Achieving native-like accuracy of French/English vowels for Canadian bilingual speakers: effects of language self-described proficiency, context of use and daily exposure time

Achieving native-like accuracy of French/English vowels for Canadian bilingual speakers: effects of language self-described proficiency, context of use and daily exposure time

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Lay Abstract

The Speech Learning Model (SLM) theorizes that the acquisition of a second language will be affected by the production of the first/native language. In addition, it theorizes that the second language can simultaneously affect the first/native language (L1). By observing the production of French and English vowels in different groups of French native speakers who later acquire English (L2) and English native speakers who later acquire French, we hope to answer the following questions.

1. How close do bilinguals get to native-like production?
2. How strong is the bilateral (L1 → L2 and L2 → L1) effect in the different groups of bilinguals?
3. Which vowels are harder for bilinguals to acquire?
4. What factors influence native-like production?

We recorded pronunciation of French and English vowels by bilinguals to achieve the goals of this thesis. By studying the pronunciation of vowels in English and French, we hoped to get a clearer picture of second language learner in the context of Canada. These pronunciations are used to compare the bilinguals to speakers who only speak French or English. The data suggests that bilinguals are the closest second language learner group to the pronunciation of both French and English vowels. The results also point to frequency of L2 use being the strongest factor for native-like production for the English native bilinguals, and proficiency being the strongest factor for the French native bilinguals. L2 → L1 effects are strongest in the groups with high proficiency, with speakers that have both English and French as native languages.

Abstract

Studies on bilingual production have not come to a consensus on the possibility of bilinguals reaching native-like production. Some studies find that bilinguals can be close to native production while others have shown that even in simultaneous bilinguals, the production cannot reach native-likeness. Flege's Speech Learning Model (Flege & Bohn, 2020) theorizes that acquiring a second language affects the production of the L1 and vice versa. The model also states that new phonemes are easier to acquire compared to existing phonemes with different production. This thesis seeks to research the production of French and English vowels in a general population of Canadians to give an accurate picture of second language learning in Canada. We also seek to determine the strength of second language effects on the production of the first language and, what factors influence proficiency in bilingual speakers.

Participants were recruited in the Montréal region to have bilinguals of different proficiency and different backgrounds. They were given a sentence list to read out loud while being recorded. The recorded data was used to study the vowel formants produced by the bilinguals. These formants were then used to create a plot of the group average that was then compared to the production plots of monolinguals. The production data was also used to create a group average distance, with the help of the Mahalanobis distance calculations, to also compare to the production from the French and English monolingual groups. The plots and the calculations were used to compare the groups between themselves and the monolingual groups.

The results from the production data are within our expectations. The simultaneous bilinguals had the closest to native-like production in both English and French compared to the other bilinguals. The data also showed that for the English native bilinguals, the frequency of L2 use is the biggest factor in native-like production while for the French native bilinguals it was L2

proficiency. Regarding the SLM, the data we collected support the claim that bilinguals acquire and produce new phonemes with more ease than modify existing phonemes. It also partially supports the claim that knowledge of a second language will affect the production of the first language. The results from our experiment demonstrate that as the L1 French – L2 English bilinguals' knowledge of English increased, their production of French veered away from the French monolinguals. However, this effect was not seen with the L1 English – L2 French bilinguals.

Acknowledgements

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1. Introduction

Bilingualism and second language learning have always been heavily researched topics in linguistics as they relate to one of the most important questions regarding language; acquisition. While the acquisition process seems incredibly natural, research has shown that is not the case. We know that young infants have the capability to differentiate between all possible phonemes (not just native ones), and prosodic cues, a skill that is lost later in life (Jusczyk et al., 1993). If we lose that capability as we grow old, it also follows that language acquisition becomes harder with age. Related to this capability is the critical age period hypothesis (Birdsong, 1999), which theorizes that there is a crucial age to learn a language and produce the phonemes in a native like manner. However, the extent of our knowledge on language acquisition is not close to complete, not to mention the many discussions about the critical age period. Many researchers doubt there is such a rigid period. If there is a critical age period, is it possible to acquire and produce a language like a native speaker as an adult or a late learner? Are there other factors that can influence native like production in individuals other than the critical age period?

The main goal of this thesis is to extend the scope of the study initially done by MacLeod (2009). They examined the production of the high English and French vowels in proficient bilinguals. We wish to add the other vowels present in both languages and include bilinguals of different proficiencies to then judge their production. We would add a strong, medium, and weak bilingual groups from English and French backgrounds. This thesis also seeks to explore some of the factors that can lead to native like production in the second language (L2) and if the knowledge of that second language influences the production of the first language (L1).

This chapter includes a brief section on the language actuality in Canada and Québec along with a literature review of relevant studies, a short introduction to the speech learning model (SLM), an introduction to Canadian English (CE) and Québec French (QF) and, concluding with the hypothesis of this thesis.

1.1 Background

Considering that the research for this thesis is being conducted in Canada, it is significant to know and understand the language environment within Canada. While Canada is a bilingual country as it has two official languages, French and English, the reality is that bilingualism in the country is concentrated around the area of the country that speaks French. The province of Québec is the only majority French speaking province in Canada and while New Brunswick is officially the only bilingual province, it is Québec that is the engine producing the bilingual population in Canada accounting for almost 60% of the total bilingual population followed by Ontario and New Brunswick at 23,1% and 4% respectively (Statistics Canada, 2022[1]). When looking at the provincial populations, Québec has almost half of its population that is French/English bilingual (46,4%) followed by New Brunswick and Ontario at 34% and 10,8% (Statistics Canada, 2022[1]).

For this thesis, we decided to recruit most of our participants in the Montréal region rather than in the Ottawa region like in MacLeod (2009). The main reason for this switch is due to population. The Montréal metropolitan region has almost four times the number of French/English bilinguals compared to the metropolitan region of Ottawa, ≈2.4 million vs ≈635,000 (Statistics Canada, 2022[2]; Statistics Canada, 2022[3]). With the greater number of bilinguals, it is easier to recruit participants from the different backgrounds.

1.2 Previous Research

As we stated earlier, the main goal of this thesis is to assess how close can bilingual speakers, of different proficiencies, achieve to native-like production in both languages. To attain that goal, we want to expand on the research completed by MacLeod in their 2009 study. The study touched on the production of French and English high vowels in early and monolingual speakers. To be considered an early bilingual, participants had to have their first exposure to their L2 before the age of 4 and have a regular use of their L2 in at least two out of three contexts (work/school, family, friends). The monolinguals on the other hand must have minimal exposure to the L2, mostly limited to school situations, and have an infrequent use of the language in all three contexts mentioned above. The experiments found that the bilinguals produced lower formants values for the lax vowels in French compared to English. They also found that the French second formants were more peripheral than the second formants in the English vowels. In all, the French vowels were more peripheral compared to the English ones (MacLeod, 2009). The bilingual participants produced near native-like vowels in both languages, they distinguished both sets of vowels by maintaining significant differences in height and advancement (MacLeod, 2009).

Flege's (1987) study examined the production of French /y/ and /i/ of English bilinguals with different levels of French and compared it to the production from French native speakers, one group in France and one group living in the United-States. The study found that the less experience an English bilingual had with French, the 'more' English their production of /u/ was, meaning a higher F2 compared to the French monolinguals. Knowledge of English was also a factor in the production of /u/ in the French group living in the US. Their vowel was the closest to the monolingual group but was not completely native-like. However, these same English

bilinguals did not have the same issues with /y/, leading credence to SLM's theory that it is easier to acquire a new phoneme than modify a similar one. In another study with French speakers, Birdsong (2003) demonstrated that it is possible for late learners to acquire and produce a second language at a native-like level. While they only looked at vowel length and used accent rating from monolinguals to determine native-likeness in the bilinguals, 10% of the participants were rated by native speakers to have a native-like production. The results from these studies on French speaking bilinguals seem to indicate that bilinguals can have native-like production, even for late learners albeit at a much lower percentage.

Additional studies also come to the same position. A study on young German and Turkish bilinguals found that while the bilinguals had shorter vowels and less flexibility than native speakers, they were native-like in production except in the exact position of the vowels (Darcy & Kruger, 2012). Another study on young Mandarin-English bilinguals demonstrated that high level bilinguals had established separate vowel systems and suggested that simultaneous bilinguals are more likely to establish how native-like contrastive systems (Yang & Fox, 2017). A study on bilinguals of different native languages link performance of production to perception of that same language: ''Accuracy in production was related to accuracy of perception'' (Flege, 1997, p.467).

However, research studies in other languages do not all come to the same conclusions. Authors of studies from Spain on contrasts between Spanish and Catalan are torn on native-like production from bilinguals. One study from Barcelona on bilinguals from Spanish-Catalan and Catalan only households found that while both groups committed mistakes in producing the /e/-/ɛ/ contrast, the group from Spanish-Catalan household produced more errors compared to the Catalan only households. Even if the Spanish-Catalan households had more errors, they were

still able to form separate categories. The Spanish and Catalan speaking participants only used the F1 while the Catalan only speaking households relied on both the F1 and F2 to convey the distinction between the /e/-/ɛ/ contrast (Bosch & Ramon-Casas, 2011). However, another study on Catalan-Spanish speakers in Mallorca found the opposite with the /ɔ/-/o/ contrast (Amengual, 2016). They found that the Spanish dominant speakers had a higher degree of overlap in the contrast compared to the Catalan dominant participants (Amengual, 2016). A possible reason for the discrepancies in these studies might be due to a difference in the Catalan variety the speakers used. Amengual mention that there is a merger of /ɔ/-/o/ in the variety of Catalan spoken in Barcelona, while the contrasts is still present in Mallorca. Echoing the latter study, Mayr & al. (2018) found a neutralization of both /e/-/ɛ/ and /ɔ/-/o/ contrasts present in Galician in three groups of speakers: Spanish dominant, Galician dominant, and Dual Switch (Galician at birth, Spanish in childhood and back to Galician in adulthood). Even with the neutralization in both contrasts, the Dual Switch maintained more contrasts compared to the other groups (Mayr & al., 2018). A separate study on Korean-English bilinguals concluded that bilinguals did not produce both of their languages as two monolinguals (Yeni-Komshian & Flege, 2000). They found that the first language is not automatically retained in immigrants that learn English as a second language in an immersed environment. The researchers suggest that L1 experience in the home and school is necessary for the maintenance of L1 production (Yeni-Komshian & Flege, 2000).

The secondary goal of this thesis is to examine the presence of bilateral language effects in bilinguals. While there is no consensus on whether a bilingual can reach native-like production in their L2, most studies find differences in the production of those same bilinguals compared to native speakers, even if they are considered native in one of the two languages. Flege et al. (2003) studied the production of Italian-English bilinguals to examine the interaction between

the native language and L2 phonetic system. They found the late bilinguals merged the vowel category (/e/ & /eˈ/) while the early group produced the token albeit with more movement (Flege et al., 2003). It does not take a lot of time immersed in a new language environment for changes to a speaker's vowel system to appear. As seen in Chang (2011), phonetic drift was seen in vowel formants were seen in the L1 of the participants after weeks of L2 learning (Chang, 2011, p.263). Another study found that phonetic change can occur in native phonemes of participants learning similar foreign phonemes after even just an hour of training (Kartushina et al., 2016).

1.3 Speech Learning Model

The speech learning model was put forth by Flege (1986) and later revised in Flege and Bohn (2020) to account for difference seen in second language learning. These differences can vary from:

- Why are some segments harder for certain people to acquire compared to others?
- Are some segments harder for a person that speaks language A than for a person that speaks language B? Does the phonetic system reorganize during second language learning?

The model theorizes that bilingual speakers cannot achieve native-like production in their L2 due to influence from their L1 (Flege & Bohn, 2020). It also posits that while the system used for language acquisition is intact throughout a person's life, it is easier to acquire a new phone than to modify an existing phone in a speaker's L1: the similar phone will develop into a combination of L1-L2 (Flege & Bohn, 2020, p.42). The model accounts for the language effects seen in second language learning (L1 → L2) but also for effects seen in the opposite direction (L2 → L1). The SLM model gives an explanation to data from fluent L2 speakers that do not have

exactly a native-like production in their first or second language, their production seems to be a mix of both.

1.4 Canadian English & Québec French

The experiment in this thesis was completed in Canada, using the varieties of English and French present in Canada. The participants in this study were recruited from the Hamilton region, the Montréal region, and the Shawinigan region, therefore we shall not delve into regional varieties but rather stick to the general Canadian English and Québécois French. A key difference between both vowel sets is based around the dimension of contrasts of the front vowels. In Canadian English, the front vowels contrasts vowels on 3 dimensions: height, advancement and tense/lax. The Québec French front vowels contrast on 4 dimensions: height, advancement, tense/lax and rounding.

Québec French does not divert too much from metropolitan French with respects to the vowels. The main differences are the changing of position of the nasal vowels and the addition of the lax contrast in the high vowels. Canadian English is also very similar to general American English, with the only particularity being the caught/cot merger. According to (Martin, 2002), there are 19 monophthong vowels, including four nasal vowels, in Québec French /i, y, u, o, a, e, ɔ, œ, ø, ɑ, ɛ, ʊ, ʏ, ɪ, ɔ̃, œ̃, ã, ẽ / and one diphthong /ᵃe/. It is important to know that /ʊ, ɪ, ʏ/ are allophonic variations of /i, y, u/ that occur in closed syllables. Canadian English, on the other hand has nine monophthong vowels /i, ɪ, ɛ, æ, ɑ, u, ʊ, ʌ, ə/ with two semi diphthongs /oʊ, ɛɪ/ and three diphthongs /ɔɪ, aʊ, aɪ/ (Rogers, 2000; Labov et al., 2006). According to Flege & Bohn's

(2020) prediction, we expect the English natives to struggle with the production of /u, y, ɔ, a, e/ and we expect the French natives to struggle with /æ, ə, u/.

1.5 Aims of the Study

This thesis presents an experiment involving the production of the vowels present in Québec French and Canadian English by bilinguals of different backgrounds and levels. The main goal of this thesis is to examine how close bilinguals can get to native-like production in both of their languages by comparing their output to that of monolingual native speakers. To elicit this output, carrier phrases containing target vowels are presented to participants.

The focus of this experiment is to examine the first three formants in vowel production (F1, F2, F3) of all the bilingual groups to then compare their mean production to the native speakers and other bilingual groups. To compare the output of the different groups, the formant data will be visualized in vowel plots and a vowel distance calculation will be performed to have a numerical value for the distance between the groups' mean production.

This thesis has the main goal of examining bilingual vowel production, but also to examine language production through the lens of the SLM model. Are existing phonemes more difficult to acquire than non-existing phonemes? Does the level of L2, through daily use and education, influence proficiency? Are there any other factors that can promote proficiency in the L2? The other questions this thesis seeks to answer are about the predictions the SLM makes about our bilingual vowel data. For one, does the acquisition of an L2 have an effect the production of a person's first language and vice-versa? And as a follow up, does the proficiency in the L2 affect the strength of that same effect on production? In other words, does a person

with a strong level of French see more interlanguage influence on their first language compared to another speaker with a lower level of French?

The hypothesis of the main question was that the simultaneous and strong second language speakers should have a production in both languages close to that of the monolingual groups due to their high proficiency. For our second questions of this thesis, it is expected that participants that use their second language in multiple contexts and frequently should have a better production than participants who use their second language in fewer contexts and use it less frequently. Pertaining to the SLM, we anticipate seeing a second language effect on the first language of the participants and vice versa, as well as a stronger effect on the highly proficient speakers compared to the less proficient ones.

2. Methods

2.1 Participants

Sixty-one participants were recruited for this study. Ten were found through the Linguistics Research Participation System at MacMaster University while the rest were recruited through word of mouth and advertisements on social media. The participants recruited in this study were either native speakers of Canadian English; native speakers of Québec French; or native speakers of both. All participants were born in Canada or immigrated before the age of 6. The participants completed a linguistic history questionnaire to get information about their proficiency in both English and French (Weak, Medium, Strong), their age of acquisition, the language of schooling, contexts of use in both languages (work/school, friends, and family) and their weekly use of both languages (Number of days used, percentage). The sixty-one participants were divided into groups depending on their native language and their self-proclaimed level of fluency in their second language. The groups in this study are:

- English monolinguals (EM) (9 speakers; All from Hamilton, ON)
- French monolinguals (FM) (5 speakers; All from Shawinigan, QC)
- English natives with weak proficiency in French (EWF) (6 speakers; 3 from Montréal, 2 from Hamilton, 1 from Toronto)
- English natives with medium proficiency in French (EMF) (7 speakers; All from Montréal)
- English natives with strong proficiency in French (ESF) (5 speakers; All from Montréal)

- French natives with weak proficiency in English (FWE) (6 speakers; 3 From Shawinigan, 2 from Montréal, 1 from NB)
- French natives with medium proficiency in English (FME) (7 speakers; All from Montréal)
- French natives with strong proficiency in English (FSE) (8 speakers; All from Montréal)
- Simultaneous bilinguals (SB) (8 speakers; 6 Montréal, 1 Hamilton, 1 Sudbury).

	EM	EWF	EMF	ESF	SB	FSE	FME	FWE	FM
# of Speakers	9	6	7	5	8	8	7	6	5

Table 1:Table of participants

Since this is a study conducted in Canada with participants that received schooling within Canada, the monolingual participants are people with minimal knowledge of their second language outside the second language classes taken in school. Those recruited through the Linguistics Research Participation System received one-course credit for their participation while the other participants received financial compensation (15 CA$) for their time.

2.2 Stimuli

The stimuli presented in all contexts were two lists of sentences containing words with each vowel present in Canadian English; /i, ɪ, ɛ, æ, ɑ, u, ʊ, ʌ, ə/ with two semi diphthongs /oʊ, ɛɪ/ and three diphthongs /ɔɪ, aʊ, aɪ/, and Québec French; /i, y, u, o, a, e, ɔ, œ, ø, ɑ, ɛ, ʊ, ʏ, ɪ, ɔ̃, œ̃, ã, ẽ / and one diphthong / ᵃe/ (refer to 1.4 for more details). The words selected were all monosyllabic except for cases with /ə/, as reduced vowels cannot be in stressed syllables. They were also selected to be well-known and simple words. Words were chosen to have similar onsets, such as /b/ for English since there are monosyllabic words for each vowel, and /s/ for French because most of the vowels follow this consonant, to reduce any effects of a varying place or articulation on the production of the target vowels. For this reason, we avoided using words that start with velar consonants due to possible coarticulation effects. With velar consonants, the tongue must process more movements before starting on the vowel. To ensure a more natural speech production, the target words were inserted in carrier phrases in three different positions, in the beginning, inside the sentence and, at the end. These positions were selected as there are minor differences in production depending on the position in a sentence. The word at the beginning will have more stress, the words in medial positions will have a more neutral production and words at the end of sentences will have less energy. Carrier phrases were also used to ensure a more natural production of the vowels. The phrases were constructed as such: X is the best (*X est le meilleur*); Say X again (*Dis X encore*); Say Y, not X (*Dis Y pas X*). In the construction of the carrier phrases, the *Y* word was picked to be semantically related to the target word to promote a more natural sentence structure.

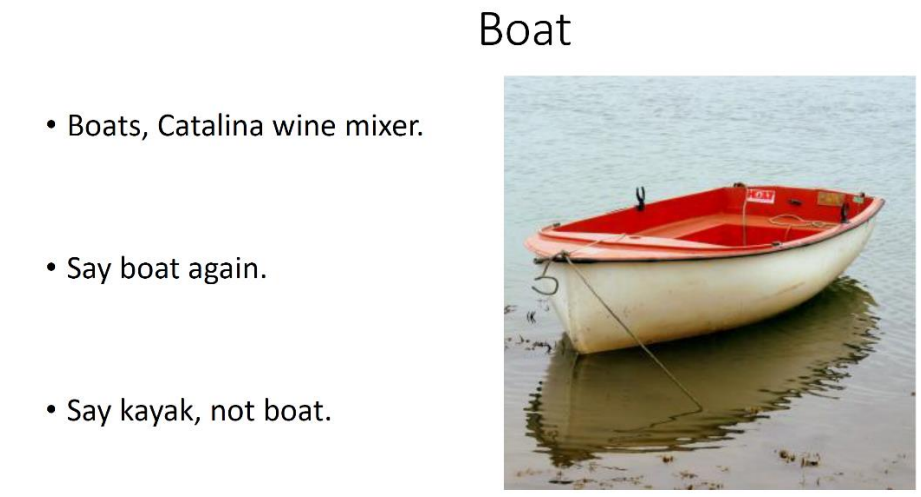

Figure 1: English sentence example

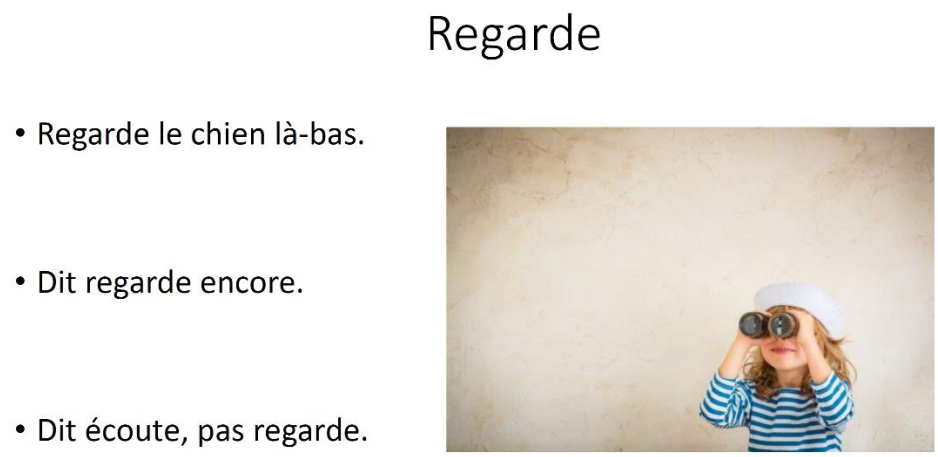

Figure 2: French sentence example

The sentences were repeated a total of three times to give more tokens per vowel. There was a total of 18 tokens per vowel, giving approximately 402 data points for Québec French and 271 data points for Canadian English.

2.3 Procedure

The experiment was designed to measure the vowel production of Canadian English and Québec French in bilingual speakers of different levels and different backgrounds, English or French natives or simultaneous natives. To test the production, the participants were asked to read a word list containing all the vowels in both languages (mentioned in 1.4).

Participants at McMaster University were placed in a soundproof booth located in the phonetics lab in the ARiEAL research centre. For the participants in the Montréal region, participants were placed in a quiet room either in the participants' house or in a room at the home of the researcher. Before starting the experiment, participants were asked to answer a linguistic history questionnaire and screening questions. The first part of the experiment was an out loud reading of the first chapter of "Le Petit Prince" (de Saint-Exupéry, 1943). The reading was done so that the participants can be in either English or French mode and have some practice before the experiment. Participants were asked to read the first chapter in French before completing the French carrier phrases and the first chapter in English before the English carrier sentences. Following the reading of the first chapter, the participants passed on to the production of phrases. They had to read through the sentence list out loud a total of three times while being recorded. All the stimuli were presented to participants in a PDF either on a separate tablet device or their computer screen for the online participants. In-person recordings used a Sennheiser MK series omnidirectional microphone and Focusrite Scarlett 2i2 audio interface in a quiet sound-treated room. The microphone was placed a few inches away from the participant and on a 45° angle to minimize the effects of plosives (that would induce distortions in the recordings). Due to the pandemic, it was impossible to have all the participants complete the experiment in person, therefore the people participating online used any microphone they had available. The only

stipulation participants had was that the microphone had to be an external microphone to minimize background noise from their computer and to achieve a similar microphone distance in speakers. Recordings were done with the help of the program Audacity (Audacity Team, 2021). There was no time limit, participants were only told to produce natural speech.

