

# SCHWA IN FRENCH OBSTRUENT-LIQUID CLUSTERS BY NATIVE SPEAKERS AND MANDARIN LEARNERS

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## ABSTRACT

This study investigates the production of French obstruent-liquid clusters in word-initial and -final positions by 5 native French speakers and 10 Mandarin speakers learning French. The frequency of schwa within these clusters and its temporal and formant characteristics are analyzed based on word position, liquid type, obstruent place of articulation, and voicing. Results show that schwa is most frequent in clusters containing a rhotic liquid for both groups. Additionally, both word position and voicing have a significant impact on the rate of schwa occurrence and on its duration. Formants of schwa vary according to position, place of obstruent articulation, and liquid type. A notable difference was found between natives and learners in terms of word-final schwa production, with native French rarely producing it and Mandarin learners producing it more frequently. It is suggested that while schwas within consonant clusters may have phonetic origins, word-final schwas are driven by phonological factors.

**Keywords:** Epenthetic schwa, French consonant clusters, Mandarin speakers, duration, quality

## 1. INTRODUCTION

Consonant sequence acquisition in non-native languages has been extensively studied over the years, with a particular focus on how learners repair illegal consonant sequences [1, 2, 3, 4]. There are various strategies learners can use to do this, including deletion, insertion, and substitution, with vowel insertion being the most common [1, 5]. This type of insertion, which often involves adding a schwa vowel between two consonants, has traditionally been seen as a phonological process used to repair an inappropriate syllable structure. However, the Articulatory Phonology perspective suggests that the inserted schwa may actually result from reduced gestural overlap between the surrounding consonants due to articulatory constraints [6, 7].

The current study investigates the insertion of the vocalic elements in the production of French obstruent-liquid (OL) sequences by Mandarin speakers learning French and compares it to the

production of native French speakers. The focus is on the occurrence of these sequences at word-initial and word-final positions. Mandarin prohibits consonant sequences, including OL [4,8], while French has a high frequency of consonant clusters in various positions within words, with OL being the most common sequence [9].

The insertion of vocalic elements within clusters has been documented in various languages around the world [10]. However, there have been relatively few studies on schwa intrusion in French consonant clusters. [11] conducted an acoustic analysis of Quebec French and Argentinian Spanish OL clusters and found that epenthetic vowels were commonly used in French. The frequency of this epenthesis depended on the type of liquid and the similarity of the cluster members in terms of manner, place, and voicing, with liquid type and voicing having the greatest influence. Epenthetic vowels were observed in almost all voiced obstruent-rhotic clusters for all speakers. [12] also examined the insertion of schwa in OL clusters in Quebec French and found fewer, but longer schwas compared to [11]. They compared the spectral characteristics of schwa and the following vowel and found similar F1 and F2 values, suggesting a vowel harmony process between the two vowels. Unlike [11], [12] did not view schwa insertion as a means of simplifying clusters, but rather tentatively attributed it to articulatory or perceptual constraints specific to these OL clusters.

To the best of our knowledge, no study has previously compared the production of schwas in French obstruent-liquid clusters by native French speakers and Mandarin speakers learning French. The current study aims to address this gap. Specifically, our objectives are to 1) compare the frequency, temporal characteristics, and formant frequencies of schwa in the two groups, and 2) analyze how the quantitative and qualitative characteristics of schwa vary across word positions, liquid types, and obstruent place and voicing.

## 2. METHOD

### 2.1. Participants

The production experiment included five native French speakers and ten Mandarin speakers learning

French. The native French speakers (F) were female university students with a mean age of 22.2. The Mandarin learners of French were divided into two groups: a beginner level group of five subjects with a mean age of 18 (M1) and an advanced level group of five subjects with a mean age of 20.5 (M2). All of the Mandarin learners of French were female university students studying French at Leshan Normal University in China.

**2.2. Stimuli**

The stimuli used in the study were 20 French words containing the target OL clusters (Table 1). Mostly common words were included, but some were rare (e.g., *blase* ‘name’, or *bagle* ‘computer worm’), and their impact was not examined. The stimuli were selected to control for the type of liquid (/l/ or /ʁ/), the place and voicing of the obstruent, and the position of the cluster within the word. All onset clusters were followed by the vowel /a/. The stimuli were presented in isolation and within a carrier sentence, but only the isolated words were analyzed for the purposes of this study. Each word was repeated seven times in a randomized order, resulting in a total of 2100 tokens.

