

On the phonetic identity of French schwa compared to /ø/ and /œ/

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Abstract

The phonetic identity of French schwa, compared to that of its front rounded neighbors /ø/ and /œ/, is examined in this study through the analysis of over 8000 vowels produced by 180 speakers in the ESTER corpus. Results show that schwa is distinguished from /ø/ and /œ/ by a shorter duration, but also by spectral differences on F1, F2, and F3. Although schwa looks closer to /ø/ than to /œ/ in the F1/F2 dimensions, it is characterized by an intermediate degree of aperture (F1) and rounding (F3), and by a higher and more variable F2 than /ø/ and /œ/. Inter-speaker variability and differences according to the influence of surrounding context are also discussed.

1 Introduction

Schwa in French is traditionally included among the front rounded vowels of the language, being fronter and more rounded than IPA schwa (Delattre 64, Carton 74, Léon 92, Ayres-Benett 01). Its exact phonetic quality, however, particularly in terms of aperture relative to the front rounded mid-closed and mid-open vowels /ø/ and /œ/, is rather controversial. In many phonological theories, it is usually taken for granted that schwa is phonetically identical to one of the mid front rounded vowels, and it is often described as being closer to the mid-open vowel /œ/ (Morin 78, Fischer 80, Tranel 87, Walker 96). In Morin, for example, the underlying vowel /ə/ is re-analyzed as a kind of instable /œ/ which has the property to alternate in particular contexts. However, while a rationale for this can be found in the fact that /ə/ and /œ/ do not contrast and are in a quasi-complementary distribution, the merging of schwa with /œ/ mostly relies on impressionistic judgments and is not supported by strong phonetic arguments. Indeed, various phonetic descriptions have been reported in the literature for this vowel. Few authors have argued in favor of a distinct quality for schwa, intermediate between /ø/ and /œ/. Rousselot (13) states that the three vowels correspond to 3 different degrees of aperture. Pleasant (56)'s acoustic study also shows that schwa has a distinct quality and that it is shorter than /ø/ and /œ/. However, the fine spectral differences observed and the fact that the author has asked the speakers to produce in isolation 3 different vowels (thus pre-defined as different) are subject to controversies (see Valdman 70). The largest acoustic study on schwa that we are aware of is the one conducted by Malécot and Chollet (77). While this study is surprisingly rarely cited in the phonological literature, its results are particularly interesting: they show that schwa is less discrete than the other French vowels and that it resembles /ø/ more than /œ/. These authors have compared more than 3000 occurrences of /ə/ with 350 /ø/ and 300 /œ/, produced in the conversations of 32 speakers. Their data show an expected great overlap between the three vowels, which is confirmed by a poor automatic discrimination (by a computer) between them. Interestingly, while 23% of the discrimination errors were found between /ø/ and /œ/, and 26% between /ə/ and /œ/, the discrimination between /ə/ and /ø/ yielded 40% errors. The distributions of /ə/ and /ø/ thus overlapped twice as much as those of /ø/ and /œ/. A linear discrimination procedure was then applied to classify the vowels for each speaker. /ə/ received the lowest (14%) identification score (followed by /œ/ and /e/, 22-23%), /ø/ and /œ/ being correctly identified 27% and 30% of the time, respectively. An analysis of the identification errors showed that /ə/ was more frequently misidentified than /ø/, thus confirming their closeness in timbre, but also that it was confused with /œ/ to the same extent as it was with /y/ or /e/. This variability in the phonetic identity of schwa has in fact been reported in many descriptions in the literature. Its pronunciation has

been said to vary between [œ] and [ø] depending on speakers, varieties of French, and segmental contexts (Delattre 47, 64; Tranel 87, Valdman 70). Cineradiographic data in Bothorel et al (86) for example show variable tongue and lips position according to consonantal context. Jetchev (03), while assuming that schwa is closer to /œ/, formalizes this variation by positing an archiphoneme /OE/ to account for the variable realization between [œ] and [ø] in open syllables, and uses the symbol /œ/ for its more open realization in closed syllables.