Vowel analysis was conducted with Praat (Boersma & Weenink, 2001) and a Praat script. The script measured the first, second and third formants and was automatic; automatic tracking selected a formant value at a selected time point that could be manually corrected with the help of an LPC and FFT spectral slice, and spectrogram. The time points were selected at the midpoint of the vowel.

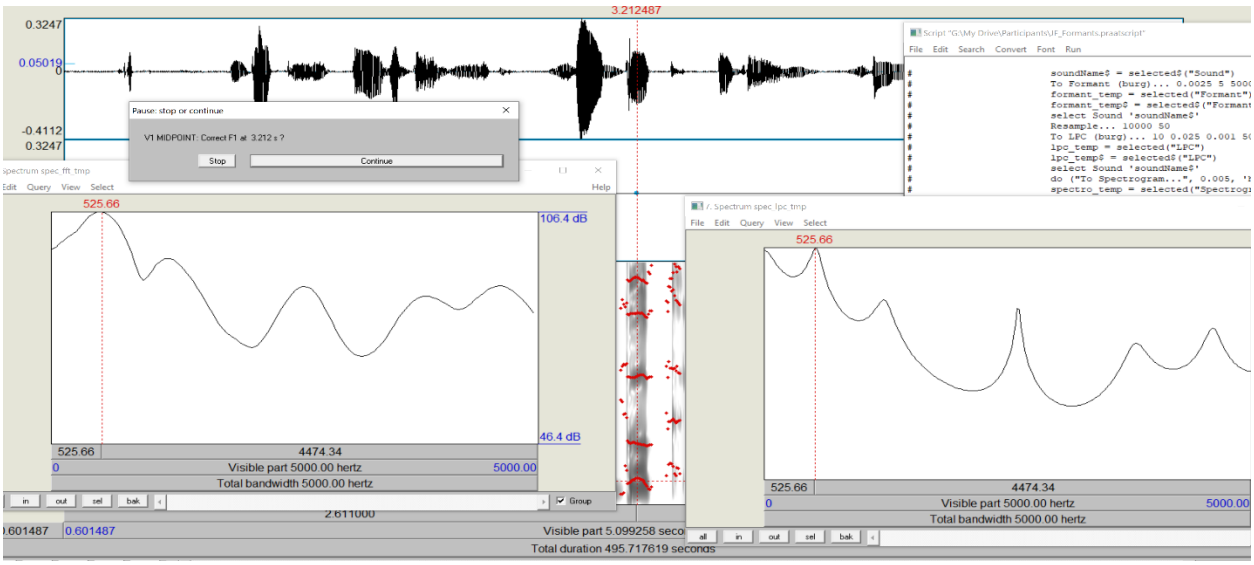

Figure 3: Formant extraction script working at selected time point

Once the data was collected, vowel normalization was applied to account for any disparity in the frequency values due to differences in the sex of the participants. The Lobanov method was used because it eliminates physiological differences while maintaining sociolinguistic speaker differences. This method also provides reduced formant variability due to speakers, and to a normalization of the vowel space (Thomas & Kendall, 2015). To obtain a numerical value of the

articulatory distance of each speaker's vowel production distribution, we used the Mahalanobis distance measurement (Mahalanobis, 1936) to establish a distance between the production of each speaker, and of our groups of bilinguals compared to the production distribution of the monolingual groups. This allows us to compare the production of each vowel for every speaker to the mean production of the monolingual group, getting an idea of how each speaker compares to native speakers. With this distance, it is then possible to compare the different groups of bilinguals based on their distance to the monolingual group.

3. Results

3.1 English Vowels

3.1.1 English Monophthongs

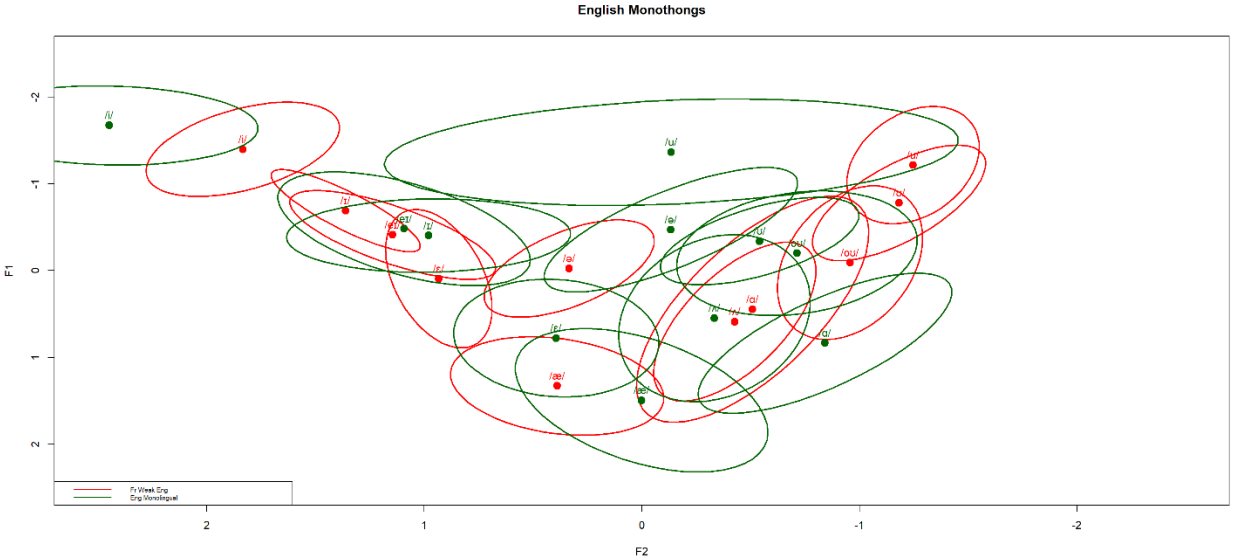

Figure 4: French (L1) weak English (L2)

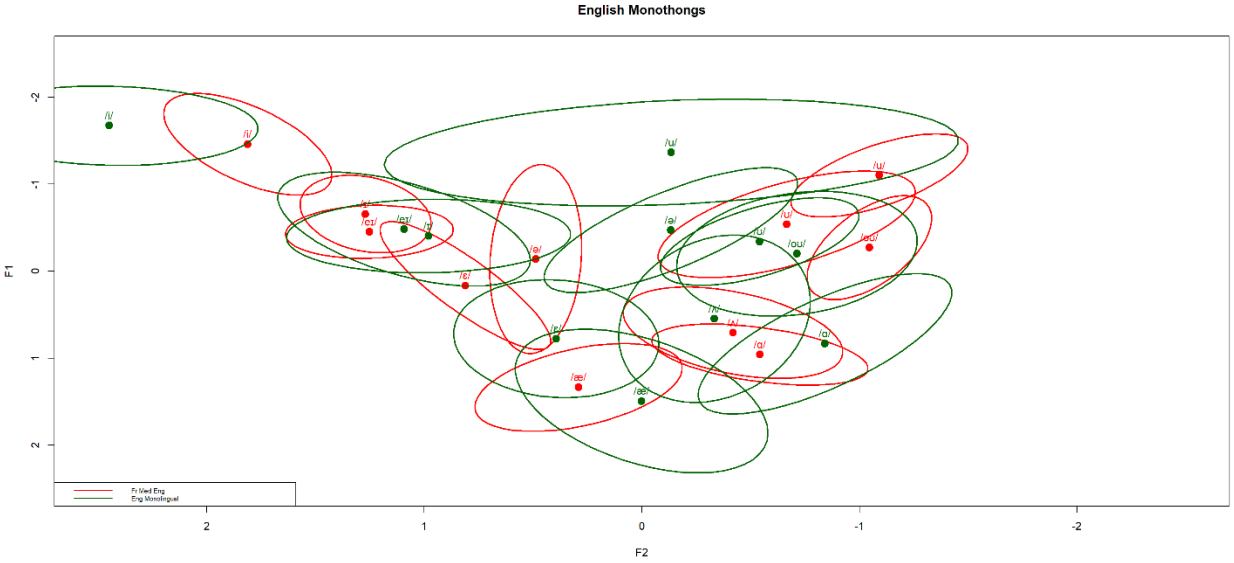

Figure 5: French (L1) medium English (L2)

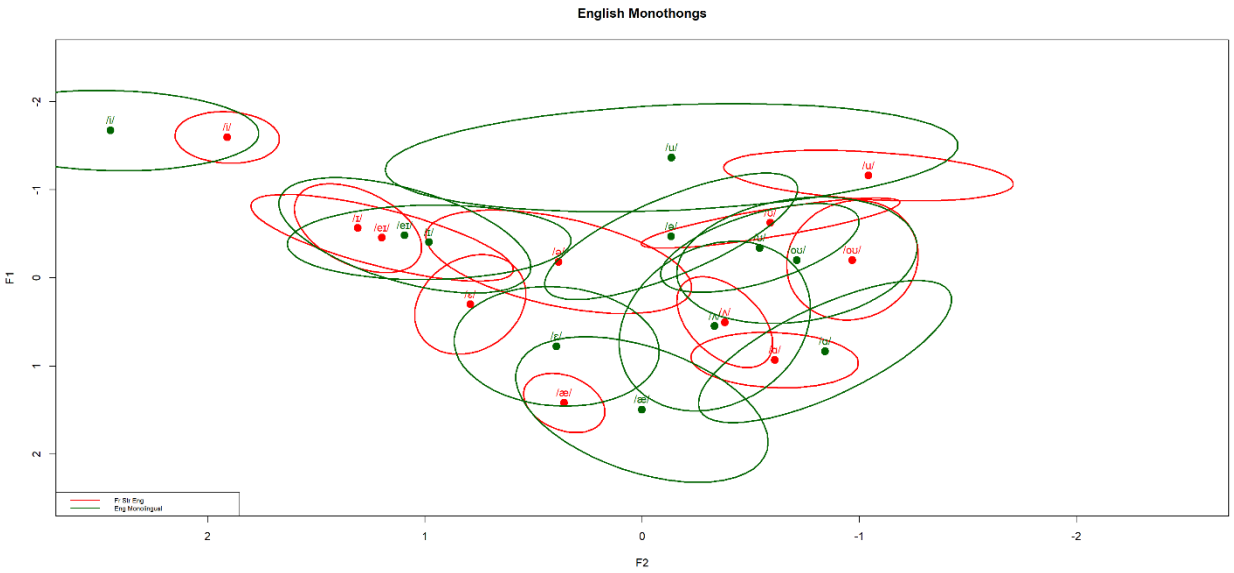

Figure 6: French (L1) strong English (L2)

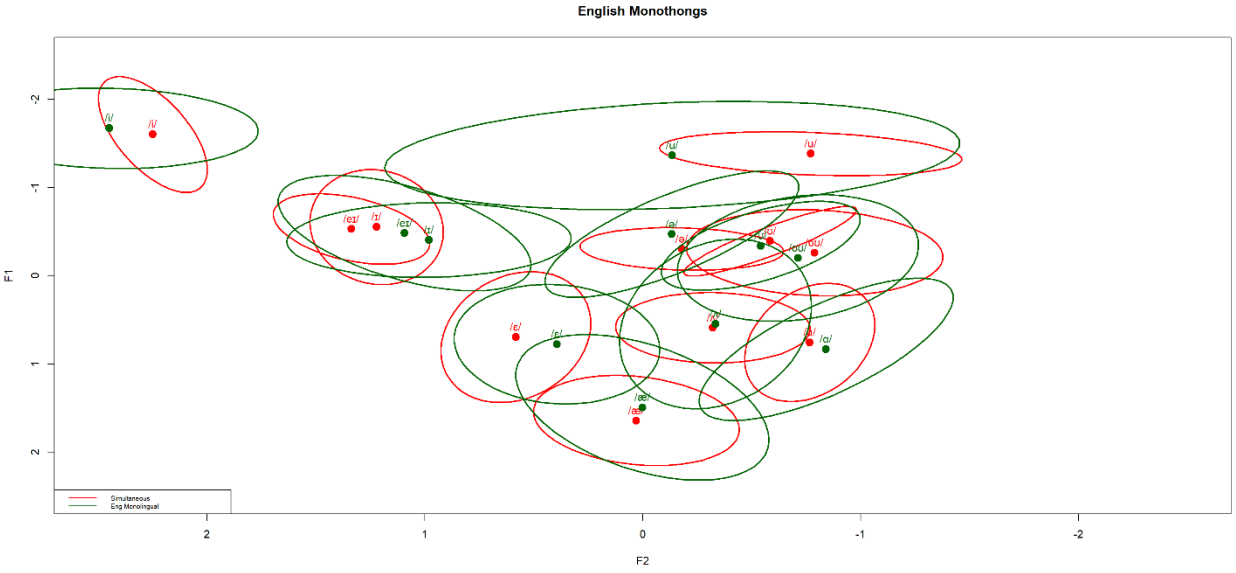

Figure 7: Simultaneous Bilinguals

The figures above show the production of the English vowel from our groups of bilinguals. The following analysis is done using only the sentence medial position vowels for

clarity. The English monolingual group is represented by the green ellipses in the plots, and the L1 French - L2 English bilinguals are represented by the red ellipses. In this section, we will compare the production of a selection of English vowels from the English monolingual group to those of our L1 French – L2 English bilinguals; the weak, medium, and strong English groups and the simultaneous bilingual group.

Vowel /i/:

The first vowel we are interested in our analysis is /i/, which is present in both languages tested in this study. While both languages share this vowel, speakers should not have to create a new category for the L2 phoneme. In our case, our L1 French – L2 English groups produced /i/ more anteriorly compared to the English monolingual mean, seemingly creating a new category.

For the groups with weak and medium fluency in English, their production mirrored the French /i/ more than the intended English /i/. To supplement the plots, we used the Mahalanobis distance to get a mean value for each vowel from each group. The lower a value is, the closer to the monolinguals that group is. For /i/ the Mahalanobis distance is (14.14) and (10.28) respectively. As the speakers' self-acclaimed English proficiency increases, the production of the English /i/ becomes more fronted and thus closer to the production of the English monolingual group. The simultaneous group is the nearest to native production, having a distance of (2.55), followed by the strong English group with an intermediate distance of (7.52) and then the two weaker groups above.

Vowel /u/:

Just like /i/, /u/ is present in both English and French with some differences in their production. The English /u/ is produced centrally with quite a lot of variation as it takes up quite a bit of the high-central to high-back vowel space compared to the French /u/ that is produced more to the posterior of the mouth. The SLM predicts low fluence speakers to struggle with the vowel due to the modification needed in the pronunciation.

The production of our L1 French – L2 English bilinguals mirrors the previous vowel, with the production of the English /u/ getting closer to the middle of the vowel space as the self-described level of English increases. We can see this with the Mahalanobis distance getting smaller as the groups get closer to the native speakers. The weak group have a distance of (6.51), the medium group have (5.94), the strong group (4.80) and then the simultaneous bilinguals are the closest with (1.86). Also, worth noting is that the L1 French – L2 English groups kept the variation of the vowel smaller compared to the monolinguals.

Vowels /æ/ & /ɑ/:

Here we examine the first vowel that is not present in French. While French does not have /æ/, it has /a/ which acts in the same way and occupies the same space albeit posterior compared to /æ/. According to the SLM, it should be an easy vowel for all speakers to produce. As such, even if the weak group strays a bit from the production of the English monolingual group, there is still a considerable amount of overlap in their production. The simultaneous bilinguals produced the vowel centrally, like the monolingual group. /æ/ is produced progressively further forward as the self-described proficiency decreases. Compared to the

simultaneous bilinguals that produce the vowel centrally, like the monolinguals. The Mahalanobis distance demonstrates this with the ordering of the weak group (3.84), then medium (2.82), strong (2.78) and the simultaneous group (1.36).

The French groups encounter the same issue with /ɑ/ where they produce the vowel further forward compared to the English baseline. The weak group produces this vowel with significant overlap with /ʌ/ (15.78) even if the latter is not present in French. The medium group gets closer to the native baseline (4.31) but keeps some overlap with /ʌ/ like the weak group. The two strong groups are much closer to the native production of /ɑ/ (2.49) for the strong group and (2.01) for the simultaneous bilinguals, as they produce the vowel further back.

Vowel /ə/:

In the introduction, we expected our bilinguals to have issues with the production of this vowel. As such, for /ə/, the analysis is complicated. It seems that the L1 French – L2 English bilinguals, other than the simultaneous bilinguals, produced the vowel further forward than the English natives, however, many of the L1 French – L2 English participants had issues with one of the stimuli due to the positioning of stress within the word. The stimulus word was record (/ɹə'koʊd/). Since French is a syllable-timed language, stress predictably changes in the last syllable (Dupoux et al., 2001; 2010). Because of that, speakers often mistakenly misplaced the stress and would often produce the target word with /i/ instead of /ə/. The Mahalanobis distance reflects the error as the medium (12.95) and strong group (10.51) have a bigger distance to the monolinguals compared to the weak (5.024) and simultaneous groups (2.84).

Vowels /eɪ/ and /ɪ/:

Onto /eɪ/ and /ɪ/, while we are comparing a vowel with a diphthong, for this comparison we are only using the beginning point of the diphthong rather than a midpoint. In all four groups, both vowels share a lot of overlap in their production and are produced close to each other. Interestingly, all the groups tend to produce both vowels more fronted than the English monolingual group. In addition, the weak, medium, and strong groups produced /ɪ/ further forward than /eɪ/ unlike both the simultaneous bilingual and monolingual groups. Following the trend seen with the other vowels, the simultaneous group produced the /ɪ/ vowel (3.91) the closest to the monolingual group, but not by much. The strong group (3.93) was very close to the simultaneous bilinguals, but the medium (4.61) and weak group (6.35) were further away. However, the weak groups had the closest production of /eɪ/ (1.17) albeit with more variation than all groups except the strong group. Interestingly, the trend reversed for /eɪ/ as the medium group (1.64) was the second closest followed by the strong (1.65) and simultaneous groups (2.01).

There was little interaction between /i/ and the clusters containing /eɪ/ and /ɪ/. While the weak English group's /i/ was closest to the cluster comparing to the other groups, there was only a small amount of overlap in the weak and medium groups.

3.1.2 English Diphthongs

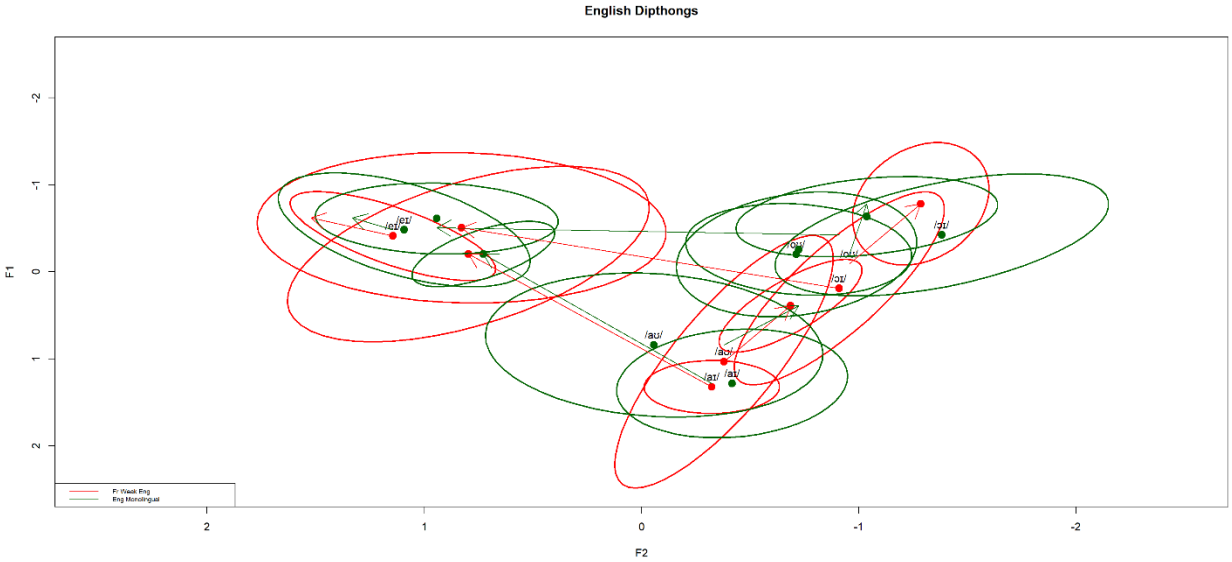

Figure 8: French (L1) weak English (L2)

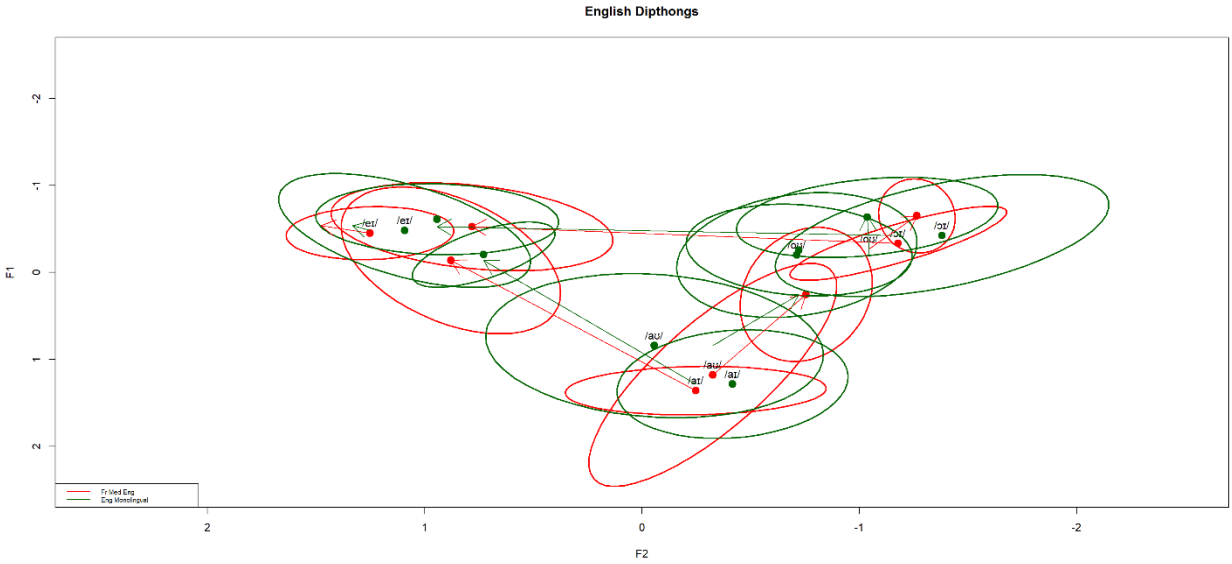

Figure 9: French (L1) medium English (L2)