	#CC	CC#		#CC	CC#
/pr/	Prague	câpre	/br/	brade	sabre
/tr/	trappe	quatre	/dr/	drague	cadre
/kr/	crabe	sacre	/gr/	grâce	tigre
/pl/	place	Naples	/bl/	blase	câble
/kl/	classe	tacle	/gl/	glace	Bagle

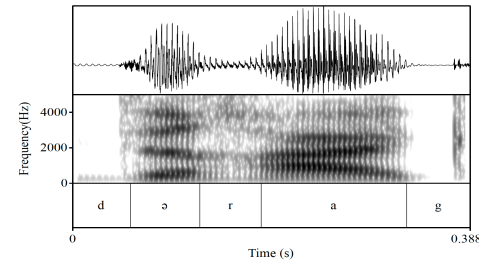
**Table 1:** Lexical items used for the experiment.

We recorded the 15 subjects using a Roland Rubix24 sound card and AKGC 520L microphone in a soundproof room at the Laboratoire de Phonétique et Phonologie in Paris (CNRS/Sorbonne Nouvelle) for the French subjects and at Leshan Normal University for the Mandarin speakers.

**2.3. Segmentation**

The acoustic data were analyzed using Praat [13] software. The determination of the presence of schwa within an OL cluster was not always straightforward and required a two-step process. A first annotator initially labeled all instances of non-ambiguous schwas and marked the ambiguous cases. These cases were then reviewed by two annotators, and a final decision was made on the presence or absence of schwa based on a combination of cues. The annotators considered as evidence of the presence of schwa an interval between two consonants with periodic vibrations and a local increase in signal

energy at the consonant release, and/or an interval after the consonant release with formant structure or energy in the F2/F3 region. These criteria for schwa identification are consistent with previous research (e.g., [14,15]). In the example presented in Fig. 1, the presence of schwa was determined based on the increase of signal amplitude after the stop release and an interval with a formant structure within the OL cluster.

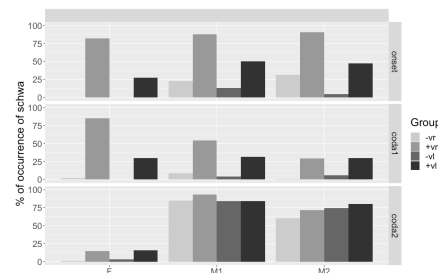


**Figure 1:** Waveform and spectrogram of the word <drague> ‘dredger’ with schwa between /d/ and /ʁ/.

We used Praat to analyze target clusters in three different contexts: within onset cluster (*onset*, e.g., [dəʁag]), within coda cluster (*coda1*, [takəl]), and after coda cluster (*coda2*, e.g., [baglə]). We extracted the duration and the formant frequencies for each inserted schwa. Only the formant frequency values obtained from the middle of the schwa are reported, despite measurements being taken at the beginning, middle, and end. We compared the presence/absence, duration, and formant structure of schwa between the group of native French speakers and the two groups of Mandarin learners, considering variations in word position, liquid type, and obstruent place and voicing.

**3. RESULTS**

Fig. 2 illustrates the rate of occurrence of schwa in the production of natives and the two groups of learners. There was a variation in the occurrence of schwa across the three groups, with a higher rate for M1 (79%) and M2 (67%) compared to F (35%).



**Figure 2:** Percentage of occurrence of schwa for French (F) and Mandarin learners (M1 & M2) (-/+v = -/+voiced).

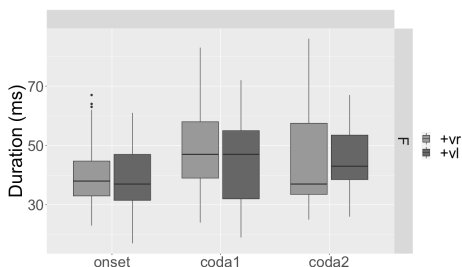
The frequency of schwa varied among the three groups based on several factors, including the voicing

of the obstruent and the type of liquid. The highest frequency occurred when the obstruent was voiced and the liquid was /ʁ/, with rates of 60% for native French speakers, 78% for beginner Mandarin learners, and 64% for advanced Mandarin learners. Additionally, the frequency of schwa differed based on word position, with Mandarin learners producing more schwas in coda2 (79%), compared to coda1 (21%) and onset (46%), while French speakers showed the opposite pattern (8% for coda2, 32% for coda1, and 30% for onset). The place of articulation of obstruents had a less important impact, although there was a trend towards /b/ sequences attracting fewer schwas in onset and coda1.

