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## ► To cite this version:

Amandine Michelas, Sophie Dufour. Gradiency vs. categoricity: How French speakers perceive accentual information in their native language?. *Speech Prosody 2022*, May 2022, Lisbonne, Portugal. pp.362-366, 10.21437/SpeechProsody.2022-74 . hal-03906409

**HAL Id: hal-03906409**

**<https://hal.science/hal-03906409>**

Submitted on 20 Dec 2022

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# Gradiency vs. categoricity: How French speakers perceive accentual information in their native language?

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## Abstract

Previous works have suggested that French speakers have difficulties to process accentual information at an abstract level of processing when they are confronted to lexical stress found in languages such as English or Spanish. However, the way they process accentual information in their own language (a language without lexical stress) deserves further investigation. In this experiment, we address the issue of the nature of the perception of native accentual information by French speakers in a categorical perception paradigm. French speakers had to identify lexical sequences on an acoustic continuum ranging from an unaccented first syllable [*depla'se*] ‘moved’ to an accented first syllable [*'de*] [*pla'se*] ‘a dice placed’. Results showed that, when tested on an acoustic continuum, French speakers perceive accentual information in a gradual manner. These results corroborate previous studies on the perception of non-native stress patterns by French speakers showing that, in simple perception tasks, their perception of accentual information is acoustically-based and not categorical.

**Index Terms:** Speech perception, Gradient/Categorical perception, Accentual information, French prosody

## 1. Introduction

Most of Germanic and Romance languages use lexical stress. In these languages, stress placement is assigned at the word level and the position of stress within word can change its meaning. Because stress has a lexically contrastive role in these languages, stress differences can be viewed as phonemic differences. Speakers of these languages thus process stress differences at an abstract level of processing ([1]) and integrate them in their mental lexicon ([2]).

Contrary to these languages, French does not have lexical stress but phrasal accent (e.g. [3],[4],[5],[6]). This means that the obligatory accent in French (namely the primary accent) always affects the last syllable of a larger unit than the word, that is the Accentual Phrase (AP). As a result, the same French word can be accented or not depending on its position within the AP. For instance, the word *dé* ‘dice’ is accented in [*On a remar'qué*]<sub>AP</sub> [*le petit 'dé*]<sub>AP</sub> [*placé sur cette 'case*]<sub>AP</sub> ‘We noticed the small dice placed on this square’ because the word is in final position within the AP. By contrast, the same word is unaccented in [*On a remar'qué*]<sub>AP</sub> [*le dé 'noir*]<sub>AP</sub> [*placé sur cette 'case*]<sub>AP</sub> ‘We noticed the black dice placed on this square’ because it is not in final position within the AP. It results that in French, when a word is accented, it is obligatory associated with an AP boundary.

There are numerous demonstrations in the literature that French listeners are able to use the presence of an accent/an AP

boundary to segment speech into words, and in particular to locate word offset in continuous speech ([7], [8], [9]). However, despite this well-established fact, we still ignore the way French listeners perceive accent/AP boundary. Two possibilities exist. First, according to the standard view of the prosodic hierarchy (e.g., [10], [11], [12], [13], [14], [15]), speakers produce and perceive prosodic boundaries in a categorical way. According to this view, speakers produce a small number of prosodic categories (each with well-defined articulatory and acoustic properties) and perceive the boundaries of these prosodic categories in a categorical way. The number of prosodic categories and the acoustic/articulatory properties cuing the boundaries are language dependent. For the French language, at least four prosodic categories have been proposed including the “no boundary” category (which corresponds to any unaccented syllable) and the AP boundary which corresponds to any accented syllable (see [3], [4], [5], [6], [16] among many others). According to the standard view of prosodic hierarchy, French listeners should thus perceive the difference between an unaccented syllable and an accented syllable in a categorical manner. In contrast, an alternative view assumes prosodic boundary production and perception to be gradient ([17], [18], [19], [20], [21]). According to this view, prosodic boundaries are not perceived as a limited number of entities, behaving categorically, but as a continuum of values of different strength. Within this framework, the strength of each boundary depends of several factor including the number and the type of acoustic indices cuing the boundary ([19], [21]) but also the location of the boundary within the utterance ([17], [18]). Such a view posits that French speakers should process the difference between an accented and an unaccented syllable in a gradual way.

