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French learners of English struggle to identify nasalised American vowels in CVN words

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English and French have different phonological systems (Roach, 2009; Walker, 2001) and French learners have difficulties perceiving some contrasts, such as the approximants /w/ – /ɹ/ (Hallé et al., 1999). They also tend to assimilate multiple English vowels to a single L1 category (Iverson & Evans, 2007). General American exhibits a raising of /æ/ in nasal environments (Carignan et al., 2016), thus creating an acoustic proximity between /æ/ and /ɛ/. The purpose of the present study was to assess the influence of CVN contexts on the perception of vowels by French university students.

We addressed this issue as part of a pedagogical project called SEPALÉ, which consists of identification and discrimination exercises involving English phonemic contrasts and within which we explored the issue of nasalisation. Thirteen Californian speakers were recorded reading CVC and CVN words, to create stimuli used by undergraduate students in discrimination and perception tasks. Their answers were recorded in logfiles, used in our analysis.

We found a higher proportion of errors when /æ/ – /ɛ/ and /ɑ/ – /ʌ/ were in a pre-nasal position and the first contrast yielded better identification and discrimination rates than /ɑ/ – /ʌ/. This finding could inform teachers' choices of perception or production exercises.

Keywords: French learners, nasalisation, identification tasks, perception, discrimination



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1 Introduction

General American (hereafter GA) vowels can be affected by nasalisation when followed by a nasal consonant. Thus, we decided to examine the possible perception impairment that they could provoke in French learners. Before /m/, /n/, and /ŋ/, the tongue follows a rising trajectory whose peak differs depending on the consonant; the velar differs from the other two, but for all three a lowering of the first formant of low vowels is generally observed. The alteration of the perceived height of low vowels when followed by a nasal (Mielke et al., 2017) begs the larger question of how a nasal consonant influences the perception of vowels by French learners of English.

SEPALE, a pedagogical project, was used as a platform to look into the possible impact of a CVN (consonant – vowel – nasal) environment on the perception of GA vowels by French learners. SEPALE¹ is a project consisting of exercises to train the perception of those vocalic contrasts which are supposed to be difficult for French learners of English. The project is part of the participant's curriculum, so the exercises were completed weekly over a period of 12 weeks, although some students were less assiduous. The results analysed in the present study are the uploaded answers to the perception tasks as done by the participants within the wider SEPALE project.

2 Previous research on the topic

There is a large body of academic work pertaining to vowel nasalisation in English. Several authors have notably shown that nasalisation may affect perceived vowel height (e.g., Beddor, 2007; Krakow et al., 1988; Wright, 1975) because of the resulting acoustic shift in the F1 region. Generally speaking, nasalisation entails a lowering of high and mid-vowels and raising of low vowels (Wright, 1975, 1986). Studies combining acoustics and ultrasound tongue imaging have demonstrated that depending on the vowel, tongue height adjustments may be used to compensate or enhance the acoustic effect of nasality. For instance, Carignan et al. (2011) showed that /i/ is produced with a compensatory higher tongue position in pre-nasal context in order to counteract the resulting raising of F1 and to avoid neutralisation with neighbouring /ɪ/. They observed no such adjustment in pre-nasal /a/, where the perceived variation in vowel height induced by nasalisation is acceptable without any risk of misidentifying the vowel. Conversely, Mielke et al. (2017) found that the tongue raising movement of /æ/ in pre-nasal environments may constitute a strategy to enhance the acoustic effect of nasalisation. Carignan et al. (2016) explain that while tongue raising before velar consonants /g/ and /ŋ/ is described as the result of coarticulation (as evidenced by a gradual raising of the tongue in anticipation of the velar constriction), such raising before other nasals peaks around the midpoint of the vowel, indicating “a distinct phonetic target” (p. 316).

Most accents of North American English, including GA, exhibit a raising of /æ/ in pre-nasal environments (Carignan et al., 2016; Labov et al., 2006), the realisation of which is generally described as involving a raising-falling trajectory before /m/ and /n/ (e.g., *pan* [peən]) and a raising trajectory before /ŋ/ (e.g., *bang* [beŋ]). As shown by Krakow et al. (1988), the discrimination of nasalised /ɛ/ and /æ/ in a contextual nasal environment (i.e., when the nasalised nucleus is followed by a nasal consonant) is unproblematic for native speakers. However, the acoustic proximity of the nasalised nuclei in e.g., *bend* and *band* might make it difficult for French learners to distinguish /ɛ/ vs. /æ/ in those environments. This difficulty

¹ SEPALE is a project that was developed at Université Paris Cité thanks to funding devoted to pedagogical innovation received from 2021 to 2022.

usually bears no equivalence with British varieties where /æ/-raising is largely absent (Mielke et al., 2017).

