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Orthographic Influences on the Production of French Nasal Vowels by English-Speaking Learners of French

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ORTHOGRAPHIC INFLUENCES ON THE PRODUCTION OF FRENCH NASAL VOWELS BY ENGLISH-SPEAKING LEARNERS OF FRENCH

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Abstract

The present study investigated acoustic differences (F1F2 vowel space and duration) in French nasal vowel productions by three participants who speak French as a first language (L1-French speakers) and ten participants who speak English as a first language and French as a second language (L2-French speakers). French nasal vowel production by L2-French speakers was acoustically analyzed in two conditions: Auditory-Orthographic (Aud-Ortho) and Auditory-Only (Aud-Only). The results indicated a larger F1F2 vowel space for L2-French speakers in the Aud-Ortho task compared to the Aud-Only task. French nasal vowel durations were slightly longer for the L2-French speakers. Spectrograms from L2-French speakers revealed the presence of postvocalic consonants and F1F2 differences relative to spectrograms from the L1-French speaker.

Literature Review

Previous research has investigated speakers' ability to perceive and produce speech sounds in their first language (L1) and their second language (L2), including the perception and production of French nasal vowels by L1-French speakers and L1-English, L2-French speakers (Detey et al., 2010; Inceoglu, 2021; Marquez Martinez, 2016; Montagu, 2002). However, limited research has examined the influence of orthography (i.e. spelling) on the acquisition of French nasal vowels by L1-English, L2-French speakers or assessed the influence of orthography through auditory-orthographic and auditory-only repetition tasks. While F1F2 vowel space differences between L1 and L2-French speakers have been examined, durational differences between these groups have not been considered.

Phonological Acquisition in L1 and L2

Learning a language after early childhood often poses significant difficulties as it requires the acquisition of a new phonology (i.e., how sound units combine to create meaning; Anderson, 2001). Speech sounds are broadly classified as phonemes or allophones. Phonemes create a distinction in word meaning while allophones are variations in how phonemes are produced and do not affect meaning. Although languages share many sound units, they differ in which are phonemes and which are allophones. For example, both the aspirated /p^h/ and unaspirated /p/ consonants are phonemes in Mandarin. English speakers produce both these sounds within words, but /p^h/ is an allophone of /p/ because aspiration does not change the meaning of words as it does in Mandarin (American Speech-Language-Hearing Association, n.d.).

Infants acquire the phonology of their L1 through selective elimination, which is a process by which the brain strengthens the neural connections that are important for the

environment in which a child is born and loses those that are not important for their environment (Geschwind & Galaburda, 1987). Children group sounds into phonemic categories from six months to one year of age (Werker & Tees, 1984). Around one year, children easily perceive the differences between sounds that are phonemic in their L1 and have a weakened ability to perceive the differences between sounds that are not phonemic in their L1 (Kuhl, 2004).

Due to the decrease in perceptual abilities with increasing age, adult L2 learners must recategorize sound units through explicit instruction rather than the implicit learning that occurs during early childhood (Archila-Suerte et al., 2012). Flege's Speech Learning Model (1995) posits that adult L2 learners often produce L2 sounds as an acoustically similar sound in their L1. In general, sounds with minimal acoustic distance are more difficult to acquire than sounds with greater acoustic distance.

Strong perceptual abilities underlie accurate phoneme production for both children acquiring their L1 and adults acquiring a L2 (Bradlow et al., 1997; Rvachew et al., 2004). Infants develop motor plans for L1 phonemes by comparing their own speech production to auditory input from their environment (Guenther, 2002). Adult learners did not receive auditory input for L2 phonemes during infancy and consequently produce them differently than L1 speakers, leading to the perception of an accent. Accentedness is a listener's judgment of the degree to which someone's speech differs from that of a L1 speaker (Munro & Derwing, 1995).

Acoustic Measures of Phoneme Production

Differences in phoneme production between L1 and L2 speakers can be investigated through acoustic analysis. In contrast to consonants, vowels are produced with minimal constriction in the vocal tract and are described by their relative jaw, tongue, and lip positions

(Behrman, 2023). The acoustic representation of vowels can be explained by the Source-Filter Theory of Speech Production (Fant, 1960). Vibration of the vocal folds within the larynx creates a sound source consisting of a fundamental frequency (F0) and subsequent harmonic multiples of the F0. The articulators within the vocal tract filter the laryngeal sound source by amplifying some harmonics and dampening others. The harmonic frequencies that resonate with the greatest amplitude are known as formant frequencies, which are measured in Hertz (Hz; Fant, 1960). Due to anatomical differences across speakers of different sexes and ages, the absolute value of formants varies. However, listeners are able to perceptually identify vowels through the *relative relationship* between the first three formants (F1, F2, and F3; Behrman, 2023). Wideband spectrograms represent speech visually by displaying time in seconds on the x-axis, frequency on the y-axis, and intensity on the z-axis through the relative darkness of shading (Behrman, 2023). The relationships between F1, F2, and F3 in wideband spectrograms of /i/ and /æ/ are shown in Figures 1 and 2.

Figure 1

Spectrogram of /i/ *vowel*

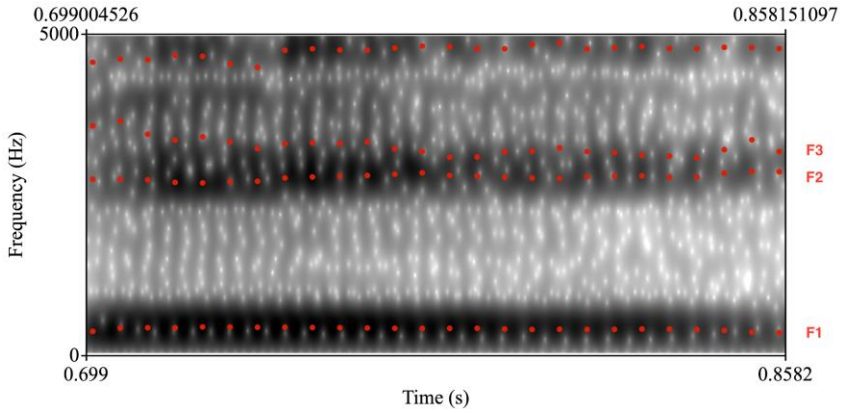
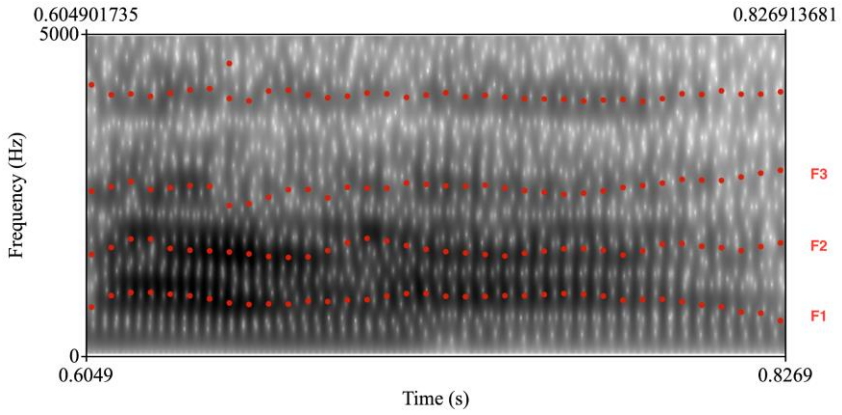


Figure 2

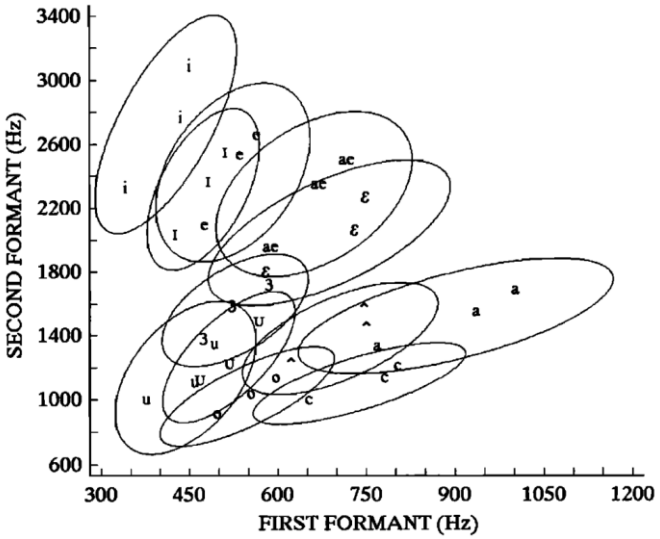
Spectrogram of /æ/ *vowel*



There is not a one-to-one relationship between articulation and the acoustic features necessary to perceptually identify vowels due to the concept of motor equivalence. Manipulating one region of the vocal tract can affect the resonant characteristics of the entire vocal tract, which allows for a multitude of articulatory postures that achieve the F1-F2 relationship for a particular vowel (Behrman, 2023).