In the following sections, we will explore the temporal and spectral properties of schwa sounds as produced by native French speakers and Chinese-speaking learners. For the purposes of this analysis, we will focus specifically on clusters containing voiced obstruents, as clusters with voiceless obstruents exhibit very few instances of schwa in the speech of French native speakers. The data were analyzed using the ANOVA function in R [16].

### 3.1. Schwa in native speakers' productions

#### 3.1.1 Durational properties of schwa



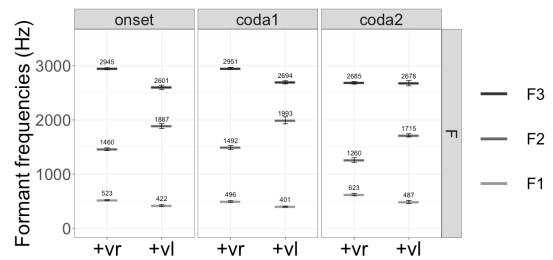
**Figure 3:** Schwa duration in different word positions for French speakers.

As shown in Fig. 3, the duration of schwa varied depending on its position within a word. The shortest duration was observed in the onset position, with values of 39 ms, 47 ms, and 46 ms for onset, coda1, and coda2, respectively. The Tukey HSD test showed that these differences were significant between onset and coda1 ( $p < 0.001$ ) and between onset and coda2 ( $p < 0.01$ ). In contrast, the manner of articulation of liquids and the place of articulation of obstruents did not have a significant impact on schwa duration.

#### 3.1.2 Formant frequencies of schwa

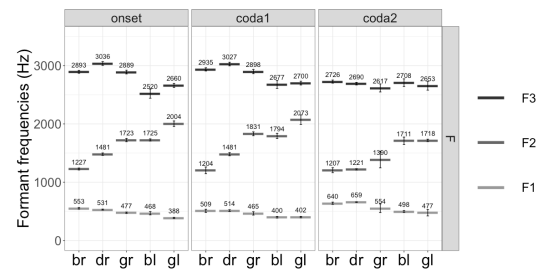
Fig. 4 and Fig. 5 present the formant frequencies for the different clusters. The analyses revealed that word position significantly impacted F1, F2, and F3 (all  $p < 0.001$ ). Specifically, coda2 had a higher F1 and

lower F2 and F3 compared to the other positions. The type of liquid also significantly influenced all three formants, with /r/ clusters exhibiting higher F1, lower F2, and higher F3 than /l/ clusters (all  $p < 0.001$ ).



**Figure 4:** Schwa formant frequencies in different contexts of French speakers.

The place of articulation of the obstruent also significantly affected F1, F2, and F3 (all  $p < 0.001$ ). /gr/ and /gl/ clusters had lower F1 than /br/ and /dr/, and /b/. F2 increased as the place of articulation moved further back in the vocal tract, and F3 displayed higher frequencies in /dr/ compared to /br/ and /gr/ ( $p < 0.001$ ).

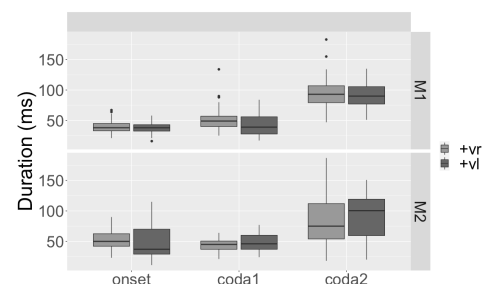


**Figure 5:** Schwa formant frequencies in different clusters for French speakers.

### 3.2. Schwa in Mandarin learners' productions

#### 3.2.1 Durational properties of schwa

As for French native speakers, the duration of schwa varied depending on its position (Fig. 6). But unlike French, the coda2 position had the longest mean duration (89 ms), while onset and coda1 displayed similar durations (45 ms and 47 ms, respectively).



**Figure 6:** Schwa duration in different word positions for Mandarin speakers.

Statistical analysis revealed the effect of position on schwa duration ( $F(2,669) = 280, p < 0.001$ ). The Tukey HSD test showed significant differences in duration between coda2 and onset ( $p < 0.001$ ) and between coda2 and coda1 ( $p < 0.001$ ). The type of liquid did not have an effect on schwa duration, but significant differences were found in relation to place of articulation ( $F(2,442) = 4, p < 0.05$ ), with /gr/ being longer than /br/ ( $p < 0.05$ ) and /dr/ ( $p < 0.05$ ). Significant differences were also observed for /gl/ which is longer than /bl/ ( $p < 0.01$ ).