Given the absence of compensatory tongue adjustment to the nasality induced raising of /ɑ/ (Carignan et al., 2011) and lowering of mid-vowels in pre-nasal environments (Wright, 1975), we also observe difficulties in French learners to correctly discriminate pre-nasal /ɑ/ and /ʌ/ (e.g., *pond* vs. *punned*).

We hypothesised that French learners of L2 English would have more difficulties in perceiving the /æ/ – /ɛ/ and /ɑ/ – /ʌ/ contrasts in pre-nasal environments (e.g., *sand* – *send* and *pond* – *punned*) than in other pre-consonantal environments (e.g., *bat* – *bet* and *cot* – *cut*).

3 Methodology

3.1 Participants

In this study, 118 second-year students from Université Paris Cité participated in the experiment during the second semester of the academic year. The students were between 19 and 21 years old and their proficiency was at or near a B2 level of English, which is the required level for admission to the *Licence LLCER Anglais* degree programme in French universities.

3.2 Stimuli creation

As the purpose of the discrimination study was to determine whether the nasal after the nucleus had an influence on the students' perception of the vowel, a list of both CVC (consonant – vowel – consonant) and CVN one-syllable words was established. The words included the /æ, ɛ, ɑ, ʌ, ɪ, i, ɔ/ vowels as a nucleus. Some items with /ɪ/ and /i/ from the final list of stimuli were adapted from Krzonowski (2020), and other CVC and CVN words were added with /æ, ɛ, ɑ, ʌ, ɔ/. We will focus on the /æ/ – /ɛ/ and /ɑ/ – /ʌ/ contrasts, but the /ɪ/ – /i/ contrast will be included as a baseline because no such nasalisation effect is known to impact its realisation.

We avoided the postvocalic liquid /l/ as mergers have been observed in this context, for example, *pull* – *pool* – *pole* may all sound alike due to /l/ (Arnold, 2015), and similarly in *feel* – *fill* (Labov et al., 2006), where the distinction between /i/ and /ɪ/ is often neutralised for the same reason. We also decided against items with a pre-velar context, such as *pag* – *peg*. Although there is usually no /æ/-raising before a velar stop in GA, the existence of a raising pattern with a rising tongue trajectory before /g/ has already been observed. As a consequence, in some regions of North America, the word *bag* is pronounced [beɪg] (Mielke et al., 2017). The list of stimuli is provided in the Appendix.

Thirteen native speakers of GA (seven women) were recruited in Southern California, all but three of whom were from California. Of those three, one stated that they were from all over the US, another from New Orleans, and someone else from New Jersey. Their ages ranged from 20 to 73 years of age, the average age being 40. The calculated standard deviation was 16, and the median value was 39.

Recordings were made using ROCme! (Ferragne et al., 2012), a program fed with an HTML file to prompt words on a computer's screen. The speakers' productions were recorded with an AT2020 USB microphone. After each item, the speakers were invited to press a gamepad button to switch to the next word. The stimuli were presented in a randomised order to avoid redundancy and fatigue. In total, they each read 161 words, twice. We used both recordings when usable; some were trimmed, others were removed when the background noise was too distracting, or when the beginning of the recording was too close to the onset.

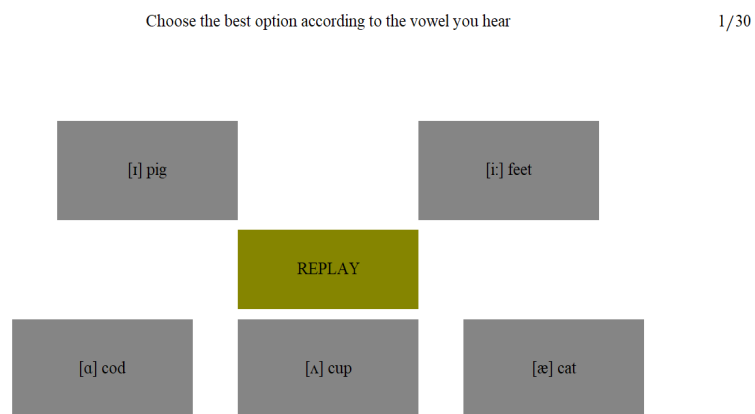
3.3 Procedure

Four types of tasks were included in the experiment. Each exercise was divided into sub-types which corresponded to the vowels involved, or the pre-nasal position of the vowel. In this way, students could choose the sub-type they wanted to focus on, and each attempt was composed of 30 prompts selected randomly out of the 161 words recorded by the 13 speakers.