Speech can also be represented acoustically through vowel space plots, which show the relationship between F1 on the x-axis and F2 on the y-axis. (Hillenbrand et al., 1995; Peterson & Barney, 1952). Figure 3 illustrates the variable formant relationships in speakers of the same language and dialect, as vowels overlap within the F1F2 vowel space plot (Hillenbrand et al., 1995). Ladefoged and Broadbent (1957) theorized that listeners compensate for this variation by identifying vowels based on their relative locations within the vowel space of an individual speaker.

Figure 3



F1F2 of American English Vowels for Men, Women, and Children

From "Acoustic Characteristics of American English Vowels," by Hillenbrand, J. M., Getty, L. A., Clark, M. J., & Wheeler, K., 1995, *Journal of the Acoustical Society of America, 97*(5), p. 3104.

L2 speakers may have reduced vowel space, meaning that vowels are less acoustically distinct (Bradlow & Bent, 2002). Speakers may produce vowels with less acoustic distinction if they have difficulty perceiving the differences between them. L1-English, L2-French speakers produced /y/, which is not an English phoneme, more similarly to the English phoneme /u/ that has a posterior tongue position relative to /y/. Speakers with greater French language experience produced these vowels with distinctive F1-F2 relationships, demonstrating L2 learners' ability to

achieve more accurate vowel production with increased exposure (Flege, 1987; Levy & Law, 2010).

Durational differences may also be present in L2 vowel productions. Bent and colleagues reported that L1-Chinese learners of English produced English vowels preceding voiced and voiceless consonants with less durational contrast compared to L1-English speakers. Listeners more accurately identified words when vowels had greater durational contrast, highlighting the role of duration in accentedness.

Vowel Nasalization in French and English

French contains three or four nasal vowels, depending on the dialect. Three nasal vowels are present in Northern Metropolitan French, which the International Phonetic Association (2015) represents as /ɑ̃/, /ɛ̃/, and /ɔ̃/. A fourth nasal vowel /œ̃/ is present in Canadian and Southern French dialects, but French speakers outside these regions typically pronounce this vowel as /ɛ̃/ (Rose & Wauquier-Gravelines, 2007).

Nasalization involves physiological movement. During production of nasal vowels, the velum (soft palate) lowers to open the velopharyngeal port and introduce airflow into both the nasal and oral cavities. Oral vowels require the velum to elevate and close or narrow the velopharyngeal port (Behrman, 2023). However, the degree of velopharyngeal closure varies for oral vowels. Vowels with relatively high tongue positions are generally produced with greater velopharyngeal closure than vowels with lower tongue positions (Kuehn & Moon, 1998). The low tongue positions of /ɑ/, /ɛ/, and /o/ may have contributed to their assimilation into nasal vowels over time as opposed to high vowels such as /i/, /u/, and /y/ (Rochet, 1976).

The acoustic result of nasalization is to decrease the intensity of formants due to sound energy being dampened by the nasal passages (Behrman, 2023). House and Stevens (1956) observed that formants of nasalized vowels have wider bandwidths than those of oral vowels, as nasalization serves to "broaden and flatten" spectral peaks (p. 225). However, nasal resonance is not the only salient feature that characterizes French nasal vowels. Multiple studies have identified lingual (tongue) and labial (lip) articulatory changes which are not present in the oral vowels /a/, /ɛ/, and /o/. Lip rounding and tongue retraction are greater for /ɛ̃/ and /ɑ̃/ compared to their oral vowel counterparts. These changes can alter the F1-F2 relationship and contribute to the perception of nasalization (Carignan, 2014; Montagu, 2002; Zerling, 1984). Lingual and labial articulation is highly variable among L1-French speakers due to motor equivalence (Carignan, 2014).

Vowel nasalization functions differently in English and French phonology. In English, vowels become nasalized due to coarticulation as a result of simultaneous phoneme production to maintain the rapid nature of speech (Behrman, 2023). The velopharyngeal port opens during production of the nasal consonants /m/, /n/, and /ŋ/ to allow airflow through the nasal cavity but the articulators occlude the oral cavity. When nasal consonants follow vowels, the velum begins to lower during vowel production in anticipation for the nasal consonant. Likewise, the velopharyngeal port remains open during production of vowels preceded by nasal consonants (Flege, 1988). Nasalized vowels in English are allophones because they do not change the meaning of words. Though not linguistically meaningful, coarticulatory nasalization is a perceptual cue for nasal consonants within words. In an eye-gaze study, English-speakers were

quicker to identify a word as “send,” transcribed /sɛnd/, as opposed to “said,” transcribed /sɛd/, when a longer portion of the vowel was nasalized (Beddor et al., 2013).

French contains both coarticulatory nasalized vowels and the phonemic nasal vowels /ɑ̃/, /ɛ̃/, and /ɔ̃/, which occur independently from coarticulation with nasal consonants and change the meaning of words. Nasalization of /ɛ/ in *pain*, transcribed /pɛ̃/, meaning “bread” is the only phonetic feature that distinguishes it from *paix*, transcribed /pɛ/, meaning “peace.” French vowels preceding or following nasal consonants are nasalized to a lesser degree to maintain acoustic contrast with words containing phonemic nasal vowels (Zellou & Chitoran, 2023).

Perception and Production of French Nasal Vowels by L2-French Speakers

L1-English, L2-French speakers have difficulty perceiving and producing French nasal vowels as a result of the differences between English allophonic nasalized vowels and French phonemic nasal vowels. According to Marquez Martinez (2016), naïve- and intermediate- level listeners perceived French nasal vowels as oral vowels followed by nasal consonants, which is a process known as nasal unpacking. Listeners perceived nasal consonants that were not present due to L1 phonological influence, as vowel nasalization signifies upcoming nasal consonants in English. Advanced listeners correctly perceived French nasal vowels, demonstrating acquisition of French nasal vowels as phonemes rather than perceiving them as allophonic nasalized vowels. L2-French speakers also have difficulty perceptually discriminating between /ɑ̃/, /ɛ̃/, and /ɔ̃/. During vowel identification tasks, Inceoglu (2021) reported that L2-French speakers misperceived /ɑ̃/ as /ɛ̃/ and /ɔ̃/ as /ɑ̃/ and more accurately perceived vowels in familiar French words.

Perceptual mistakes by L2 listeners can influence production tasks. L1-Japanese and L1-Spanish speakers, whose L1s do not contain phonemic nasal vowels, demonstrated nasal unpacking by producing nasal consonants following vowels (Detey et al., 2010). As for differentiating between French nasal vowels, Montagu (2002) observed minimal lip rounding in L1-English, L2-French speakers' productions of /ɑ̃/ and /ɔ̃/, which resulted in similar F1-F2 relationships for these vowels relative to L1-French speakers. Additionally, the L2-French speakers' oral and nasal vowels were more similar to each other, suggesting they rely on lowering the velum instead of labial adjustments to distinguish nasal vowels from oral vowels (Montagu, 2002).

There is limited research investigating the duration of French nasal vowel productions. Data from one L1 speaker of Canadian French indicated that the duration of French nasal vowels decreased when not followed by consonants and increased when vowels were followed by consonants. Since the opposite pattern occurred for oral vowels, the author posits that lengthened duration may be a supplementary perceptual cue for French nasal vowels (O'Shaughnessy, 1981).

