EFFECT OF VOICING ON THE SELF-PERCEPTION OF EFFORT IN FRENCH CONSONANTS PRODUCTION

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ABSTRACT

This study aims to understand if and how French subjects perceive vocal effort in a production task. Vocal effort is engaged through all voiced phonemes. Consonants are particularly interesting because they constrain voice production in many ways. To study vocal effort in these phonemes, which also involve articulatory effort, we first want to assess if it is possible for speakers to perceive vocal effort. Ninety-six normal subjects produced 48 minimal pairs of items with a voicing contrast and indicated the item in each pair that required a greater effort. The results show an effect of voicing on the self-perception of effort in French consonants production with a larger effort produced for voiced consonants (62%) than for voiceless ones. This effect is modulated by the manner (stop > fricative), the placement (posterior > anterior) and the context (less vocalic > more vocalic). These results complete the theory of vocal effort mechanisms.

Keywords: voice production, vocal effort, voicing contrast, consonants, articulatory effort

1. INTRODUCTION

A vocal effort is a physiological, i.e., muscular, effort made to produce the voice. This phenomenon is engaged through all voiced phonemes, but it is more commonly studied in vowels [4, 5, 9, 10, 11]. Here, we propose to study the vocal effort in voiced consonants because their articulation parameters (manner and placement) constrain voice production in ways described below. Consonants primarily involve an articulatory effort studied by Malécot [7]. During their production, voicing could involve an additional effort (the vocal effort). We decided to study this vocal effort in French speakers because the voicing contrast is simple in this language: it only occurs on the vocal folds vibration and not on the glottal aspiration [3].

The aim of our work is to complete the theory of vocal effort mechanisms at different production levels: aerodynamic, articulatory, acoustic, etc. In this particular study, we question the self-perception of vocal effort during French consonant production. Indeed, subjects are not always conscious of their vocal effort as speakers may present an abusive vocal effort, leading to vocal folds lesions, such as nodules, or even dysphonia. Therefore we question people’s ability to perceive a normal vocal effort: Are normal subjects sensitive to changes in muscular tension that are necessary for modulating air pressure in order to produce voice during speech? To investigate, we compared voiced and voiceless consonants with a similar articulatory effort, i.e., the same articulation manner, same articulation place and same vocalic context.

Voice production requires adduction of the vocal folds and a build-up of transglottal pressure to initiate and sustain a vocal folds vibration [1]. In consonants, unlike in vowels, the airway constriction increases the supraglottal pressure [2], therefore decreasing the transglottal pressure. Thereby, voice production during consonants requires an increase of the vocal folds adduction, an increase of the subglottal pressure level, or both. Consequently the vocal effort, i.e., the muscular tension, is greater in voiced consonants than in vowels and, therefore, it should be perceived more easily. In the present study, our hypothesis is that the self-perception of the production effort is greater in voiced consonants, which involve an articulatory effort plus a vocal effort, compared to voiceless consonants, which only involve an articulatory effort.

For voiced consonants, the increase of supraglottal pressure varies according to manner and placement parameters. Regarding the articulation manner, the supraglottal pressure increases more for stop than for fricative consonants. Indeed, the supraglottal cavity is closed during stop consonant production; thus, the air pressure increases to the maximum, whereas the supraglottal cavity is slightly open during fricative consonant production; thus, some air flows out and the pressure does not reach its maximum value. Therefore, the effort to initiate and sustain a vocal folds vibration is theoretically greater in stop consonants than in fricative ones. Regarding the articulation place, the transglottal pressure increases faster for posterior than for anterior consonants. Indeed, the supraglottal cavity is smaller during posterior consonant production; thus, the air pressure quickly reaches a ceiling value, whereas the supraglottal cavity is bigger during anterior consonant production; thus, the air pressure slowly reaches the ceiling value. The effort to initiate and sustain a vocal folds vibration is theoretically greater in posterior consonants than in anterior ones.