The alternative forced choice exercises 2AFC and 5AFC played one word and provided the participants with two or five boxes, respectively, from which to pick a match for the vowel heard in the word played. For example, in the 5AFC exercise, participants heard a one-syllable word, and had to determine which vowel corresponded to the nucleus. Five options were provided in the form of boxes, as shown in Figure 1. The purpose of these tasks was to test the participant's ability to identify the vowels involved.

Figure 1

5AFC Window



In the AX exercises, participants heard two stimuli and had to determine if they were the same words or if they were different. In this task, two boxes labelled “Same” and “Different” were shown on the screen, and participants had to choose the option corresponding to their answer. This exercise evaluated their ability to differentiate vowel sounds in two minimal pairs. Finally, in the Oddity exercises, three stimuli were heard and the odd one out had to be found. Thus, there were three boxes carrying a number and corresponding to each stimulus. In this last task, their capacity to discriminate sounds was tested.

Participants could hit the “REPLAY” button as many times as they wished. At the end of each attempt, they received feedback in the form of a pop-up window, indicating: the number of wrong and right answers, the total time spent doing the exercise, and the number of times the “REPLAY” button was pressed. Answers were recorded in the logfiles created at the end of each attempt, as well as the number of errors and the response times.

4 Data analysis and results

Logfiles were analysed with SQLite² (Gaffney et al., 2022) and Python³ functions. Table 1 presents the error percentage per type of exercise throughout the study. The exercise type Oddity has the lowest percentage of errors, with AX at the other side of the spectrum.

Table 1

Percentage of Errors per Type of Exercise

Type of exercise	Error percentage (%)
Oddity	12.38
2AFC	19.83
5AFC	23.19
AX	25.49

The same observation emerges from Table 2, which shows the percentage of errors in both a non pre-nasal and in a pre-nasal context for the different types of exercises. The lowest percentage of errors in both contexts was found in the Oddity type of exercise, and the highest for CVN was recorded in AX exercises. The impact of nasalisation is shown in the last column, where the subtraction of the CVN error percentage from the CVC's is given. For each of the 118 participants, the mean percentage of errors across all exercises was computed for CVC and CVN contexts separately. In order to determine whether performance was, as expected, poorer in the CVN context, we ran a paired Wilcoxon signed rank test with continuity correction. The test corroborated our hypothesis, as it showed a significant value ($V = 232$, $p < 0.0001$).

Table 2

Percentage of Errors per Type of Exercise in a CVC and CVN Context

Type	Error percentage when CVC (%)	Error percentage when CVN (%)	Difference (%CVN - %CVC)
Oddity	10.59	16.46	5.87
5AFC	19.09	26.78	7.69
2AFC	14.93	24.99	10.06
AX	18.79	31.10	12.31

² SQLite (Version 3.31.1) [Computer software]. SQLite Development Team. Retrieved November 11, 2022. Available at <https://www.sqlite.org/download.html>

³ Python Software Foundation. Python Language Reference, version 2.7. Available at <https://www.python.org/downloads/release/python-3810/>

Table 3 displays the error percentage for the vowels involved in the study in CVC and CVN contexts. The percentage of errors increases for every item, except for /i/ which was inversely affected by its pre-nasal position, since students actually performed better when the vowel was nasalised. On the other hand, /ʌ/ appears to be the most affected vowel, with an increase in misperceptions of 17.82% when followed by a nasal; /æ/ was also quite affected (16.72%), as was /ɪ/ (15.21%).

Table 3

Percentage of Errors per Vowel in CVC and CVN Contexts and Impact of Nasalisation (Last Column) in 2AFC and 5AFC Exercises

