: in a study of listeners' perception of boundaries in French discourse, F0 gave the strongest distinction between final and non-final syllables [10]. (It appears that [10] was examining statements only, as they say the final syllables had lower F0 than non-final syllables, and questions would have had higher F0.)

Because intonation seems to indicate the end of the sentence less clearly in rise-final questions than in statements or Wh-questions, it was hypothesized that speakers would make greater use of other means of marking the end of the sentence in rise-final questions. In other words, rise-final questions should show more evidence of the segmental modifications that are typically associated with the end of a sentence (or other prosodic unit).

1.2. Modifications in prosodically final positions

Both initial and final position in a prosodic unit have been shown to affect the production of individual speech sounds in French and other languages (see, e.g. [6], [7], [1], [11] and many others). One of the most well-known effects is the tendency for lengthening of vowels in final position relative to vowels occurring earlier in a prosodic constituent (word, phrase, utterance). In particular, lengthening of sentence-final vowels seems to be a robust effect in French [5]. Such lengthening would therefore be expected in the last vowel of any sentence, regardless of the type of sentence. The present study tests to see if there is more final lengthening at the end of questions whose final H% may not be as clear a marker of the end of the utterance as the final L% of statements and Wh-questions.

Another sentence-final modification that French speakers sometimes make is devoicing of the final vowel. This devoicing is perhaps most noticeable in the frequent pronunciation of "oui" as something like [wiç]. Informal listening suggests that the phonological context for devoicing is vowels, most often high vowels, in final open syllables, and that it therefore qualifies as a marker of prosodic finality. The interest of devoicing in the present study is to investigate whether its occurrence is affected by the type of sentence, and whether it is used to reinforce the finality of a prosodic boundary. Since published data on the devoicing phenomenon are either non-existent or scarce (but see [4]), it is also not clear which acoustic parameters will best distinguish the 'voiced' and 'devoiced' vowels. Because of this uncertainty, the vowels were measured in two different ways, one to identify extent of voicing, one the amount of breathiness.

2. METHOD

2.1. Materials

The goal of the study was to compare the occurrence in statements and questions of two processes which are associated with marking the finality of a prosodic boundary: lengthening and devoicing of the final vowel. In order to compare the occurrence of these processes in sentences of different types, sets of sentences were constructed such that the sentences in each set were as similar as possible. Each set consisted of five sentences: two statements, one Echo question, one WH-question and one question with inverted subject and verb. One of the statements and all of the questions ended with the same target word and contained the same total number of syllables. The other statement used the target word in non-final position as a control, and did not necessarily contain the same number of syllables as the test sentences. A sample set of sentences with the target word "pie" [pi] (magpie) is given below.

statement	Le chat tigré regardait la pie.
	(The tabby cat watched the magpie.)
echo ?	Le chat tigré regardait la pie?
	(The tabby cat watched the magpie?)
Wh ?	Quel animal regardait la pie?
	(Which animal watched the magpie?)
inverted ?	Le chat a-t-il regardé la pie?
	(Did the cat watch the magpie?)
non-final	La pie donnait à manger à ses petits.
control	(The magpie gave food to its babies.)

Table 1. Set of sentences with target word "pie"

In half of the sets of sentences, the target word ended in an open syllable (a potential devoicing environment); in the other half, the target word ended in a closed syllable with the same vowel. A total of ten sets of sentences were recorded; the analysis of four sets is reported here. The target words in the sets reported on here were "pie" [pi] (magpie) and "pic" [pik] (peak), "cou" [ku] (neck) and "coupe" [kup] (cup).

2.2. Recording technique and measurements

Six native speakers of French were recorded reading the sentences. All were graduate students or faculty in linguistics, who normally worked in the laboratory where the recordings were made. They were all naïve as to the purpose of the experiment.

Each speaker read the fifty sentences six times, in six different orders. They were recorded on a Sony Professional Walkman WM-D6C in a sound-proof room. These recordings were later digitized on a Kay Elemetrics' CSL system, at a sampling rate of 10 kHz. Data from two speakers, one male (Speaker M) and one female (Speaker F), are reported here.