For voiced consonants, the vocal folds adduction and the build-up of transglottal pressure vary according to the context. They both sustain greater increases between silence and a voiced consonant (C) than between a vowel (V) and a voiced consonant. Indeed, during a silence, the vocal folds are abducted and there is no transglottal pressure; whereas during the production of a vowel, the vocal folds are already adducted and there is positive transglottal pressure. Thereby, the effort to initiate or sustain a vocal folds vibration is theoretically greater with no vocalic context (#C#) than with a vocalic context (VC# to initiate; #CV to sustain) and greater with a partial vocalic context than with a complete vocalic context (VCV).

In this study, we question normal subjects' ability to perceive their vocal effort during the production of consonants. We state in the primary hypothesis that there is an effect of voicing on the self-perception of effort in consonant production with voiced consonants requiring more effort than for voiceless consonants. We state three secondary hypotheses:

- There is an effect of articulation manner with a larger voicing effect for stop consonants than for fricative consonants.
- There is an effect of articulation place with a larger voicing effect for posterior consonants than for anterior consonants.
- There is an effect of context with a larger voicing effect for less vocalic contexts than for more vocalic contexts.

2. EXPERIMENT

2.1. Subjects

Ninety-six subjects participated in this study. They were volunteers with no voice, articulation, hearing, reading or cognition disorders. The subjects were equally distributed in 2 sex groups (female; male), 4 age groups according to the decade in which they were born (1960s; 1970s; 1980s; 1990s) and 2 instruction groups described below (difficult; easy).

2.2. Materials

Six pairs of French consonants (C) with a voicing contrast were selected. They differed from each other in manner and placement, as presented in Table 1. The pairs of consonants were set in 4 contexts with the open vowel (V) /a/: nonsyllabic (unvocalic: #C#), monosyllabic (prevocalic: #CV; postvocalic: VC#) and disyllabic (intervocalic: VCV). These 24 pairs were presented in 2 orders (item_1-item_2; item_2-item_1).

Table 1: Classification of the 12 studied French consonants

Place		Voicing	Manner	
			Fricative	Stop
Labial	Labial	+		b
		–		p
	Dental	+	v	
		–	f	
Apical	Alveolar	+	z	d
		–	s	t
	Postalveolar	+	ʒ	
		–	ʃ	
Dorsal	Velar	+		g
		–		k

The 48 pairs of items were mixed with 188 filers (pairs with a context contrast, a manner contrast or a placement contrast) and presented in a randomized order through 4 blocks (pages of 4 columns and 21 lines). The first block was performed on average in 8m 54s (SD = 1m 57s) and the last one in 6m 17s (SD = 1m 32s).

2.3. Methods

The experiment took place in a quiet environment with 2 different groups of subjects. The subjects were asked individually to read each pair aloud, marking a silent pause between the 2 items and circling the item they found either more difficult or easier to produce, according to instruction. They were allowed to repeat the items. They were not allowed to whisper. A 5 minute rest was made between blocks.

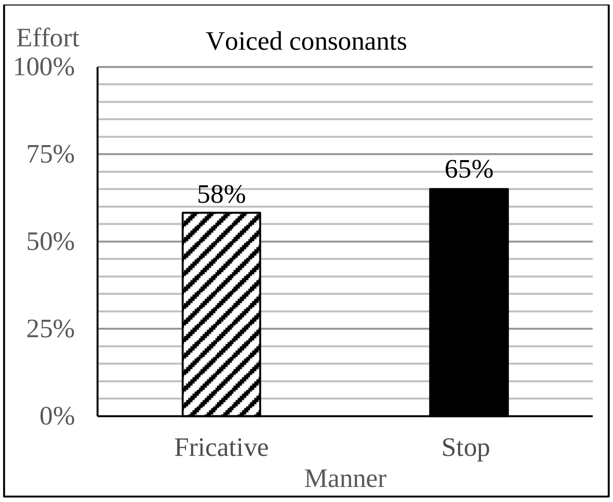
Data were manually encoded in an Excel sheet (item_1: 1; item_2: 2). Statistical analysis (ANOVA) were performed with Statview software. We calculated the Fisher's value (F), the p-value (p) and the effect size (R^2).