Orthography and L2 Acquisition

Orthography (i.e. the written representation of language) may further complicate L2 phonological acquisition. Alphabetic languages represent phonemes with letter symbols called graphemes, which are used inconsistently across languages. Numerous studies conclude that orthography promotes acquisition of L2 phonemes when phoneme-grapheme correspondences in the speaker's L1 and L2 are similar but impedes acquisition when they are dissimilar (Bassetti, 2008; Erdener & Burnham, 2005; Escudero & Wanrooij, 2010).

French nasal vowels are represented by multiple graphemic variations, including, but not limited to, <an, am, en, em> for /ɑ̃/, <in, ein, ain, aim> for /ɛ̃/, and <on, om> for /ɔ̃/. French orthography relies on <n> and <m> graphemes to indicate vowel nasalization. In the context of French nasal vowels, these graphemes are not pronounced as the nasal consonant phonemes they represent in English orthography. Detey and colleagues (2010) reported a negative effect of orthography as the incidence of nasal consonants following French nasal vowels was higher during a reading task compared to a repetition task. However, L1-French listeners more accurately identified participants' productions of /ɔ̃/ during the reading task. This likely occurred because /ɔ̃/ has only two graphemic variations, which aided learners in differentiating it from /ɑ̃/ and /ɛ̃/. While this study provides insight on how orthography affects French nasal vowel production by L2-French speakers, research specific to L1-English, L2-French speakers is limited.

The effect of orthography on L2 phonological acquisition is often attributed to the opacity or transparency of a speaker's L1 (Erdener & Burnham, 2005). Orthography is described on a continuum, with transparent languages utilizing fewer graphemic variations for a single phoneme and opaque languages utilizing multiple graphemic variations for a single phoneme. Both French and English orthographies are considered opaque (Gimenes et al., 2020). Katz and Frost (1992) theorized that speakers of opaque languages process words visually as a whole while speakers of transparent languages map individual graphemes to phonemes. Meschyan and Hernandez (2006) reported greater activity in visual areas of the brain when reading opaque orthography and greater activity in phonological processing areas when reading transparent orthography via neuroimaging.

Cross-linguistic research on the relationship between orthography and phonological acquisition has offered varied results. Zampini (1994) reported that L1-English, L2-Spanish speakers substituted /v/ for the correct /b/ phoneme when reading Spanish words containing <v> graphemes. Misalignment between English and Spanish phoneme-grapheme correspondences hindered Spanish learners' ability to accurately produce Spanish phonemes. Similarly, L1-English, L2-German speakers produced /s/ instead of /z/ at the beginning of words because <s> does not represent /z/ in the beginning of English words (Young-Scholten & Langer, 2015). In contrast, Steele (2005) observed positive effects of orthography on consonant cluster production by L1-Mandarin, L2-French speakers. Participants exposed to French orthography were more likely to produce both sounds within the consonant cluster, while participants not exposed to orthography omitted the second consonant in the cluster.

The aforementioned research examined the effects of orthography on phoneme production through reading tasks rather than auditory-orthographic tasks. Rafat (2015) investigated Spanish consonant production by L1-English speakers across auditory-orthographic tasks and auditory-only repetition tasks. Productions were significantly different between the two tasks, revealing that orthography can affect speech production even when combined with auditory stimuli. Similarly, Bürki and colleagues reported that L1-French, L2-English speakers had less English-like formant patterns for English vowels produced in the auditory-orthographic condition compared to the auditory-only condition (Bürki et al., 2019).

The purpose of the present study is to further investigate vowel space and durational differences in French nasal vowel production by L1-French speakers and L1-English, L2-French speakers as well as the influence of orthography on L2 phoneme production. The present study

may contribute to the understanding of the interaction between auditory-orthographic and auditory-only stimuli in French nasal vowel production by L1-English, L2-French speakers.

Research Questions

1. How does F1F2 vowel space for French nasal vowels differ between L1 and L2-French speakers?
2. How does the duration of French nasal vowels differ between L1 and L2-French speakers?
3. How does the type of stimuli (Auditory-Orthographic vs Auditory-Only) influence L2-French speakers' production of French nasal vowels?

Methodology

Participants

All recruitment and testing procedures were approved by the University of Northern Iowa's Institutional Review Board for research involving human subjects (IRB-FY24-56). Three L1-French speakers (2 males and 1 female; Mean age = 27, Range = 24-29) and ten L2-French speakers (6 males and 4 females; Mean age = 23.3, Range = 19-49) were recruited through the Department of Languages and Literatures at the University of Northern Iowa. The L1-French speakers spoke French as a native language and region of origin was not an exclusionary factor. L1 P1 was from Haiti, L1 P2 was from Burkina Faso, and L1 P3 was from Eastern France. L2-French speakers spoke American English as a native language and were currently or previously enrolled in a UNI French course or had studied French at the secondary level (See Table 1).

Table 1

L2 Group Language Experience

Participant	Age at Time of Study	Age at Onset of French Acquisition	Semesters of French Instruction (or Equivalent)	Other Language Experience
L2 P1	19	19	1	Spanish
L2 P2	19	14	6	none
L2 P3	21	20	2	Spanish
L2 P4	22	14	10	Afrikaans
L2 P5	20	14	8	none
L2 P6	21	20	3	Spanish
L2 P7	22	14	5	none
L2 P8	20	15	4	none
L2 P9	49	24	3	Italian, German
L2 P10	20	13	8	none

Stimuli

The task consisted of 15 monosyllabic French words containing a single consonant onset followed by a nasal vowel nucleus (five words contained /ɑ̃/, five contained /ɛ̃/, and five contained /ɔ̃/). All consonants were either stops or fricatives that are present in American English to control for the effects of coarticulation. Words with a variety of graphemic variations were selected to examine the effect of orthography on vowel production. The carrier phrase "*Je vois le…*" ("I see the…") preceded all words (See Appendix A). Phrases were randomized and

presented three times each (total of 45), one at a time in large font through a PowerPoint presentation.

Procedures

All procedures were conducted in the Voice and Respiratory Laboratory at the Roy Eblen Speech and Hearing Clinic. The participants completed informed consent and a questionnaire prior to testing (See Appendix B). L1-French speakers were asked to provide their region of origin. L2-French speakers were asked to provide the number of semesters of French instruction they had completed (or equivalent if taken in high school; 1 year = 1 semester of college instruction), the age at which they began studying French, and their experience with other languages. Participants were fitted with a unidirectional, head-mounted Audio-Technica ATM-75 microphone placed five centimeters from the mouth. Utterances were recorded in the Time Frequency Analysis 32-bit software program (TF32) for acoustic analysis and edited into individual utterances for subsequent analysis using Praat acoustic software.

L1-French speakers completed one task (orthographic condition) during which they read the 45 phrases. Audio recordings from L1 P1 were embedded in the PowerPoint presentation and utilized as auditory stimuli for the L2-French speakers, who completed two tasks. During the Auditory-Orthographic (Aud-Ortho) task, participants repeated each phrase after listening to its respective audio recording from L1 P1 while simultaneously viewing its orthographic form on the screen. During the Auditory-Only (Aud-Only) task, participants repeated the same 45 phrases following audio recordings but did not view the phrases' orthographic forms.

Analysis

The second production of each word within both tasks was analyzed in Praat acoustic software using wideband spectrograms and their corresponding waveforms. The onset of the vowel was marked at the onset of periodicity in the waveform and the offset of the vowel was marked at the point where the waveform became aperiodic. F1 and F2 across time and duration in seconds were recorded for each vowel. Independent variables included group (L1 and L2) and task (Aud-Ortho and Aud-Only) and dependent variables included F1F2 vowel space and duration. The presence of postvocalic consonants and differences in F1-F2 relationship were qualitatively assessed through spectrograms.