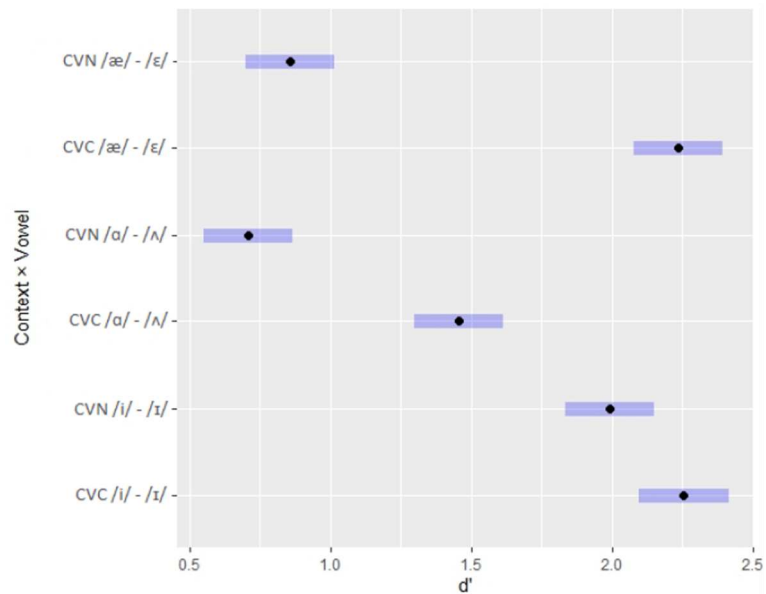
Vowel	Error percentage when CVC (%)	Error percentage when CVN (%)	Difference (%CVN - %CVC)
/i/	25.33	9.92	-15.41
/ɑ/	24.80	28.19	3.39
/ɛ/	15.47	29.49	14.02
/ɪ/	15.10	30.31	15.21
/æ/	6.26	22.98	16.72
/ʌ/	12.63	30.45	17.82

We then focused on the discrimination (AX) exercises, as they naturally lend themselves to the computation of the relatively unbiased d' sensitivity index from Signal Detection Theory (Green & Swets, 1966). A mixed-effects model was fitted to the data in R software with the lmer function from the lmerTest package, with d' as a dependent variable. We added Context and Vowel as fixed effects, as well as the interaction between Context and Vowel. We included Participant as a random effect. Both factors and their interaction were significant ($p < 0.0001$). Post-hoc comparisons were performed with the emmeans⁴ package and Figure 2 shows these findings. Three distinct groups appear: 1) the /æ/ – /ɛ/ contrast, for which students performed better when the vowel was not in a pre-nasal position; 2) /ɑ/ – /ʌ/, which showed moderate results in a CVC environment and poor results when the vowels were followed by a nasal; and 3) /ɪ/ – /i/, which obtained good results in both CVC and CVN contexts.

⁴ <https://cran.r-project.org/web/packages/emmeans/index.html>

Figure 2

Sensitivity Indices (d') for Each Combination of the Factors Vowel and Context in the AX Experiments.



Note. Higher d' values show better discrimination. Blue bars show 95% confidence intervals: non-overlapping bars reflect significant differences.

Figures 3 and 4 display the average rate of errors for the /a/ – /ʌ/ and /æ/ – /ɛ/ contrasts. The dotted line corresponds to the linear regression and shows a subtle decreasing trend. On average, students seem to have made more mistakes when the vowel was in a pre-nasal position. The percentage of errors for these pairs followed by a nasal approaches the 0.5 line, while in a non-nasal environment the students seem to have performed better, with a lower average rate of errors for each contrast. Moreover, the line corresponding to the CVN environment never overlaps with the other, the two trends remain almost parallel throughout the period.

Figure 3

Average Rate of Errors During the Second Semester of 2022 for the /ɑ/ – /ɔ/ Contrast

