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French schwa is not acoustically distinct from its two lexical neighbors /ø/ and /œ/

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Abstract

French schwa, or mute-e, is one of the most studied topics in French phonology, yet its exact phonetic quality remains debated. In particular, whether schwa is acoustically similar to or distinct from its two mid front rounded neighbors has given rise to contradictory results. The main issue is that past studies generally compare schwa and its neighbors without controlling for stress, yet the latter can be stressed while the former can never be, which is bound to impact their respective realizations. In this paper, we present a pilot study to investigate the quality of schwa compared to its neighbors while controlling for stress. Twenty-two French words with schwa or with its neighbors, were embedded in carrier sentences and read aloud among filler sentences. The data from 20 native speakers of Parisian French indicate that, when controlling for stress as well as orthography, schwa and its neighbors are acoustically very similar, in terms of both formants and duration.

Index Terms: French phonology, schwa, Parisian French

1. Introduction

French schwa, sometimes also called "mute-e", is probably one of the most studied topics in French phonology. It is usually defined as a central vowel, noted /ə/, that is present lexically, although restricted to unstressed syllables, but can be omitted. For instance, the word *semaine*, 'week', can be pronounced either with schwa, as [səˈmɛn], or without, as [smɛn].

Yet, the exact quality of schwa has been up for debate for more than a century now. Some researchers propose that it is a neutral vowel with no clear articulation [1]. Others on the contrary claim that it is a full-fledged vowel, acoustically distinct from its neighbors /ø/ and /œ/ [2, 3, 4], while some claim that it is pronounced like one of the full vowels, either /œ/ [5, 6, 7, 8, 9] or /ø/ [10]. However, most of these claims rely on the linguists' own intuitions or on self-assessment by naive speakers.

Even with the development of phonetic methodologies and the increasing use of large speech corpora, the issue has not been fully settled. The first large-scale study of schwa quality, based on 3000 schwas produced in conversations by 32 speakers and analyzed automatically, suggests that schwa is rather produced like /ø/ [11] but is less discrete than the other French vowels, meaning that schwa is more prone to phonetic variation than other vowels and thus more confusable with other vowels than lexical vowels with each other. However, what counts as a schwa in [11]'s study is unclear as it is not properly defined: For instance, the only example for schwa in this study is the word *vendredi*, 'Friday', traditionally transcribed as [vɑ̃dʁədi], but which can actually never be pronounced *[vɑ̃dʁdi]: Since the vowel in the word is not deletable, it can hardly be considered a schwa. Two other large-scale studies investigating schwa either in radio-broadcast speech [12] or in read speech [13], on the contrary, suggest that schwa is a distinct unit differing from both /ø/ and /œ/, although some partial overlap can be observed, in particular with /ø/. However, in all these studies, it is not clear whether the occurrences of /ø/ and /œ/ to which schwa is compared are in unstressed syllables. This is problematic because comparing a vowel that is necessarily unstressed (schwa) with a vowel that can be either stressed or not (/ø/ and /œ/) is methodologically unsound: All things being equal, a vowel will necessarily display different qualities in stressed vs. unstressed syllables [14, 15], both in formant values (unstressed vowels being more centralized than their stressed counterparts) and in duration (unstressed vowels being shorter).

In the present paper, we propose to bring some additional evidence to this debate by comparing schwa and the full front rounded mid-vowel in the speech of 20 native speakers of Parisian French uttered in a controlled setting. In the remainder of this paper, we will present our experimental setting in Section 2 and our results in Section 3 before concluding on the practical and theoretical implications of our study in Section 4.

2. Methodology

2.1. Material

For this pilot study, we created a balanced set of test-items that we controlled for a number of factors.

First, we compiled a set of words containing schwa. We defined schwa here as a mid rounded vowel in a word-internal simplex syllable that can be omitted with no effect on grammaticality. Schwa has to be in word-internal position because the scientific consensus agrees that word-final schwa in Standard French is non-lexical [16]. Schwa also has to occur in a simplex, i.e., CV syllable because (i) it can never occur in a closed (CVC) syllable, and (ii) if it is preceded by a complex onset (in a CCV syllable as in *ven**dre**di*), then it will be surrounded by three consonants or more, which is a well-known phonotactic constraint against vowel elision in French [17]. In sum, the mid rounded vowel had to be deletable, which was verified by a native speaker (who was not part of the cohort).