Considering the discrepancies in the various descriptions of French schwa, our aim in the present study is to carry out a thorough quantitative examination of its acoustic realizations based on a relatively large natural corpus of spoken French, including various different lexical items and thus phonetic contexts, many speakers, and multiple occurrences. The first question we address is whether schwa differs from the front rounded mid-closed and mid-open vowels /ø/ and /œ/ in its durational properties and in its spectral characteristics. The phonetic identity of the schwa is determined in this study not only by F1 and F2, but also by F3, which is particularly important to describe the front rounded vowels in French. Our second research question is related to the particular phonological status of French schwa. The hypothesis we want to test is whether the optional nature of this vowel translates into a greater variability compared to the full, non-alternating vowels /ø/ and /œ/.

2 Method

Our comparison of the phonetic properties of /ə/, /ø/, and /œ/ is based on the analysis of a subset of the ESTER corpus, a material developed for the evaluation campaign for the Rich Transcription of French Broadcast News (Galliano et al. 2005). This corpus includes 24h of radio broadcasts (included both pre-planned and spontaneous parts) produced by a total of 574 speakers. In order to select the appropriate lexical items in the corpus, a repertory of 18553 French words containing a schwa (obligatory or optional, excluding schwas appearing at word or clitic boundaries or in a compound) was constituted by merging several French lexical databases. The ESTER corpus was then searched for spoken occurrences of these words. In the present study, we are considering only *optional schwas*¹, and we are discarding lexical items where the schwa occurs before derivational suffixes or inflectional endings and words appearing less than 6 times in the corpus. This optional status was determined first on the basis of the automatic transcription of the corpus given by the recognition system developed at IRISA: words that were recognized in the corpus with both a schwa-full and a schwa-less pronunciations were categorized as containing an optional schwa, the others were classified as obligatory schwas. Since this criterion depends on the recognition performance, the variants included in the lexicon of the system, and the particular speaking style of the corpus, a manual correction was then applied to the categories on the basis of the authors' judgments on whether the schwas were elidable or not. For comparison, we selected 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 similar as possible to that of schwa-words. In order to compare the 3 vowel categories, 180 speakers producing at least one occurrence of all three vowels were selected for analysis. Finally, after eliminating the vowels with extreme duration (over +/- 3 standard deviation from the vowels mean duration), a total of 8236 vowels (3294 /ə/, 2031 /ø/ and 2911 /œ/) were selected.

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. F1, F2, F3 values were then filtered in order to reject erratic items, with respect to the acoustics of the vocal tract (see Gendrot & Adda-Decker 05) and a Gerstman (68) normalization procedure was applied on the data for speaker normalization.

¹ A comparison of optional schwas with the few obligatory (or non-alternating, as in 'belette', *weasel*) schwas occurring in the corpus can be found in Fougeron et al. (to appear). Optional schwas are found to be more open than obligatory schwas (the latter being closer to /ø/). No difference was found in F2, F3, nor in duration.

3 Results

3.1 Spectral and durational properties: a comparison of 4511 vowels, produced by 180 speakers, in a non-uvular context

For a first comparison of the spectral and durational properties of the three vowels pooled over the 180 speakers' productions, we chose to exclude the vowels produced in a uvular context. Rational for this can be found in the fact that the distributions of the vowels are particularly unbalanced in this context and because /R/ is known to affect greatly formant frequencies, as will be discussed in section 3.3. Thus, excluding both following and preceding uvular contexts, 1857 occurrences of /ə/ are compared with 1912 /ø/ and 742 /œ/.

Schwa is found to differ significantly from both /ø/ and /œ/ by a shorter duration [$F(2,4508)=182$, $p<.0001$]. Schwa is in average 50 ms long ($\sigma=17$ ms) and this duration corresponds to an average of 15% of word length, while the duration of /ø/ and /œ/ is 65 ms ($\sigma=29$ ms; 33% of word length) and 64 ms ($\sigma=31$; 23% of word length), respectively².