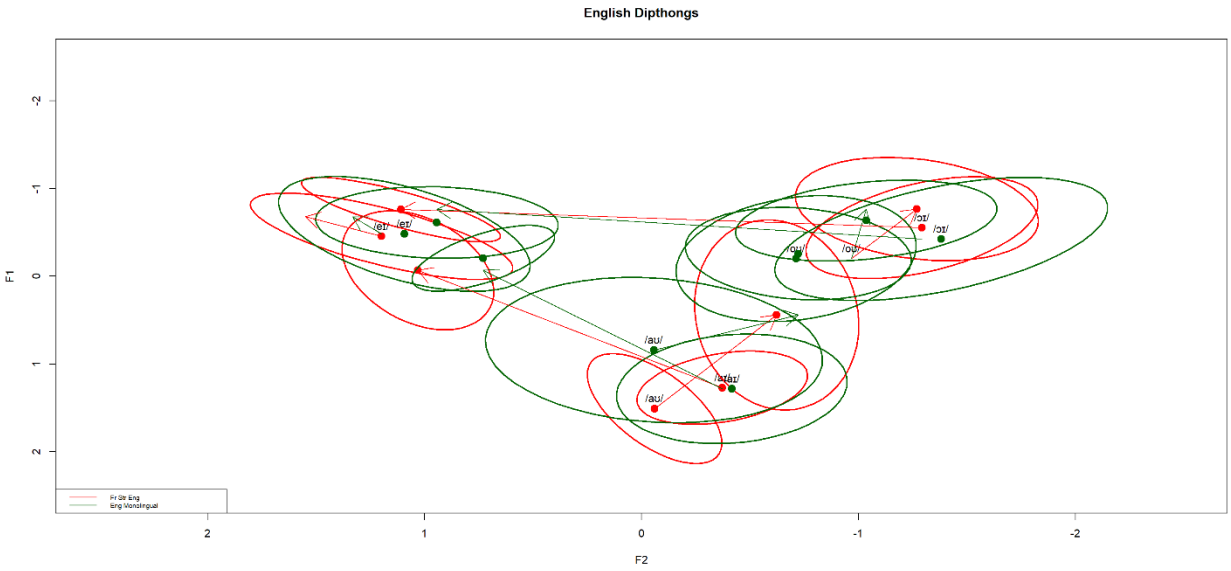

Figure 10: French (L1) strong English (L2)

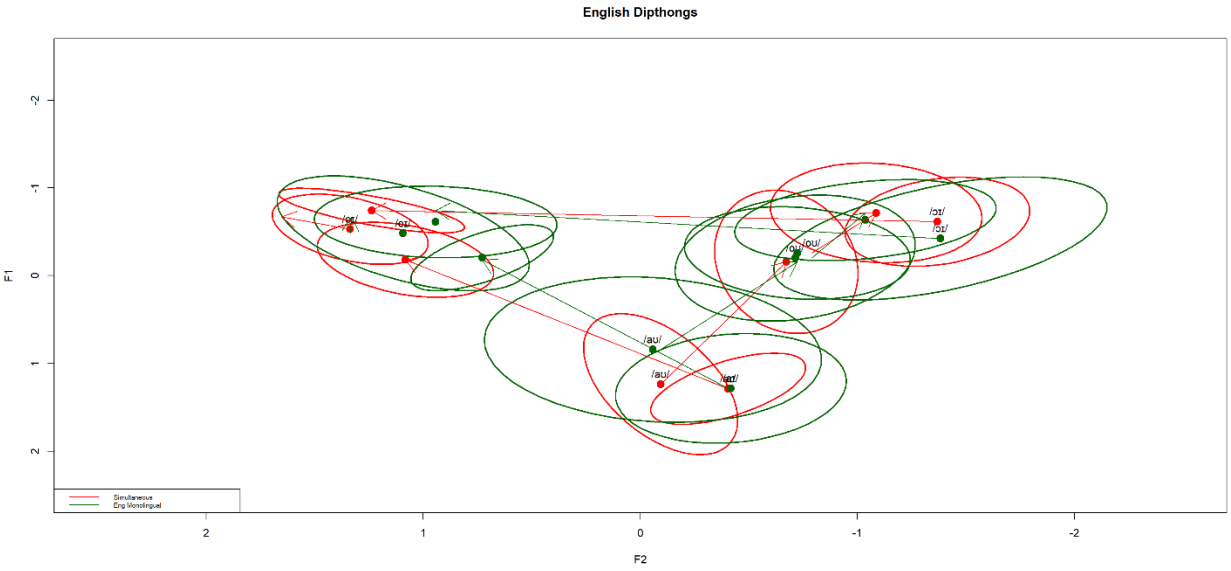

Figure 11: Simultaneous Bilinguals

In the previous section, we touched on some of the diphthongs, /eɪ/ and /oʊ/. As they are considered to act more like semi-diphthongs, their movement is minimal compared to the other

diphthongs present in English. Again, the English monolinguals are represented in green, and the L1 French – L2 English groups are in red.

Diphthongs /eɪ/ and /oʊ/:

We'll start this section with the two semi-diphthongs mentioned above. Looking at the plots, we notice that the French natives seem to produce both semi-diphthongs on the periphery of the vowel system compared to the English natives. While /eɪ/ was fronted in the L1 French – L2 English bilinguals, there was not much distance between their production and that of the monolinguals. All four groups were close to the monolinguals in their production, with the weak group being the closest (1.17), preceded by the medium (1.64), strong (1.65), and simultaneous groups (2.01). The participants that self-reported lower proficiency in English produced /oʊ/ more to the anterior. The placement of the groups for /oʊ/ follows the overall trend, where the simultaneous group is the closest to the monolinguals (1.61), followed by the strong (2.34), medium (2.94), and then the weak group (3.07).

Diphthong /aʊ/:

Moving to the next diphthong /aʊ/, the lower proficiency speakers tended to produce the diphthong more to the anterior compared to the monolinguals. As the level of English increases, the diphthong production gets closer to the native speakers. The simultaneous group showed the smallest Mahalanobis distance (2.32), followed by medium (4.26), the weak (4.38) and strong group (4.55).

Diphthong /aɪ/:

For the last diphthong, /aɪ/, the vowel was produced more centrally. Only the weak English group produced the vowel much lower than the English monolinguals, while the medium group was lower but closer than the weak group. The weak (0.69), strong (0.89) and simultaneous group (0.72) matched the production from the monolinguals, while the medium group was further away (1.92).

3.2 French Vowels

3.2.1 French Monophthongs

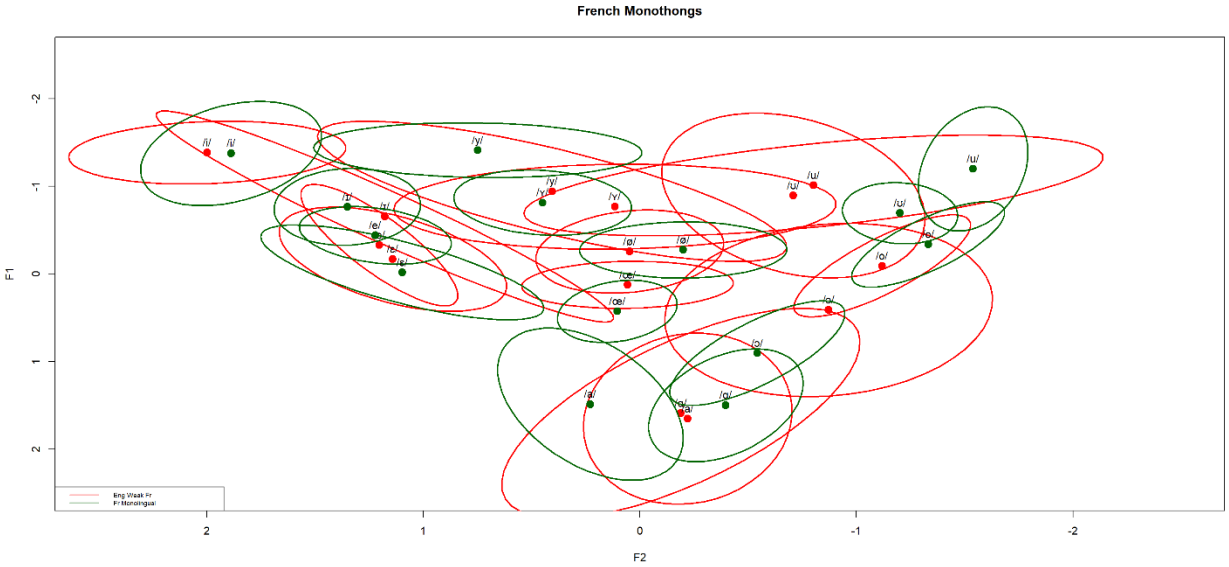

Figure 12: English (L1) weak French (L2)

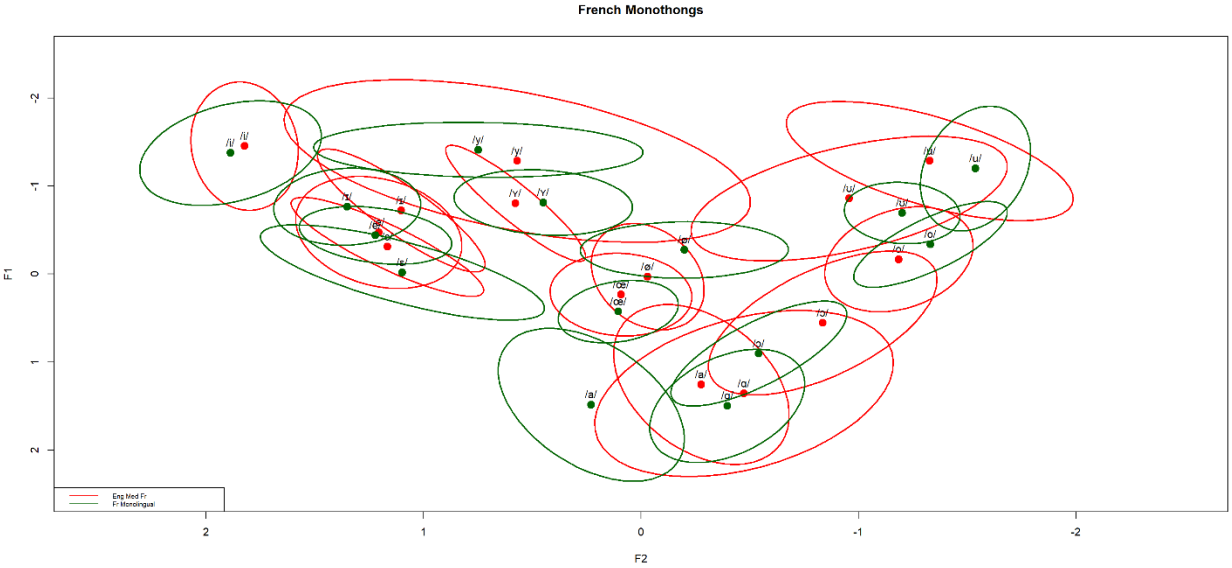

Figure 13: English (L1) medium French (L2)

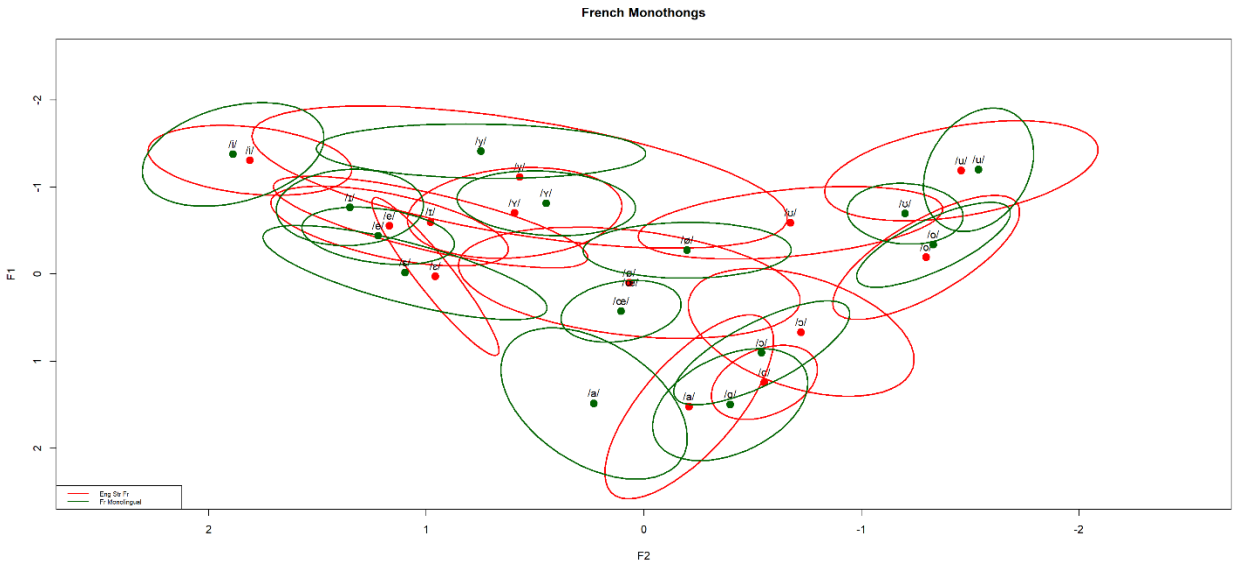

Figure 14: English (L1) strong French (L2)

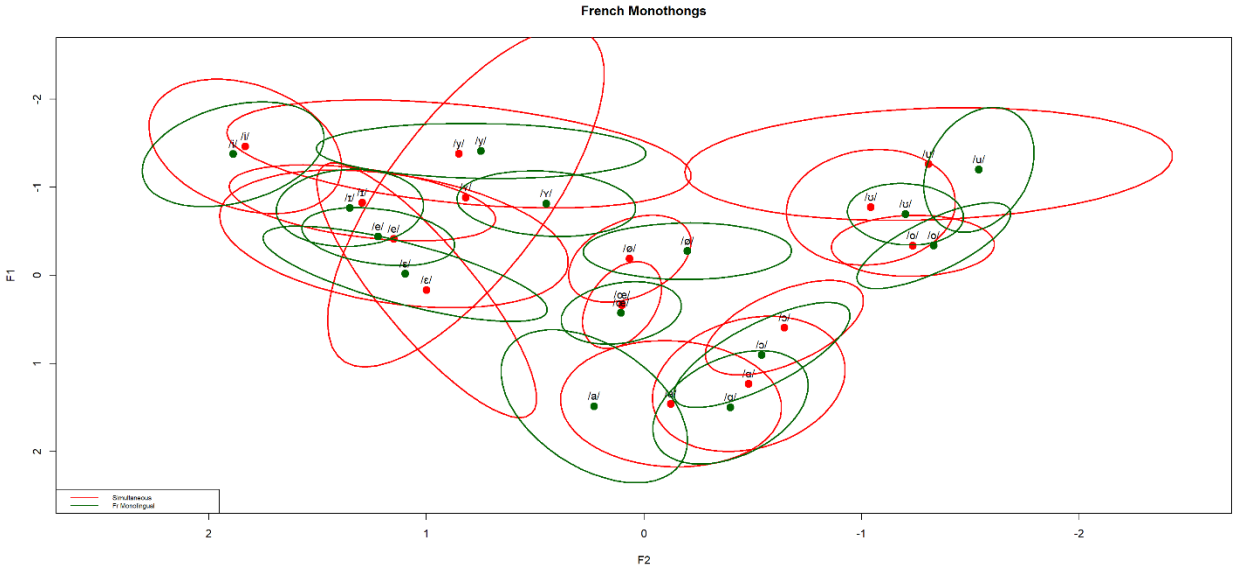

Figure 15: Simultaneous Bilinguals

Just like in the previous plots, the French monolingual group is represented by the green ellipses, and the L1 English – L2 French bilingual and the simultaneous bilingual groups are represented by the red ellipses. In this section, we will cover the results of the L1 English – L2

French bilinguals' production of the Québec French vowels and compare them to those from the monolingual group. Since we had a small number of monolingual French speakers, the weak English group was added to the group for the comparison to have similar numbers between both groups of monolinguals.

Vowel /i/:

Let us start with the high front vowel /i/. As stated in the previous section, both languages share this same vowel albeit they both have some minor production differences. Therefore, the SLM predicts some difficulty in producing the vowel native-like. As we saw with our English monolingual group, they produced the vowel further forward compared to our French monolinguals. While our groups of L1 French – L2 English bilinguals had an anterior production of the vowel compared to the English monolinguals, the L1 English – L2 French groups did not have that same problem. All four groups (L1 English – L2 French), simultaneous bilinguals included, were quite close to the production of the French monolinguals. When looking at the Mahalanobis distance, the simultaneous group (3.13) is the furthest from the natives, followed by the weak group (2.92), then the strong (2.05), and medium (1.20).

Vowel /ɪ/:

For /ɪ/, the results are the opposite of those seen for /i/. While all groups did not stray too far from the mean native production of /ɪ/, the weak French group could not keep a constant production of /ɪ/. The variation demonstrates that the weak group had bigger articulatory differences than the monolingual group. The Mahalanobis distances shows us another picture,

the weak (17.35) and strong group (13.43) were far from the production of the monolinguals, while the medium (6.83) and simultaneous group (4.06) were closer.

Vowels /y/ and /ʏ/:

The rounded front vowels are where we expect our L1 English – L2 French bilinguals to struggle with production. While the SLM states that it is easier for second language learners to acquire a new vowel than modify an existing category, we still theorize that our least proficient French speakers will encounter some difficulty balancing a more crowded vowel space. Results from our plots give credence to our thoughts as the weak French group had difficulty coping with the production of both /y/ and /ʏ/. Both vowels were produced more centrally compared to the French monolinguals and the rest of the L1 English – L2 French groups. The other three groups (Medium, Strong, and Simultaneous) have a close to native-like production compared to the weak group. The simultaneous group had a surprising outcome where both /y/ and /ʏ/ are fronted compared to the French monolinguals while the strong and medium groups both produced /ʏ/ further forward than the monolinguals. Another interesting finding was that all the groups had less variation in their production of /ʏ/ compared to /y/.

The Mahalanobis distances give a different look on the production of both vowels. The weak group (20.82) being the furthest from the monolinguals followed by the strong group (12.80). The medium group was close to native-like (10.15) while the simultaneous bilinguals were the closest (5.14). For /ʏ/ the weak group (10.72) is further than the medium (3.57) and strong group (4.34). However, the simultaneous group were further than all the other groups (32.43), possibly due to the variation seen in their production.

Vowels /ø/ and /œ/:

For the two other rounded front vowels /ø/ and /œ/, all the groups produced /ø/ slightly more fronted and /œ/ a little higher than the monolinguals. One more commonality shared between all four groups is that they have more overlap between both vowels than the monolinguals, the latter had almost no overlap between /ø/ and /œ/. The overall trend is present again with /œ/, the simultaneous group is the closest (2.41), then the strong (3.03), medium (4.71) and weak group (7.60). Surprisingly, the weak group (4.10) had the best score for /ø/ compared to the simultaneous (4.57), medium (9.33) and strong group (15.21).

Vowels /a/ and /ɑ/:

For the low vowels /a/ and /ɑ/, we observe a complete overlap between them in the L1 English – L2 French weak group. The strong overlap is still seen with the medium group albeit it is not a complete overlap. Even in the strong and simultaneous group, there is an overlap present between both vowels although not as sizeable as the two weaker groups. The Mahalanobis distance score shows us that the weak group were the furthest from the monolinguals for both /a/ (8.54) and /ɑ/ (9.95). The medium group were the second best for /ɑ/ (5.51) but the worst for /a/ (14.92). The strong group were the closest to native-like for /ɑ/ (2.25) but second closest for /a/ (10.55). The simultaneous bilinguals followed the strong group for /ɑ/ (3.86) while being the closest to the monolinguals for /a/ (7.53).

Vowel /ɔ/:

/ɔ/ is an interesting vowel to study for our English natives as it is not present in the vowel category for Canadian English. Known as the cot-caught merger, /ɔ/ gets assimilated to /ɑ/. The SLM predicts the L1 English – L2 French bilinguals to encounter difficulty in creating a new category for this phoneme. The weak French group produced the vowel closer to /o/ than to /ɑ/ with lots of variation, overlapping with their production of /o/ and /ɑ/. In the medium group, the production approaches /ɑ/ and /ɔ/ rather than /o/ and has less variation than the weak group. The strong and simultaneous groups have a close to native-like production of /ɔ/, with the simultaneous group being the closest of the two. While the plots show the strong group closer to the monolinguals than the medium group, their Mahalanobis score are the opposite. The simultaneous group are the closest to the natives (3.68), followed by the medium (7.04), strong (8.79) and weak group (15.39).

Vowel /u/:

Just like /i/, /u/ encounters the same problem where the production between both languages is not similar. While the monolinguals produce /u/ very far in the back of the mouth and high, the weak French group kept the English production of /u/ where their production reaches further forward compared to the less variable production seen in the French monolinguals. The same occurs in the medium and strong groups, albeit not to the same extent. An unexpected finding here, the simultaneous group had a production similar to that of the weak French group rather than a production closer to the monolinguals. This finding is mirrored in the

Mahalanobis distances. The weak (76.94) and simultaneous (24.64) group are quite far from the monolinguals compared to the medium (12.81) and strong groups (6.11).