Results

FlF2 Vowel Space

Mean F1 and F2 values for L1 P1 are shown in Figure 4. The relationship between the L2 group's productions of /ɑ̃/, /ɛ̃/, and /ɔ̃/ (Figure 5) generally aligns with that of L1 P1, with /ɛ̃/ having a higher F1 and F2 than /ɑ̃/ and /ɔ̃/. The L2 Group's F1F2 vowel space plot demonstrated greater F1-F2 variability with a wider range of F1 and F2 values for /ɑ̃/ and /ɔ̃/ in the Aud-Ortho condition (Figure 6) compared to the Aud-Only condition (Figure 7).

Figure 4

L1 P1 F1F2 Vowel Space

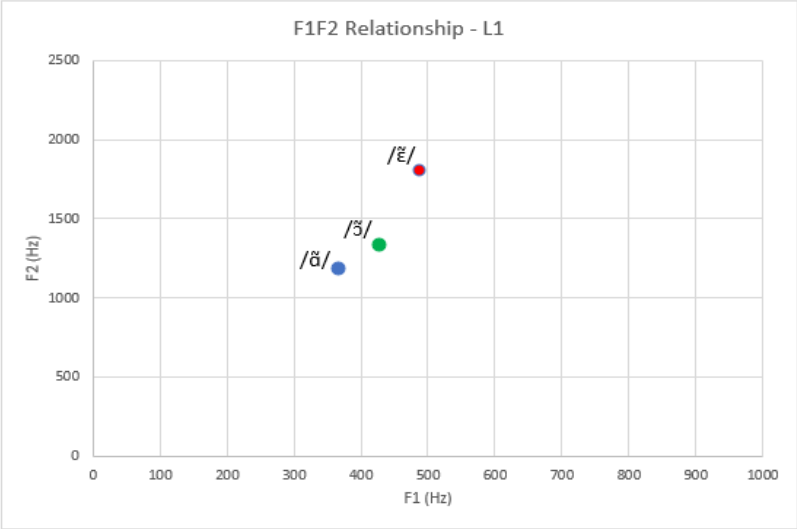


Figure 5

L2 Group F1F2 Vowel Space

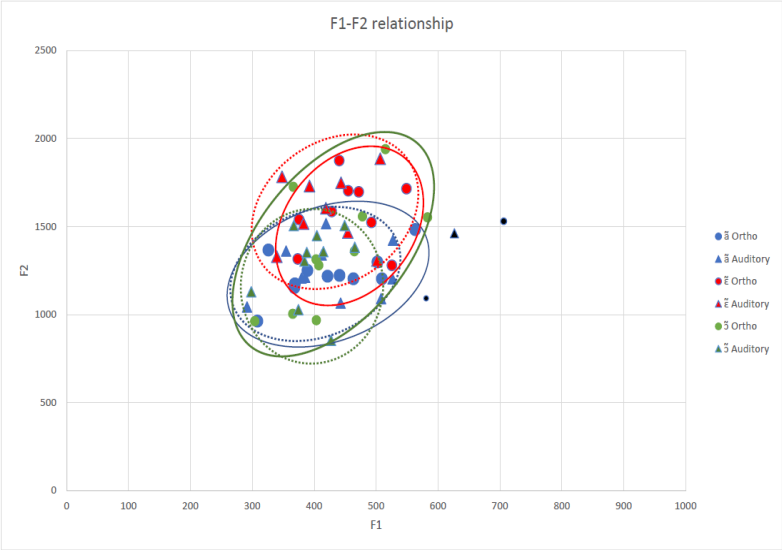


Figure 6

L2 Group Vowel Space: Aud-Only Condition

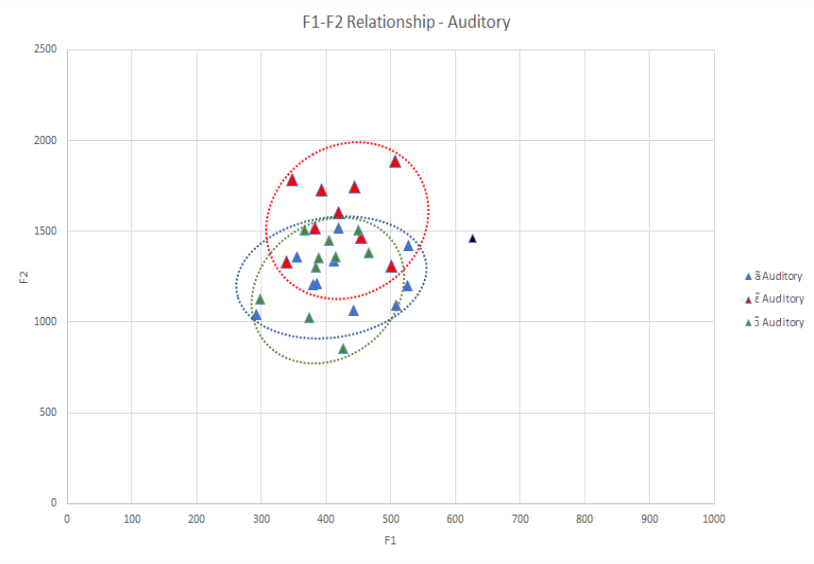
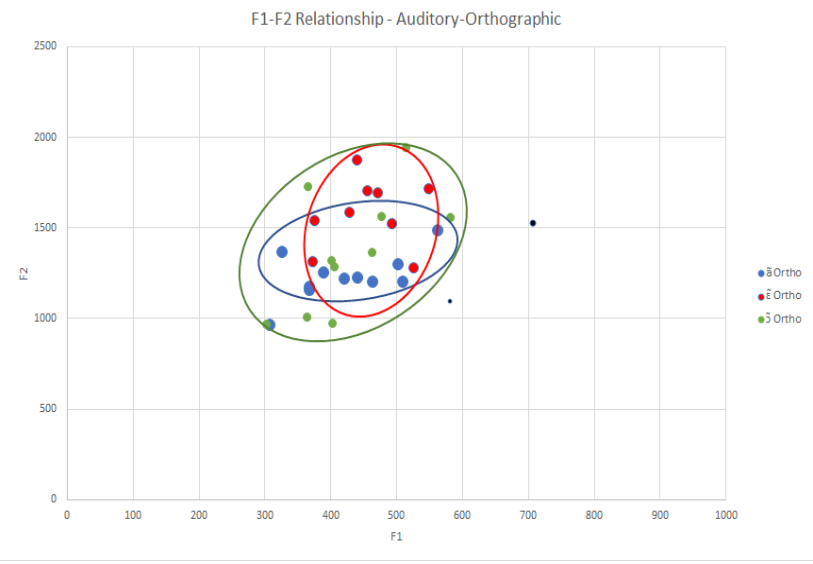


Figure 7

L2 Group F1F2 Vowel Space: Aud-Ortho Condition



Duration

There were slight durational differences between the L2 group and L1 P1, with mean duration in seconds (s) for each vowel being shorter for the L2 group compared to L1 P1 (Figure 8). The L2 group's vowels are slightly longer in the Aud-Ortho task than the Aud-Only task (Figure 9). In general, /ɛ̃/ has the longest duration for both L1 P1 and the L2 group.