In this study we try to tease apart these two opposite views by examining the nature of the perception of accentual information by French speakers. To do so, we tested participants on an acoustic continuum between an unaccented first syllable [*depla'se*] and an accented syllable [*'de*] [*pla'se*]. The continuum was created via the manipulation of both the f0 contour and the duration of the syllable which are the two main correlates of accentuation in French ([3], [4], [5], [6]). The stimuli formed 8 equally-spaced points along the continuum and participants had to determine whether the ambiguous sequence they heard correspond to the *déplacé* sequence ‘moved’ or the *dé#placé* sequence ‘a dice placed’. If French speakers perceive the difference between an unaccented and an accented syllable in a categorical manner as predicted by the standard view of the prosodic hierarchy, the percentage of *déplacé* responses should show a typical, sigmoid-like decrease from the unaccented to the accented endpoint of the continuum. By contrast, if French speakers perceive the difference between an unaccented and an accented syllable in a gradual manner as hypothesized by the alternative view, the percentage of *déplacé*

responses should show a linear-like decrease from the unaccented to the accented endpoint of the continuum.

## 2. Method

### 2.1. Participants

Thirty native speakers of French participated in the experiment. Each participant gave informed consent prior to experiment and was remunerated for his/her time.

### 2.2. Materials

The material used was derived from natural versions of the phonemic sequence /deplase/ which is lexically ambiguous between *déplacé* ‘moved’ and *dé#placé* ‘a dice placed’. A native speaker of French read both sequences within carrier sentences. Within these sentences, the lexically ambiguous syllable /de/ was either accented ([*On a remar'qué*]<sub>AP</sub> [*le petit 'dé*]<sub>AP</sub> [*placé sur cette ca'se*]<sub>AP</sub> ‘We noticed the small dice placed on this square’) or unaccented ([*Le 'pion*]<sub>AP</sub> [*est dépla'cé*]<sub>AP</sub> [*sur cette ca'se*]<sub>AP</sub> ‘The pawn is moved to this square’) depending on the location of the syllable within the AP. Acoustic analysis conducted on the ambiguous syllable /de/ confirmed that the syllable was longer and associated with higher f0 values in the *dé#place* sequence (syllable length: 209ms; f0 min: 204 Hz; f0max: 351; % of f0 slope: 72%) than in the *déplacé* sequence (syllable length: 146ms; f0 min: 159Hz; f0 max: 159; % of f0 slope: 0%). Figure 1 reports spectrograms, f0 curves, tonal labelling and textgrids for the two /deplase/ sequences.

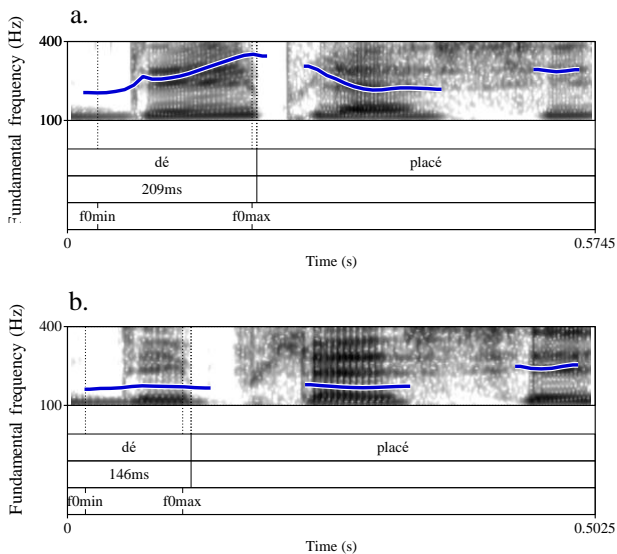


Figure 1: spectrograms, f0 curves, tonal labelling and textgrids for the *dé#placé* sequence in a. and the *déplacé* sequence in b.