The first stage in analyzing the data was to examine pitch tracks of the sentences to ensure that the speakers had produced the expected sentence-final intonation. These pitch tracks were generated with the Macquirer software package displaying all 6 repetitions of each sentence simultaneously, in order to facilitate comparison of the intonation patterns. For some sentences, a single speaker produced two or even three different patterns of intonational phrasing among the 6 repetitions. There was, however, great consistency in the sentence-final F0 patterns produced, which conformed to the expectations.

2.2.1. Duration measurements. Other measurements of the acoustic signal were made using the Kay CSL system. The duration of the vowel in each target word was measured from the waveform, with a spectrogram displayed as an additional aid. The beginning of the vowel was identified as the beginning of voicing. The end of the vowel was at the end of any noise in the signal, for sentence-final vowels, or at the beginning of closure for a following consonant, if present. Using the spectrogram, the end of voicing during the vowel was identified as the time at which the voice bar ended. If the end of voicing was before the end of the vowel, the vowel was considered to be (partially) devoiced. A count was made of the number of repetitions of each sentence in which the final vowel was voiced during less than its total duration. All vowels had a voice bar during at least part of their duration.

2.2.2. Cepstral measurements. The final acoustic measurement that was made was to determine the breathiness of the vowels in target words. Breathiness was investigated in this study because it may be related to devoicing. A breathy vowel, having greater airflow, might be more likely to devoice than a vowel with modal voicing. The measure of breathiness that was chosen was cepstral peak prominence (CPP) [8]. The CPP is a measure of signal periodicity: signals that are strongly periodic will have a very prominent peak in their cepstrum, while breathy signals, in which the fundamental is less dominant, will have a peak that is lower relative to the overall amplitude of the cepstrum. Both [8] and [2] found that CPP had the highest correlation with perceived breathiness in vowels for any of the acoustic measures of breathiness that they tested.

The version of CPP used here is like that used by [2], a slight modification of the technique used by [8]. Calculation of the CPP was as follows. At a given point in the vowel, an FFT was calculated with a 256-point window, and then the cepstrum was calculated from this FFT. In the cepstrum, the quefrency above 1.8 ms that had the maximum amplitude was then identified. The difference was then calculated between this maximum amplitude and the mean amplitude of all quefrencies above 1.8 ms. The reason for excluding values below 1.8 ms is that they generally reflect vocal tract resonances, rather than the characteristics of the glottal signal. (Note that [8] and [2] only excluded values below 1 ms, but the cepstra in this experiment seemed to require the exclusion of values up to 1.8 ms.) The difference between the peak amplitude and the mean amplitude is the value of the CPP. A larger CPP value corresponds to a more prominent peak and a more periodic signal; a smaller CPP corresponds to a less prominent peak and a more breathy signal.

CPP values were calculated over windows starting at the onset of voicing for the vowel, and at 50 ms intervals during this vowel, with the final measurement at a point 50 ms before the end of the vowel. For vowels of less than 50 ms duration, only one measurement was made, at the beginning of the vowel. The minimum and maximum CPP values during each vowel were identified. These minimum and maximum values were subject to statistical analysis.

2.3. Numerical Analyses

The data for each of the two speakers were analyzed separately. The duration measurements were analyzed in an ANOVA with independent factors of word (one of the 4 target words: "pie", "pic", "cou", or "coupe") and sentence-type (statement, echo-question, Wh-question, inverted question, or non-final). The dependent variable was either the total duration of each vowel, or just the voiced portion of each vowel (excluding the devoiced portion, if any). The significance level used was $p < .01$. Scheffé's post-hoc test was used to determine which levels of the factors were significantly different.

The cepstral measurements were also analyzed with a similar ANOVA. In this case the dependent variable was either the minimum or maximum CPP value for each vowel.