3. RESULTS

There is a significant effect of the voicing on the self-perception of effort in French consonant production ($F(1,4607) = 261$; $p < 0.0001$; $R^2 = 5.4\%$) with a greater effort for voiced consonants (62% of effort) than for voiceless consonants. However the effort for voiced consonants varies across subjects from 33% to 94% ($F(95,4512) = 3$; $p < 0.0001$; $R^2 = 6.3\%$).

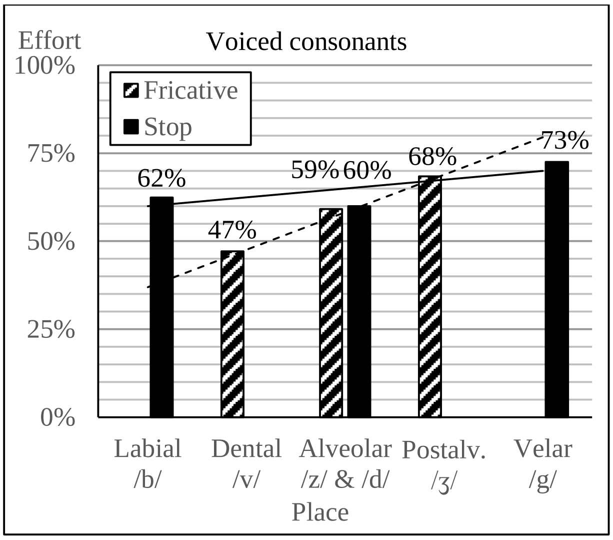
This voicing effect is slightly modulated by the articulation manner with a larger effect for voiced stop consonants than for voiced fricative consonants ($F(1,4606) = 22$; $p < 0.0001$; $R^2 = 0.5\%$) as shown in Figure 1. In addition, the voicing effect is maintained for all items with stop consonants (from 55% of effort for "ada" to 79% of effort for "g"); whereas it is reversed for a quarter of the items with fricatives ("va" and "ava": 34% of effort; "aza": 46% of effort).

Figure 1: Percentage of effort in the production of voiced consonants, according to the articulation manner.



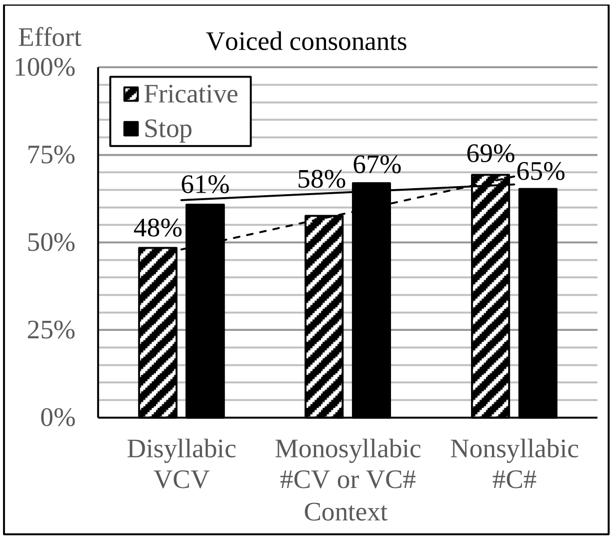
The voicing effect is modulated by the placement parameter ($F(4,4603) = 32$; $p < 0.0001$; $R^2 = 2.7\%$) with a greater effort for voiced posterior consonants than for voiced anterior consonants. There is a crossed interaction with the articulation manner ($F(2,4602) = 9$; $p < 0.0001$; $R^2 = 0.4\%$): the effect size is larger for the fricative consonants than for the stop consonants, as illustrated in Figure 2.

Figure 2: Percentage of effort in the production of voiced consonants, according to the articulation place and the articulation manner and linear trend line, according to the articulation manner.



The voicing effect is also modulated by the context parameter ($F(2,4605) = 20$; $p < 0.0001$; $R^2 = 0.9\%$) with a greater effort for voiced consonants in less vocalic contexts than for voiced consonants in more vocalic contexts. There is an interaction with the articulation manner ($F(2,4602) = 10$; $p < 0.0001$; $R^2 = 0.4\%$): the effect size is greater for the fricative consonants than for stop consonants, as illustrated in Figure 3.