3.2.2 Diphthong and Nasals Vowels

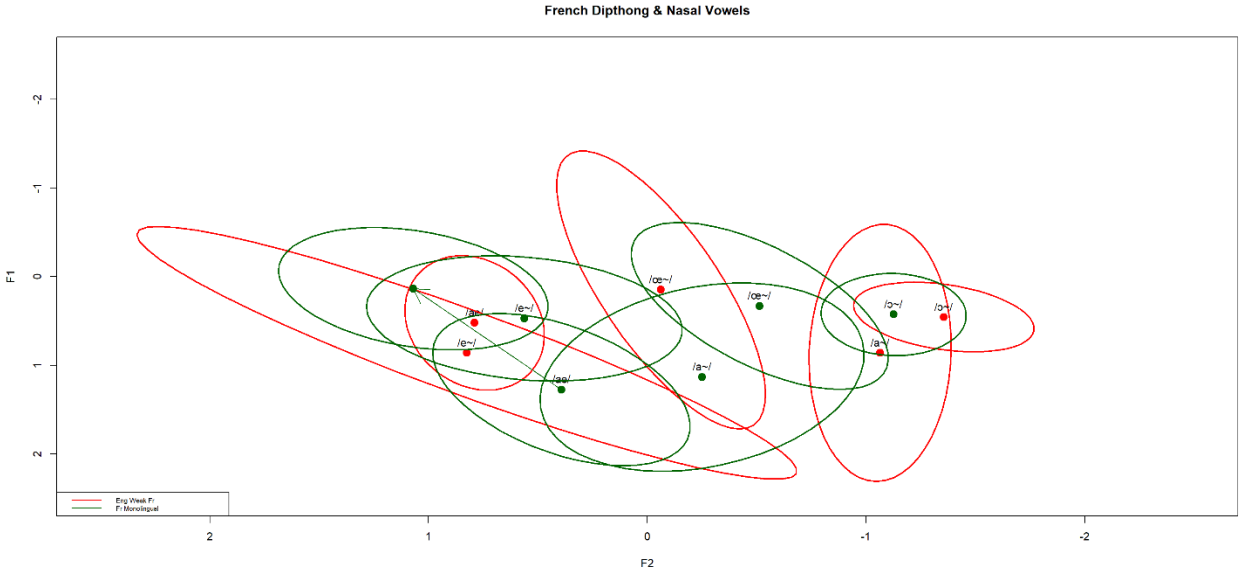

Figure 16: English (L1) weak French (L2)

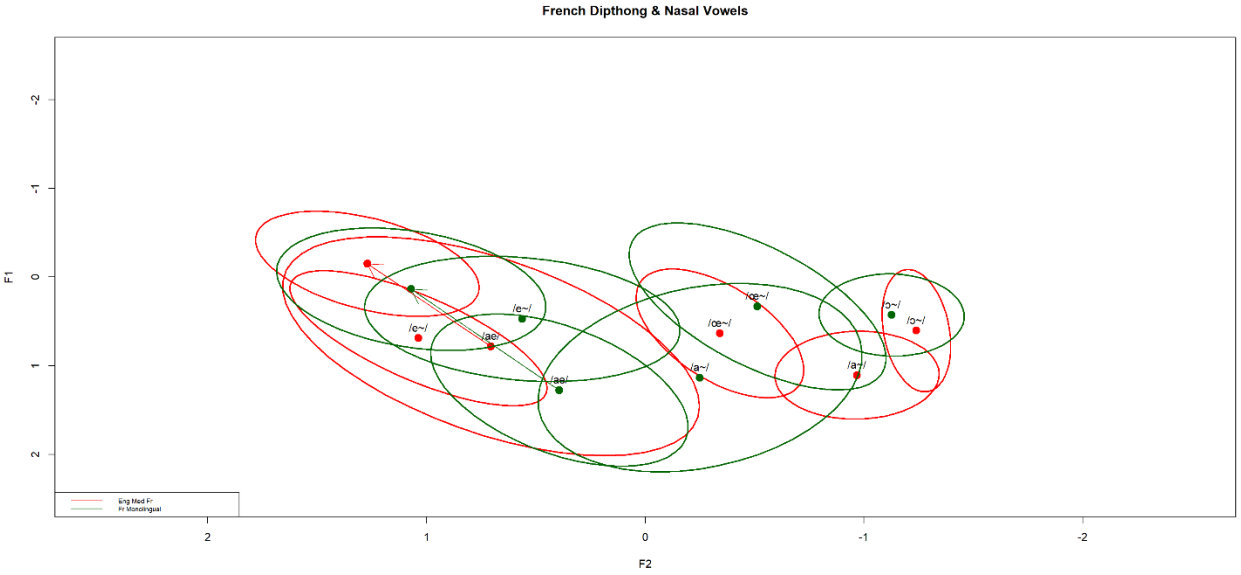

Figure 17: English (L1) medium French (L2)

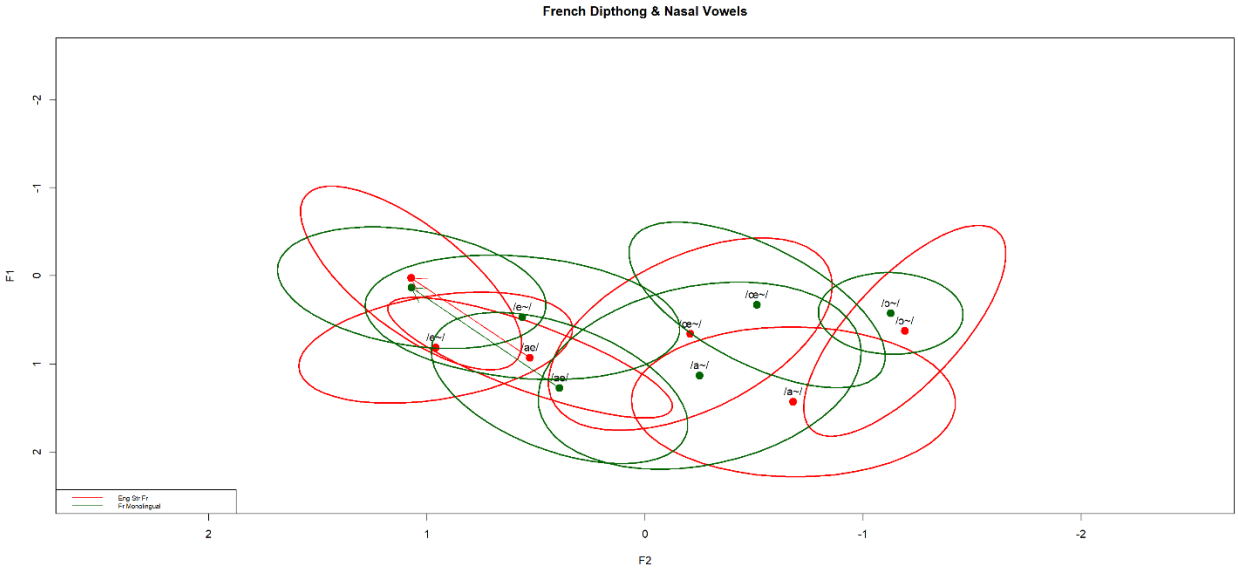

Figure 18: English (L1) strong French (L2)

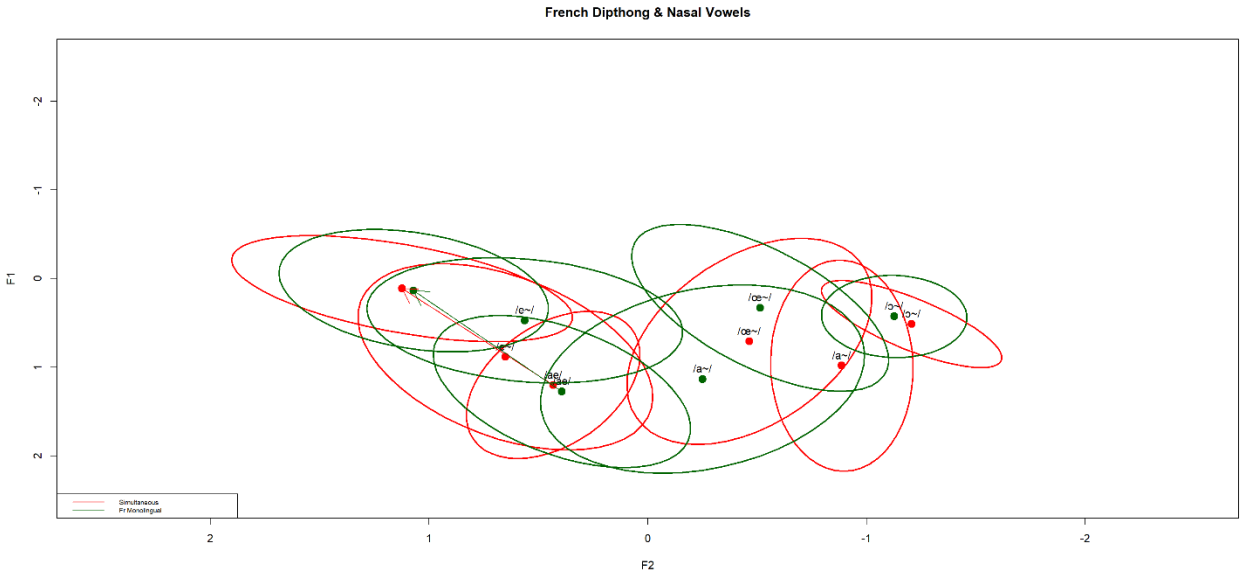

Figure 19: Simultaneous Bilinguals

Here we will detail the findings in the production of the French diphthong and nasals by our bilingual groups. Considering that all the nasal vowels are new phonemes for L1 English – L2 French speakers, the SLM predicts that they will acquire these new phonemes with more ease

than existing ones. It is important to note that for the diphthong, not all the participants produced it as a diphthong; some produced the intended target as a monophthong. Thus, some groups will not have enough data to reach a conclusion. As with the previous plots, the monolingual French speakers are represented by the green ellipses and the L1 English – L2 French groups by the red ones.

Diphthong /ᵃe/:

Starting with the diphthong /ᵃe/, the weak group did not produce the diphthong as intended, instead producing a monophthong. They produced the vowel in between the starting point and end point of the monolingual group. The medium group had movement in the vowel; however, they tended to start and end the vowel further forward compared to the French monolinguals. Both the strong and simultaneous groups had better production than the two weaker groups, with the strong group only having a fronted starting point, while the simultaneous bilinguals had a native-like production. The medium (6.34) and weak group (6.17) were not close to the monolinguals, while the strong (2.20) and simultaneous (1.93) groups were closer to native-like.

Nasal Vowel /ɛ̃/:

All four groups of bilinguals had bigger articulatory differences with /ɛ̃/ contrasting the monolingual group. They produced the vowel lower and further forward compared to the monolingual French group while still retaining some overlap. The simultaneous bilinguals were the group that had the closest to native-like production as they had the most overlap with the

French natives. There is no real difference between the Mahalanobis scores of the medium group (5.36) and the strong group (5.15), but following the overall trend, the weak group were the furthest from the monolinguals (9.19), while the simultaneous bilinguals are the closest (4.99).

Nasal Vowel /ã/:

Just like /ẽ/, the four groups of bilinguals were ways away from the native-like production of /ã/. They produced the vowels further to the anterior compared to the French natives. The weak group did not have much overlap with the monolinguals, but it was the strong French group that had the most overlap, not the simultaneous group. The Mahalanobis distance scores support the plot for /ã/. The strong group had the best score (4.56), followed by the simultaneous bilinguals (5.81), the medium group (6.34), and then the weak group (9.05).

Nasal Vowel /œ̃/:

In contrast to our French monolingual group, our L1 English – L2 French bilinguals produced /œ̃/ further forward, more to the middle of the vowel space. We can observe the production get closer to native likeness with the increase in the group's ability in French, with the simultaneous group having the best production.

Unlike what is seen on the plot, the Mahalanobis distance shows something different. It was the medium group that had the most native-like production (3.97) rather than the simultaneous bilinguals (6.45). This is possibly due to the simultaneous group having more variation in their

overall production. Also countering the overall trend in the results, the strong group (10.58) had the furthest from native-like production and not the weak group (7.29).

3.3 Overall results

Simultaneous Bilinguals	2.8838
French Strong English	4.91523
French Medium English	5.72793
French Weak English	7.19703

Table 2: French Native Mahalanobis Scores

Simultaneous Bilinguals	7.49915
English Strong French	7.77911
English Medium French	6.73026
English Weak French	13.3312

Table 3: English Natives Mahalanobis Scores

Does the data from the plots combined with the data from the Mahalanobis distances demonstrates the general idea we had at the beginning of this research project; the simultaneous bilinguals are the closest to native-like production in both English and French? For the English vowels, the vowel distances paint the picture that the simultaneous group is the closest to native-like proficiency compared to the other groups. It also shows that, in general, as speaker proficiency improves, so do their distance scores. However, this trend is not mirrored in the French vowels. The weak French group had the highest distance scores compared to the monolinguals, as expected, but surprisingly it was the strong French group that followed them. Going against the trend again, the medium group had the closest to native-like proficiency rather than the simultaneous bilinguals.

These scores tell us how the vowel production of the bilingual groups compare to those of the monolingual groups. To identify whether the differences between groups were significant we performed t-tests on the Mahalanobis scores of each vowel of each speaker in the bilingual groups to examine if the distance between them is significant (i.e., the t-tests are performed between two groups of speakers). We used the two samples of unequal variance t-tests to obtain our p-values. We used the one-tail values and performed the Bonferroni corrections to obtain a threshold of significance of p=0.016 (three comparisons: p=0.05/3). For our study, rather than invalidating or confirming our results, the significance of the results will only tell us if the variance between groups is too small to have significant differences in their production when comparing groups.

English Vowels	
Groups	p-value
Simul vs FSE	**0.003302**
FSE vs FME	0.187176
FME vs FEW	0.07375

French Vowels	
Groups	p-value
Simul vs ESF	0.188564
ESF vs EMF	0.420647
EMF vs EWF	**0.006139**

Table 4: p-values of the significance of difference between group Mahalanobis scores

As we observe in the table above, the only differences that are significant are the distance between the simultaneous bilingual and the French native group with strong English and, the distance between the English natives with medium French and English natives with weak French. The significant differences between the groups indicate that the groups have clear improvement when comparing their proficiency levels. To clarify, that does not mean that the accuracy of production of vowels does not improve between comparisons in the other groups. It just implies a bigger, and thus significant improvement compared to the distance in other groups.

Also worth noting, these calculations were done on outlier corrected mean scores, which will be discussed in section 4.

3.4 Relationship Between Vowel Production and Extralinguistic Factors

Earlier, we stated that one of the questions we wish to answer is what factors can lead to native-like production in a speaker's L2. With the Mahalanobis distances calculation in the previous section, we can now start to examine which factors influence native-like proficiency. During the recruitment process, we asked participants to answer some questions regarding their linguistic history: What is their native language, their frequency of use of both languages, the contexts in which they use both English and French, and whether they received their schooling in English or French among others. With these answers, it is possible to get an idea of the influence of each of these factors on participants' production of English and French and see which of these factors have the strongest influence. The three factors we used for our correlation are: the speaker's self described proficiency, the number of contexts in which they use their L2, and their frequency of use of that L2. In our calculations, we coded the speaker's self-reported proficiency on a scale of one to four, four being simultaneous bilingual. The contexts on a scale of three, where the maximum is the speaker using their L2 in all 3 contexts (Work/School, Family, Friends/Social). Frequency was coded on a seven point scale based on the approximate number of days per week where speakers use their L2 (7 being the max).

Starting with proficiency, we can observe that proficiency was a strong predictor for the distance scores of the L1 French – L2 English bilinguals. It was also the strongest out of all three factors. The next strongest factor is the contexts of use, followed by frequency as the lowest.

	Prof vs Maha	Cont vs Maha	Freq vs Maha
Fr Correl Eng	-0.7535627	-0.6867653	-0.4924460

Table 5: French Natives Correlation Results

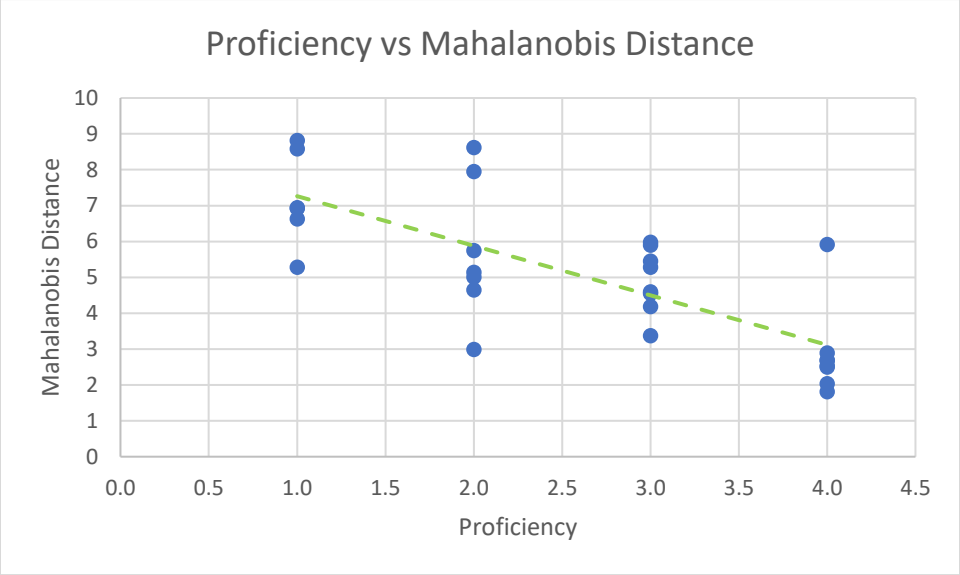

Figure 20: Correlation of proficiency vs Mahalanobis distance of French (L1), English (L2)

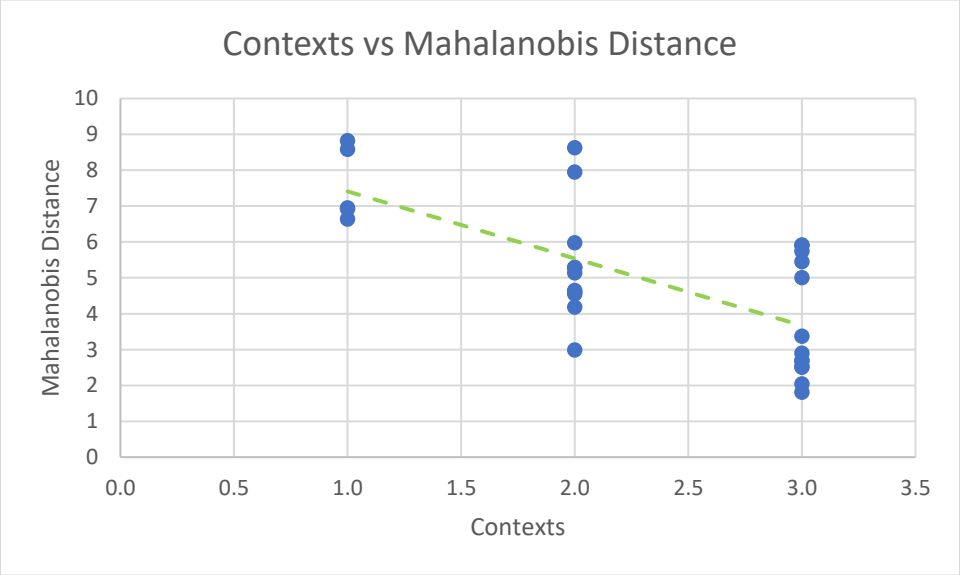

Figure 21: Correlation of contexts of use vs Mahalanobis distance of French (L1), English (L2)

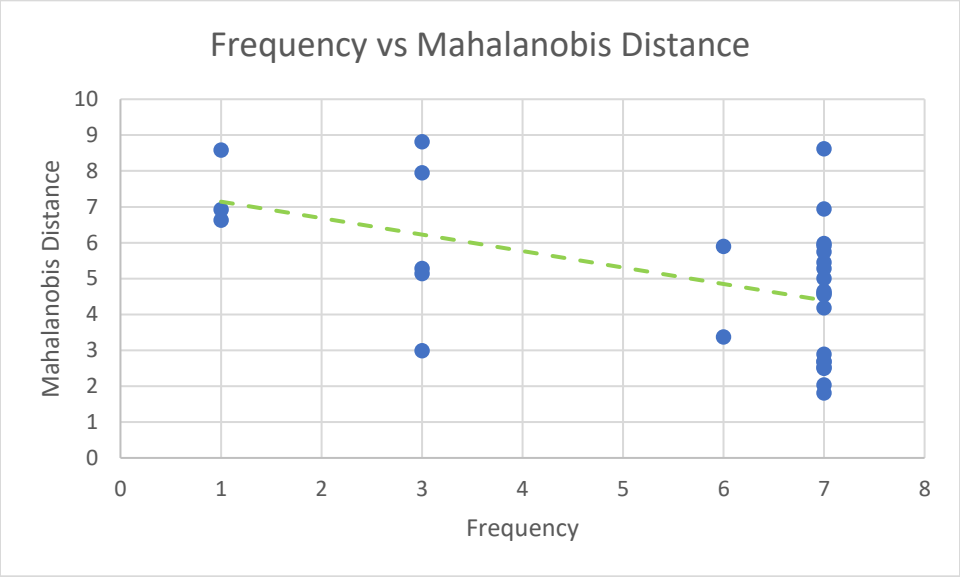

Figure 22: Correlation of frequency of use vs Mahalanobis distance of French (L1), English (L2)

The results of the correlation for the L1 English – L2 French bilinguals are the opposite of that seen for the L1 French – L2 English bilinguals. The strongest predictor of production for the English natives is the frequency of use of the L2 followed by the contexts of use and then the speaker's proficiency.

	Prof vs Maha	Cont vs Maha	Freq vs Maha
Eng Correl Fr	-0.3515239	-0.4600708	-0.5195931

Table 6: English Natives Correlation Results

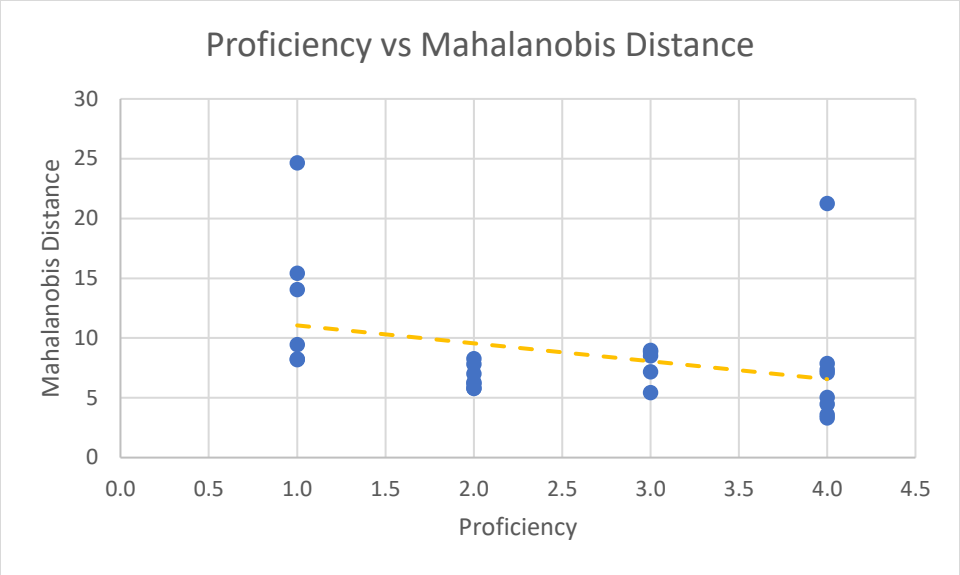

Figure 23: Correlation of proficiency vs Mahalanobis distance of English (L1), French (L2)

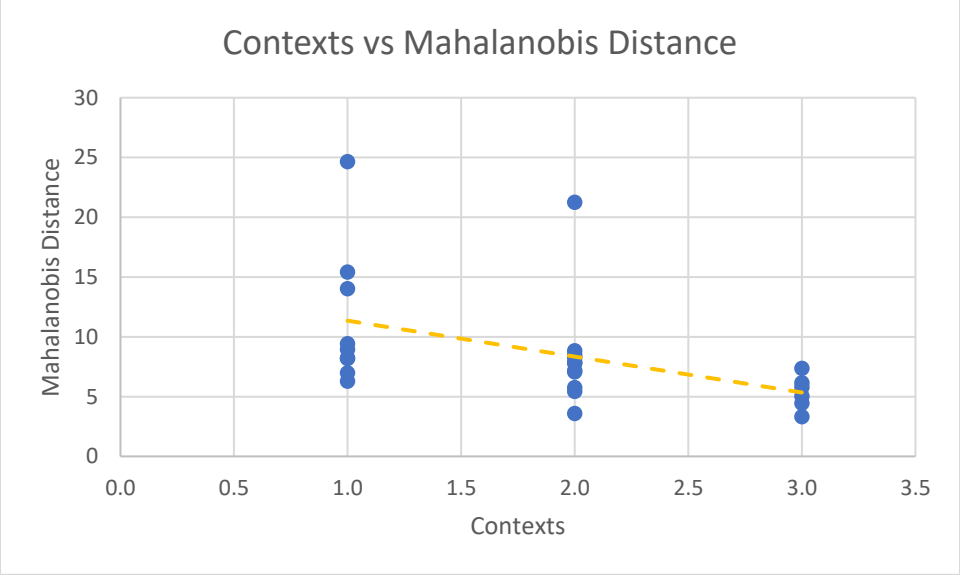

Figure 24: Correlation of contexts of use vs Mahalanobis distance of English (L1), French (L2)

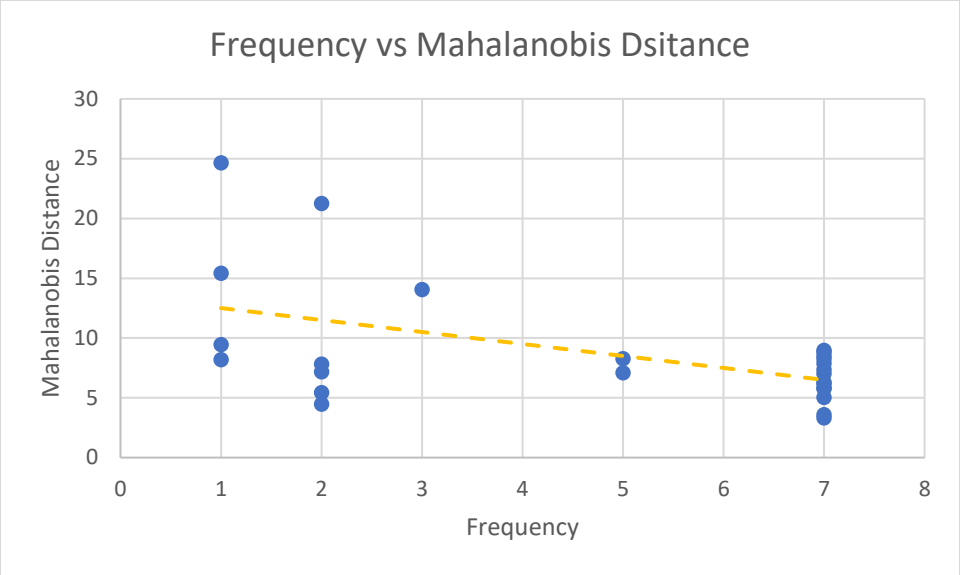

Figure 25: Correlation of frequency of use vs Mahalanobis distance of English (L1), French (L2)

4. Discussions

4.1 L2 Production

4.1.1 English Vowel Production

Why do the distance scores for the L1 French – L2 English bilinguals' line-up with our hypothesis but not the L1 English – L2 French bilinguals? Are the differences between the medium group and strong group less apparent in the L1 English – L2 French bilinguals than in the L1 French – L2 English bilinguals? Is there more to speech production and precise articulation than just a speaker's language proficiency?