3. RESULTS

The results showed differences between statements and questions, with regard to vowel duration, likelihood that a vowel is devoiced, and amount of breathiness. These three different types of measurements combine to suggest that, contrary to the initial hypothesis, phrase-finality in statements is marked by more different indicators than phrase-finality in questions.

3.1. Likelihood of devoicing

The only sentences in which the final vowel was devoiced were those that ended in open syllables, as predicted. Furthermore, only vowels in sentences ending with a L% (statements and Wh-questions) were subject to devoicing. Table 2 shows the number of repetitions of each sentence (out of 6 total repetitions) that were devoiced.

	Speaker F		Speaker M	
	"pie"	"cou"	"pie"	"cou"
statement	6	1	4	5
Wh-question	0	0	3	1

Table 2. Number of repetitions in which the vowel was devoiced.

There is clearly a tendency for statements to be devoiced more often than Wh-questions. There was no apparent relation between the length of the final stress group of a sentence (measured in syllables) and the likelihood of the final vowel being devoiced. Statements are characterized by slightly lower sentence-final F0 values than are Wh-questions, possibly because statements may be more likely to occur at the end of a complete discourse than questions. Devoicing of vowels may be a marker not just of sentence-finality, as proposed, but more so of discourse finality.

3.2. Vowel durations

3.2.1. Total vowel duration. Final lengthening was observed consistently. This was demonstrated by a difference between the control sentences with the target word in non-final position, compared to the test sentences in which the target word was in final position. For the male speaker, the ANOVA for total vowel duration showed a significant effect ($p<.01$) of sentence type and word identity as well as a significant interaction between them. Post-hoc tests showed that the vowels in non-final position were shorter than vowels at the end of any type of sentence.

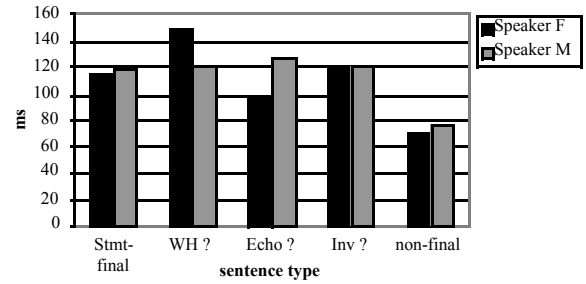

Figure 1. Total vowel duration, averaged by sentence type.

Results were similar for the female speaker, with a significant effect of sentence type and word identity as well as a significant interaction between them. Non-final vowels were significantly shorter; in addition, vowels at the end of Wh-questions were longer than in any of the other sentence types.

These results suggest that while final lengthening is a robust marker of the end of a sentence, its effect is not amplified at the end of questions ending with a H%. The results for the female speaker also contradict the original hypothesis in that greater lengthening was found just in those questions (Wh-questions) that end with the unambiguously final L%.

In addition to final lengthening, devoicing may also contribute to the longer duration of statement-final vowels, as compared to vowels in non-final position. The total vowel duration of devoiced vowels was on average longer than the voiced tokens of the same word.

3.2.2. Voiced vowel duration. In the analysis of the voiced portion of the vowels, the durations in statement-final position were shorter than in question-final position. Sentence type and word identity were again significant for both speakers, as was the interaction between the two factors. The post-hoc tests showed that for the male speaker, voiced vowel duration was significantly shorter in statements (sentence-final position and non-final position) than in any of the questions. (There was no significant difference between sentence-final and non-final position in statements.) The same was true for the female speaker, and in addition, her vowels at the end of Wh-questions were significantly longer than for any of the other sentence types, and vowels at the end of inverted questions were longer than all except Wh-questions.

The difference between analyzing total vowel duration and voiced vowel duration affects the sentence types in different ways, resulting in different rank orderings of their durations in the two analyses. All of the sentence-final vowels would be expected to show the effect of final lengthening. However, the voiced part of the vowels in statement-final position had a duration similar to those in non-final position, so it appears that the additional duration, which can be ascribed to final lengthening, is devoiced. As mentioned in section 3.2.1, it is possible that some of the extra duration in the devoiced part of the statement-final vowels may be related to the presence of devoicing, rather than just to final lengthening.