Second, we compiled a set of words containing the full front rounded mid-vowel. To ensure comparability between vowels, the full vowel also had to occur in a word-internal, i.e., unstressed position. Since, in unstressed syllables, the /ø∼œ/ distinction is neutralized [18], we will, from now on, refer to this vowel as the archiphoneme /œ/, or "non-schwa". To minimize the possible effects of left and right phonetic contexts, we paired, as much as possible, each schwa word with a non-schwa word where the vowel was in a similar consonantal environment (e.g., *genou*, 'knee' and *genêt*, 'broom (flower)' both have their vowel of interest between [ʒ] and [n]).

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Another possible issue is that of orthography. Schwa is mostly written with the letter <e>, while /œ/ is usually noted with the digram <eu>. However, there are numerous exceptions. We therefore decided to control for orthography by selecting schwa and non-schwa words that were either written with <e> or with something else (mostly <eu>, and one <on>). The resulting word list is presented in Table 1.

Table 1: *Test-items for the production task, organized by vowel quality (schwa vs. non-schwa) and by orthography (<e> vs. other). The vowel of interest is in bold.*

	/ə/	/œ/
<e>	dég**e**ler, 'unfreeze' g**e**nou, 'knee' p**e**tit, 'small' m**e**nu, 'menu' s'ag**e**nouiller, 'to kneel' m**e**sure, 'measure' G**e**nève, 'Geneva'	surg**e**ler, 'freeze' g**e**nêt, 'broom (flower)' p**e**sant, 'weighing' M**e**lun, 'Melun (city)' barb**e**cue, 'barbecue'
Not <e>	déj**eu**ner, 'lunch' j**eu**nesse, 'youth' raj**eu**nir, 'get younger' p**eu**t-être, 'maybe' m**on**sieur, 'sir'	équ**eu**ter, 'trim (vegetables)' j**eu**nots, 'youngsters' M**eu**don, 'Meudon (city)' p**eu**reux, 'coward' m**eu**nier, 'miller'

The test-items were then embedded in carrier sentences, thus resulting in 22 test-sentences. These were then pooled together with 26 filler sentences in which the vowels of interest were avoided.

Additionally, since word frequency is known to influence vowel reduction [19], word frequency was reported for each test item using the Lexique 3.83 database (freqfilms2) [20, 21].

2.2. Experimental design

Twenty young native speakers of French from the Paris area participated in the study. Among them were 10 female and 10 male speakers. They were all between 18 and 29 years old (mean age=23.35, sd=2.60).

Each participant was asked for their informed consent and then read the carrier sentences presented in random order on a computer screen. They were recorded in a quiet room using a Zoom APH-4N Pro recorder.

The reading task was chosen to ensure that schwa would be pronounced more often than not, since read speech is less prone to segmental reduction than spontaneous speech [19].

2.3. Data processing and analysis

The audiofiles (1 per speaker) were automatically aligned using WebMAUS for French [22], which generated the resulting alignments as textgrids in Praat [23]. The statistical pronunciation model behind WebMAUS has been shown to perform as well as humans for German connected speech [24, 25, 26] and the boundaries set by WebMAUS for French to differ from manual correction by ∼0.01 second [27].

The textgrids were then analyzed using Praat's built-in formant detection algorithm. For each target vowel, formants (F1, F2 and F3) and duration were automatically extracted.

Each acoustic metric was statistically analyzed in R, using linear mixed effects models (LMMs) [28, 29]. This allowed us to assess the significance of the effects of all the tested independent variables (hereafter IV: Orthography, Nature of the target vowel, Previous and Following consonants, Word frequency, Age of the speaker and Gender of the speaker) and their interactions. The formula is as follows:

$$Measure \sim SchwaOrNonSchwa * Orthography * PreviousLabel * FollowingLabel * WordFrequency * Age * Gender + (1|Speaker)+(1|Word)$$

We built the model shown above for each of our four metrics (F1, F2, F3, and duration) and compared them with similar models (+/− each independent variable and interaction). These comparisons were carried out using a likelihood ratio test (LRT) [30].