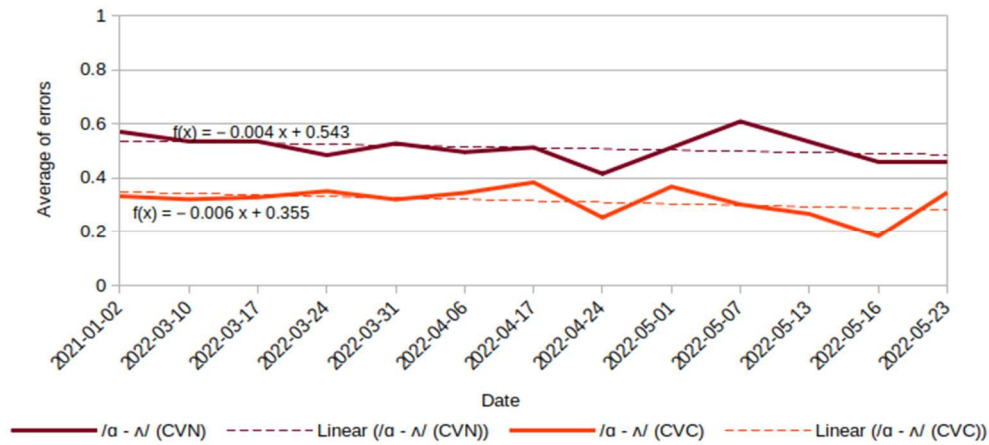
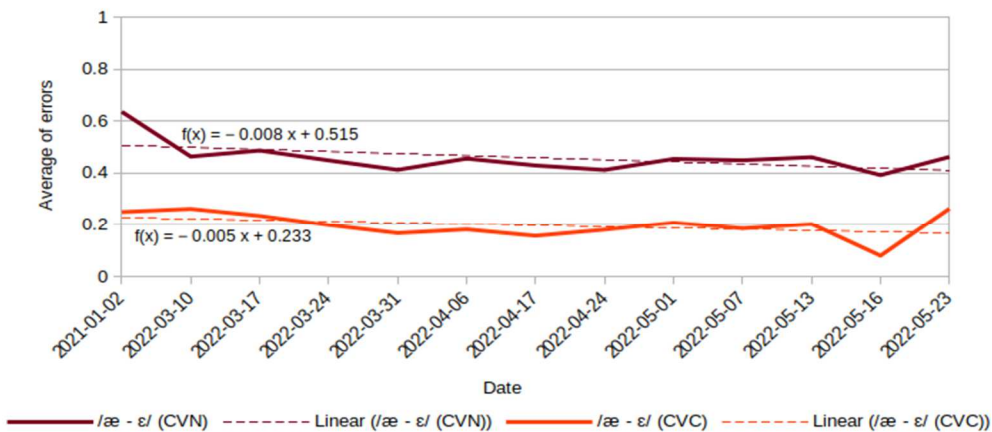


Figure 4

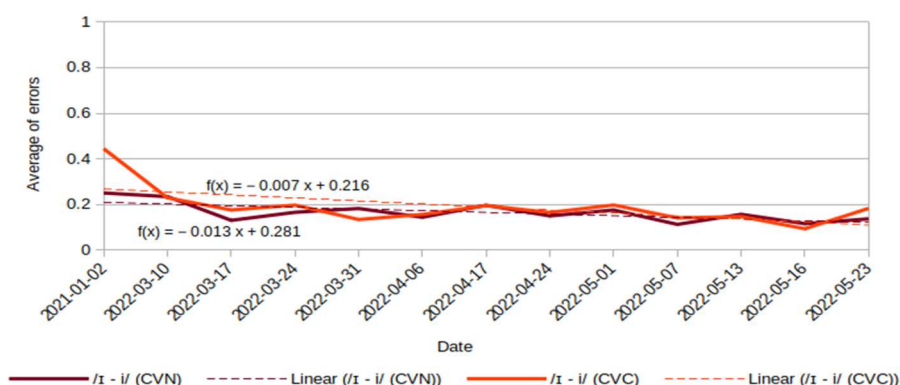
Average Rate of Errors During the Second Semester of 2022 for the /æ/ – /ɛ/ Contrast



By way of comparison, Figure 5 shows the average rate of errors through the course of the semester for the /i/ – /i/ vowels, for which the trend of the linear regression is also negative, therefore indicating a slight decrease. The lines corresponding to the CVC and CVN environments overlap, and the average rate of errors, independent of the context, never goes above 0.3.

Figure 5

Average Rate of Errors During the Second Semester of 2022 for the /ɪ – i/ Contrast



5 Discussion and implications

In the course of this study, we sought to determine whether the pre-nasal position of /æ/ – /ɛ/ and /ɑ/ – /ʌ/ vowels could have an influence on the perception of said vowel by French learners of English. Our results show that the presence of a nasal after these vowels has an impact on the perception of the nucleus by French learners. The data showed an increase in the percentage of errors for every item, except for /i/, for which the percentage was surprisingly low in a CVN environment. The tongue height adjustment strategy at play in nasalised /i/ does seem to favour the identification of /i/, as evidenced by the radical drop in misidentified /i/ tokens in 2AFC and 5AFC exercises. The other vowels were impacted by their pre-nasal position, ranging from a 14.02% to a 17.82% increase in the error percentage in a CVN context for /ɛ, ɪ, æ, ʌ/. In contrast, /ɑ/ shows relative stability but yields poor performance even in a CVC context.

The influence of nasalisation is especially visible for the /æ/ – /ɛ/ and /ɑ/ – /ʌ/ vowels. The results demonstrated that these pairs were better recognised in a non-nasal environment than when followed by a nasal. Similarly, the /æ/ – /ɛ/ contrast seems to have been less difficult to recognise than the other pair, since it accounted for fewer errors than the /ɑ/ – /ʌ/ pair whether in a CVC or a CVN environment.