3.3. Breathiness

Final vowels in all types of questions were less breathy than vowels in statements. Analyses were made of both the maximum and minimum cepstral peak prominence values (CPP) for each vowel token. The results for the analyses of the maximum and minimum values were very similar, in terms of which effects were significant, although the numerical values were, of course, somewhat different. Only the analyses of the maximum CPP values are reported here.

For both speakers, the ANOVA results showed significant effects ($p<.01$) for sentence type and word identity, and for the interaction between them. Post-hoc tests showed that for both speakers, the CPP was significantly lower for statement-final vowels than for vowels at the end of questions, or for non-final vowels in statements. This pattern, shown in Figure 2, was true for all four target words. These results suggest that statements are produced with greater breathiness in the final vowel, regardless of whether it occurs in an open or closed syllable.

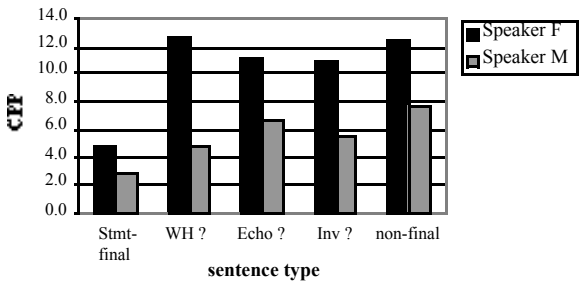

Fig. 2. Maximum CPP values, averaged over each sentence type, showing the smallest values were for statement-final vowels.

In addition, for the male speaker, the CPP value for non-final vowels was significantly higher than for vowels at the end of statements, Wh-questions or inverted questions. This result supports the notion that increased breathiness is used more in sentence-final position, and can therefore be considered a marker of prosodic finality.

Since both statements and Wh-questions end with a low F0, but only statements show increased breathiness, it appears that the intonation pattern alone is not enough to specify where the breathiness will be found – the sentence type must be specified. Increased breathiness was found in the same environment as showed the greatest likelihood of devoicing. Both breathiness and devoicing can arise from similar conditions in the vocal tract, such as increased airflow through the glottis, and therefore it is not surprising that they may occur in similar environments.

4. DISCUSSION

Previous work has demonstrated that prosodic structure is important in determining the articulatory and acoustic properties of speech segments. This study shows that, in addition, the type of sentence must be considered as an influence on production.

The starting hypothesis for this study was that final lengthening and vowel devoicing would be used more in questions that end with a H%, potentially confusable with the end of a non-final stress group, than in questions or statements that end with a L%, which in itself is an unambiguous indicator of the end of an Intonation Unit. This hypothesis was shown to be false. Devoicing occurred only in sentences ending with a L%. But the usefulness of devoicing as a marker of finality is limited to these phonological contexts where it occurs, namely vowels in open syllables. Breathiness, which can occur in any phonological context, was also shown to be greater in vowels at the end of statements than at the end of any type of question, even Wh-questions whose intonation pattern is most like that of statements. This provides further evidence that breathiness and devoicing are not a concomitant of any particular intonation pattern, but rather a property of a type of sentence.

Vowel duration also distinguished statements from questions. Because of the greater length of the devoiced vowels, contexts in which devoicing occurred were characterized by longer vowels. This was particularly true for statements with final open syllables. Greater final lengthening provides another piece of evidence that statements were produced with more indication of finality than questions.

Why would statements, plausibly the "unmarked" sentence type, be characterized by more markers of finality than questions? One explanation may be that the end of a statement is a potential endpoint in speech, whereas the end of a question is asking for a response from another speaker, and therefore is not likely to be the last word spoken in a discourse.

Despite the apparent similarity of the intonation patterns of non-final stress groups and Intonation Unit-final questions, French speakers do not seem to make other modifications to increase the difference between the final and non-final syllables. The more important difference seems to be between statements and questions.

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