

## CONTEXTUAL AND LEXICAL EFFECTS IN THE IDENTIFICATION OF FRICATIVES

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### ABSTRACT

This research studies the respective roles of the phonetic context and of the lexicon in the identification of [s] and [ʃ]. In a first experiment, subjects had to identify fricatives combined with different vowels. Results showed that vowel effects occurred at a post-perceptual stage of processing only. In a second experiment, the lexical status of the carrier string and the adjacent vowel were both manipulated. Lexical and vowel effects appeared to be non-additively combined in the identification of fricatives.

### INTRODUCTION

Phonetic segments are not produced independently of one another. Coarticulation is in fact considered to be a source of great acoustic variability. However, listeners do not seem to have major problems in identifying segments in the speech chain. It is assumed that a processing mechanism of some kind enables them to factor out any influence that segments have on each other. This is confirmed by experimental evidence which shows that listeners do indeed make compensatory adjustments in the identification of a segment as a function of its phonetic context.

In this domain, a great deal of attention has been devoted to context-dependent variations in the identification of coronal fricatives. In an /s/+V sequence in particular, the fricative acous-

tic shape is known to be sensitive to the rounded/unrounded character of the subsequent vowel. When combined with a rounded vowel, /s/ is most often produced with an anticipatory rounding of the lips, which results in a lengthening of the front cavity, and therefore in a lowering of the noise frequency in the fricative spectrum. Perceptual studies have shown that such acoustic variations appear to be compensated for in an identification task, as a fricative on a [s]-[ʃ] continuum is more frequently identified as /s/ in the vicinity of a rounded vowel [4, 10].

This research studies the respective roles of the phonetic context and of the lexicon in the identification of /s/ and /ʃ/ in French. Two major issues have been addressed. First, I have attempted to determine the level of processing at which the phonetic context comes into play in a fricative identification task. While some theories of speech perception (e.g. [2]) postulate that one segment can have a direct influence on how an adjacent segment is perceived, it may be also hypothesized that the phonetic context is only taken into account at a post-perceptual stage of processing, as a decision bias [7]. Second, I have examined how the influence of adjacent segments may interact with contextual effects of another nature, namely lexical effects. Previous work has shown that the /s/-/ʃ/ categorical boundary can shift as a function of the lexical status of the carrier string [3]. However, to my knowledge, there is

still no study on how informations from both the phonetic context and the lexicon are combined, especially when these two types of information provide conflicting cues concerning the identity of the fricative.

### EXPERIMENT 1

The goal of Experiment 1 was to examine whether vowel effects in [s] and [ʃ] identification can also be observed in French. In addition, an attempt was made to characterize the stage of processing at which such contextual effects are likely to occur.

### Material and Method

An 11-step [s]-[ʃ] continuum was created from one natural [s] and one natural [ʃ], using the procedure described in [3]. Each of the fricative stimuli was then combined with either [a], [i] or [u] (natural tokens). In total, the material was made up of 33 CV syllables which were presented to 30 listeners in a fricative identification task (forced choice).

It was assumed that the identification scores would vary as a function of the vowel degree of lip rounding (more "s" responses for [u]) as well as of the vowel place of articulation (less "s" responses for [i], see [10]).

### Results

The proportions of "s" responses for each fricative stimulus and each adjacent vowel are presented in Figure 1 (the [s] and [ʃ] endpoint stimuli are on the left and on the right, respectively). This figure shows that the vowel effects on fricative identification described in previous work were replicated here. As predicted, the [s]-[ʃ] categorical boundary moved toward the [ʃ] endpoint in the context of a back rounded vowel ([u]), and toward the [s] endpoint in the context of a front unrounded one ([i]). Differences in the mean percentage of "s" responses (averaged over the 11 fricative stimuli), as a function of the adjacent vowel, were sig-

nificant ( $F(2, 58) = 13.93, p < .001$ ).

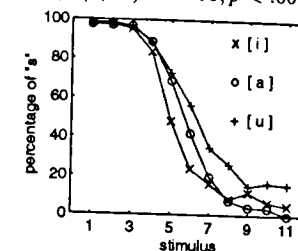


Fig. 1. Effect of vocalic context on fricative identification.

To determine at which processing stage the vowel came into play in the identification of fricatives, two models making different predictions on this point were tested against the results. The first model was formally identical to Masaro's Fuzzy Logical Model of Perception (FLMP) [5, 6]. In this model, the fricative and the adjacent vowel were considered as two independently-evaluated sources of information. It was hypothesized that the vowel had an effect on the fricative categorization, but did not have any influence on how the fricative was internally represented in terms of features. The fricative acoustic structure was represented by one continuous-valued feature ( $F_1$ ), ranging from 0 ([ʃ]) to 1 ([s]). The vowel acoustic structure was also represented by one feature ( $F_2$ ), ranging from 0 ([i]) to 1 ([u]). The degree of match with the prototypes /s/ and /ʃ/ was determined by means of multiplicative combination rules.