Figure 3: Percentage of effort in the production of voiced consonants, according to the vocalic context and the articulation manner and linear trend line, according to the articulation manner.



4. DISCUSSION

The purpose of this study was to assess if French subjects could perceive their vocal effort while producing consonants. The primary hypothesis was that subjects would perceive more effort during the production of voiced consonants than during the production of corresponding voiceless consonants. This hypothesis is confirmed: the results show that normal subjects are able to perceive different steps of vocal effort during their production of voiced consonants. However, only 62% of all the voiced consonants are perceived to require more effort to produce than voiceless consonants. It means that a third of the voiceless consonants are perceived to require more effort to produce than the voiced ones. These results may be due to the articulatory effort: voiceless consonants referred as “tense” can involve a larger constriction than voiced consonants referred as “lax” [6, 7, 8]. There is also a wide range of subject effect in the perception of voice production in consonants (from 33% to 94%). In French consonants, the voicing contrast occurs only on the vocal folds vibration. Further studies could be conducted in another language with a voicing contrast occurring also on the glottal aspiration to investigate if the additional abduction movement in aspirated voiceless consonants increases or decreases the perception of effort during the production of these phonemes. Thereby, it could help the comprehension of the proprioception mechanism involved during speech production: Are normal subjects more sensitive to muscular tension or to air pressure?

The three secondary hypotheses are confirmed. The voicing effect is larger for stop consonants than for fricative consonants. Furthermore the voicing effect is constant for the stop consonants: Voiced ones are perceived as requiring more effort than voiceless ones for every articulation place and in every context. However, there is a lot of variation for the fricative consonants: Voiced ones are perceived as requiring the same or less effort than voiceless ones according to the dental placement and in the disyllabic context.

The voicing effect is larger for the posterior consonants than for the anterior consonants. This result seems to be due to the cavity size. However, other parameters can be involved. Indeed, the effect size is greater for the fricative consonants than for the stop consonants even when accounting for the distance between the most posterior (postalveolar) and the most anterior (dental) fricative consonants. Thus the difference in the cavity size is smaller than the distance between the most posterior (velar) and the most anterior (labial) stop consonants. This can be related to muscular control during the articulatory effort of producing fricative consonants: To manage the transglottal pressure, the subject may increase constriction during the production of a posterior fricative consonant but decrease it during the production of an anterior fricative consonant. Further studies could be conducted in other languages, allowing comparisons between stop and fricative consonants in the same articulation places to answer this question.

The voicing effect is larger for the less vocalic contexts than for the more vocalic contexts. Obviously, the production of a single consonant without vocalic context is an unnatural task. Consequently, it was not surprising that subjects found this context more difficult, especially for voiced consonants because the vocal folds vibration has to be produced for a very short sequence. The voice production in vowels is theoretically easier than in consonants because there is almost no supraglottal pressure in vowels; thus, there is no resistance against the vocal folds adduction and no restriction to the build-up of transglottal pressure. As a consequence, a vocalic context can facilitate voice production of adjacent consonants. Another explanation of this effect can be the consonant duration, which is smaller for the intervocalic (VCV) consonants than for the postvocalic (VC#) and prevocalic (#CV) consonants [12]: Subjects could have perceived more effort in longer consonants. Here again, the effect size is greater for fricative than for stop consonants. Because the airway is closed during stop consonants, the resistance against the vocal folds adduction and the restriction of transglottal pressure is more constant than in fricative consonants for all contexts.

The accuracy of our results may have been reduced by some procedural parameters. Subjects may have been less focussed on the perception of their production than on the reading task. Moreover, they were asked to read phonetic symbols, especially /ʃ/ and /ʒ/. In addition, the task duration was long, leading to reading mistakes and loss of attention. Further studies could be conducted in French with a repetition task or a listening task. In a repetition task, subjects may focus more on their production than on the items, which would not be written. In a listening task, subjects may preferably focus more on their own perception than on the task, because they would have nothing to do but make a choice.

In conclusion, our results show that vocal effort during consonants production can be perceived by normal subjects. Thus, we will conduct further studies on vocal effort in consonants to complete the theory of vocal effort mechanisms.

4. REFERENCES

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