Four continua of 8 steps were generated. For the first continuum, we used as base stimulus the natural *deplacé* sequence (see Fig 1b). For the second continuum we used as base stimulus the natural *dé#placé* sequence (see Fig 1a). Because as illustrated in Fig 1, the two /plase/ sequences had not the same acoustic characteristics, they can influence participant decisions. To avoid that, we generated two others continua in which the base stimulus was created by cross-splicing. For the third continuum, we cross-spliced the unaccented /de/ syllable with the /plase/ sequence of the de accented syllable. In the same way, for the fourth continuum,

we cross-spliced the accented /de/ syllable with the /plase/ sequence of the unaccented /de/ syllable.

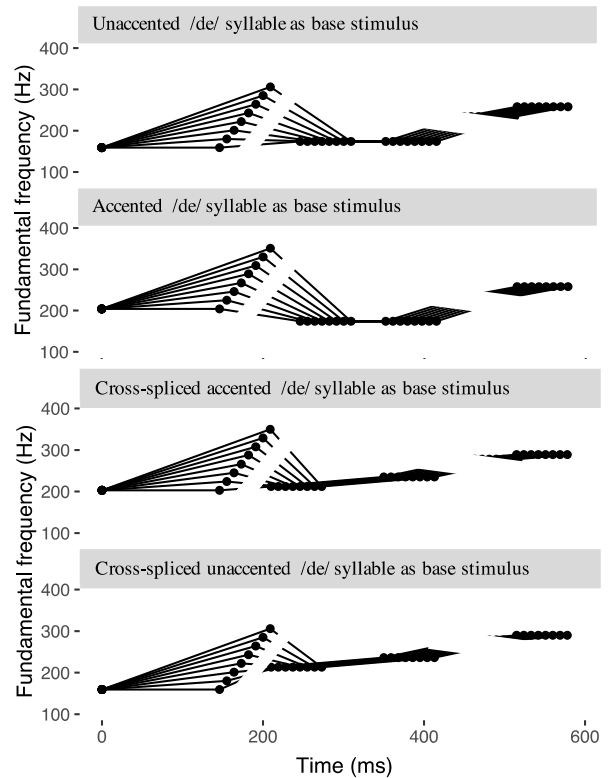


Figure 2 : Acoustic continua from the four base stimuli.

For each base stimulus we generated a re-synthesis file that contains duration and pitch points at the beginning and the end of the /de/ syllable. For each base stimulus, the duration of the /de/ syllable was manipulated by creating a continuum between 146ms (corresponding to the length of the unaccented /de/ syllable; see Fig. 1b) and 209 ms (corresponding to the length of the accented /de/ syllable; see Fig. 1a) by steps of 9ms (=8 steps). For the pitch manipulation, because f0 minima were not the same in the accented version and in the unaccented version of the stimuli (see Fig. 1), the different steps were generated separately for the accented base stimuli and for the unaccented base stimuli. For the two base stimuli with the accented /de/ syllable, a continuum was created between 204 Hz and 351 Hz. For the two base stimuli with the unaccented /de/ syllable, a continuum was created between 159 Hz and 356 Hz. As a result, for both the accented and unaccented /de/ syllable, we obtain an increase of 147 Hz between the f0 min and the f0 max by steps of 21Hz (=8steps). Pitch contours were obtained via interpolation between the first and the second pitch points.

All acoustic manipulations were done using the Pitch Synchronous Overlap and Add method (PSOLA, [21], [22], [23]) which is known for the high degree of naturalness achieved. Table 1 reports acoustic properties of steps 1-8 for each base stimulus. RMS amplitude of all stimuli was equated to 50 dB.

Table 1 : Acoustic characteristics of the ambiguous /de/syllable for steps 1-8 depending on the base for stimuli.