The second model was itself similar to the featural modifier model (FMM), also presented in [6]. In this model, the context was represented by one parameter,  $C_j$ , which was combined with the fricative stimulus information at the prototype matching stage by means of the following rules:

$$\begin{aligned} /s/ &= F_1^{C_j} \\ /ʃ/ &= (1 - F_1)^{C_j} \end{aligned}$$

This model postulates that the vocalic context has a direct influence on

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the fricative stimulus-to-feature mapping ([6]; see also [7, p. 369]). The root mean square deviation (RMSD) between the observed and predicted values was calculated for each model and each subject. It appeared that the FLMP made more accurate predictions than the FMM for a majority of subjects (24 out of 30). The average RMSD was significantly higher for the FMM (.1) than for the FLMP (.05;  $t(29) = 4.87, p < .001$ ).

In a second step, the observed results were submitted to a sensitivity analysis. It was assumed that, if the adjacent vowel directly affected sensitivity<sup>1</sup> in the fricative identification task, than the discriminability between adjacent stimuli along the [s]-[ʃ] continuum would differ depending on the vowel category [5, 9]. The fricative discriminability was determined on the basis of the  $d'$  measure. A  $d'$  value was computed for each pair of adjacent fricative stimuli and each vowel from the proportions of "s" responses [5]. The cumulative sum of  $d'$  averaged over the 30 subjects for each vowel is presented in Table 1.

Table 1. Mean cumulative  $d'$

V2	N	mean	SD
a	30	5.23	1.16
i	30	5.45	1.31
u	30	4.91	1.42

Although differences in the mean cumulative  $d'$  were observed between vowels, a one-factor ANOVA showed that these differences were not significant. Thus, the  $d'$  analysis and the model assessment gave convergent results. They both tended to indicate that the vowel played a significant role at the decision stage only, in the identification of fricatives.

## EXPERIMENT 2

The goal of this experiment was to characterize the way in which a potential influence of the lexicon on fricative categorization, would be combined with

<sup>1</sup>And not only bias.

that of the phonetic context. The main issue was whether one of these two effects would dominate the other, when they push the subject to make opposite predictions about the fricative category.

## Material and Method

The material was composed of 16 11-step [s]-[ʃ] continua embedded in different carrier sequences. For one half of the continua, the [s] endpoint formed a word and the [ʃ] endpoint a nonword (ex.: *soulier-choulier*). For the other half, the [ʃ] endpoint formed a word and the [s] endpoint a nonword (ex.: *sapeau-chapeau*). The lexical status of the carrier string was orthogonally combined with two other variables, namely a) the identity of the vowel following the fricative ([a], [u]) and b) the position of the fricative within the carrier string (initial, median). The stimuli were presented to 26 subjects in a fricative identification task.

## Results

Figure 2 shows the mean percentage of "s" responses for the two adjacent vowels, when the [s] endpoint formed a word (upper line), and when it formed a nonword (lower line). There was a main effect of the adjacent vowel ( $F(1,25) = 11.54, p < 0.005$ ), a main effect of the lexicon ( $F(1,25) = 28.17, p < 0.001$ ), and a significant vowel  $\times$  lexicon interaction ( $F(1,25) = 11.87, p < 0.005$ ). Thus, there was an effect upon the fricative categorization both of the following vowel and of the lexical status of the carrier string. Moreover, these two effects did not appear to be statistically independent of each other.

An attempt was made to characterize the origin of this interaction, by testing two different models against the results, as in Experiment 1. The first model was derived from the FLMP already presented above. The only difference was that a third feature ( $F_3$ ), representing the degree of "s-lexicality" was introduced.

The values of  $F_3$  ranged from 0 ([s] endpoint forms a nonword) to 1 ([s] endpoint forms a word).

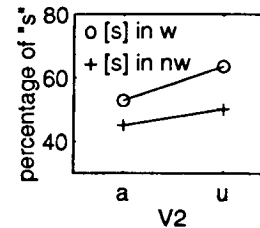


Fig. 2. Effect of vocalic context and of lexicon on fricative identification

The second model was identical to the first one, except that the features were combined with each other using an additive rather than a multiplicative rule. This model predicted that the vowel effect and the lexical effect would not interact with each other. The results showed that the multiplicative rule accounted for the observed results more accurately than the additive rule for 24 out of 26 subjects. The average RMSD was significantly lower for the first model (.08) than for the second one (.11;  $t(25) = 6.26, p < .001$ ).

## CONCLUSION

Our results tend to indicate that while the quality of the adjacent vowel may modify the respective probabilities of alveolar and post-alveolar responses in an [s]/[ʃ] identification task, it does not have any influence on sensitivity. Such results are in good agreement with segmental models of speech perception in which the phonetic context comes into play at a post-perceptual level only, to bias responses in one direction or another [1, 7]. When the lexical status of the carrier string was manipulated as well as the adjacent vowel, both factors had an influence upon the fricative categorization. Although the interaction that was observed between these two factors might

be simply due to a floor effect (the percentage of alveolar responses could not come down below a certain threshold, whatever the phonetic and lexical context), it may also indicate that vocalic and lexical cues to the fricative category are non-additively combined in a fricative identification task.

## ACKNOWLEDGEMENTS

Work supported by the Swiss Federal Office for Education and Science (project # 93.0351). I am grateful to Uli Frauenfelder for helpful comments.

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