

ON THE ACOUSTIC CHARACTERISTICS OF FRENCH SCHWA

Fougeron¹, C., Gendrot¹, C. & Bürki^{1,2}, A

¹Laboratoire de Phonétique et Phonologie, UMR 7018, CNRS-Paris 3/Sorbonne Nouvelle, France

²Laboratoire de Psycholinguistique expérimentale, Université de Genève, Suisse
{cecile.fougeron ; cedric.gendrot}@univ-paris3.fr, audrey.buerki@pse.unige.ch

ABSTRACT

This paper presents an acoustic study on the phonetic properties of French schwa based on the analysis of a large corpus of radio broadcasted news. In order to address the question of whether the optional status of schwa correlates with a specific phonetic nature, optional French schwa is compared to its neighboring full front rounded vowels /ø/ and /œ/, and to obligatory schwas. While optional schwas overlap with the acoustical space of its neighbors (being closer to /ø/), it differs from both /ø/ and /œ/ in terms of aperture, degree of rounding, duration and variability of F2. Optional schwas differ from obligatory schwas by a greater aperture.

1. INTRODUCTION

Optional schwa (or mute-e) in French is defined as a vowel alternating with Ø in the same lexical context (e.g. ‘fenêtre’ can be pronounced as [fənɛtʁ] or [fnɛtʁ]). While multiple factors are known to favour the elision or non elision of the schwa, this process is quite hard to predict. Alternating (optional) schwa can occur word internally or at various boundaries (word-, clitic-, derivational suffixe- or inflectional ending-boundaries) (see [1] for a review).

While the process of schwa elision in French has been extensively studied in the phonological literature, the exact phonetic nature of French schwa is rather controversial. A survey of the phonetic and phonological literature shows that if claims about its nature are given on several occasions, few quantitative analysis of the realization of this vowel are presented. First, the same few studies are being systematically quoted while they are generally restricted to the production of a few speakers and a few words, when they are not simply based on impressionistic judgements (see [6, 2] for a review). Second, the results of these studies show a lack of unanimity concerning its phonetic realization. In a few

studies, schwa is described as having a specific spectral quality, being more central, with an intermediate aperture between [ø] and [œ] and a shorter duration (e.g. [8]). However, in most of the existing studies schwa is presented as a vowel lacking a specific timbre (or even target), and is said to neutralize with either [ø] or [œ] or both. Its realization is also mentioned to vary depending on speaker, French varieties or context and in the evolution of French pronunciation.

In several phonological theories, however, it is assumed that schwa is closer in quality to [oe] and is represented as an optional /œ/ (e.g. [7, 10]). This representation is surprising when considering the results of [6], the largest statistical study we are aware of. This study is based on 3000 schwas produced in conversations by 32 speakers. Although this paper does not offer a precise description of the material used (e.g. types of schwas, of words), nor numerical values allowing a spectral definition of the vowel, the authors describe schwa as being shorter than full vowels, and closer in timbre to /ø/ than to /œ/. Interestingly, they show that if the discrimination (by a computer) is poor between /ə/ and /ø/, /ə/ is also confusable with /œ/ as well as with /e/ and /y/.

In the present study, our main objective is to carry out a thorough quantitative examination of the acoustic realization of schwa based on a relatively large natural corpus of spoken French, including a large number of lexical items, and thus phonetic contexts, various speakers and multiple occurrences. The first question addressed is whether schwa differs in its spectral and durational properties from the front rounded mid-closed and mid-open vowels /ø/ and /œ/. Our second research question concerns the particular phonological status of schwa in French. Is the optional nature of the schwa reflected by a difference in the phonetic nature of this vowel? The hypothesis is that the optional nature of the vowel may correspond to a greater spectral and/or durational variability compared to full, non-alternating vowels. To

address these questions the phonetic properties of optional schwa are compared to that of /ø/ and /œ/, and to that of obligatory (or non-alternating) schwas occurring in certain French words with the particularity to be always pronounced (e.g. 'belette' *weasel* [bølet]). Comparisons are made in terms of durational properties, spectral characteristics on F1 and F2, but also F3, as well as in terms of acoustic stability.

2. METHOD

Several French lexical databases (Brulex, Lexique, ILPho, completed by Le Grand Robert) have been merged in order to constitute a repertory of 18.553 French words containing a schwa (obligatory or optional), excluding schwas appearing at word or clitic boundaries or in a compound.