Figure 8

Mean Duration of L1P1 and L2 Group by vowel and condition

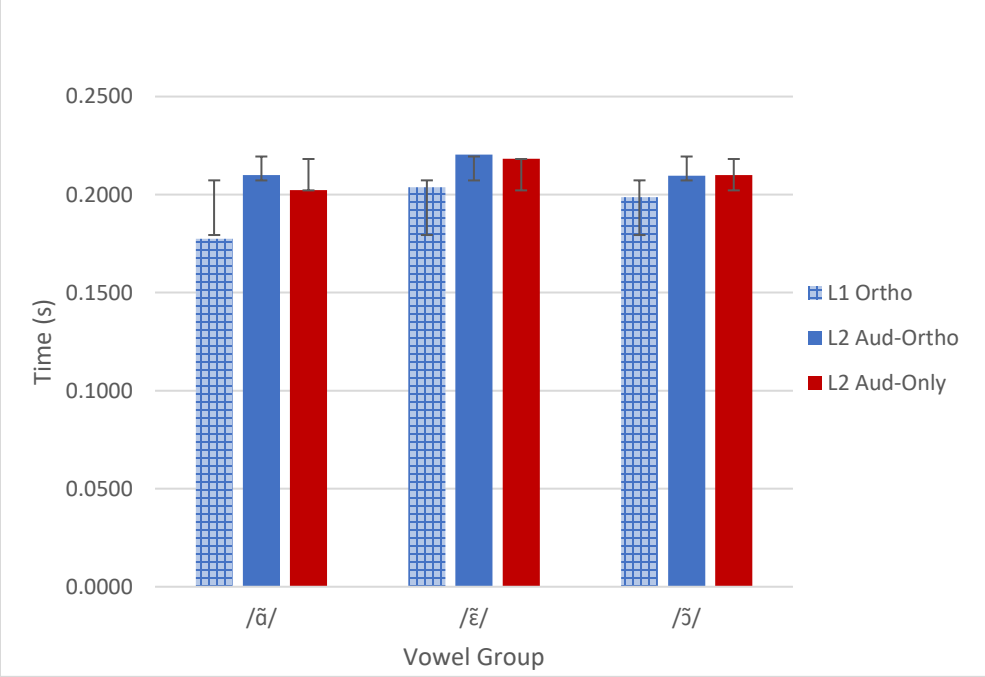
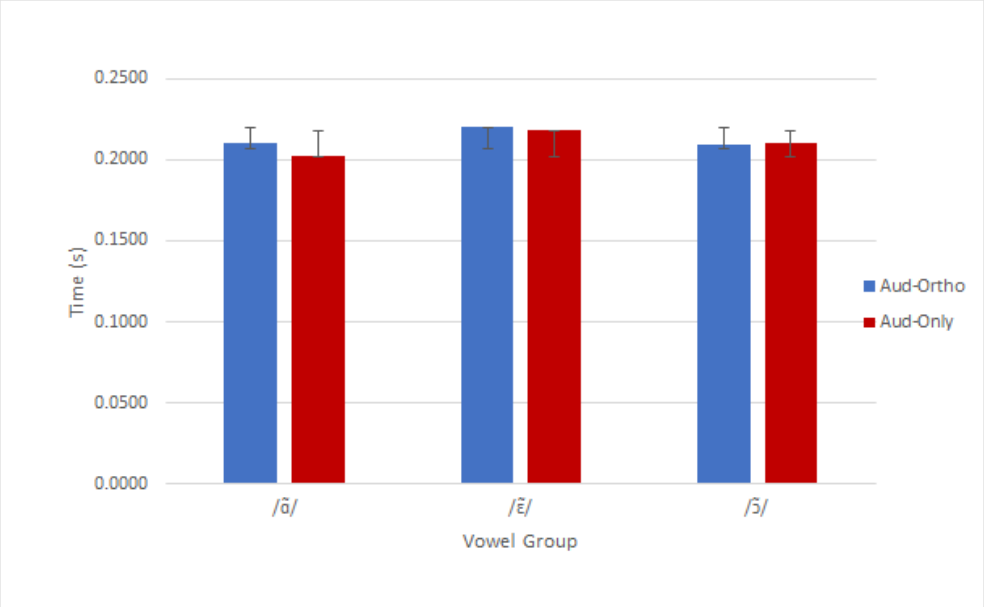


Figure 9

Mean Duration for L2 Group by vowel and condition



Spectrographic Differences

The presence or absence of a nasal consonant following /ɛ̃/ in "*bain*" are shown in Figures 10-12. F1 and F2 can be visualized throughout the entirety of L1 P1's vowel production (Figure 10). In contrast, the "nasal murmur," which is the concentration of low frequency energy, indicates a nasal consonant following the vowel in the L2 speaker's production (Figure 11; Behrman, 2023, p. 333). Figure 12 more closely resembles Figure 10 as there is no acoustic evidence of a nasal consonant.

Figure 10

L1 P1 “Bain”

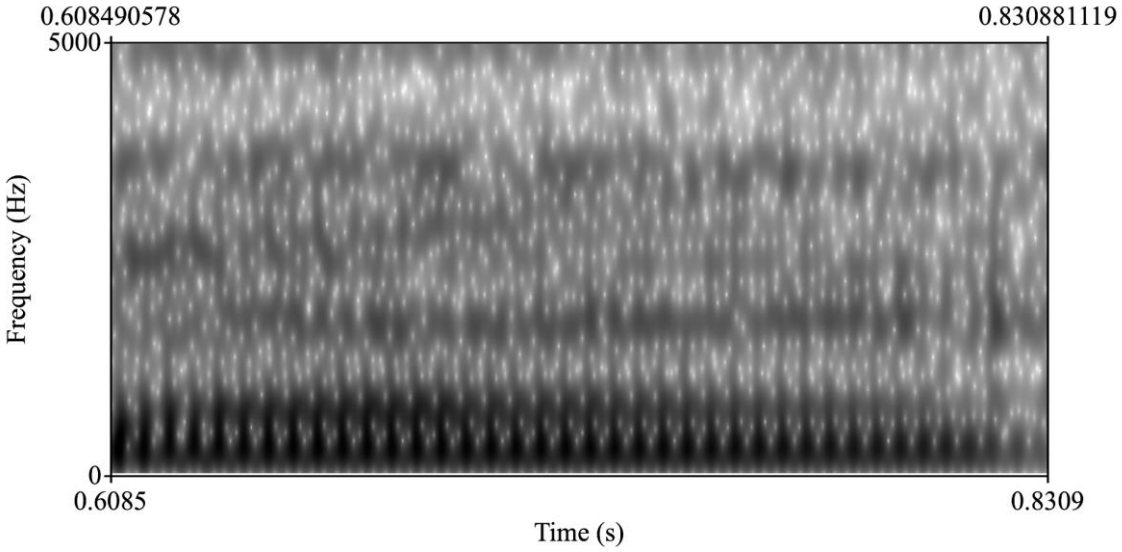
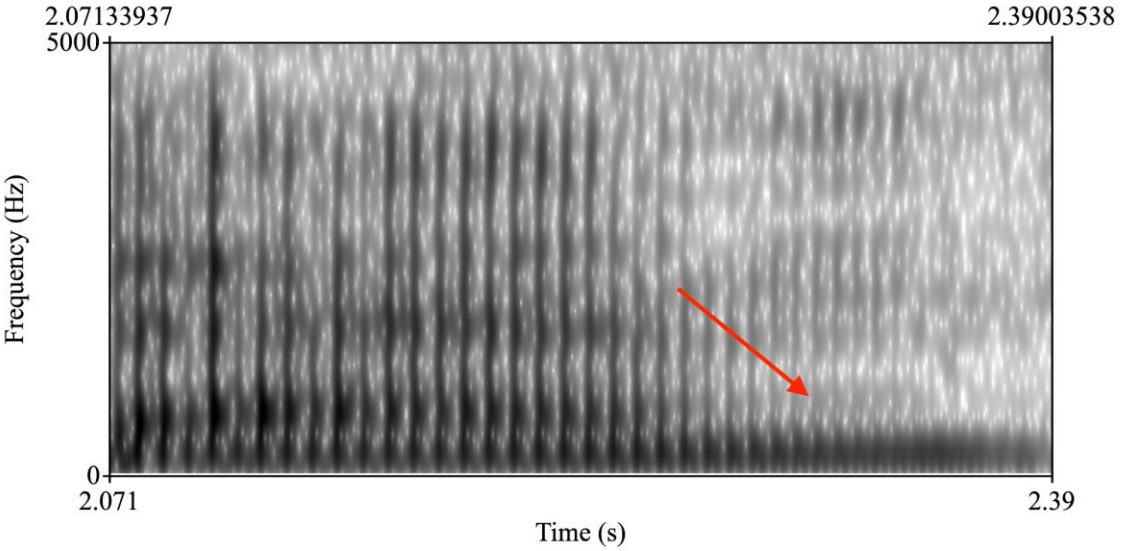