Finally, we computed post hoc tests (Tukey's HSD) to be able to report two-by-two comparisons of each level of our IV of interest.

3. Results

In this section, we present the results for the formant analysis in 3.1 and duration measurements in 3.2.

3.1. Formants

Our results for the formant values[1] are displayed in Table 2[2].

Table 2: *Mean values in Hertz (Hz) for the first, second and third formants for schwa and non-schwa.*

	Schwa (N=215)	Non-schwa (N=199)
F1	447 Hz (sd=193)	459 Hz (sd=206)
F2	1782 Hz (sd=164)	1717 Hz (sd=213)
F3	2688 Hz (sd=237)	2620 Hz (sd=256)

First, it should be noted that our measurements for schwa are in line with those reported in previous studies. Léon [31]'s formant values for schwa were 500 Hz for F1, 1,500 Hz for F2 and 2,500 Hz for F3, while Bürki et al. [13] report a mean ∼400 Hz for F1, ∼1760 Hz for F2 and ∼2890 Hz for F3.

Moreover, our LMMs show that there is no overall significant effect of Schwa vs. Non-Schwa on the F1, F2 and F3 measures. Most interactions between the *Schwa vs. Non-Schwa* variable and other IV from the model also show no significant differences in formant values. The only significant effect that we can report regarding the variation in formant values is the effect of the consonantal environment on both schwas and non-schwas. This effect mostly coincides with the consonants' manner of articulation (plosives and/or liquids vs. fricatives), whether it is the following consonant or the interaction of the following and preceding consonants affecting F2 ($0.003<p<0.018$) or the preceding consonant, the following consonant and the interaction between the two affecting F3 ($0.004<p<0.017$). The other parameters, i.e., the nature of the vowel (schwa or non-schwa) as well as gender, age, word frequency or orthography, all fail to have a significant effect on the formant values.

As can be seen in Figure 1, schwa and non-schwa have a very similar mean value for F1 (Δ=12 Hz, $p\approx0.6$).

[1]The tables report mean values resulting from marginal values as computed by the model while the figures show the raw data. We chose to report our findings this way in order to give the reader a mean to compare raw and modeled results. This statement is also valid for the results on duration in section 3.2.

[2]Out of the 440 potential vowels (22 test-items * 20 speakers), 25 schwas and 1 non-schwa were either not pronounced, or too short for their formants to be detected by Praat.

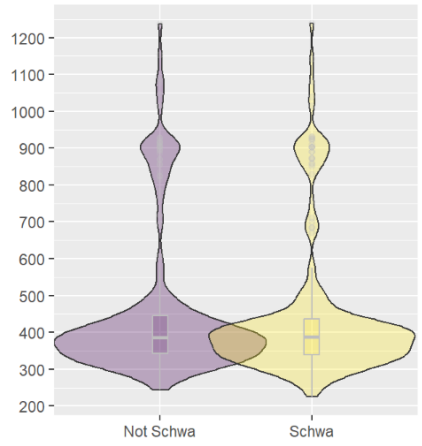

Figure 1: *Mean F1 (in Hz) and variance for non-schwa (left) and schwa (right).*

Regarding the second formant, displayed in Figure 2, schwa has a slightly higher mean value than non-schwa (Δ=65 Hz), but the difference is not statistically significant ($p>0.2$).

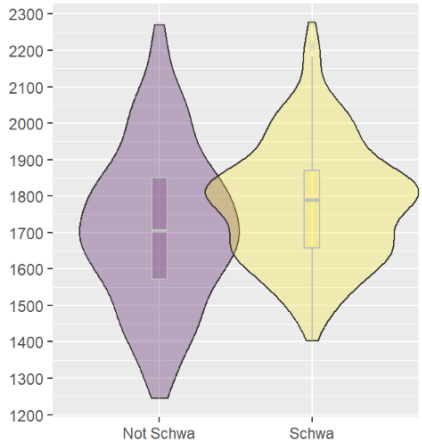

Figure 2: *Mean F2 (in Hz) and variance for non-schwa (left) and schwa (right).*

Similarly, for F3 displayed in Figure 3, schwa also has a slightly higher mean value than non-schwa (Δ=68 Hz). The difference again is not significant, although very close to the standard significance level ($p=0.052$), which indicates that more data might reveal a higher F3 for schwa than non-schwa.