When we compare these results to the average rate of errors for the /ɪ – i/ contrast, we find a clear difference between this contrast and the other two. The superimposition of the two lines corresponding to the CVC and CVN environments indicates that in the case of this pair, vowels do not seem to be affected by their pre-nasal position. This comparison clearly suggests that nasalisation has a major impact on the /æ/ – /ɛ/ and /ɑ/ – /ʌ/ contrasts, supporting the findings of previous studies. In fact, the raising-falling trajectory of /æ/ in pre-nasal environments mentioned by Carignan et al. (2016) and Labov et al. (2006) brings the vowel closer to the realisation of /ɛ/, making the distinction between both sounds more difficult for French learners. Similarly, our findings concur with the observation of a lowering of mid-vowels (such as /ʌ/) in pre-nasal positions (Wright, 1975), and with the absence of compensatory tongue adjustment to the raising of nasalised /ɑ/ (Carignan et al., 2011), since participants performed less well when the vowels were followed by a nasal.

In terms of pedagogical implications, these findings could be used to assess the extent to which example word lists or minimal pairs in textbooks are appropriate for French learners of English. Teachers could then sequence lexical items in relation to their CVC or CVN context, or at least be aware that the CVN context may prove more challenging for learners to perceive.

For example, in the first section of Hancock (2012), the vowel sound /æ/ is explored through different words. A note draws together words such as *ask* and *dance*, and explains that the vowel is generally produced with /æ/. In addition, it is stated that the sound may be /ɑ:/ in South-East England. In this case, a supplementary note could have indicated that in GA, the vowel sound in a pre-nasal position is closer to what Carignan et al. (2016) transcribe as [eə]. This would raise awareness about the dialectal differences in the pronunciation of /æ/ vowels in a CVN context.

6 Conclusion

The purpose of this paper was to analyse the influence of nasalisation on the perception of GA vowels by French undergraduates studying English. SQL queries, tables and plots were used to isolate tendencies in the effects of a nasal after a vowel, revealing a greater impact on the /æ/ – /ɛ/ and /ɑ/ – /ʌ/ vowels. Our paper signals the importance of drawing the attention of teachers to the influence of nasalisation on GA vowels and to the way they are perceived by French learners, since we have shown that nasalised /æ/ – /ɛ/ and /ɑ/ – /ʌ/ vowels are more difficult to discriminate.

A potential improvement to our study would be to consider the effect of the speaker's gender on vowel perception. Krzonowski et al. (2018) highlighted, in their acoustic study, a difference in the production of vowels by female and male English native speakers. As an example, a slight overlap was observed in the production of the /ɪ/ – /i/ vowels when produced by English female speakers, and this was exacerbated when pronounced by male speakers. It may therefore be the case that the difference between /ɪ/ – /i/ when produced by male speakers in our SEPALE exercises is harder for our students. We have included the speaker gender in the scripts which create the database, and further SEPALE studies could request that participants indicate their gender prior to doing the exercises. This way, the difference in terms of vocal tract sizes and vowel frequency between women and men could be compared to the success rates in vowel perception.

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Appendix

List of Stimuli

Context	/æ/	/ɛ/	/ɑ/	/ʌ/	/ɔ/	/ɪ/	/i/
/_p/	cap	-	cop	cup	-	kip	keep
/_t/	cat mat pat tat	met pet	bot cot not pot rot tot	but cut mutt nut putt tut	bought caught naught taught wrought	-	-
/_k/	back knack lack pack	beck neck peck	bock lock pock stock tock	buck luck puck	stalk talk baulk chalk	bik lick pick	beak leak peak
/_d/	cad dad had mad rad sad	dead head med red said	bod cod mod nod sod	bud cud	baud gnawed sawed	did	deed
/_m/	cam ham stamp tam	hem	bomb pomp stomp tom	bum chump come hum pump	-	dim	deem
/_n/	ban bland can dan dance land man pan ranch sand tan	ben dense ken lend men pen send ten wrench	blonde con don fond non pond	bun done fund nun pun punned tun	-	bin kin min	bean keen mean
/_ŋ/	-	-	bong honk long	bung hunk lung	-	-	-
/_f/	-	-	cough	cuff	-	-	-
/_s/	-	-	-	crust	crossed	-	-
/_r/	-	-	bar bard card farm par parch spar star	-	bore bored form porch pore spore store tort	-	-

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