Base stimuli in which the /de/ syllable was originally unaccented								
Steps	1	2	3	4	5	6	7	8
Duration (ms)	146	155	164	173	182	191	200	209
f0 min (Hz)	159	159	159	159	159	159	159	159
f0 max (Hz)	159	180	201	222	243	264	285	306
Base stimuli in which the /de/ syllable was originally accented								
Steps	1	2	3	4	5	6	7	8
Duration (ms)	146	155	164	173	182	191	200	209
f0 min (Hz)	204	204	204	204	204	204	204	204
f0 max (Hz)	204	225	246	267	289	309	330	351

### 2.3. Procedure

Participants were tested in a sound attenuated booth of the *Laboratoire Parole et Langage*, and the stimuli were presented over headphones at the sound level of 60dBA for all participants. Participants were informed that they would hear sequences containing either one single word (*déplacé*) or two words (*dé#placé*) and their task was to decide as quickly as possible whether the sequence was extracted to the sentence *Le pion est déplacé sur cette case* ([Le 'pion]<sub>AP</sub> [est dépla'cé]<sub>AP</sub> [sur cette 'case]<sub>AP</sub>) 'The pawn is moved to this square' or to the sentence *On a remarqué le petit dé placé sur cette case* ([On a remar'qué]<sub>AP</sub> [le petit 'dé]<sub>AP</sub> [pla'cé]<sub>AP</sub> [sur cette 'case]<sub>AP</sub>) 'We noticed the small dice placed on this square'. They give their responses on a button box placed in front of them. Half of the participants were asked to press the left button for "déplacé" and the right button for "dé#placé" and the reverse was true for the other half. Each participant heard the stimuli of each continuum. For each continuum, the stimuli relative to each step were presented ten times. As a result, each participant thus heard 320 trials randomly presented (4 continuum \* 8 steps \* 10 repetitions). The experiment lasted approximately 30 minutes. An inter-trial interval of 1500ms elapsed between each participant's response and the beginning of the next stimuli. The participants began the experiment with a block of 8 practice trials.

## 3. Results

The mean percentage of *déplacé* responses is displayed in Figure 2.

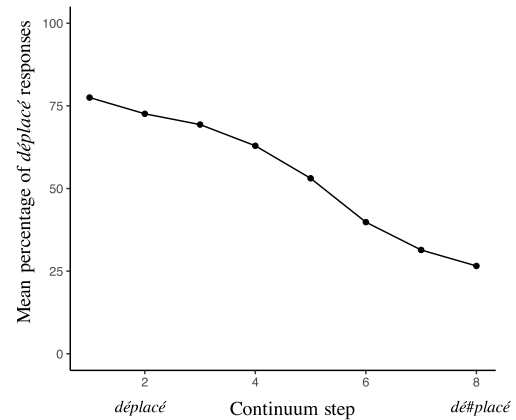


Figure 2. Mean percentage of *déplacé* responses for each stimulus of the *déplacé*-*dé#placé* continuum.

The type of response (1= *déplacé* response, 0= *dé#placé* response) was first analyzed using a mixed-effect regression model (lme4 package in R-studio statistics Version 1.1.456) with a logistic linking function ([24]). The model included step (1-8) as fixed effect, participants as random intercept, plus random slope for the within-participant factor step ([25]). Since our data set was too large for the default fitting methods in glmer.nb, it was necessary to implement the function options nAGQ=0 and optimizer="nloptwrap" for the model-fitting process to converge ([26]). Significance of the main effect was assessed using the Anova function from the car package ([27]). As expected, the model revealed a significant main effect of step ( $X_2 = 31.677$ ,  $p < .0001$ ). As shown in Table 2, all steps significantly differ from each other thus indicating that the percentage of *déplacé* responses progressively decrease from one point to the other point of the continuum.

Table 2 : z and p-values for pairwise comparisons between each step of the continuum

	z-value	p-value
Step 1 vs. 2	-4.104	<.0001
Step 2 vs. 3	-2.296	<.05
Step 3 vs. 4	-2.889	<.01
Step 4 vs. 5	-3.574	<.001
Step 5 vs. 6	-4.146	<.0001
Step 6 vs. 7	-4.337	<.0001
Step 7 vs. 8	-4.237	<.0001

Probit analysis ([28]) was also used to determine whether the identification curve has a sigmoidal shape rather than a linear shape (see [29], [30], [31], [32]). Regression lines were fitted to both the raw data (i.e., the percentage of *déplacé* responses for each step of the continuum) and to their transformed probit values. Since the regression lined fitted the raw data ( $X_2 = 0.4868$ ) more closely to the transformed data ( $X_2 = 0.4583$ ), it confirms that the identification curve has more a linear shape than a sigmoidal shape. Hence, it confirms that there is no sign of plateau at the beginning and the end of the continuum as it would be expected in case of categorical perception of accent by French listeners.