As illustrated in Figure 1, the three vowels have a rather central position. Schwa appears closer to /ø/ than to /œ/ in the F1 and F2 dimensions, and there is a large degree of overlap in their distributions. A statistical comparison with a multivariate analysis of variance (MANOVA, F value and significance level being estimated by Wilk's Lambda) was used to test for an effect of vowel type (/ə/ vs. /ø/ vs. /œ/) on the 3 formants taken together. Interestingly, these results show that schwa is in fact a distinct vowel in the three F1, F2, and F3 dimensions ($F(6, 9012)=238,9$, $p<.0001$). Schwa has an intermediate degree of aperture: it is more open than the mid-closed /ø/ with a significantly higher F1 than /ø/ but less open than the mid-open /œ/ with a significantly lower F1 ($p<.001$). Schwa also differs from the full vowels by an intermediate degree of rounding: it is less rounded than /ø/ with a higher F3 ($p<.0001$) and more rounded than /œ/ with a lower F3 ($p=.004$). Surprisingly, schwa also has a higher F2 than both /ø/ ($p<.0001$) and /œ/ ($p<.0001$). This difference in F2 is not fully understood. F2 height can be affected by a combination of several factors. F2 correlates with anteriority and schwa with a higher F2 would be fronter than /ø/ and /œ/. F2 is also affected by rounding: a higher F2 for schwa would mean a less rounded vowel. This holds true compared to more rounded /ø/ but not compared to less rounded /œ/, as determined by F3 values. F2 is also very much affected by consonantal context. Observation of the distribution of the three vowels according to the type of surrounding context shows that the 3 vowels are not distributed in the same way in the different following [$\chi^2(6)=774$, $p<.0001$] and preceding [$\chi^2(8)=664$, $p<.0001$] contexts. Nonetheless, schwa does not occur strikingly more frequently in contexts known to raise F2 (dental or post-alv/velar: 46% of /ə/ distribution, 27% for /œ/, 61% for /ø/). However, we cannot exclude that the F2 of schwa is higher than that of /œ/ because schwa occurs more often in a following context that raises F2.

In order to evaluate whether the 3 vowels differ in terms of variability of their 3 formants across tokens, a comparison was performed on the absolute deviation of F1, F2, and F3 from their mean values, according to vowel type. Since the achievement of articulatory targets (and thus formant patterns) does depend on the duration of the vowels, this analysis was done on a subset of the occurrences having comparable duration. After excluding the longer vowels (mostly /ø/ and /œ/), we selected vowels with a duration comprised in the interval corresponding to the mean duration of schwa ± 2 standard deviations, i.e. vowels inferior to 90 ms. 1648 /ø/, 629 /œ/ and 1825 /ə/ are concerned. Within this duration interval, the duration of /ə/ (50ms) remains significantly shorter than that of /œ/ (54ms) and /ø/ (56ms), and the spectral differences discussed above were replicated (i.e. schwa differs by an intermediate F1 and F3, and a higher F2). Variability of F1, F2, and F3 are found to vary according to vowel type (Wilks Lambda $F(6, 8194)=42.7$, $p<.0001$). F1 variability is found to decrease significantly from /œ/ to /ə/ to /ø/; F2 variability is greater for /ə/ compared to /ø/ and /œ/, and F3 variability is greater for /œ/ compared to the 2 other vowels. Thus, F2 of schwa, being on average higher than that of /ø/ and /œ/ for several possible raisons, is also more variable in the corpus.

² It has to be noted that these values are based on automatic segmentation with a resolution limited to 10ms and that the minimum duration of a segment is 30ms.

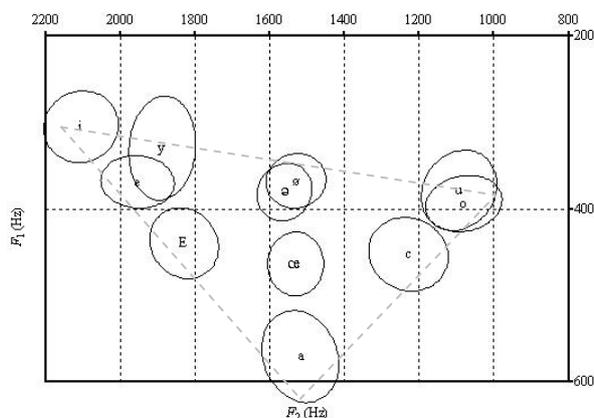


Figure 1: Distribution in the F1/F2 plans of /ə/, /ø/, and /œ/ produced by the 180 speakers in a non-uvular context. Other vowels produced by the same speakers in the whole corpus are included for comparison. For readability, non-normalized values are plotted.