This goes against the results of a past study [12] where schwa is said to differ from /ø/ by significantly higher F1, F2 and F3, and from /œ/ by a significantly lower F1, higher F2 and lower F3. This is not surprising given that, in unstressed syllables, the two full vowels tend to neutralize.

Figures 1, 2 and 3 also allow to see that, contrary to what has been claimed [13, 32, 33], schwa is not more, or even as variable than non-schwa, but less variable.

Finally, orthography is shown not to influence the realization of schwa vs. non-schwa, as can be seen in Figure 4.

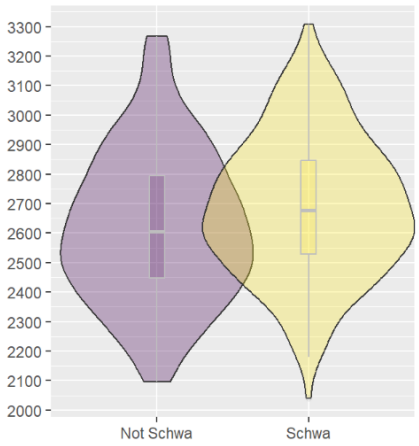

Figure 3: *Mean F3 (in Hz) and variance for non-schwa (left) and schwa (right).*

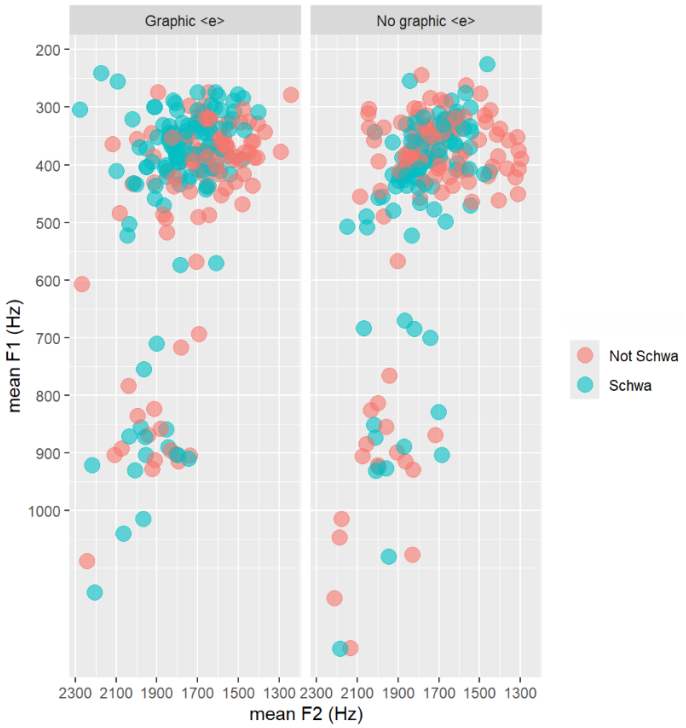

Figure 4: *Dispersion of each vowel in the F1 x F2 space (in Hz) for schwa (blue) and non-schwa (red) as a function of orthography: either the vowel is written <e> or it is written <eu, on>.*

3.2. Duration

As can be seen in Figure 5, schwa is slightly shorter than non-schwa (Δ=7 ms), with a mean duration of 0.076 seconds (sd=0.0477, N=219[3]) and 0.083 seconds (sd=0.0432, N=200) respectively.

However, this difference is not significant either ($p>0.19$). Only the previous consonant ($p<0.0012$), the following con-

[3]Out of the 440 potential vowels (22 test-items * 20 speakers), 21 schwas were either not pronounced, or too short to be either detected by WebMAUS (30ms threshold) or measured by Praat.