With the correlation results described in the previous chapter, we observe that the factors do not have the same weight between the bilingual groups. For the L1 French – L2 English bilinguals, their self-reported proficiency was the best correlation of their production of English vowels. Unsurprisingly, proficiency is an important factor in vowel production. The next highest factor was the contexts in which the French natives use their second language, followed by the frequency of L2 use. The high frequency of use seen in all the groups, save for the weak group, reflects life in a bilingual city. Participants in all groups that live in a bilingual city will naturally use their L2 more often than those that do not live in a bilingual environment. In turn, the high frequency of L2 use, combined with an immersive environment will result in a better production of the L2 as seen in Yang & Fox (2017). The high proficiency groups of L1 French – L2 English bilinguals would use their L2 in more contexts than the weaker groups, demonstrating the high correlation between the Mahalanobis distance scores and contexts of use.

The production of English vowels by the L1 French – L2 English bilinguals is in line with our hypothesis. The weak English group are the furthest from the native speakers, and in association with their production, they have the least frequent use of their L2 and tend to use

their L2 in fewer contexts than the other groups. As the groups' self-described proficiency rises, their production of English vowels gets closer to native-like. This result aligns with the findings in MacLeod (2009), Bosch & Ramon-Casas (2011), Darcy & Kruger (2012), and Yang & Fox (2017) and thus provides more evidence to the previous L2 literature.

Our findings are also in line with one of the tenants of the SLM that it is easier to acquire a new phoneme than modify an existing one. We can point to the Mahalanobis distances scores of /ʌ/ and /u/ in our groups to support this claim. In this example, /ʌ/ is a new phoneme for the French natives while /u/ is an existing one.

	/boot/	/but/
Simul	1.857489	1.114077
FSE	4.798074	0.606964
FME	5.940205	2.022801
FEW	6.510931	1.543309

Table 7: Mahalanobis Distance of /u/ and /ʌ/

We can observe in this table that the scores for the 'new' phoneme do not change all that much as the group's proficiency rises. The opposite is seen with the existing phoneme /u/. The French weak English group Mahalanobis distance score is the furthest from native-like production than the other groups, demonstrating that less experience in their L2 is related to a more 'French' production of the English /u/. This finding has been echoed in research done by Flege (1987) with English and French bilinguals and in another study on SLM (Flege, 1997).

As stated in the result section, we encountered a problem with the production of /ə/. For French speakers, /ə/ is a difficult vowel to produce. It is not only very similar to an existing

vowel, but also the English vowel is always in an unstressed syllable. The positioning of stress is a problem for these speakers possibly because syllables containing /ə/ are shorter, something that is absent in French, causing a 'stress deafness' (Dupoux et al., 2001; 2010). Because of this, some French speakers will misplace the stress inducing mistakes in production. An example of this happened in our experiment. We used two carrier words for /ə/ (about /**ə**'boʊt/, record /ɹ**ə**'koʊɹd/). The L1 French – L2 English participants only had issues with one word, 'record', mostly due to how common 'about' is seen. The positioning of the stress in 'record' would mistakenly be placed on the first syllables rather than the second as there is a word with the same spelling that has the stress on the first syllable (/'ɹɛkoʊɹd/), eliciting the vowel /i/ instead of /ə/.

In our data, one result that is contrary to the results found in MacLeod (2009) is the positioning of the vowel /i/. In their study, they found that the French bilinguals produced the French vowel on the periphery, while their English bilinguals produced their vowel more centrally. In our study, we found the opposite. It was the L1 English – L2 French bilinguals /i/ that is produced on the periphery and not the L1 French – L2 English bilinguals /i/.

4.1.2 French Vowel Production

Starting with the correlations done in the section above, we observe that the results for the L1 English – L2 French bilinguals is the reverse of the results seen for the L1 French – L2 English bilinguals. The biggest predictor for native-like production of the French vowels was frequency, followed by contexts of use. With frequency being the highest predictor for native-like production, it follows the findings in Yang & Fox (2017). High use of L2 in an immersion environment will promote a better production of that language. Another observation relating to

frequency and contexts of use is the difference between the weak group to the other groups. The weak group has low frequency and number of contexts compared to the other groups where the frequency and contexts of use jump up. This is consistent with our hypothesis: speakers that use their L2 in more contexts will have better production than those that do not.

While frequency is the highest predictor of production for the L1 English – L2 French bilinguals and the lowest predictor for the L1 French – L2 English bilinguals, the correlation scores of both groups are quite close (-0.49) for the French, (-0.52) for the English. Both groups have on average a high frequency of L2 use, save for a few speakers in the L1 English – L2 French bilinguals. This could be due to environment where these speakers reside, as these speakers are some of the few that are not in Montréal and therefore have fewer opportunities to use their L2. The lowest correlation was the groups' self-described proficiency, which was again the opposite seen in the L1 French – L2 English bilinguals. This could be due to the English native participants being a bit more reserved towards their proficiency in their second languages.

When it comes to the Mahalanobis distances, there is a stark contrast between the results seen in the L1 French – L2 English bilinguals compared to the results of the L1 English – L2 French bilinguals. Although the weak French group have the highest Mahalanobis distance out of all four groups, which falls in line with our predictions, the rest of the groups do not match up to our hypothesis. It is rather the medium French group that has the closest to native-like production, not the simultaneous bilinguals like we predicted. The simultaneous group had the 3rd best score, and the strong French group had the second best. At first these results seem to go against our hypothesis. However, the simultaneous group had one participant who was clearly an outlier. While the group mostly scored between 3 and 8, the outlier had a Mahalanobis distance

of 21. When we take this person out of the group, the simultaneous bilinguals now have the closest to native-like production.

Simultaneous Bilinguals			
NS	5.0342909	NS	5.0342909
EL	7.3663136	EL	7.3663136
SB	7.8729252	SB	7.8729252
KH	4.4612581	KH	4.4612581
KP	3.5895478	KP	3.5895478
JW	7.0869009	JW	7.0869009
ST	3.3204101	ST	3.3204101
SONA8	21.26152		
MEAN	7.4991458	MEAN	5.5330924

Table 8: Simultaneous Bilingual Mahalanobis distance scores

It is odd to have a participant fit in the simultaneous bilingual group to have a distance that high. In this simultaneous group, the participants all have different backgrounds. Some had their education in French, others in English but all participants acquired both languages before the age of six. Six are from Montréal, one is from Hamilton and one from Sudbury. A possible reason for the high distance score from this speaker is due to the environment where they grew up. While they acquired both languages before the age of five, they received their schooling in English and do not use their French very often.

Just as one outlier speaker changed the score of the simultaneous group, the strong French group had one vowel that acts like an outlier (/ʊ/). Most of the group had high distance scores of that vowel, thus we decided to take that vowel out of the calculation. With the outlier accounted for, the strong French group end up with the second closest to native-like production. It is important to note that there is a relatively low number of speakers in this group (five).

If we account for the outliers seen in the groups mentioned above, we can observe the English natives now fall within our hypothesis. As proficiency rises, the groups scores get closer to native-like production. Also following our hypothesis, speakers who use their L2 in more contexts and use it more frequently tend to have better production. Our (outlier-corrected) results now thus in line with our hypothesis and results from studies by MacLeod (2009), Bosch & Ramon-Casas (2011), Darcy & Kruger (2012), and Yang & Fox (2017).

Like in the English vowel section, we encountered some problems during the experiments. Most of these issues are due to the choice of target words. One issue with the stimuli comes down to spelling, since some of the words had the exact same spelling in English and French. Because of this, some participants pronounced these target words in English rather than the intended French. The words that were the cause of the issue are: 'rat, pipe, porc and sue'. For example, 'rat' /ɹæt/ in English instead of /ʁɑ/ in the intended French. While the participants used a different pronunciation, most of them were able to self-correct themselves and accurately produce the intended word. The other issue we came across is related to word choice for the /ɛ/ and /e/ vowels. In trying to have minimal pairs throughout the vowels in French, we chose two words that can use both vowels without changing the meaning (s'est and ces). While participants in all groups and for both native languages interchanged the vowels in

the words, there is no change in the overall results, even if we take out the Mahalanobis distances for /ɛ/ and /e/.

Furthermore, we tried to elicit two diphthongs, /øʏ/ and /oʊ/, however, all our participants did not produce them, either due to not having the phoneme in their vowel category, or some social pressure as there is a negative connotation related to the production of diphthongs. Both vowels were recategorized as extra tokens (/ø/ and /o/) in our experiment, with the diphthong /oʊ/ acting like a long vowel, as Québec French kept the long and short vowel distinction (Martin, 2002).

Just as we saw in the L1 French – L2 English bilinguals' production of English vowels, one prediction from the SLM is substantiated by our data. The 'new' category /œ/ was acquired with more ease than the modified vowel /ʊ/.

	/peur/	/bouche/
Simul	2.414666	7.341068
ESF	3.032075	31.688533
EMF	4.708729	16.361738
EWF	7.594604	31.768059

Table 9: Mahalanobis distance of /œ/ and /ʊ/

This table illustrates the ease of acquiring the new phoneme against modifying an existing phoneme. While the weak French group are the furthest with their production of /œ/, as the proficiency improves, so does the production from the rest of the groups. With the existing vowel, we can see that all groups had trouble getting close to the French native-like production

of /ʊ/. Like the L1 French – L2 English bilinguals, our L1 English – L2 French bilinguals tend to produce the modified vowel closer to the English phoneme than the French when they have less experience. This finding follows the results found in Flege (1987, 1997).

An interesting area of research concerning the L1 English – L2 French bilinguals is their production of the /ɔ/ and /ɑ/ contrast. As we said in the introduction, Canadian English has /ɔ/ and /ɑ/ merged into a single category. We were curious to see where the English natives produced the new /ɔ/. Would it be closer to /o/ or closer to /ɑ/? We found that the lower proficiency groups tended to produce the vowel closer to /o/. Perhaps producing the new phone near /o/ due to the rounding present in /ɔ/. Another interesting finding regarding the contrasts is the amount of separation in the contrast between the L1 French – L2 English bilinguals and the L1 English – L2 French bilinguals. The L1 French - L2 English bilinguals produced more separation in the /ɔ/ and /ɑ/ contrast compared to the L1 English – L2 French bilinguals. Our plots demonstrate that speakers with a more French background keep more distance in the contrast. Amengual (2016) found similar results in their study on the Catalan /ɔ/ and /o/ contrast in Catalan and Spanish bilinguals. They found that Catalan dominant bilinguals produced the contrast with less overlap than the Spanish dominant bilinguals.

4.2 L1 Production

The SLM does not just make predictions about L1 to L2 effects, but it also posits some predictions of the effects of second language knowledge on the production of the first language. The model states that the L1 of a bilingual speaker will drift towards L2 and vice versa. Research has shown this effect in bilinguals that are immersed in an L2 environment (Kartushina et al.,

2016). Additionally, the L2 → L1 effects were mostly seen in proficient bilinguals while the less proficient L2 speakers' production was unchanged. While all speakers are immersed in both English and French, bilinguals with less proficiency will have a smaller L2 → L1 effect due their weaker proficiency and due to less experience. Therefore, we should see both the proficient groups to have this L2 → L1 effect, while the less proficient groups are expected to have a smaller immersion effect. As we did for the L2 production, we also calculated the Mahalanobis distances for the participants' L1. At first, the results of the French natives do not meet our expectations.

Simul	5.533092
FSE	5.070544
FME	5.833799
FWE	1.817384

Table 10: French Natives Mahalanobis Distance of French Vowels

However, as in the previous section, one speaker is an outlier in the French medium group. Although the rest of the group distances range between 2.9 and 4.2, the outlier speaker has a distance of 19. Once the outlier is taken out of the mean calculation for the group, the mean score falls to 3.6. As the proficiency of the groups rises, so does the Mahalanobis distance. Our results now follow the prediction set by the SLM model and results found in previous research (Kartushina et al., 2016; Chang, 2011; Flege, 1987; 1997; Yang & Fox, 2017). It is interesting that a speaker in the medium English group scored such a high distance in their native language. Perhaps the distance is due to the environment the speaker resides in. They worked in a primarily

English environment and married an English spouse. The production plots also fall within the claim made by the SLM. When we look at the plots of the simultaneous bilinguals, we can observe the production of the French /u/ that while close to native-like is a mix of the French and English production.

While the results from our L1 French – L2 English bilinguals fall within the claims of the SLM, the results from the L1 English – L2 French bilinguals do not. The weak French should have the closest distance to the English monolinguals, but our data shows them being the furthest away from native-like production. We expect the simultaneous bilinguals to have the furthest score, not the weak French group. Instead, the simultaneous group have the second lowest distance score.

Simul	2.883801
ESF	3.31901
EMF	2.6547
EWF	3.88076

Table 11: English Natives Mahalanobis Distance of English Vowels

Throughout our study, there have been outliers that affect our results. After accounting for these outliers, the data lines up with our hypothesis and the previous research. In the L1 English – L2 French bilingual groups, there is one vowel where the strong French group had a much bigger distance compared to the other vowels tested. Unfortunately, taking that vowel out of the calculation does not change the overall results in the table. The medium is still the closest to the English monolingual production, while the weak French group is the furthest. Thus, the L1 English – L2 French bilinguals do not follow the prediction from the SLM. There could be

multiple reasons for these results, one possible explanation could be due to the environment. While Montréal is very bilingual, 56% are French/English bilingual, French is still the majority language in the city with 60% of the population have French as their mother tongue and 69% use majority French as the language used in the home (Statistics Canada, 2022[2]). This could mean that the immersion effects from French have more weight compared to the effects from English as it is much more prevalent in the city because more people would use French in their everyday life before English even in the case of bilinguals. Another possible reason could be related to schooling. There were also some participants in the L1 English – L2 French bilingual group that attended either a French immersion school or, in the case of one participant, attended a school where classes are given in German.

5. Conclusion

We started this thesis with the goal to answer questions about bilingualism and to expand the scope of the study done by MacLeod et al. (2009). Our main goal was to examine bilingual speakers' production of French and English vowels, and to see how different groups of different proficiency compare their L2 production to that of native speakers. The secondary goals of this thesis were to examine what factors lead to native-like proficiency in bilinguals, and to test the predictions set by the SLM model on the data from our bilinguals. We explored whether knowledge of a second language can influence the first language of a speaker and vice-versa? Our hypothesis was that the simultaneous bilinguals should be the closest to native-like production compared to the other bilingual groups, and for the second question of our thesis, we expected to see a stronger effect of second language influence on the first language in more L2 proficient bilingual groups.

Regarding the first question, at first glance, the results did not confirm our hypothesis. However, after correcting some outliers present in the data, the results are within our expectations. Both languages follow the same trend. The simultaneous bilinguals are the closest to native-like production out of all the groups, preceded by the strong and then medium groups, with the weak group being the furthest from the monolingual speakers. While the simultaneous group is the closest to the native speakers in both languages, do they produce their vowels like monolinguals? Previous studies have not come to a clear conclusion. One study says that bilinguals have two monolingual-like vowel categories (Yang & Fox, 2017) while another says bilinguals have their own 'bilingual' vowel categories (Yeni-Komshian & Flege, 2000). It is hard to conclude based on our data; while the results from the English vowels suggest the group

produces the vowels like monolinguals, the data from the French vowels point otherwise. This could be due the speakers using English more in their everyday life, or maybe also due to the presence of English media. Further study on this question is warranted to reach a fruitful answer.

Within our hypothesis, the English native bilinguals' frequency of L2 use was the strongest factor related to native-like production with the number of contexts of L2 use as the second strongest. The opposite was found for the French native bilinguals. Their self-proclaimed proficiency was the highest related factor to their accuracy of production, followed by the contexts of use while frequency of L2 use was the lowest. Although we expected both bilingual groups to have frequency as the strongest factor, previous research has shown that experience is also a factor in L2 production (Flege, 1997). Our results also support part of the SLM; we observe the bilinguals having more ease with the production of new phonemes while the opposite is seen with producing modified existing phonemes.

For the second central theme of our thesis, the data from the French native bilinguals indicate that knowledge of English as an L2 *does* affect their production of French. When comparing the French bilinguals to the monolinguals, the more proficient the group is, the further from monolingual production they are. This finding is in line with previous research on the SLM (Flege, 1987; Flege, 1997; Kartushina et al., 2016). Unexpectedly, the English native bilinguals, while showing effects from the knowledge of the second language, did not demonstrate the same trend as the French native bilinguals: Data from the weak French group showed that their production was further from the monolinguals compared to the simultaneous bilinguals when they should be the closest group.

In the end, our results give support to previous literature, however, there is a need for further studies. One area worthy of further research is the L2 effects seen in our English native

bilinguals. Why did they show a stronger effect compared to the French native bilinguals? While Montréal is a bilingual city, French is still the language of the majority. Would the effects from French have more weight compared to English or another minority language? Another avenue that warrants further research is the effects of English media in a bilingual environment. American media is extremely widespread, given the proximity to the United-States, but also since most of the popular content is produced in English. Many in the younger generations (Millennials, Gen Z) listen to this content in the original language, whether it is movies, tv shows or music. It would be an interesting line of further research to explore the effects of consumed media on language production in bilinguals.