3.2 Phonetic identity for 12 selected speakers

In order to perform a comparison of the production of the three vowels for different speakers, we selected speakers producing at least 15 occurrences of the 3 vowel categories. Only 12 speakers out of 180 could be compared on this basis. Examination of their realizations (excluding the uvular context) replicates the speaker dependent realizations of schwa mentioned in the literature. Four different patterns emerged, the first three shared by a minority: (a) one speaker does not distinguish between the three vowels; (b) one speaker merges /ə/ with /œ/ (spk 5, fig. 2a); (c) two speakers distinguish /ə/ from /œ/ but merge it with /ø/ (e.g. spk 8, fig.2b); (d) but, for the majority of the speakers, 8 out of 12, schwa differs from both /ø/ and /œ/. Replicating the differences observed when the 180 speakers were pooled, /ə/ is characterized by an intermediate degree of aperture for 4 out of these 8 speakers (with F1 > to /ø/ and < to /œ/) (e.g. spk7 figure 2b); /ə/ has a higher F2 than /ø/ for 4 speakers and than /œ/ for also 4 speakers; and /ə/ has an intermediate F3 for only 1 speaker, but 5 speakers have a higher F3, hence less rounding, for /ə/ than /ø/.

Presented in a different way, this inter-speaker analysis shows that /ə/ differs from /ø/ in the production of 9 out of 12 speakers. This is shown by a difference on either one (6 spks), two (1spk) or three formants (2 spks). In turn, /ə/ differs from /œ/ in the production of 10 speakers, as shown by a difference on either one (4 spks) or two formants (6 spks).

3.3 Consonantal influence on the spectral properties of schwa vs. /ø/ and /œ/

In order to test whether the 3 vowels are influenced by consonantal context in a different way, we tested for interaction between the effect of following and preceding contexts (labial vs. dental, labial vs. uvular) and vowel types (/ə/ vs. /œ/, /ə/ vs. /ø/) on F1, F2, and F3. Modification of the 3 formants depending on surrounding context is discussed in comparison to the labial context taken as reference. Only significant interactions and change in formant values are reported.

The effect of the type of *preceding* context appears to be quite dependent on vowel type, as illustrated for the F1/F2 dimensions in figure 2d. Significant interactions are found when comparing the effect of dental vs. labial contexts on /ə/ vs. /ø/ for F1, F2 (marginally for F3), and on /ə/ vs. /œ/ for F3 (marginally for F2). As shown in figure 2d, compared to the labial context, a preceding dental raises slightly F1 of /ə/ but lowers F1 of /ø/, it raises slightly F2 of /ə/ but strongly that of /ø/. The dental context also raises F3 of the 3 vowels but in a lesser extent F3 of /ə/. Thus compared to the labial context, the formants of schwa (at least F2 and F3) are less modified by a preceding dental than do the formants of /ø/, and to a lesser extent /œ/. To quantify this, a rough measure of the deviation is calculated by averaging the differences of the 3 formants values for each vowel between the 2 contexts: we observe a global deviation of 28% relative to the labial context for /ø/, 12% for /œ/, and 11% for /ə/. On the other hand, when

considering the effect of a preceding uvular vs. a labial context, this trend is reversed: /ə/ is more affected than the other vowels (63% deviation from the labial context for /ə/ vs. 15% for /ø/ and 29% for /œ/). A significant interaction between context (labial vs. uvular) and vowel type is found on F1 and F2 when comparing /ə/ to /œ/ and F1, F2, F3 when comparing /ə/ to /ø/: a preceding uvular context raises F1 of the 3 vowels but in a greater extent F1 of /ə/, it lowers F2 of the 3 vowels but the lowering is larger for /ə/, it raises F3 of /ə/ and /ø/ but again with a larger raise for /ə/. However, interpretation of these results needs to consider that there are much fewer /rœ/ (69 occ) and /Rø/ (86 occ) than /Rə/ (1201 occ).