## 4. Discussion

In this study, we tried to tease apart the two main opposite views regarding the perception of prosodic boundaries. We thus examined whether French speakers perceive accentual information in a gradual manner or in a categorical manner. To do so, we tested participants on an acoustic continuum between an unaccented first syllable [depla'se] and an accented syllable [dɛ] [pla'se]. We obtain a linear identification curve rather than a S-shaped curve thus arguing in favor of a view assuming prosodic boundaries perception to be gradual. This gradual perception was confirmed by the fact that each point of the continuum significantly differed from each other and thus by the fact that the percentage of *déplacé* responses progressively decreased from the beginning to the end of the continuum.

It seems important to underline that we obtain a gradual perception in a paradigm known to favor categorical perception ([33]). This could suggest that the default processing of accentual information in French speakers is acoustically based. Nonetheless this does not mean that they are not able to build abstract categories on the basis of accentual information. Indeed, in an EEG experiment, we found some evidence for an abstract processing of accent ([34]). In this study, participants heard five words and made same/different decisions on the final word. The first four words were produced by four different female speakers and the last target words was produced by a male speaker. In the control condition, the five words had the same accentuation (/ʃu/-/'ʃu/-/'ʃu/-/'ʃu/-/'ʃu/) while in the different condition, they differed in accentuation (/ʃu/-/ʃu/-/ʃu/-/ʃu/-/'ʃu/). We observed a significant difference between the same condition and the different condition on the P200 component which is known to reflect phonological/abstract processing. It should be noted that this abstract processing of accentual information has been demonstrated in a situation that encourages participants to process accent abstractly by introducing acoustically variable stimuli produced by different speakers. Hence, when acoustic variability is introduced in the stimuli, French speakers rely on abstract processing of accentual information to classify a syllable or a word as accented or not.

Based on these studies, it seems that acoustic processing occurs in simple tasks in which only one speaker is used while abstract processing is rendered possible in more complex tasks when several speakers are used (see also [1] for non-native accentual contrasts). Further studies could be done in the future with the categorical perception paradigm and several speakers to see whether the perception of accent in this particular situation becomes categorical.

The claim that categorical or gradual process of accent could be dependent of the task is somewhat compatible with an alternative view of prosodic hierarchy assuming that the way speakers perceive prosodic boundaries in a categorical or gradual manner depends of several factor. Among these factors, the number and the type of acoustic indices cuing the boundary ([19], [21]) and the location of the boundary within the utterance have been proposed ([17], [18]). In an interesting study, Petrone et al. [21] showed that the same IP boundary can be perceived either in a categorical manner or a gradual manner depending on the acoustic cue cuing the boundary. In this experiment, German participants were asked to identify bracketed lists on an three acoustic continuum ranging from a late Intonation Phase (IP) boundary (*Lola oder Mona*)<sub>IP</sub> (*und Lena*) to an early IP boundary (*Lola*)<sub>IP</sub> (*oder Mona und Lena*). The first acoustic continuum was created by manipulating

pauses from one point to the other point of the continua. Syllable duration and f0 were manipulated to obtain the second and third continuum. The results show that listeners gave more categorical responses when pauses were manipulated while they gave more gradual responses when duration and f0 were manipulated. Hence all these results concur in showing that the same information can be processed either in a categorical manner or in a gradual manner according to the experimental situation.

## 5. Conclusion

To conclude, our study shows that when tested on an acoustic continuum, French speakers process accentual information in a gradual manner. Because abstract processing of accentual information has also been reported in other experimental tasks, an alternative view of the prosodic hierarchy that takes into account the experimental situation seems the most appropriate framework to account for the nature of accent perception, at least in the French language.

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