Figure 11

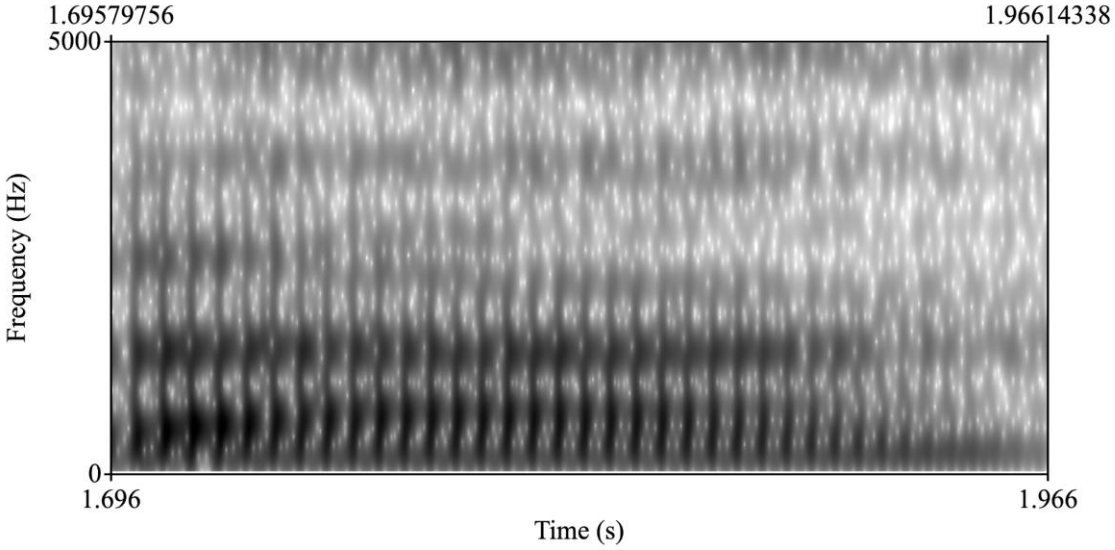
L2 P3 “Bain” *in Aud-Only Condition*



Note. The arrow indicates the nasal murmur.

Figure 12

L2 P7 "Bain" *in Aud-Only Condition*



Differences in L1 P1 and L2 P4's productions of /ɑ̃/ and /ɛ̃/ are shown in Figures 13-16. L1P1's /ɑ̃/ in "*vent*" and /ɛ̃/ in "*vin*" have distinctive F1-F2 relationships (Figures 13 and 14). F1 and F2 are close together in /ɑ̃/ and farther apart in /ɛ̃/. In contrast, L2 P2's vowels in "*vent*" and "*vin*" (Figures 15 and 16) are indistinct and both resemble the formant structure of /ɑ̃/.

Figure 13

L1 P1 "Vent"

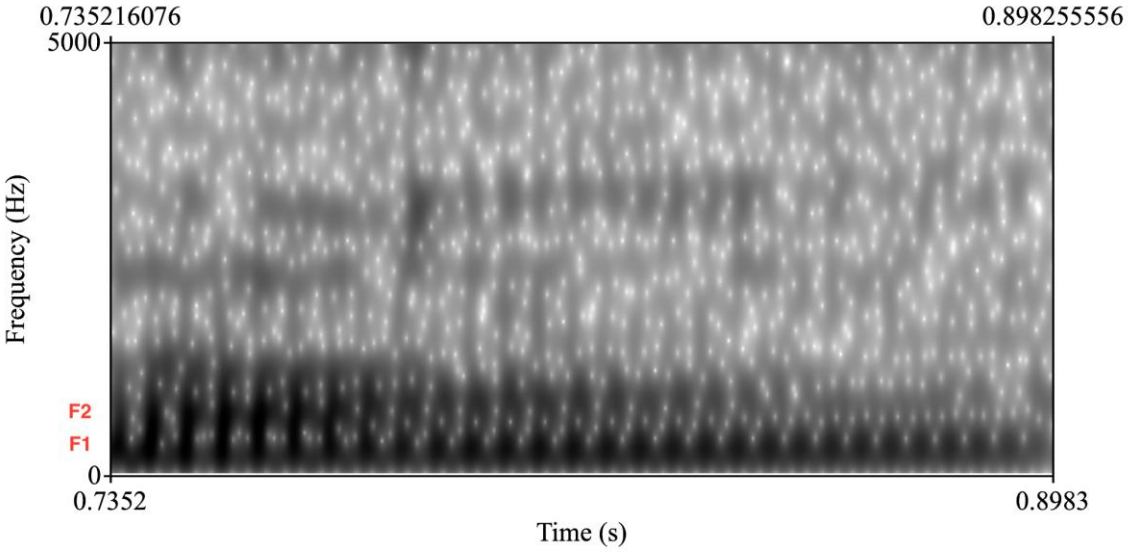


Figure 14

L1 P1 "Vin"