The *following* context (not illustrated here) is modifying the formant values of the 3 vowels in a lesser extent than the preceding context. When averaging all the formant deviations for the 3 vowels, 7% deviation from the labial context is found when considering the following context, while 26% deviation can be attributed to the preceding context. There is also less interaction between the type of following context and the vowel identity. Compared to a following labial, a following dental context affects differently F1 of /ə/ and /œ/: it lowers F1 of /œ/ but does not modify much that of /ə/. An interaction is also found for F3 when comparing /ə/ and /ø/: a following dental lowers F3 of /ə/ but raises F3 of /ø/. A following uvular context affects also differently /ə/ and /œ/ with an interaction for the 3 formants: F1 is raised by a following uvular for both vowels but to a greater extent for /ə/, F2 and F3 are raised for /ə/ but lowered for /œ/. Again, these results have to be interpreted with caution since there are many more /œR/ (2145 occ) than /əR/ (236 occ). No comparison is made with /ø#R/ occurring only 36 times.

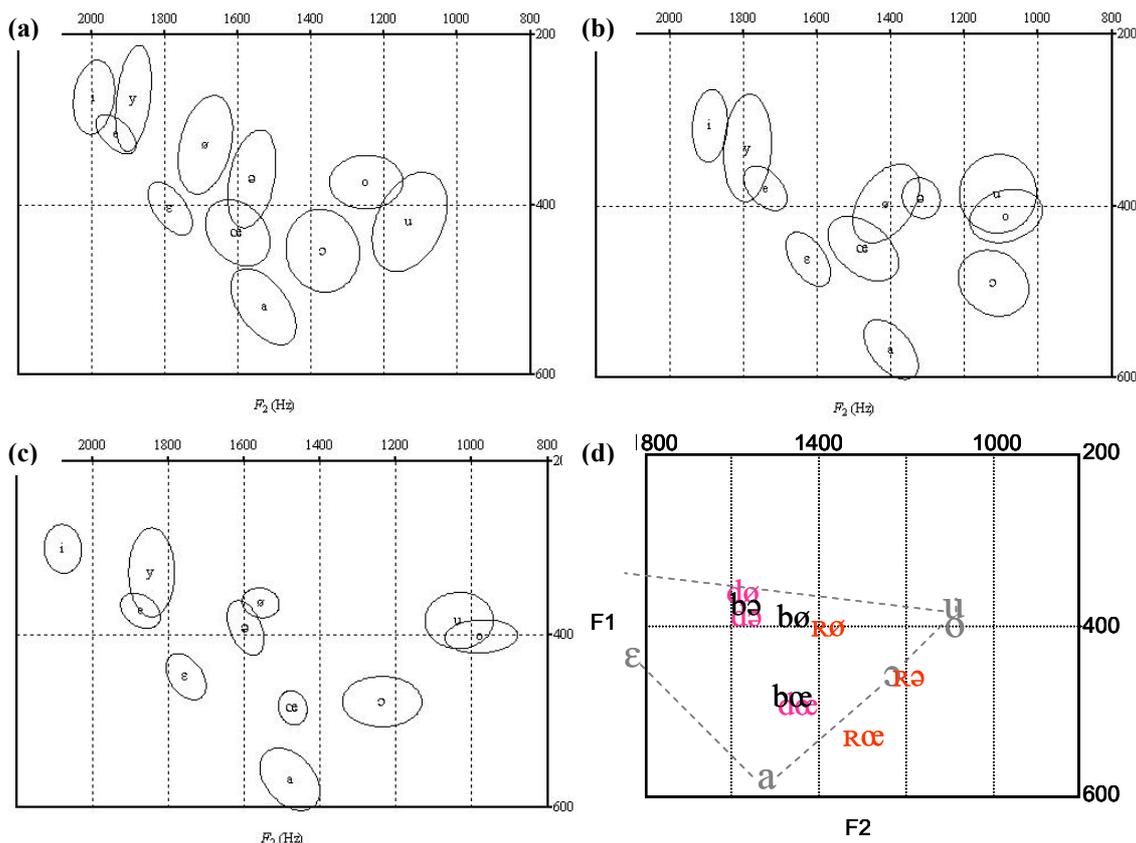


Figure 2: (a-c) Acoustic distribution of the vowels (in a non-uvular context) for selected speakers: spk5 (a), spk7 (b), spk8 (c). In (d) Distribution of /ə/, /ø/, and /œ/ preceded by a labial (bV), a dental (dV), and an uvular (RV).