The categorization of schwas as optional or obligatory was not straightforward. We first tried a manual coding of the frequency to which we estimated that the form could be 'heard' without its schwa. The examination of a sample of the corpus revealed a great disparity in the judgements of the 3 authors. We thus chose a more objective method based on the analysis of the actual realization of these words in a speech database. The ESTER corpus developed for the evaluation campaign for the Rich Transcription of French Broadcast News [3] was used. It includes 24h of speech for a total of 574 speakers. On the basis of the transcription given by the automatic recognition system developed at IRISA, we categorized the words occurring in the corpus as having an obligatory schwa if they had always been recognized by the system as produced with schwa. Optional schwas, on the other hand, were those occurring in words that were produced in the corpus both with and without elision. As the automatic transcription results are highly dependent on the pronunciation dictionary, a manual correction was done for the recognition errors and for the words obviously containing an optional schwa but appearing in the corpus only with the schwa (e.g. 'jeter' *to throw*).

Then, we selected for the comparison two sets of words containing a /ø/ or a /œ/, which were produced in the ESTER corpus in a pre-consonantal position, and whose structure was as closed as possible to that of schwa-words.

For a first analysis, we decided to eliminate the schwas occurring before derivational suffixes or inflectional endings (non-nucleus schwas [9]), and occurring in words appearing less than 6 times. Due to

the large influence of /R/ on formant frequencies and to the unbalanced distribution of the 4 vowel categories (/ø/, /œ/, obligatory and optional /ə/) in this context (due to phonotactic constraints), we decided to first consider only the vowels occurring in a non-uvular context.

In order to compare the 4 vowel categories, 180 speakers producing at least one occurrence of all four vowels were selected for analysis. The vowels were segmented automatically by the recognition system. Vowel duration and F1, F2, F3 values were computed with Praat. Measurements were taken respectively at 1/3, 1/2, 2/3 of the vowel segment, and then averaged to provide a single formant value. Formant values were then filtered in order to reject erratic items, with respect to the acoustics of the vocal tract (see [4]) and a Gerstman [5] normalization procedure was applied on the data for speaker normalization. Table 1 gives a description of the material used for the comparisons of the 4 vowels categories, extracted of a total of 370 different words corresponding to a total of 4843 occurrences. In order to minimize the effect of the unbalanced samples in each of the 4 vowel categories statistical comparison was performed with unpaired t-tests.

Table 1: Distribution of the 4 vowel categories according to their number of occurrences and the different words in which they occur in the corpus.

Categories	Occurrences	Diff. words
optional /ə/	1857	167
/ø/	1928	99
/œ/	748	64
obligatory /ə/	310	40

3. RESULTS

3.1. Comparison with /ø/ and /œ/

As shown in the selected examples of Figure 1, optional schwa appears to overlap in the acoustic space with the full vowels /ø/ and /œ/, and it looks closer to /ø/ than to /œ/. However, statistical comparison of formant values pooled over the 180 speaker productions shows that optional /ə/ is a distinct vowel in the three F1, F2 and F3 dimensions, as shown in Table 2 and 3. It differs from /ø/ by a higher F1 ($t(3783)=3.2$, $p<.001$), F2 ($t(3783)=5$, $p<.0001$) and F3 ($t(3783)=9.7$, $p<.0001$). It also differs from /œ/ by a lower F1 ($t(2603)=32.1$, $p<.0001$), a higher F2 ($t(2603)=4.9$, $p<.0001$) and a lower F3 ($t(2603)=2.9$, $p=.004$). Taken together these results suggest that /ə/

has an intermediate degree of aperture (more open than the mid-closed /ø/ but less open than the mid-open /œ/) and is less rounded than /ø/ (as shown by a higher F3) and more rounded than /œ/ (lower F3). Interpretation of the difference in F2 with /œ/ and /ø/ (higher for /ø/) is uncertain. It could be due to a difference in fronting, rounding, or contextual coarticulation effects. Although a closer examination of the influence of the consonantal contexts remains to be done, the two vowels do not differ tremendously in their distribution. Nonetheless, schwas occur slightly more frequently in a coronal context than /œ/, which could explain a raise of F2.

Schwa also differs from the full vowels in terms of duration. Schwa vowels (50 ms, 15% relative to word length) are in average more than 15 ms shorter than that of /ø/ (67 ms, 34% of word length) and /œ/ (65 ms, 23% of word length).