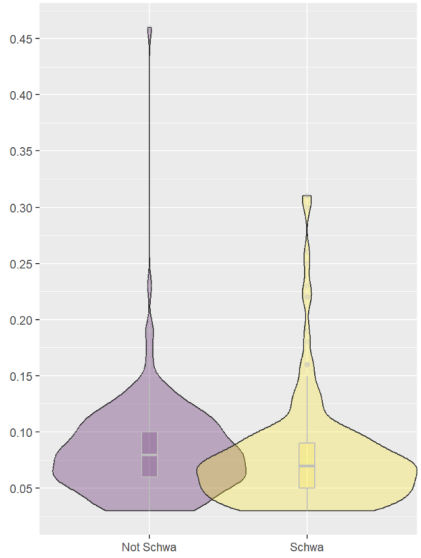

Figure 5: *Mean duration (in seconds) and variance for non-schwa (left) and schwa (right).*

sonant ($p<0.0008$) and the interaction between the two ($p<0.0052$) have a significant effect on the duration of the vowels (both schwas and non-schwas).

In our data, schwa and non-schwa thus do not differ significantly from each other, either in terms of formants or in terms of duration. However, an additional equivalence test [34, 35] also indicated that the two groups (schwa vs. non-schwa) were not strictly equivalent, neither on formant values nor on duration, and therefore that the lack of significance does not allow to conclude categorically that the two vowel sets are similar. To confirm our results, more data is needed, as developed in Section 4.

4. Discussion and Conclusion

In this paper, we present a preliminary study to investigate the acoustic quality of schwa in a controlled setting designed to avoid a common bias in past investigations of schwa, namely its comparison with a potentially stressed vowel when itself can never be stressed. Moreover, we gathered very recent data, thus bringing additional information on how Parisian French is pronounced today.

To that extent, we recorded 20 young native speakers of Parisian French reading 22 randomized test-items embedded in carrier sentences pooled together with filler sentences. Our results show that schwa is largely realized like its non-schwa counterpart, both in terms of formants and duration. This result confirms the results from the first large-scale study on schwa's acoustic quality [11]. However, it seems to invalidate more recent large-scale acoustic studies [12, 13]. In these studies, schwa is reported to be an intermediate between the two full vowels /ø/ and /œ/, hinting towards a three-way distinction /ø∼ə∼œ/ (itself in line with past accounts [2, 3, 4]). However, an intermediate between /ø/ and /œ/ is possible only if /ø/ and /œ/ are distinct, which they are not in unstressed syllable. Thus, by taking the precaution to control for stress, we can conclude that schwa has the same acoustic quality and duration than its discrete, full counterpart, /œ/.

In future work, we plan on gathering data from more speakers from more various age groups and regions, both in France and abroad, to establish whether our results are confirmed for Parisian French and can be extended to other varieties of the language. Moreover, given the effect of adjacent consonants on the formants and durations of both vowel types indifferently, we will extend the list of test items to increase the phonetic environments of the vowels of interest. Along the same line, more test items will be added to control for the quality of the following (accented) vowel, to ensure that a possible effect of vowel harmony [36] is taken into account.

Finally, our results on acoustic measurements will also be tested against articulatory data on the one hand, and human perception on the other. Indeed, to confirm that French schwa involves the rounding of the lips like /œ/ does, we will use the improved version of the present protocol to gather not only audio, but also video data matched to a lip gesture recognition system. On the other hand, to confirm that schwa and non-schwa are indistinguishable not only in production but also in perception, we plan on testing how native speakers of French discriminate /ə/ and /œ/ in artificial stimuli constructed using the measurements from the present study and its follow-up.

This line of research should be beneficial to computational linguists and theoretical phonologists alike. On the one hand, computational linguists and speech technologists are often challenged by schwa transcription and (automatic) alignment, especially in large, uncontrolled data [16, 37]. On the other hand, phonologists are often puzzled by the varying acoustic quality, cross-linguistically, of schwa or weak vowels in general, and how it questions universals in segmental phonology. Notably, work based on formal universal constraints usually rejects the possibility that weak (i.e., deletable) as well as epenthetic (i.e., inserted) vowels can be round [38], yet our results indicate that the French weak vowel is acoustically similar to its two rounded neighbors /ø/ and /œ/. Our findings thus suggest that French aligns with the majority of the world's languages, where the weak vowel is similar in quality to another lexical vowel from the system [39], but also raise interesting issues regarding the phonological universals constraining which lexical vowel is an acceptable candidate.

5. Acknowledgements

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