4 Discussion and conclusion

Contrary to traditional assumption in the phonological literature, French schwa is found in the present study to have a distinct vowel quality from /ø/ and /œ/ as shown by its durational and spectral differences with these vowels on both F1 and F2, but also on F3. Moreover, schwa is rather closer to /ø/ than to /œ/ in the F1/F2 space, and to /œ/ in the F3 dimension. Considering the productions of the 180 speakers, as well as those of the 12 selected speakers, results show that /ə/ can be distinguished from its front rounded neighbors, firstly by a shorter duration, and secondly by its spectral quality on at least one of its first 3 formants. Schwa tends to have an intermediate degree of aperture (F1) between the mid-open and mid-closed vowel, an intermediate degree of rounding (F3), and a higher F2.

Concerning our hypothesis of a potential greater variability of schwa compared to the full vowels that would be linked to its particular phonological status, three measurements of variability were examined here: inter-token variability, inter-speaker variability, and variability according to contextual influence. The first measurement reveals that schwa is less stable than its full neighbours only when considering F2 values. Since F2 is much affected by coarticulation, and since the distribution of the vowels according to consonantal contexts is unbalanced, we cannot determine whether schwa is intrinsically more permeable to context or whether this fact only reflects the composition of the corpus. Nonetheless, the examination of the contextual variability of the three vowels reveals that they behave differently. The 3 vowels are found to be more affected by preceding than following context. More interestingly, the influence of the preceding context differs according to the vowel type: using the labial context as a reference, schwa is less modified by the dental context than the other vowels but more modified by the uvular context. This influence of the uvular context, which makes schwa more open and more posterior, can be interpreted in regard of a contemporary tendency to shift the pronunciation of schwa towards one of the mid-back rounded vowels [o, ɔ], particularly in a /R_/ context (eg. ‘reblochon’ usually produced as [ʁobloʃɔ̃]), as well as in other contexts (Malderrez 00, Coveney 01). These comparisons show the importance of taking into account the contexts surrounding the vowels when one wants to compare them. In our study, however, when controlling the preceding context for analysis, the following one was not fixed, and vice-versa. Thus, the opposite context can explain some of the differences between vowel types. A more systematic study of coarticulatory influence cannot be pursued on this kind of data, a laboratory controlled corpus should rather be designed for this particular purpose.

Considering inter-speaker variation, schwa is described in the literature to adopt realizations that range from [œ] to [ø]. Our examination of 12 selected speakers shows that the pronunciation of schwa indeed varies in the corpus, as illustrated in the F1/F2 plots presented in figure 1 and 2. This dispersion mirrors that of the other French vowels, and the overlap found in the small F1/F2 acoustic space shared by the 3 vowels (and especially between /ə/ and /ø/) resembles that found between /u/ and /o/ for most speakers. However, for most speakers (9-10 out of 12), schwa is found to have a phonetic quality distinct from /ø/ and /œ/. It is interesting to recall Coté’s claim that in Quebec French, schwa is invariably pronounced as [œ] and that in Standard French, the exact quality of the vowel is less stable. Unfortunately with the kind of material analyzed in this study, we do not have specific information about the geographical origin of the speakers. In our selection of the speakers included in this study, we have discarded the recordings where a foreign accent could be heard, and we have a strong feeling that most of the remaining ones are speakers of Standard French. However, we can not ascertain that. Nonetheless, it appears that only one out of 12 speakers neutralizes schwa with /œ/. Implications of these results for the phonological representation of optional schwas have thus to be considered.

To conclude, the observation of over 8000 vowels produced by a large number of speakers in the type of spoken corpus we used in this study, is nowadays a feasible task thanks to the help of automatic and semi-automatic pre-treatments. However, one has to underline a particularly inconvenient aspect of dealing with this kind of material. While it offers a great diversity of productions and is thus more realistic than traditional laboratory speech, it suffers by definition from a lack of control. Hence, systematic investigations of specific factors (such as phonemic context) are often limited to the data available. We therefore believe that for the full understanding of such phenomenon, corpus-based studies as well as controlled laboratory recordings need to complement each other.

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