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Annex A: Language History Questionnaire

Sona							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
Sona1	Birth	2	3	1	English	7	0
Sona2	Birth	7	3	1	English	7	0
Sona3	Birth	5-6	3	1	English	7	0.5
Sona4	Birth	7-8	3	1.5	English	7	1
Sona5	Birth	6-7	3	1	English	7	0.5
Sona6	Birth	10	3	1	English	7	0.5
Sona7	Birth	8-9	3	1	English	7	0.5
Sona9	Birth	10	3	2	English	7	1
Sona10	Birth	10	3	1	English	7	0

English Monolinguals

Eng Weak Fr							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
AM	Birth	3	3	1	German	7	7
BP	Birth	4	3	1	Fr Immersion	7	1
DK	Birth	14	3	1	English	7	1
DR	Birth	7	3	1	English	7	1
RY	Birth	5	3	1	English	7	1
TL	Birth	7-8	3	1	English	7	3

English Weak French

Eng Med Fr							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
BC	Birth	4	3	1	Little Fr, Eng	7	7
BL	Birth	6	3	3	English	7	7
BM	Birth	5	3	1	English	7	7
CT	Birth	5-6	3	3	English	7	7
JL	Birth	4-5	3	2	English	7	2
ML	Birth	6-7	3	2	Both	7	7
TO	Birth	6-7	3	2	Little Fr, Eng	7	5

English Medium French

Eng Str Fr							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
ER	Birth	5-6	3	2	English	7	2
GA	Birth	10-12	3	1	English	7	7
MC	Birth	2-3	3	2	Both	7	7
RE	Birth	4	3	2	French	7	2
TS	Birth	5-6	3	2	English	7	7

English Strong French

Fr Mono							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
Dom	10	Birth	0	3	French	0.5	7
Jul	10	Birth	0	3	French	0.5	7
PL	12	Birth	0	3	French	0	7
MH	12	Birth	0	3	French	0.5	7
OL	10	Birth	1	3	French	0	7

French Monolinguals

Fr Weak Eng							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
MT	12	Birth	2	3	French	3	7
LD	12-13	Birth	1	3	French	7	7
CC	12	Birth	1	3	French	1	7
DL	12	Birth	1	3	French	1	7
IA	10	Birth	1	3	French	3	7
AN	9-10	Birth	1	3	French	1	7

French Weak English

Fr Med Eng							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
BT	7-8	Birth	2	3	French	3	7
DM	7-8	5	3	3	French	7	7
GG	6	6	2	3	French	7	7
JT	7	Birth	2	3	French	3	7
MD	10	Birth	2	3	French	3	7
MK	11	Birth	3	3	French	7	7
YB	8-10	Birth	2	3	French	7	7

French Medium English

Fr Str Eng							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
AF	4	2-3	3	3	French	6	7
CLP	3.5	Birth	3	3	French	6	7
FM	4.5	Birth	2	3	French	7	7
JD	10	Birth	2	3	French	7	7
MC	7.5	Birth	3	3	French	7	7
PP	10	Birth	2	3	French	7	7
SA	6.5	Birth	2	3	French	7	7
VH	6	Birth	2	3	French	7	7

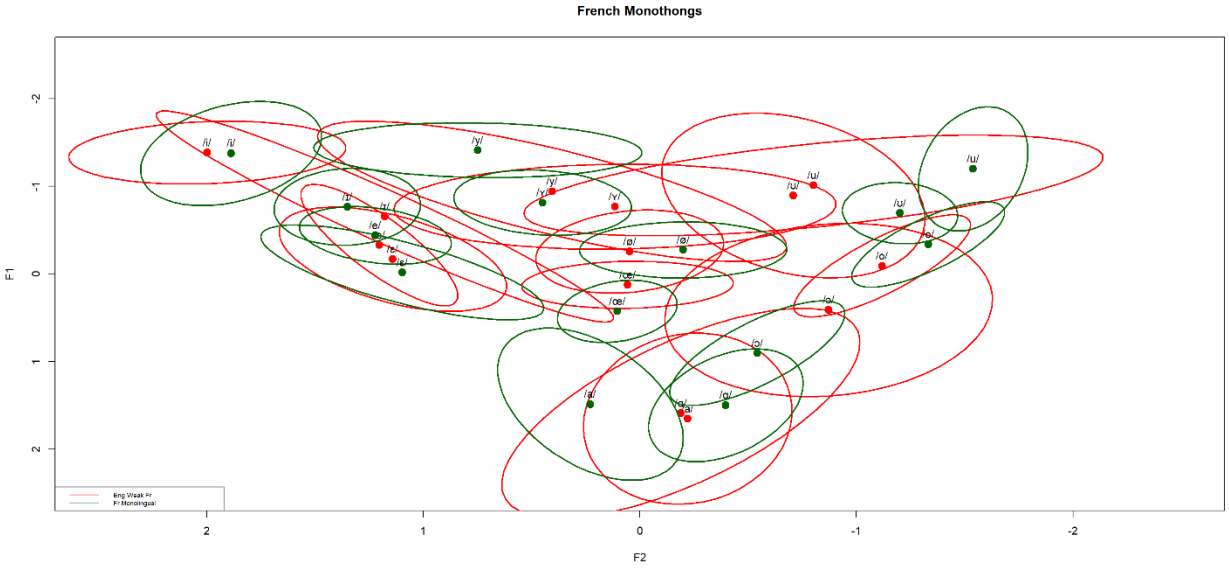
French Strong English

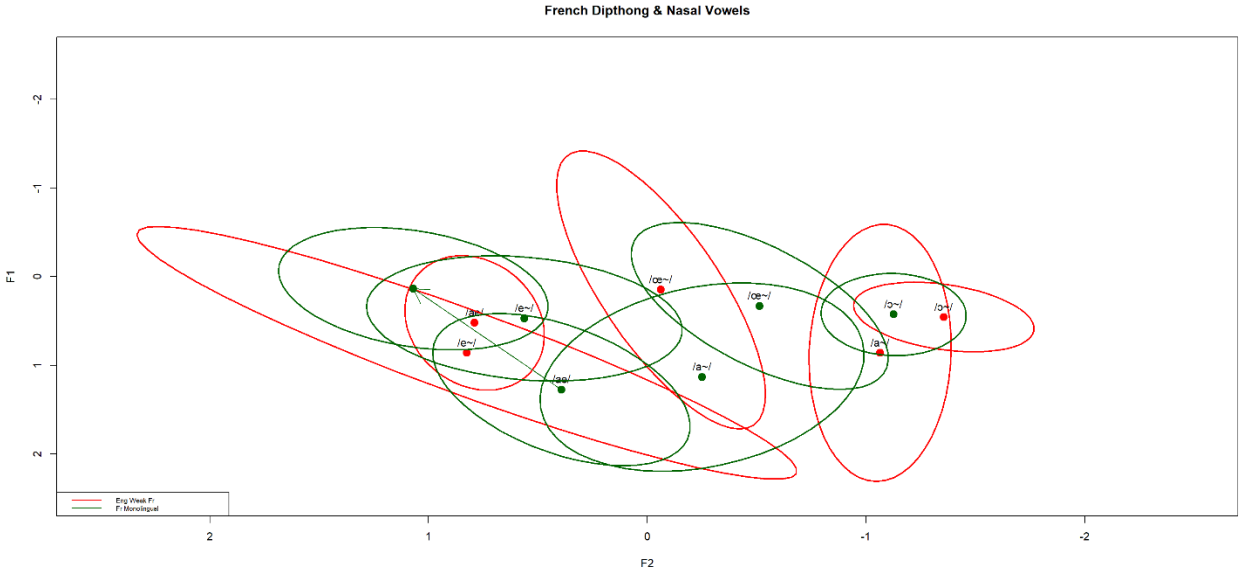
Simultaneous							
	AoA Eng	AoA Fr	Situ Eng	Situ Fr	Schooling	Freq Eng	Freq Fr
EL	Birth	4-5	3	3	English	7	7
JW	3	3	3	2	French, Eng Uni	7	5
KH	Birth	Birth	3	3	French, Eng Uni	7	2
KP	2	4	3	2	English	7	7
NS	5	5	3	3	French	7	7
SB	Birth		3	2	French/English	7	7
SONA8	Birth	Birth	3	2	English	7	2
Steph	Birth	3	3	3	French	7	7