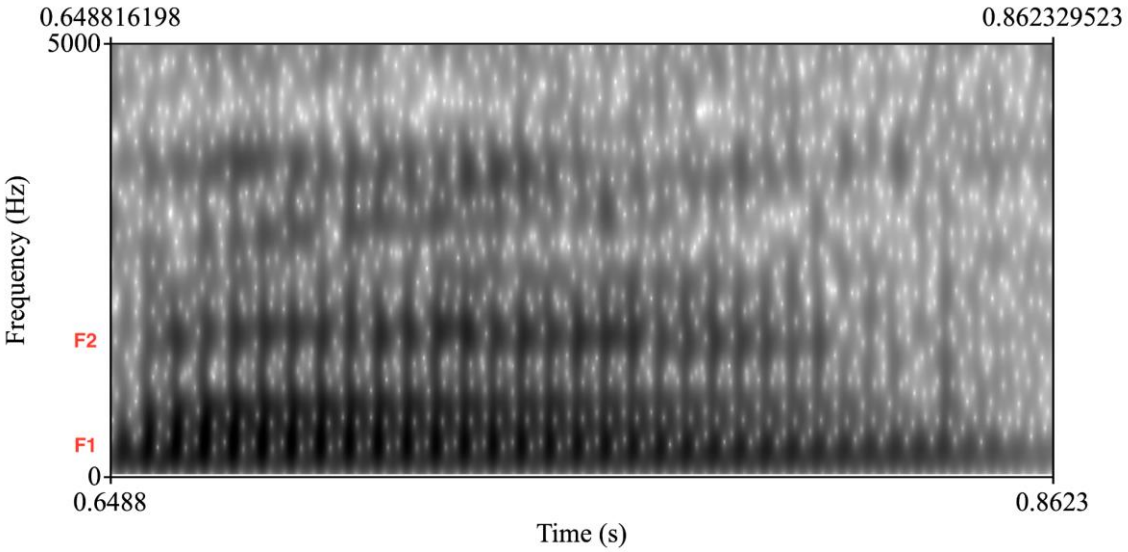


Figure 15

L2 P4 “Vent” *in Aud-Only Condition*

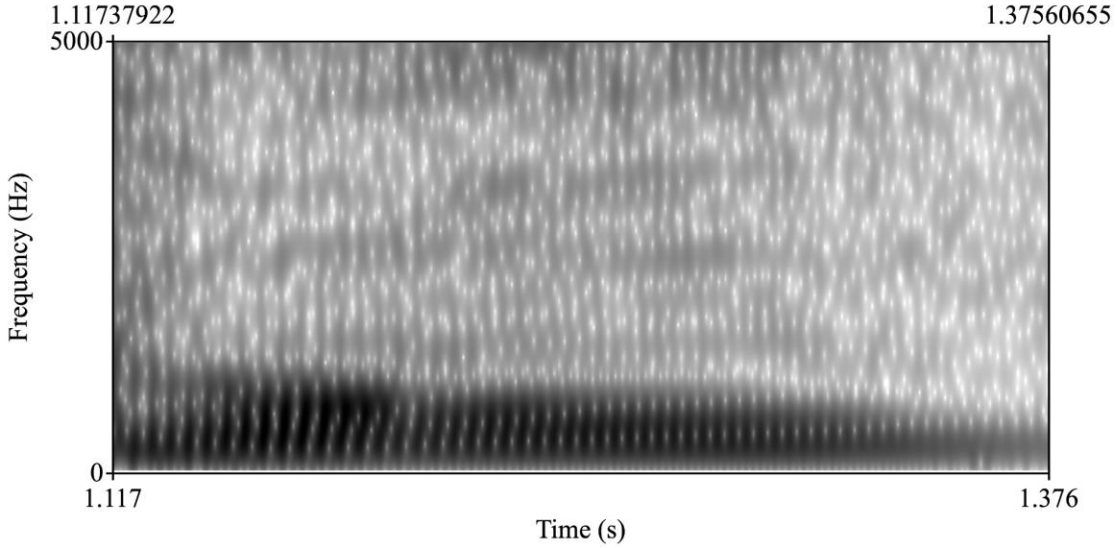
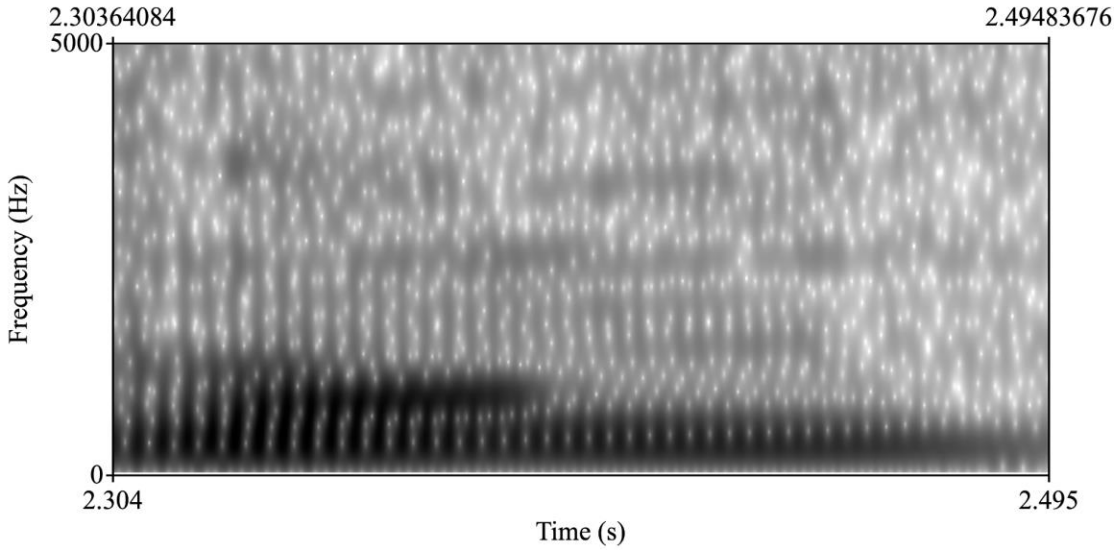


Figure 16

L2 P4 “Vin” *in Aud-Only Condition*



Differences in L2 P8's productions of *"pont"* across the Aud-Ortho and Aud-Only conditions, relative to L1 P1's production, are shown in Figures 17-19. In Figure 18, the lack of sound energy following the vowel indicates a stop gap followed by a burst release for the glottal stop consonant /ʔ/. A stop consonant is not present in L2 P8's production during the Aud-Only task, but there is a nasal murmur. (Figure 19).

Figure 17

L1 P1 "Pont"

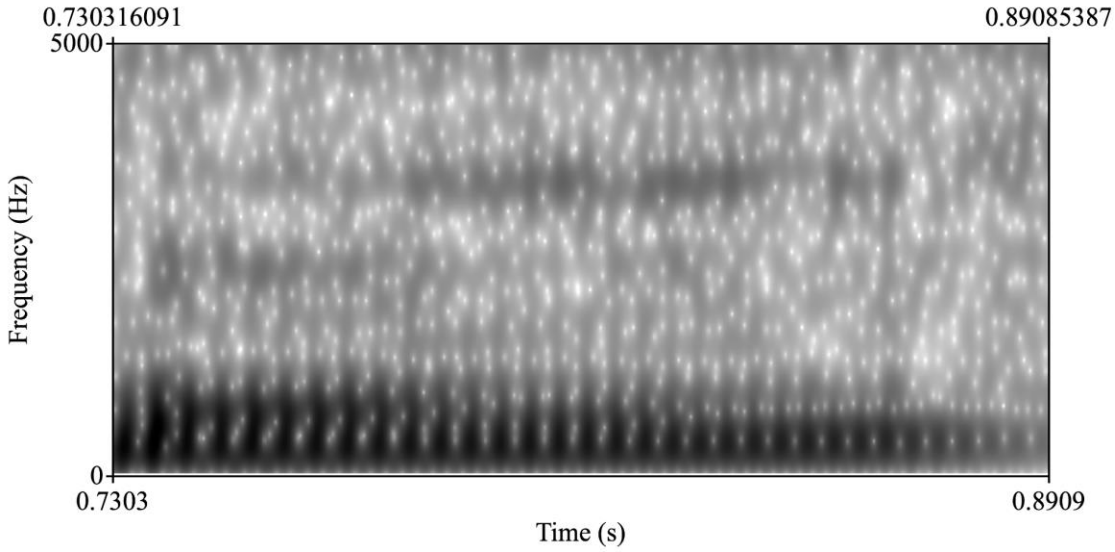
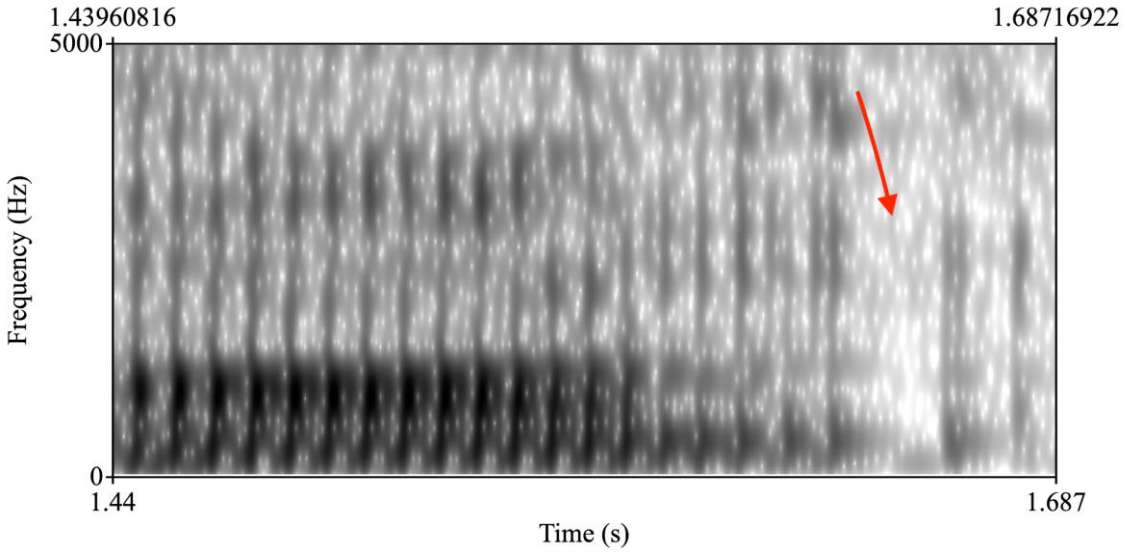


Figure 18

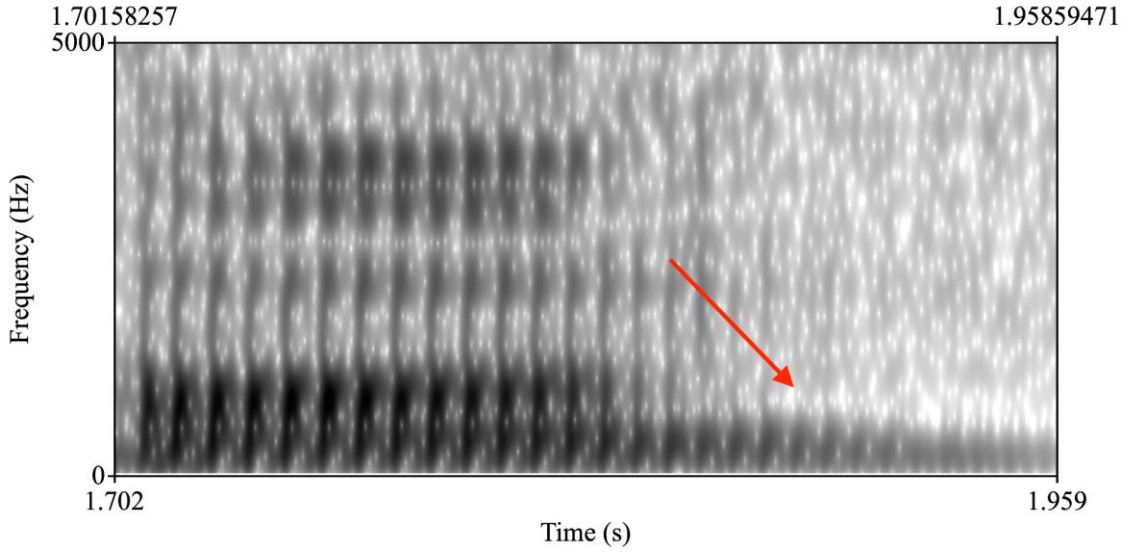
L2 P8 "Pont" *in Aud-Ortho Condition*



Note. The arrow indicates the stop gap.