### 3.2.2. Formant frequencies of schwa

Fig. 7 and Fig. 8 present the frequencies for the different clusters. The F1 of schwa was affected by word position ( $F(2, 669) = 6, p < 0.001$ ), with coda1 displaying a lower F1 than onset ( $p < 0.001$ ) and coda2 ( $p < 0.05$ ). The place of articulation and type of liquid did not have a significant effect. F2 was also affected by position ( $F(2, 669) = 14, p < 0.001$ ), with schwas having higher F2 in onset compared to coda1 and coda2 (all  $p < 0.001$ ). Place of articulation of the obstruent also had an effect ( $F(2, 442) = 44, p < 0.001$ ), with significant differences found between /br/ and /gr/ and /dr/ ( $p < 0.001$ ). Similar to French, schwa in the context of /r/ displayed lower F2. F3 was marginally affected by word position ( $F(2, 669) = 4, p < 0.05$ ), type of liquid ( $F(1, 669) = 24, p < 0.001$ ), and place of articulation ( $F(2,442) = 4, p < 0.05$ ).

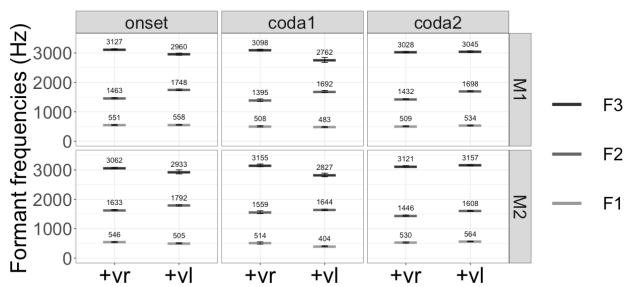


Figure 7: Schwa formant frequencies in different word positions for Mandarin speakers.

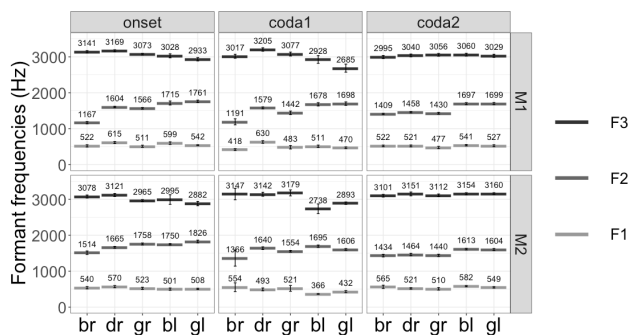


Figure 8: Schwa formant frequencies in different clusters for Mandarin speakers.

## 4. DISCUSSION AND CONCLUSIONS

This study explored French obstruent-liquid clusters produced by French native speakers and two Chinese learner groups, focusing on schwa presence and characteristics. Our findings revealed that all three groups produced schwas in the clusters we analyzed, but with varying frequencies. As expected, Chinese learners used schwas at high rates, with 79% of beginner learners and 67% of advanced learners inserting them. It was also notable that native French speakers frequently used schwas, though at a lower rate. This suggests that the presence of these vocalic elements may be a common feature in the production of these consonant clusters, regardless of the speaker's language background. Notably, the highest rate of schwa production occurred for both native French speakers and Chinese learners when the obstruent was voiced and the liquid was /ʁ/. The frequent occurrence of schwa in this position prompts the question of its origin. From the perspective of Articulatory Phonology [17], this vocalic element may be seen as a transitional vocoid that does not have its own distinct articulatory gesture, but rather is a result of the way in which the consonant gestures are phased and articulated. The fact that the spectral characteristics of schwa are very much influenced by the place of articulation of the obstruent and the manner of articulation of the liquid may be considered as evidence that schwa in this context does not have its own distinct articulatory gesture.

The fact that schwas are more frequent in /Cr/ compared to /Cl/ may be due to differences in the way the gestures associated with these consonants overlap. /Cr/ sequences tend to have a more sequential articulation of gestures with no overlap, while laterals tend to have overlapping and blending gestures [18]. There was a higher prevalence of schwa insertion at word-finally among Mandarin learners. Only 8% of schwas were produced in this way by native speakers, a figure that is similar to the 6% reported in [19] which analyzed the production of French CR clusters in a corpus of about four hours of speech. Word-final schwas in Mandarin speech can be explained by the prohibition of codas (except /n/ and /ŋ/) and coda clusters. Some suggest that the presence of schwa in this position in French may be due to the need to retain the cluster by resyllabifying it as a complex onset [20]. The results of this study can guide future experiments with more speakers and consonant clusters to expand our understanding of the topic.

## 5. ACKNOWLEDGEMENTS

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