Simultaneous Bilinguals

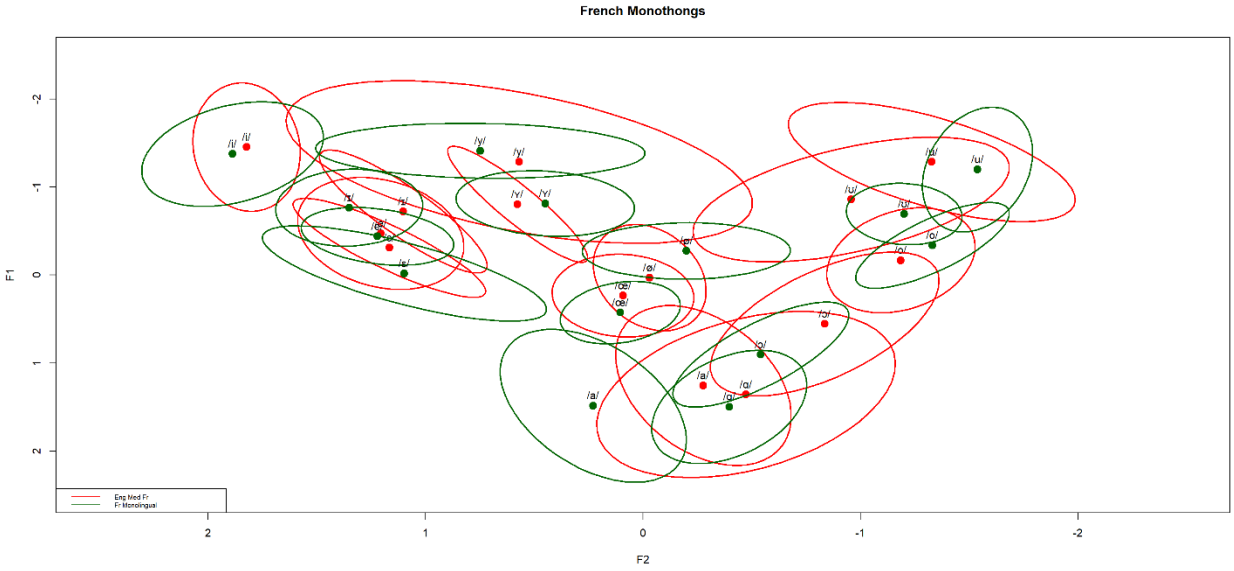
Annex B: L2 plots

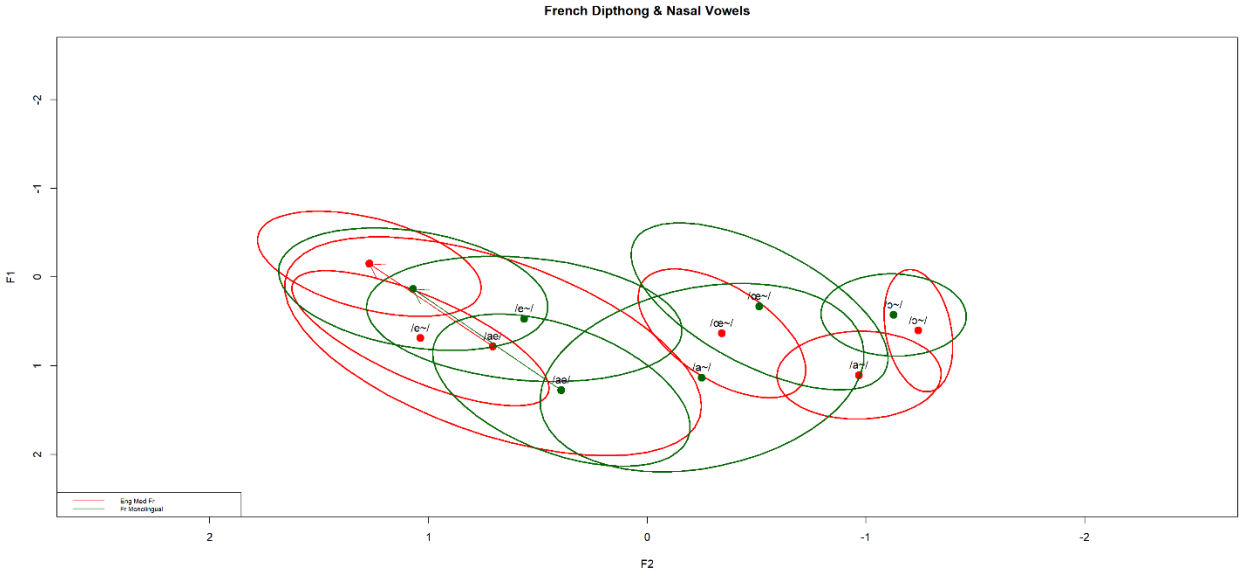
English Weak French



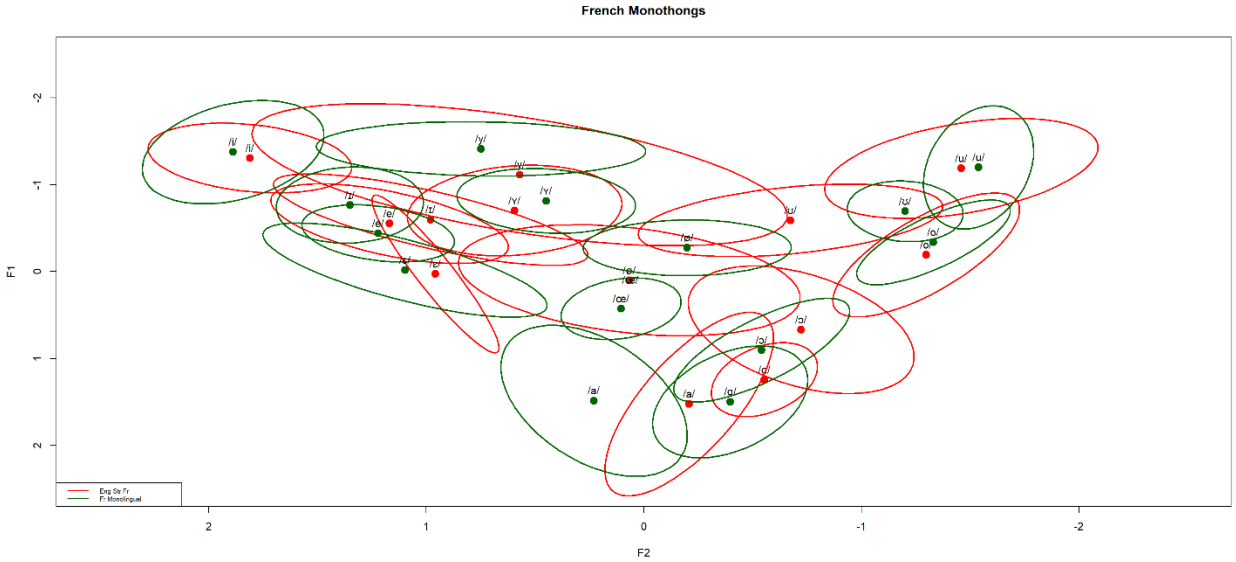


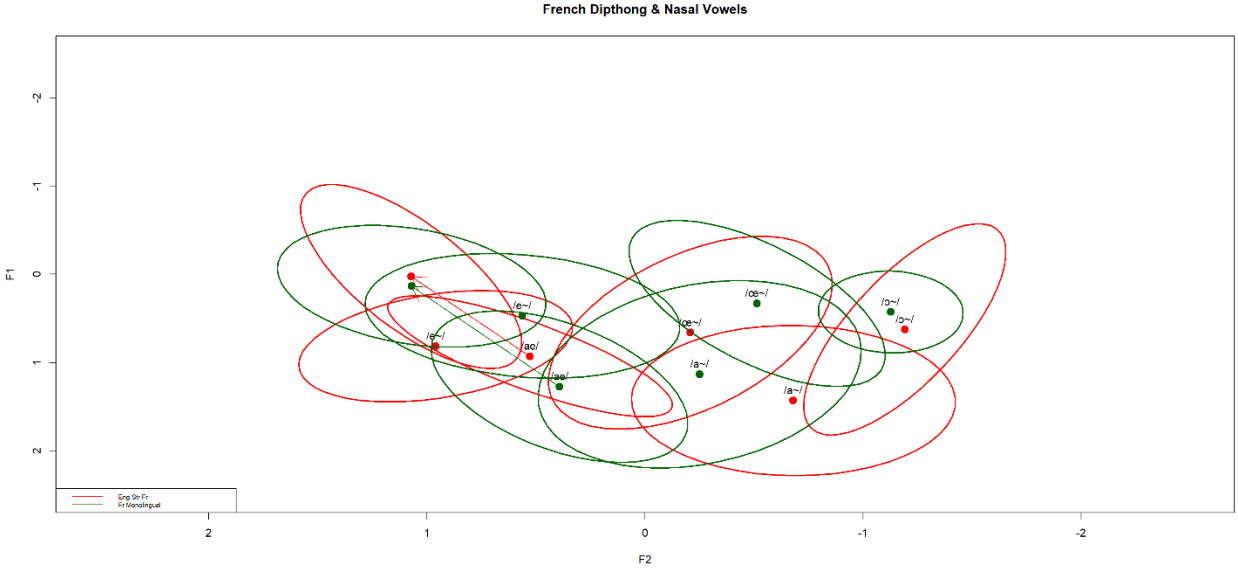
English Medium French



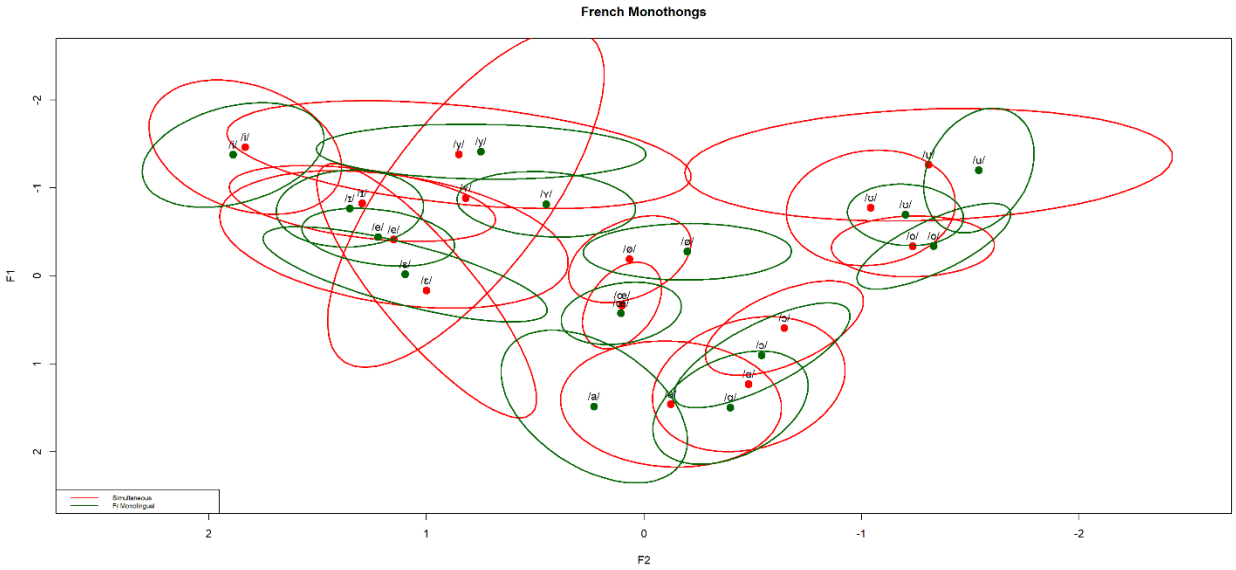


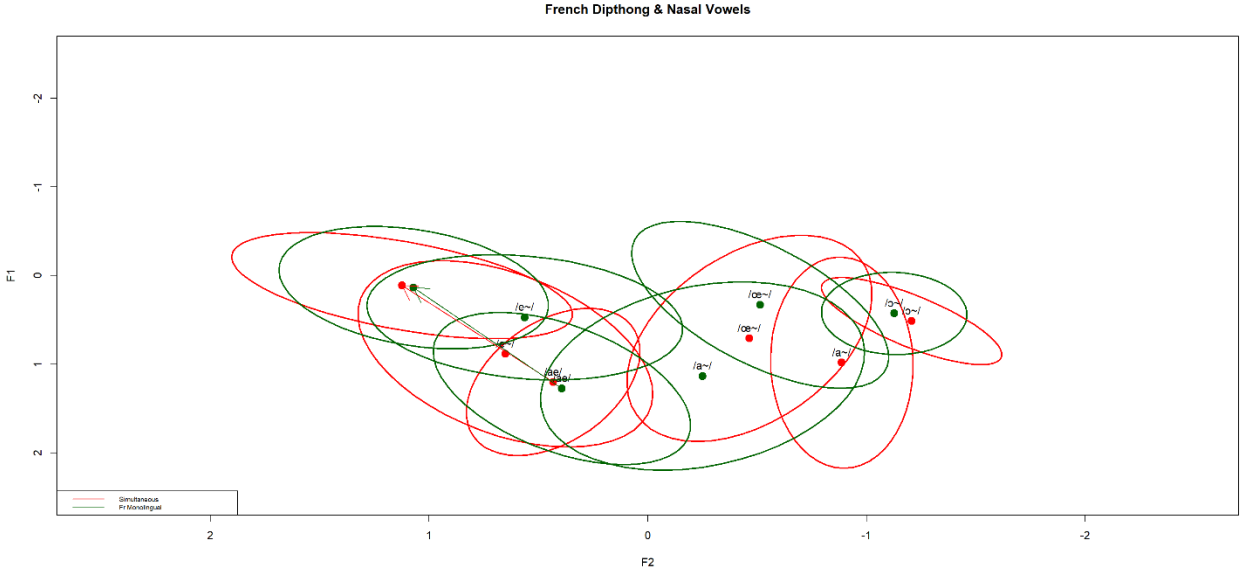
English Strong French



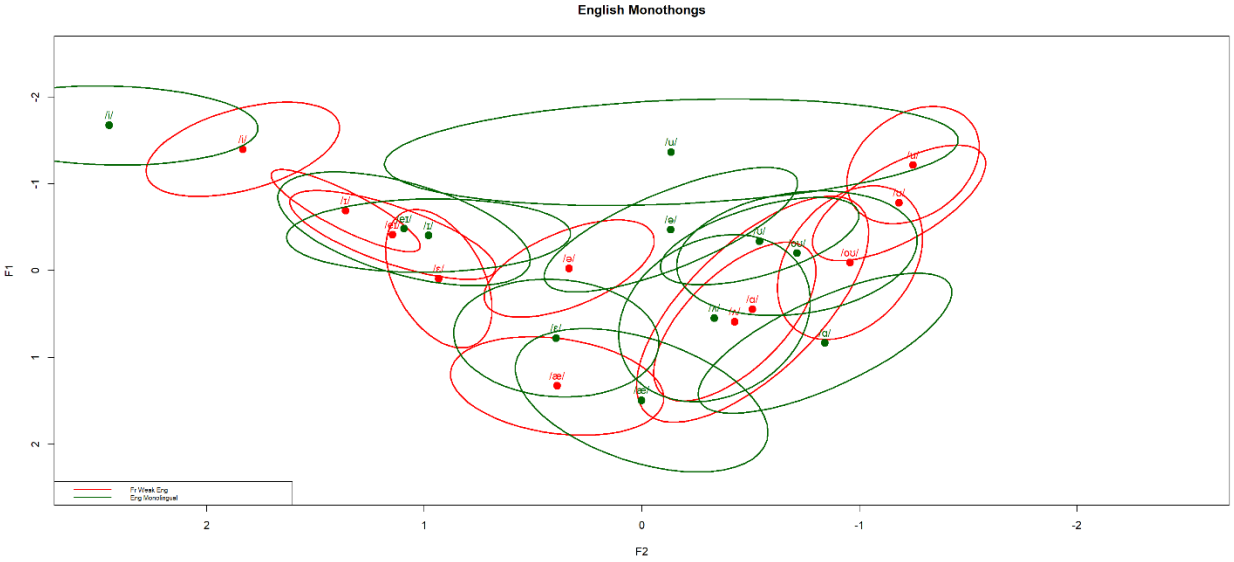


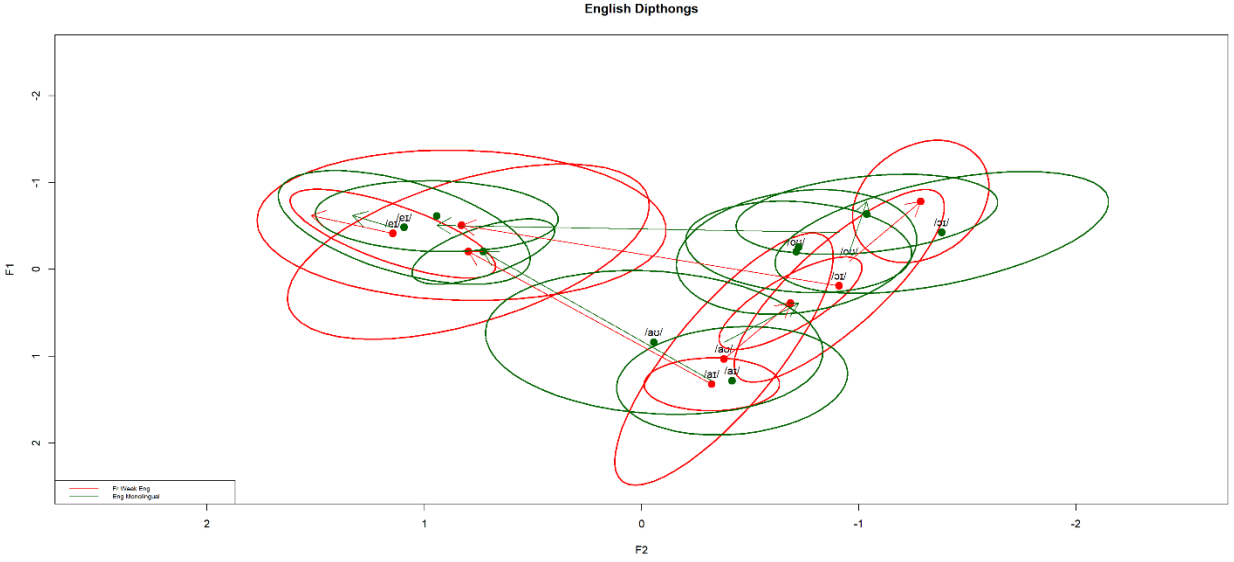
Simultaneous Bilinguals



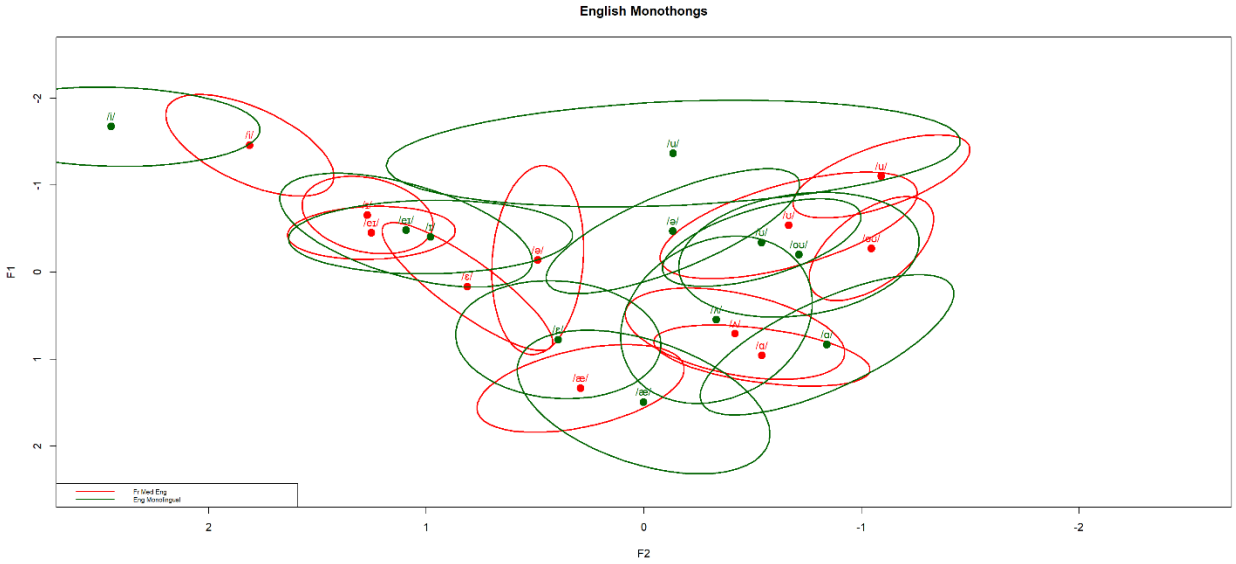


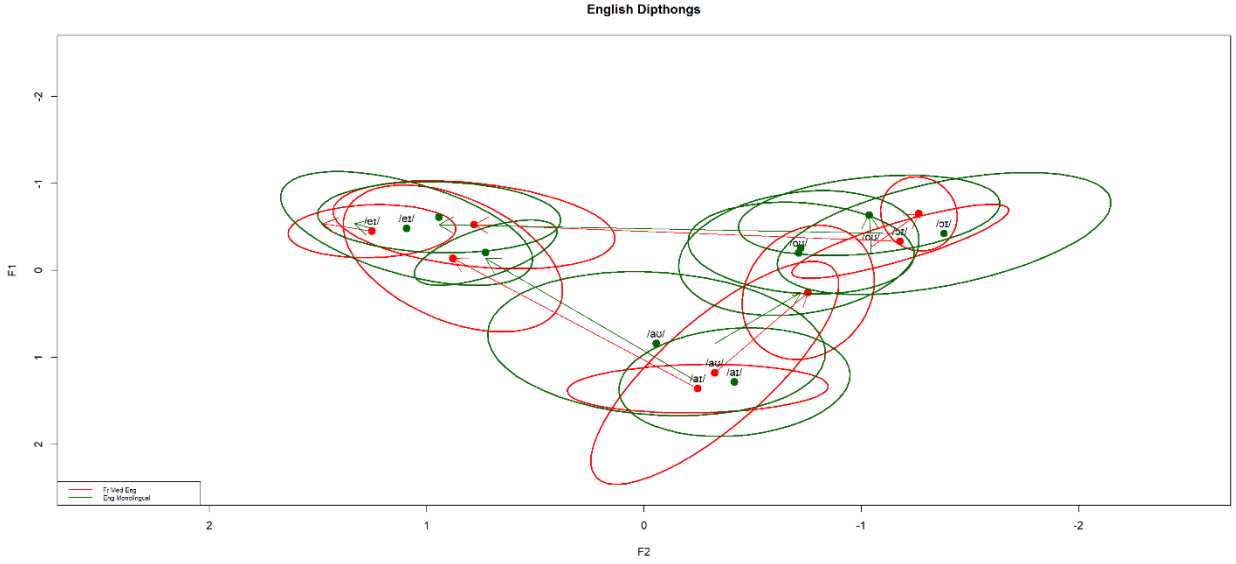
French Weak English



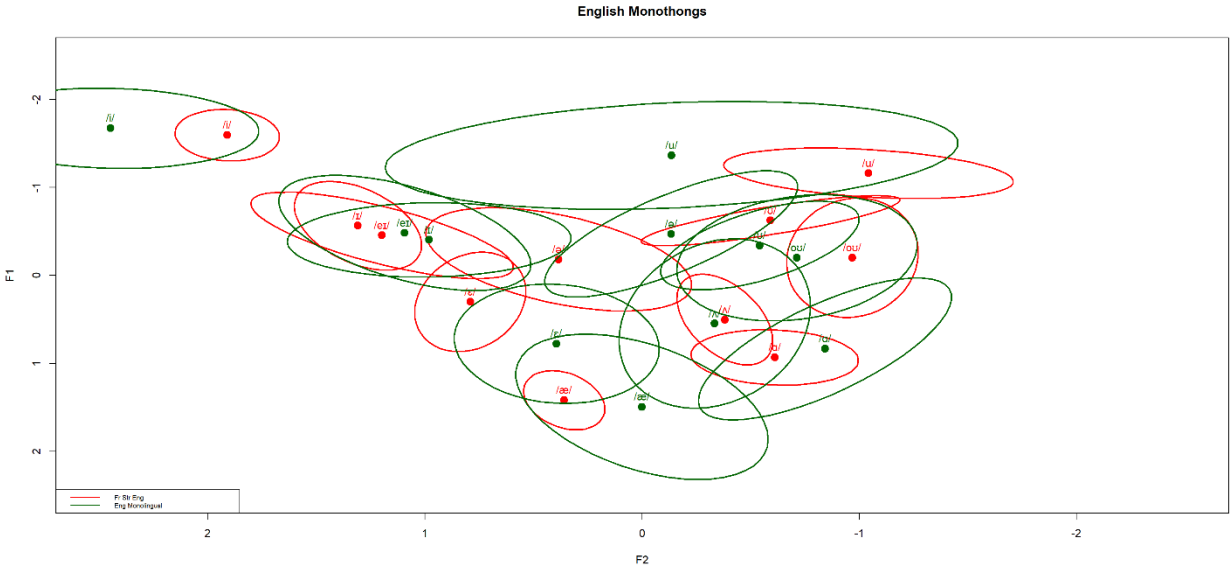


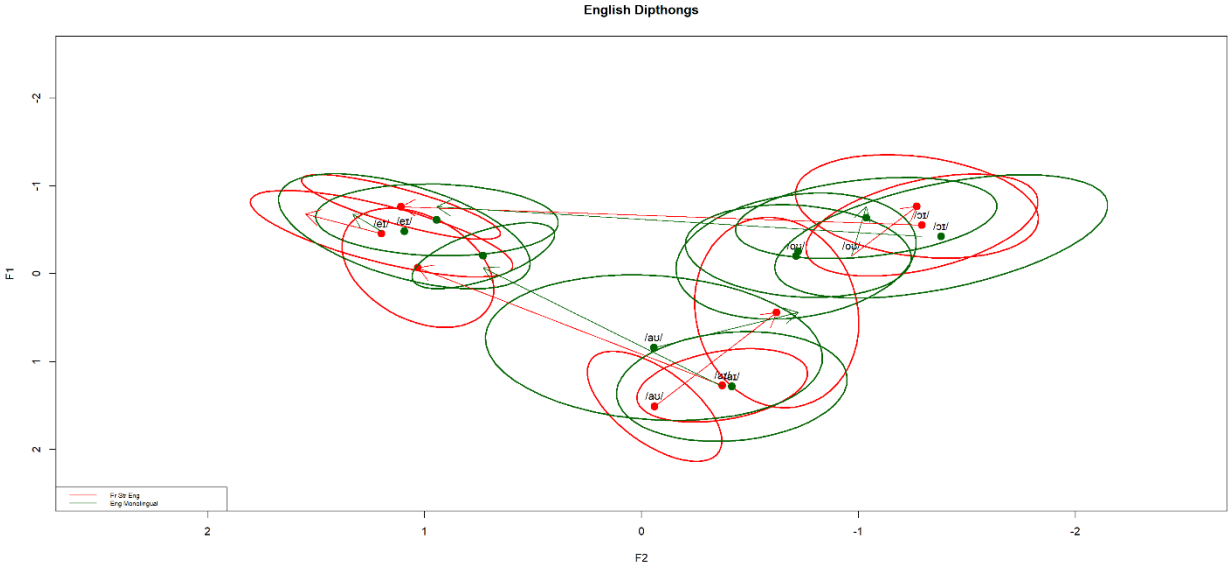
French Medium English



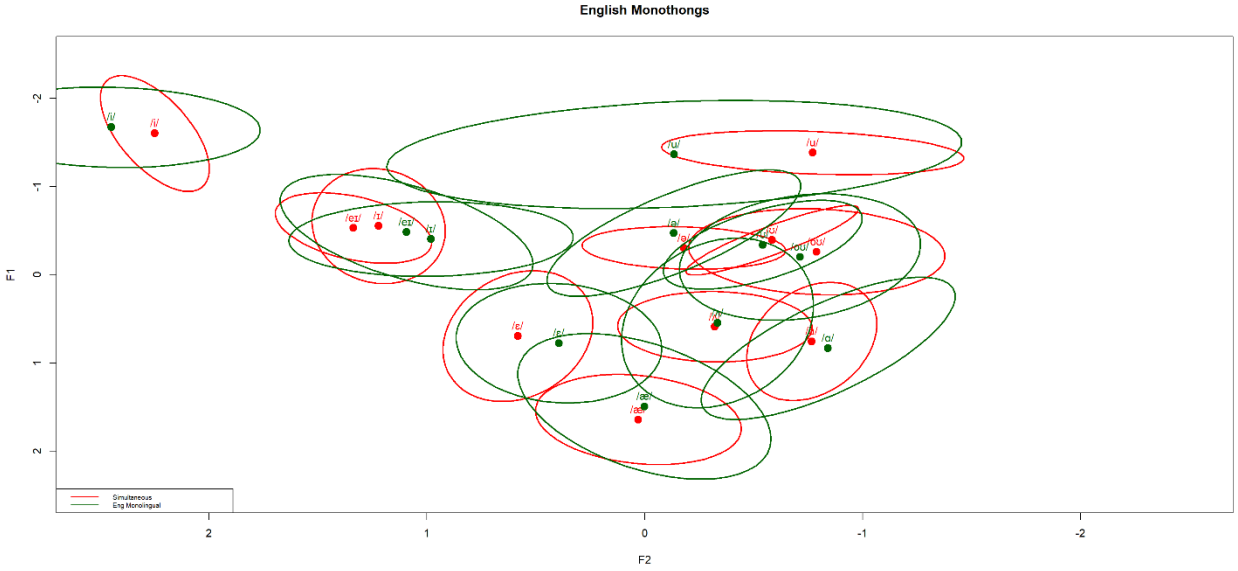


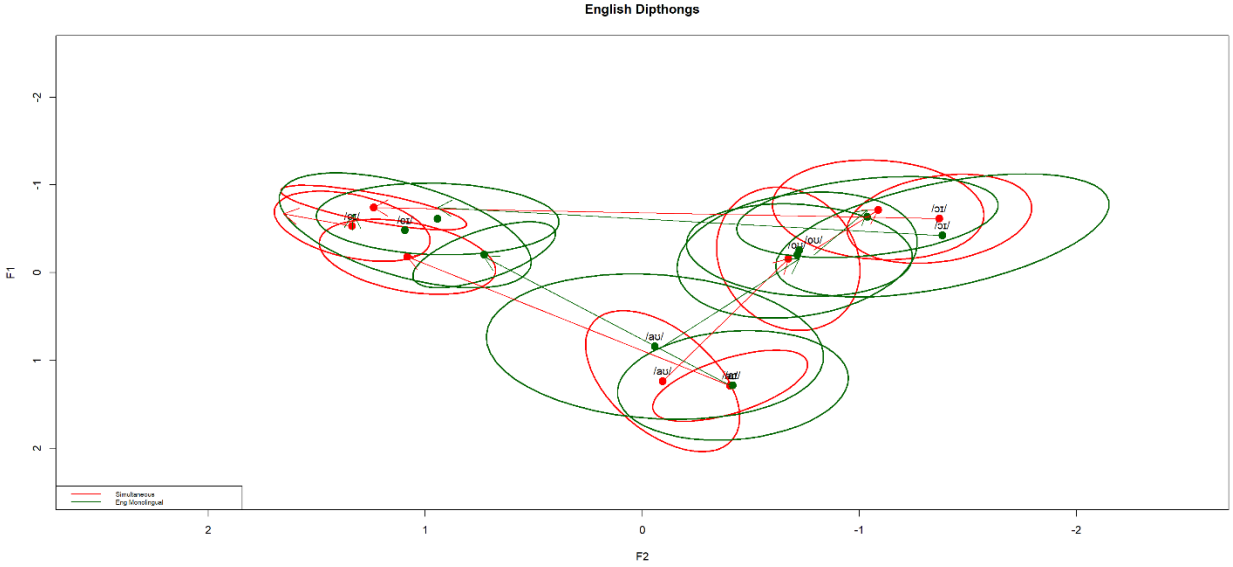
French Strong English





Simultaneous Bilinguals





Annex C: Mahalanobis Distance

French Natives Mahalanobis Distance of English Vowels

Simultaneous Bilinguals																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	Average
NS	11.7284	3.61767	2.34565	1.48445	5.72037	1.11261	4.35377	0.63876	0.15809	0.10375	2.08638	0.06298	5.63625	1.60841	1.441	2.32461	1.13779	2.68006
EL	2.70247	2.30941	0.52367	3.4382	0.13926	0.63201	1.19134	1.40611	4.38627	0.2107	1.14701	0.22929	67.2784	1.9329	9.47927	3.41818	0.1496	5.91613
SB	1.42723	0.44709	0.44016	1.72738	0.74449	2.06495	2.11954	1.1107	0.23964	2.79099	1.20715	1.13497	17.5143	0.88072	0.55882	2.57744	12.2211	2.89451
KH	4.82828	7.00337	0.42016	1.06773	0.73302	0.37627	4.73864	9.42493	0.65669	3.69611	1.5873	0.08501	4.29083	1.79066	0.76657	1.83963	2.51321	2.6952
KP	1.68542	0.2642	0.82144	2.46706	1.2002	0.37653	2.0381	0.88219	0.836	1.21634	4.18438	1.45959	13.8008	3.26889	6.4947	1.94186	0.08978	2.53103
JW	1.55379	6.82491	2.15918	0.2172	0.51966	1.86452	1.73589	3.16168	1.27819	0.25889	5.33257	0.80305	8.32162	1.0355	1.36205	2.84814	3.24912	2.50153
ST	6.12304	1.03862	0.7104	3.98256	5.68671	0.68269	2.38652	0.77103	0.92562	2.91102	0.44251	0.55157	3.28489	0.31606	2.11471	1.96289	0.78457	2.03973
SONA8	1.20455	1.2522	0.11046	0.47533	1.31344	1.80304	1.82946	2.70985	2.4226	1.72388	0.12923	1.42604	8.54596	1.03805	1.11913	1.64291	2.06179	1.81223

	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	
MEAN	3.90665	2.84468	0.94139	1.85749	2.00715	1.11408	2.54916	2.51316	1.36289	1.61396	2.01457	0.71906	16.0841	1.4839	2.91703	2.31946	2.77587	2.91291

Simultaneous Bilinguals

French Strong English																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	Average
CLP	2.00652	2.5179	4.78439	10.8558	5.92606	0.14266	5.65816	3.427	2.65807	0.2017	0.30768	1.57082	5.24526	1.96196	1.34558	7.64104	1.07556	3.37213
AF	3.65505	32.8165	2.03477	7.38828	2.69017	0.84058	9.8019	2.88122	4.03274	2.79309	1.13891	0.6463	7.0052	2.58927	1.049	2.35266	16.6291	5.90263
FM	2.32771	4.65957	0.71079	4.44986	0.50192	1.25088	13.9239	4.96907	3.13156	1.57355	0.13852	0.94573	14.3026	1.26049	1.03003	7.23531	27.4497	5.28595
VH	0.72902	4.94701	7.81342	4.12378	8.38604	0.07894	6.34685	4.96097	4.76465	0.54797	0.56368	0.33602	10.2221	1.61115	0.30211	1.26571	21.1193	4.59522
MC	5.87245	4.78794	3.43783	3.48432	0.89383	0.20481	8.27074	5.9453	0.93976	3.59432	6.40171	0.75052	13.7954	4.34768	0.17941	5.64141	24.1407	5.45224
SA	1.5714	7.81938	2.1992	3.46003	0.44065	0.71493	3.67647	1.89825	2.26309	5.48193	1.89321	1.871	22.2405	0.35313	2.09181	7.61192	11.8066	4.55256
JD	13.2415	4.51335	4.33587	2.94598	0.00131	0.60953	5.95223	5.19776	2.55304	3.44386	1.75135	1.01049	19.1375	0.54345	1.78684	3.43749	0.65249	4.18318
PP	2.03969	22.0512	7.46935	1.67652	1.05185	1.01339	6.5247	4.76483	1.8675	1.5427	0.97904	0.02268	15.0219	0.24759	11.7526	1.23845	22.3607	5.97792

	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	
MEAN	3.93042	10.5141	4.0982	4.79807	2.48648	0.60696	7.51937	4.25555	2.7763	2.39739	1.64676	0.89419	13.3713	1.61434	2.44217	4.553	15.6543	4.91523

French Strong English

French Medium English																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	Average
JT	1.44579	8.59589	2.36139	4.02157	5.12925	1.34791	3.16805	3.49331	0.79665	1.75957	2.31264	0.12577	4.38623	2.5244	0.2648	8.06555	0.98086	2.98704
YB	0.99555	17.9206	1.01908	9.56957	0.44195	0.68025	3.14848	5.27115	2.35059	3.22422	0.01514	0.39954	19.3495	0.33975	6.0565	4.91098	3.31935	4.64778
BT	5.16331	13.0315	2.67409	5.80628	1.9009	0.29237	8.68249	11.758	1.13784	2.05529	2.5315	1.1324	8.81537	0.09673	6.56893	4.1739	11.5936	5.14203
DM	4.41386	10.0492	0.49489	7.99819	3.48502	1.00614	7.77421	5.93382	2.82349	2.49153	3.57003	3.89948	18.2172	0.08062	1.58378	3.85702	7.38403	5.00367
MD	14.2109	11.409	10.004	5.72362	8.3226	1.79246	27.7526	14.0011	1.82421	3.68347	0.18802	0.09543	9.52975	2.12555	2.81651	3.05641	18.6144	7.95
MK	3.35737	17.7897	6.03007	5.28974	9.42585	3.00052	15.6384	8.12209	9.74798	5.63179	0.17544	2.32238	5.81988	0.78432	2.75886	1.60431	0.13454	5.74313
GG	2.65889	11.8641	2.76258	3.17246	1.43997	6.03996	5.82501	6.09738	1.09041	1.76435	2.68383	5.45918	76.0166	0.60207	1.92849	4.17553	12.9908	8.62186

	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	
MEAN	4.60652	12.9514	3.62088	5.94021	4.3065	2.0228	10.2842	7.81097	2.82445	2.94432	1.63952	1.91917	20.3049	0.93621	3.1397	4.26339	7.85965	5.72793

French Medium English

French Weak English																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	Average
MT	9.09803	5.2585	6.97342	4.2591	2.20441	2.75299	9.79393	8.09276	1.16679	2.27591	1.68908	0.63978	15.4318	5.02489	6.22655	2.59853	6.30375	5.28178
LD	6.94789	5.8651	11.8464	4.39744	8.53781	0.37136	12.6706	4.59326	0.54364	3.69698	1.12918	1.40893	24.1633	5.5102	13.8461	2.4391	10.0885	6.94446
CC	9.46145	0.77147	21.8231	4.05846	19.8399	3.92799	29.1988	11.4516	5.36605	0.47732	0.40638	0.3269	1.75501	1.26652	2.43284	3.53551	1.57016	6.92174
IA	0.39657	7.89721	11.7747	10.9435	42.0821	0.3105	13.6764	10.8288	1.76509	2.23218	1.27936	1.10869	16.0332	6.29325	4.20645	4.16495	14.9324	8.81914
AN	4.11935	7.56259	16.0651	7.68173	11.9543	1.20295	8.07729	9.218	5.53184	5.47741	0.02093	0.29007	16.0212	14.0152	12.4632	6.871	19.3118	8.58142
DL	8.06943	2.79199	14.4293	7.72538	10.0714	0.69406	11.4242	4.79895	8.67358	4.28625	2.53015	0.35891	5.8723	10.8686	1.2321	6.68399	12.2617	6.63366
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	
MEAN	6.34879	5.02448	13.8187	6.51093	15.7817	1.54331	14.1402	8.1639	3.84116	3.07434	1.17585	0.68888	13.2128	7.16312	6.73454	4.38218	10.7447	7.19703

English Natives Mahalanobis Distance of French Vowels

Simultaneous Bilinguals

Simultaneous Bilinguals	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
NS	0.70486	3.60673	0.99086	3.91936	2.29389	0.86631	1.23276	2.03706	4.07707	8.28278	2.25728	52.4466	1.49811	4.26114	0.06298	5.63625	2.32461	1.13779	1.60841	1.441	5.03429
EL	0.57253	7.68042	3.76653	5.1513	2.59412	3.21814	5.4588	2.16963	2.61205	1.0955	6.19042	14.3865	8.92621	1.01641	0.22929	67.2784	3.41818	0.1496	1.9329	9.47927	7.36631
SB	12.2678	9.68137	5.12027	13.5135	3.81718	4.73476	5.65289	1.65248	18.1764	3.3507	3.22574	15.96	15.1088	10.3093	1.13497	17.5143	2.57744	12.2211	0.88072	0.55882	7.87293
KH	5.15139	3.10319	16.9385	6.5435	1.38851	8.37701	1.34806	0.13922	0.75184	16.1613	5.00667	6.32375	3.06065	3.64566	0.08501	4.29083	1.83963	2.51321	1.79066	0.76657	4.46126
KP	0.96062	5.42441	2.892	17.9776	0.43331	0.50504	0.30221	2.08274	3.93176	0.40654	2.86684	6.59765	0.00554	0.34901	1.45959	13.8008	1.94186	0.08978	3.26889	6.4947	3.58955
JW	8.69742	1.28125	6.94193	15.1641	8.58628	9.38103	6.37363	1.06474	8.8345	3.11441	0.50555	5.03626	47.4066	1.73086	0.80305	8.32162	2.84814	3.24912	1.0355	1.36205	7.0869
ST	0.23238	2.05127	8.81139	4.89195	5.16903	2.38194	0.59508	0.37647	6.09851	3.60734	9.94009	5.8869	3.67564	3.67553	0.55157	3.28489	1.96289	0.78457	0.31606	2.11471	3.32041
SONA8	4.5193	3.75815	151.637	10.1698	6.62367	11.6787	4.11501	9.79498	15.7268	22.7099	2.48205	152.774	8.98373	4.42318	1.42604	8.54596	1.64291	2.06179	1.03805	1.11913	21.2615
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	
MEAN	4.13829	4.57335	24.6373	9.6664	3.86325	5.14287	3.13481	2.41467	7.52612	7.34107	4.05933	32.4265	11.0832	3.67639	1.9344	1.96399	2.80327	5.81098	4.98949	6.45447	7.49915