Figure 19

L2 P8 "Pont" *in Aud-Only Condition*



Note. The arrow indicates the nasal murmur.

Discussion

L2-French speakers demonstrated greater variability in F1F2 vowel space for two French nasal vowels during the Aud-Ortho task compared to the Aud-Only task, suggesting that exposure to orthography increased variability in the L2 speakers' vowel production. L2-French speakers may achieve more L1-like French nasal vowel production when only exposed to auditory stimuli. The similarity in the L2-French speakers' productions of /ɑ̃/ and /ɛ̃/ is in line with Montagu's (2002) observation of similar F1-F2 relationships in L2-French speakers' productions of /ɑ̃/ and /ɔ̃/ as well as Inceoglu's (2021) report of L2-French speakers having difficulty perceptually discriminating between French nasal vowels. There were only slight differences in vowel duration between the L1 and L2 speakers and duration may not be a salient acoustic cue in distinguishing French nasal vowel productions between these two groups.

The process of nasal unpacking described by Marquez Martinez (2016) was present in the L2-French speakers' productions. The presence of nasal consonants following vowels in both the Aud-Ortho and Aud-Only tasks revealed that L2-French speakers produce nasal consonants following vowels even when not presented with <n> and <m> graphemes. These findings are similar to those of Detey and Colleagues (2016), who observed postvocalic consonants in both reading and repetition tasks. Differences across conditions were present in L2 P8's productions, as a glottal stop consonant was produced in response to <t> only during the Aud-Ortho condition. The lack of orthographic influence in the majority of participants' productions may be due to the opacity of French and English orthographies (Gimenes et al., 2020).

Conclusion

This study sought to identify acoustic cues that differentiate French nasal vowel productions by L1-French speakers and L1-English, L2-French speakers, including F1F2 vowel space, duration, and the presence of postvocalic consonants. Potential orthographic influences on French nasal vowel production by L2-French speakers were explored through Auditory-Orthographic and Auditory-Only repetition tasks. The results indicated greater variability in the L2 speakers' F1F2 vowel space during the Auditory-Orthographic condition but only slight differences in duration were found between the L1 and L2 groups. These data provide insight on acoustic differences between L1 and L2-French speakers' French nasal vowel production and how it is affected by type of stimuli.

Limitations

This study has several limitations related to participants, stimuli, and analysis. The small sample size (n =10) makes examining acoustic trends related to language experience level difficult. Participants were only asked to list the number of semesters of French instruction they had completed and were not asked specific questions regarding their degree of French exposure through reading, writing, listening, or speaking.

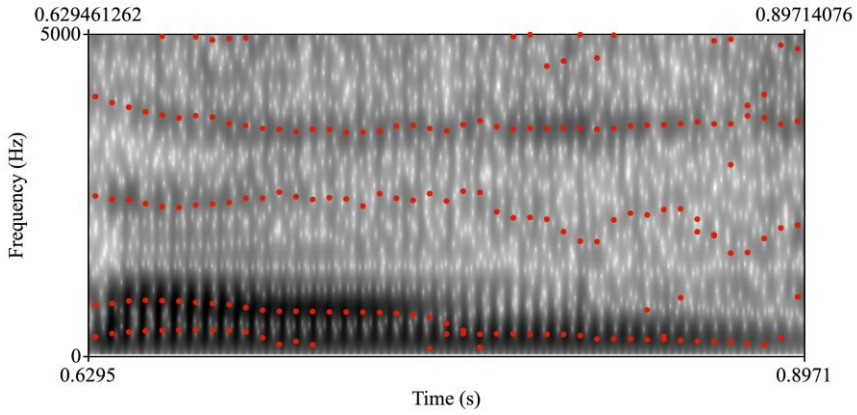
The vowels were produced within carrier phrases and may not reflect participants' natural speech patterns. Consonant inventories for each vowel were inconsistent. Due to coarticulation, consonants influence the formant structure of the vowels they are followed by (Hillenbrand et al., 2001), which may have affected participants' F1F2 vowel space. The selected words also varied in how often they occur in the French language. L2-French speakers may have had greater difficulty recognizing nasal vowels in unfamiliar words. The Aud-Ortho task was always

completed prior to the Aud-Only task; therefore, orthographic exposure may have influenced participants during the second task.

F1 and F2 values obtained from Praat acoustic software may be inaccurate, as acoustic software may misidentify formants of nasal sounds that are close together (Ladefoged, 1996). A large upward shift in the F2 of /ɔ̃/ is shown in Figure 20.

Figure 20

Spectrogram of /ɔ̃/



Future Research

Future research could include a larger number of participants with varying degrees of French language experience to investigate the relationship between vowel production and proficiency level. Stimuli could contain words with different phonetic contexts (e.g. multisyllabic words, words with postvocalic consonants) to assess how word complexity affects the realization of French nasal vowels. Analysis could include all 45 productions from both tasks

to gain insight on within-speaker vowel variability between the L1 and L2 groups. Dialectal differences between the three L1-French speakers could also be investigated.

Significance in Speech-Language Pathology

With the bilingual and multilingual population in the United States growing (Dietrich & Hernandez, 2022), it is essential that speech-language pathologists understand phonological aspects of languages other than English as clinicians must consider the client's L1 in assessment and intervention for all communication disorders. This research also provides insight on speech perception and production differences between L1 and L2 speakers, which need to be accounted for when serving clients who are L2-English speakers (American Speech-Language-Hearing Association, nd.). Additionally, acoustic analyses can be applied clinically to provide more objective measures of speech production rather than relying on perceptual judgments. Clinicians can implement spectrograms as visual cues to assist clients in reaching their treatment goals.

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Appendix A: Stimuli

/ɑ̃/

1. Je vois le **champ**
2. Je vois le **gant**
3. Je vois le **vent**
4. Je vois le **sang**
5. Je vois le **temps**

/ɛ̃/

1. Je vois le **daim**
2. Je vois le **bain**
3. Je vois le **teint**
4. Je vois le **pin**
5. Je vois le **vin**

/ɔ̃/

1. Je vois le **pont**
2. Je vois le **gond**
3. Je vois le **fond**
4. Je vois le **don**
5. Je vois le **bond**

Appendix B: Participant Information

SPEECH PRODUCTION BY NATIVE AND NON-NATIVE SPEAKERS OF FRENCH
Intake Questionnaire

Please respond to the following questions to determine your eligibility to proceed in participating in this study. You may skip any questions that you prefer not to answer. All responses will remain confidential.

Participant number:_____ Sex_____ Gender_____ DOB_____

Home City and State: _____

Please list any languages (other than French) that you speak or have studied:
_____

L1-French Speakers
Do you speak French as a native language? Yes No

What is your country of origin? _____

L2-French Speakers
Do you speak American English as a native language? Yes No

Do you speak French at home as a native language? Yes No

How many semesters of formal French instruction have you completed? _____
(high school and university-level)

At what age did you begin formally studying French? _____