Acoustic stability of the vowels was compared in terms of the variability in F1, F2 F3 and duration. Statistical comparison (t-tests) is made on the absolute deviations from the mean for these measures. Results show that the optional vowel, compared to the full /ø/ and /œ/ vowels, is more variable in terms of F2, while it is less variable in terms of F3 compared to /œ/ and in its duration compared to the two full vowels.

3.2. Inter-speaker variability

In order to perform inter-speaker comparison, we selected speakers having at least 15 occurrences of the 3 vowels categories: optional schwa, /ø/ and /œ/. Only 12 speakers out of 180 could be compared on this basis. Examination of their realization replicates the speaker variation often mentioned in the literature, as illustrated by the pattern of the two speakers presented in Figure 1.

For 3 of the 12 speakers, optional /ə/ is pronounced as /ø/, while none of our speakers merged it with /œ/. Speaker 12, presented in Figure 1, illustrates such a neutralization of optional /ə/ with /ø/ (note that for this speaker there is a large overlap between all the vowels). For the other 9 speakers, optional /ə/ are significantly distinct from /ø/, but the way the vowel differs is speaker dependent. Two speakers distinguish the two vowels by their 3 formant values. Speaker 10, illustrated in figure 1, is one of them. The other 7 speakers have a difference in either F1, (2/7 spks), F2 (3/7 spks), or F3 (2/7 spks). Differences with /œ/ also vary according to speakers: only one speaker differentiates optional schwa from /œ/ by its 3 formants, 6 speakers by F1 alone (among them:

speakers 10 and 12), 4 speakers by F1 and F2, and 1 speaker by F1 and F3.

Table 2: Significant statistical differences between the 4 vowel categories according to the parameters measured. OPT for optional and OBL for obligatory schwas, D for duration.

	/ø/	/œ/	OBL
OPT	F1 F2 F3 D	F1 F2 F3 D	F1
/ø/		F1, F3	F2, F3, D
/œ/			F1, F2, D

Table 3: Mean (& standard deviation) formant values for the 4 vowel categories averaged across the 180 speakers with a Gerstman's speaker normalization (all values reset from 0 to 1000 normalized Hertz).

	F1	F2	F3
OPT	260 (168)	638 (165)	457 (202)
/ø/	244 (159)	609 (186)	392 (211)
/œ/	514 (214)	602 (172)	483 (226)
OBL	233 (147)	632 (160)	470 (194)

3.3. Phonetic properties of optional schwas compared to obligatory schwas

Optional schwas appear in our corpus as more open than obligatory schwas as shown by a higher F1 ($t=2.7$, $p=.007$). Indeed obligatory schwas have a similar F1 as the mid-closed /ø/ (see table 2). The two types of schwa do not differ in F2, F3, or in duration. No comparison is made for the acoustic stability of the vowels since obligatory schwas appear in our corpus in a much limited set of words, hence context types, than the other vowels (see Table 1). This limited set for this vowel does not allow either inter-speaker comparison.

4. DISCUSSION AND CONCLUSION

The present analysis of about 2000 optional schwas produced by 180 speakers shows that schwa has a distinct acoustic identity (duration, F1, F2, and F3) from the full front-rounded vowels /ø/ and /œ/. Although some speakers do neutralize schwa with /ø/, acoustic differences are shown by most of the speakers we could analyze individually. Implications of these results for the phonological representation of optional schwas have to be considered.

Nevertheless, in the small acoustic space shared by these vowels, a large degree of overlap is striking. The contextual variability and articulatory reduction typical of the continuous style of speech analyzed in this study may explain part of it. In our comparison of the acoustic variability of the vowels, optional schwa appeared more unstable compared to its neighbouring

non-alternating vowels only in its F2 dimension. Knowing that F2 is greatly influenced by consonantal context, a closer examination of its permeability to consonantal influences has to be done. A comparison with the acoustical overlap of the other vowels produced by the same speakers would also help us to determine whether optional schwa is intrinsically more unstable. Moreover, schwa is also defined as the only syllable nucleus being never accented. Indeed, optional schwas in our corpus are characterized by lower f_0 values. Since unaccented syllables are shorter and possibly hypoarticulated, we have to investigate whether the observed acoustic properties of schwa are related to its shorter duration and lower f_0 .

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Figure 1: Acoustic realization of the 4 vowel categories in F1/F2 (left) and F2/F3 (right) dimensions by speaker 12 (higher panel) and 10 (lower panel). Labels are placed at mean values and ellipses represent a 10% degree of confidence. Gerstman's speaker normalization is used (all values reset from 0 to 1000 normalized Hertz).