English Strong French

English Strong French	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
TS	1.34664	32.9203	21.3678	4.9127	2.03812	18.3409	1.1066	4.79658	4.73657	41.6754	1.25248	13.8257	3.95603	14.6469	0.19491	1.0213	0.34521	0.50993	7.3691	0.43908	8.84011
MC	2.84351	12.2322	4.15863	3.95835	1.66958	6.41434	3.38814	2.6557	1.60347	47.4428	26.3745	0.03971	2.21279	6.20444	2.50314	3.62325	2.63588	3.08986	8.03097	28.9127	8.49969
GA	12.6748	25.249	1.88499	7.23166	0.41231	35.7825	0.91527	3.59375	23.1659	5.40171	4.49628	4.37197	0.47405	2.82441	3.12953	0.481	16.2222	11.9711	0.32611	18.5006	8.95545
ER	0.60183	1.58137	1.79126	4.7926	1.64226	1.44321	4.07568	1.42313	6.12295	7.66773	34.443	0.80118	2.44245	8.86425	4.52066	5.18478	15.895	2.05018	2.33721	0.90105	5.42909
RE	1.45745	4.09011	1.33882	0.57084	5.51122	2.02593	0.74912	2.69122	17.101	56.255	0.59785	2.6863	10.5413	11.4376	0.65963	1.16499	6.46837	5.16588	8.74164	4.16938	7.17119
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	
MEAN	3.78485	15.2146	6.1083	4.29323	2.2547	12.8014	2.04696	3.03208	10.546	31.6885	13.4328	4.34498	3.92533	8.79553	2.20157	2.29506	8.31333	4.55738	5.36101	10.5846	7.77911

English Medium French

English Medium French	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
CT	4.27173	1.71293	3.83789	4.66115	7.77477	7.90992	1.83656	10.5097	13.1677	14.6328	2.62356	1.18891	1.19294	5.20818	19.1092	6.99583	3.16531	5.68594	5.62956	2.41344	6.1764
TO	3.39688	9.06871	30.4974	4.05483	9.92398	3.52093	2.94507	9.54492	29.1817	0.30969	16.5531	1.34486	3.55567	18.803	1.45898	0.06922	1.12497	7.07171	6.15774	6.5615	8.25724
BL	7.12	2.49356	23.346	10.1262	2.03085	3.97826	0.38759	3.2846	10.9754	9.12743	0.66324	5.54303	0.31029	7.62238	10.0533	0.8659	0.41321	6.09563	8.36546	3.17122	5.79868
BM	4.52164	19.4995	7.07644	9.57628	3.68427	8.70622	0.38398	0.89191	19.4001	11.9059	5.91604	3.58381	13.661	8.38949	2.51378	2.16172	0.96393	4.09049	7.54457	5.61461	7.00428
BC	3.53489	6.63918	0.00259	2.2217	1.45404	0.36736	1.93752	0.73571	17.0144	49.6666	5.01243	5.18981	1.3624	0.45966	4.04621	1.59499	12.4423	2.83957	3.56479	5.86943	6.29778
ML	5.35042	18.3058	16.2342	0.04338	0.43637	5.07402	3.68859	2.38679	7.23235	14.9615	6.15713	7.86244	6.92679	1.885	0.87249	1.00919	6.21852	7.48613	3.1627	0.08605	5.76899
JL	5.89349	7.6238	8.68484	0.51003	13.2974	41.4936	2.80755	5.60745	7.48994	13.9283	10.9068	0.24965	2.25665	6.92407	6.35492	4.50577	0.79628	11.1317	1.64454	4.06218	7.80845
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	
MEAN	4.86987	9.33479	12.8113	4.45623	5.51453	10.15	1.99812	4.70873	14.9231	16.3617	6.83319	3.56607	4.18082	7.04168	6.34412	2.45751	3.58922	6.34302	5.15277	3.96835	6.73026

English Weak French

English Weak French																				
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
TL	5.72989	0.33928	83.8643	1.67247	17.7538	61.4989	1.027	2.74193	1.24605	6.68038	3.37967	28.565	1.76665	16.9263	8.45427	10.2076	4.16124	9.29018	12.814	2.69274	14.0406
DR	2.54481	2.45999	81.5425	0.51961	2.01157	10.315	2.2864	15.9634	10.2571	54.851	51.4522	0.63026	2.75752	6.1375	7.97615		2.23714	9.75628	23.9363	5.36114	15.4208
DK	1.93593	7.85564	22.3049	17.2484	14.0805	18.501	0.74272	5.74367	4.55616	13.6008	2.24548	13.0964	5.10998	16.0992	8.14547		1.72208	10.577	4.56629	11.2367	9.44044
BP	8.41904	0.06843	253.304	0.00749	0.13827	15.7722	11.1617	14.7683	14.0646	62.7168	16.4831	1.37335	6.20587	18.4625	6.1463		17.1059	10.0199	2.31992	9.76059	24.6473
RY	2.09485	3.81121	20.3878	1.15869	3.89374	17.6	1.58794	0.6414	15.1365	32.4176	1.01051	2.09939	1.6809	25.4224	2.30655	4.36944	1.68046	8.83399	8.67479	9.1782	8.19932
AM	5.11349	10.0838	0.26533	7.92177	13.3446	1.21737	0.70343	5.70892	14.466	20.3418	29.5131	18.5273	0.30627	9.30911	3.99798		1.53054	5.80433	2.84459	5.53766	8.23881
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	
MEAN	4.30634	4.10305	76.9448	4.75474	8.53708	20.8174	2.9182	7.5946	9.95441	31.7681	17.3473	10.7153	2.9712	15.3928	6.17112	7.28854	4.73955	9.04695	9.19266	7.29451	13.3312

English Natives Mahalanobis Distance of English Vowels

Simultaneous Bilinguals

Simultaneous Bilinguals																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	Average
NS	11.7284	3.61767	2.34565	1.48445	5.72037	1.11261	4.35377	0.63876	0.15809	0.10375	2.08638	0.06298	5.63625	1.60841	1.441	2.32461	1.13779	2.68006
EL	2.70247	2.30941	0.52367	3.4382	0.13926	0.63201	1.19134	1.40611	4.38627	0.2107	1.14701	0.22929	67.2784	1.9329	9.47927	3.41818	0.1496	5.91613
SB	1.42723	0.44709	0.44016	1.72738	0.74449	2.06495	2.11954	1.1107	0.23964	2.79099	1.20715	1.13497	17.5143	0.88072	0.55882	2.57744	12.2211	2.89451
KH	4.82828	7.00337	0.42016	1.06773	0.73302	0.37627	4.73864	9.42493	0.65669	3.69611	1.5873	0.08501	4.29083	1.79066	0.76657	1.83963	2.51321	2.6952
KP	1.68542	0.2642	0.82144	2.46706	1.2002	0.37653	2.0381	0.88219	0.836	1.21634	4.18438	1.45959	13.8008	3.26889	6.4947	1.94186	0.08978	2.53103
JW	1.55379	6.82491	2.15918	0.2172	0.51966	1.86452	1.73589	3.16168	1.27819	0.25889	5.33257	0.80305	8.32162	1.0355	1.36205	2.84814	3.24912	2.50153
ST	6.12304	1.03862	0.7104	3.98256	5.68671	0.68269	2.38652	0.77103	0.92562	2.91102	0.44251	0.55157	3.28489	0.31606	2.11471	1.96289	0.78457	2.03973
SONA8	1.20455	1.2522	0.11046	0.47533	1.31344	1.80304	1.82946	2.70985	2.4226	1.72388	0.12923	1.42604	8.54596	1.03805	1.11913	1.64291	2.06179	1.81223
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/toy/	/toy2/	/ow/	/ow2/	
MEAN	3.90665	2.84468	0.94139	1.85749	2.00715	1.11408	2.54916	2.51316	1.36289	1.61396	2.01457	0.71906	16.0841	1.4839	2.91703	2.31946	2.77587	2.91291

English Strong French

English Strong French																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/ow/	/ow2/	/toy/	/toy2/	Average
TS	3.82485	5.82821	0.28875	0.8687	0.00705	0.10456	0.87217	0.79832	2.63869	1.27117	4.40937	1.77065	1.91557	4.18525	3.569	2.71205	2.83167	2.22918
MC	0.26825	5.12744	1.0992	0.66945	2.32513	0.71522	1.96887	4.89337	2.07223	1.56418	3.27142	6.48197	7.06253	0.27439	17.6911	2.27287	2.22119	3.52816
GA	1.85173	30.6293	2.22176	8.16422	1.19953	0.5497	0.05294	4.48835	0.48964	8.562	0.12255	1.12427	8.74398	0.44912	38.5599	2.44964	0.66514	6.48963
ER	2.65806	0.86184	0.59182	2.00567	0.43221	5.34752	0.48892	2.89752	0.73657	1.51154	1.11884	1.85779	4.26662	0.16476	27.0452	3.00235	1.36485	3.31483
RE	1.16442	0.13915	0.03595	0.4937	0.49089	0.13317	0.01624	0.41326	0.85009	0.03746	2.54559	0.02524	2.64531	2.01165	0.14124	2.08833	4.33335	1.03324
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/ow/	/ow2/	/toy/	/toy2/	Average
	1.95346	8.51718	0.8475	2.44035	0.89096	1.37004	0.67983	2.69816	1.35744	2.58927	2.29355	2.25198	4.9268	1.41704	17.4013	2.50505	2.28324	3.31901

English Medium French

English Medium French																		
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/ow/	/ow2/	/toy/	/toy2/	Average
CT	0.91713	6.32099	2.16417	1.26585	0.70604	0.52059	1.02114	3.22816	0.55338	0.49079	2.96343	2.79877	5.23157	2.01592	3.61765	2.64436	0.58324	2.17901
TO	1.093	6.818	2.53454	1.64613	0.47527	1.73557	2.10693	1.83636	1.04301	0.14499	2.87562	0.09013	16.148	0.24104	0.63896	4.08649	1.77703	2.66418
BL	0.3126	12.1791	0.01804	1.68109	0.17867	1.4989	2.44885	0.99695	2.69391	1.44522	2.27477	1.67001	2.78741	1.54945	3.53633	7.92845	0.9321	2.59599
BM	2.50198	3.48862	0.89348	0.93735	0.98489	0.32829	0.6393	0.84788	0.29584	0.13551	3.16282	3.98912	0.81267	0.30535	1.01328	0.85926	0.60476	1.28238
BC	1.02783	10.1734	4.43189	2.78343	1.74713	2.23933	2.5549	1.14585	0.38707	0.71426	2.96446	0.20089	13.0837	4.03779	23.9796	1.35192	0.57152	4.31735
ML	1.61353	1.52679	0.39265	1.33864	0.35216	0.57755	1.70893	3.87217	0.20187	1.68958	9.8142	2.50801	4.87151	0.09343	3.56843	0.05534	3.6382	2.22488
JL	2.92253	6.44417	0.98364	1.36071	0.39953	0.13947	0.71846	0.75084	0.84628	0.68109	4.31729	0.34111	14.9206	0.5994	9.49917	10.1713	1.32932	3.31911
	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/ow/	/ow2/	/toy/	/toy2/	Average
	1.48409	6.70729	1.6312	1.57331	0.69195	1.00567	1.59979	1.81118	0.86019	0.75735	4.05323	1.65686	8.26507	1.2632	6.55049	3.87102	1.34802	2.6547

English Weak French

	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/ow/	/ow2/	/toy/	/toy2/	Average
TL	0.40687	2.62028	1.41772	0.99876	0.19281	0.14813	5.6172	2.64179	2.82564	2.22955	0.21932	0.24009	70.2291	0.3226	4.83795	0.52239	1.58157	5.70893
DR	0.08463	4.1429	0.02533	1.23234	1.42239	0.08727	0.8844	2.37128	0.10527	0.01872	0.83975	0.11359	55.9488	2.1467	0.50276	1.06476	18.6084	5.27054
DK	0.0689	14.8509	0.55272	1.74789	1.328	1.36913	4.22043	4.52149	3.87271	5.83779	3.51718	1.2181	2.15141	0.77073	9.68609	0.74968	4.47151	3.58439
BP	0.20137	1.75373	0.97533	1.81776	2.97534	0.15923	0.17368	3.61582	0.42093	1.02088	2.41025	0.05439	10.2946	0.79882	1.05698	0.72649	4.0573	1.91252
RY	1.95425	14.5585	8.80079	1.13247	1.26333	0.36442	2.41617	1.02772	0.65388	0.84644	2.12378	0.7191	10.6793	2.96217	5.10275	0.46649	1.78713	3.34463
AM	3.38016	11.7079	6.53173	0.33066	0.51508	0.30614	3.8732	1.31612	1.63508	0.50144	3.81712	0.65705	12.2875	1.00657	6.50143	2.73821	1.77443	3.46352

	/bit/	/about/	/book/	/boot/	/father/	/but/	/bet/	/beet/	/bat/	/boat/	/hey/	/eye/	/eye2/	/ow/	/ow2/	/toy/	/toy2/	Average
	1.01603	8.27238	3.0506	1.20998	1.28283	0.40572	2.86418	2.58237	1.58558	1.74247	2.15457	0.50039	26.9318	1.3346	4.61466	1.04467	5.38005	3.88076

English Weak French

French Natives Mahalanobis Distance of French Vowels

Simultaneous Bilinguals

	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
NS	0.70486	3.60673	0.99086	3.91936	2.29389	0.86631	1.23276	2.03706	4.07707	8.28278	2.25728	52.4466	1.49811	4.26114	0.06298	5.63625	2.32461	1.13779	1.60841	1.441	5.03429
EL	0.57253	7.68042	3.76653	5.1513	2.59412	3.21814	5.4588	2.16963	2.61205	1.0955	6.19042	14.3865	8.92621	1.01641	0.22929	67.2784	3.41818	0.1496	1.9329	9.47927	7.36631
SB	12.2678	9.68137	5.12027	13.5135	3.81718	4.73476	5.65289	1.65248	18.1764	3.3507	3.22574	15.96	15.1088	10.3093	1.13497	17.5143	2.57744	12.2211	0.88072	0.55882	7.87293
KH	5.15139	3.10319	16.9385	6.5435	1.38851	8.37701	1.34806	0.13922	0.75184	16.1613	5.00667	6.32375	3.06065	3.64566	0.08501	4.29083	1.83963	2.51321	1.79066	0.76657	4.46126
KP	0.96062	5.42441	2.892	17.9776	0.43331	0.50504	0.30221	2.08274	3.93176	0.40654	2.86684	6.59765	0.00554	0.34901	1.45959	13.8008	1.94186	0.08978	3.26889	6.4947	3.58955
JW	8.69742	1.28125	6.94193	15.1641	8.58628	9.38103	6.37363	1.06474	8.8345	3.11441	0.50555	5.03626	47.4066	1.73086	0.80305	8.32162	2.84814	3.24912	1.0355	1.36205	7.0869
ST	0.23238	2.05127	8.81139	4.89195	5.16903	2.38194	0.59508	0.37647	6.09851	3.60734	9.94009	5.8869	3.67564	3.67553	0.55157	3.28489	1.96289	0.78457	0.31606	2.11471	3.32041
SONA8	4.5193	3.75815	151.637	10.1698	6.62367	11.6787	4.11501	9.79498	15.7268	22.7099	2.48205	152.774	8.98373	4.42318	1.42604	8.54596	1.64291	2.06179	1.03805	1.11913	21.2615
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	
MEAN	4.13829	4.57335	24.6373	9.6664	3.86325	5.14287	3.13481	2.41467	7.52612	7.34107	4.05933	32.4265	11.0832	3.67639	1.9344	1.96399	2.80327	5.81098	4.98949	6.45447	7.49915

Simultaneous Bilinguals

French Strong English

	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
CLP	2.22849	5.1904	32.5131	0.44955	7.39618	51.9855	0.0339	0.178	3.18732	1.17752	2.44266	7.45102	5.7556	35.464	7.27926	2.461293	0.14938	2.16355	2.05203	7.72952	8.86441
AF	5.5431	4.1023	0.139	5.60587	0.40572	6.53131	3.30608	2.32068	1.70302	4.33947	0.47187	5.0352	1.65753	3.66378	4.41025	0	7.41469	9.51771	4.41614	0.78205	3.56829
FM	3.81061	0.5702	2.19835	8.98717	2.41555	9.88226	3.84769	8.81239	7.05288	6.86728	5.72254	4.74699	0.63926	2.83011	2.15469	0	2.44543	1.42423	1.69045	8.52259	4.23103
VH	1.57345	3.08163	5.41068	1.81361	3.99342	3.4303	3.18109	8.99677	0.50749	7.44936	0.59835	1.44104	2.0126	4.49985	0.48028	5.797919	0.78852	0.92533	1.69525	1.31183	2.94944
MC	3.44435	6.43947	10.732	0.69182	2.06624	4.37764	4.32826	3.23124	5.42189	6.68141	2.05871	7.09542	0.06092	3.15281	5.96085	0	2.42314	6.60497	2.19602	8.8547	4.29109
SA	7.06327	1.92004	11.3357	0.26851	3.94563	0.71509	1.38272	0.57181	0.49022	35.8159	0.74364	0.45387	1.44725	1.74849	0.70806	0	5.94939	5.10193	5.02629	5.76184	4.52249
JD	0.98318	3.36833	2.36092	5.02798	1.15259	10.9242	0.4711	0.00659	0.00575	5.24302	1.87853	1.07662	1.38774	5.54783	0.28328	0.91782	0.33612	2.82331	0.30522	13.4253	2.87627
PP	19.5369	8.19006	6.11502	5.26701	7.34458	13.1667	3.0024	6.99642	15.4985	25.9284	22.5349	0.25159	4.4305	12.661	0.62225	3.787048	0.85683	0.28423	0.14821	11.117	8.38697
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
	5.52292	4.1078	8.8506	3.51394	3.58999	12.6266	2.44416	3.88924	4.23338	11.6878	4.5564	3.44397	2.17393	8.69597	2.73737	3.24102	2.54544	3.60566	2.1912	7.18811	4.96125

French Strong English

French Medium English

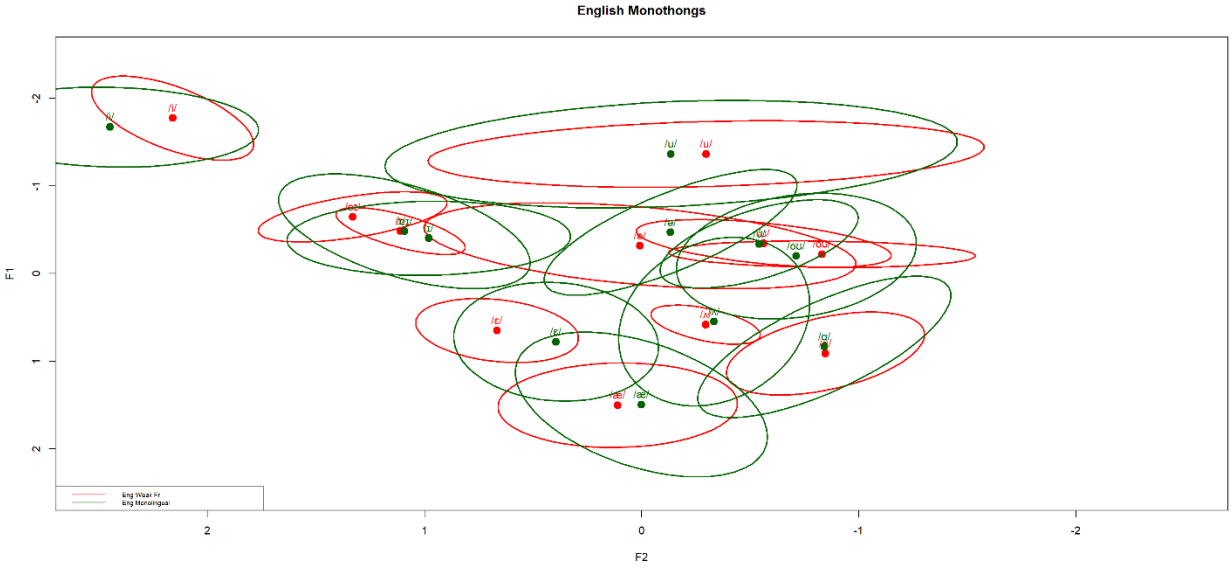
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
JT	0.9399	7.32633	0.47481	1.4609	1.6625	3.43639	2.0678	0.76048	10.9281	2.29698	2.38298	3.2038	9.43233	2.9214	5.19343	0.864059	0.89898	1.07095	0.5161	1.30016	2.95692
YB	1.24044	1.90144	7.52873	2.20338	0.03997	2.76362	8.59224	4.25764	8.33392	0.81856	1.47178	1.90727	4.41295	1.22313	3.65321	0	5.63243	4.40191	2.72692	7.36603	3.52378
DM	2.10953	2.46282	2.338	14.761	0.43389	9.80936	0.83871	0.08097	0.69763	25.744	3.3258	6.94114	1.16725	0.15825	0.30853	0.000717	3.95777	1.82109	1.99491	5.07354	4.20125
MD	0.49577	1.91552	3.36015	5.69921	0.18957	0.41068	1.3269	0.75971	4.32019	4.68108	11.3899	5.45556	1.36525	3.97884	0.33623	7.563675	5.62231	3.7142	0.53692	0.88191	3.20018
MK	4.02959	6.01758	180.005	7.41488	5.67237	17.3262	10.0634	45.3208	0.99154	6.78677	11.3853	2.04347	14.9118	17.0588	2.39604	3.862506	31.5764	0.60956	1.26934	17.6564	19.3199
GG	3.09209	6.55978	6.90411	2.292	10.719	0.4268	1.26143	0.65341	5.02636	7.05641	0.93148	0.36086	4.89702	1.31156	2.11093	0.236896	2.33502	5.05132	4.01173	0.15115	3.26946
BT	0.66082	2.37529	3.40532	1.75446	6.91777	2.00603	3.08498	2.67208	2.22506	22.2506	1.61648	1.5221	0.47839	6.41121	1.82453	0.692931	3.76232	3.03452	2.33683	14.5615	4.17966
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
	1.79545	4.07982	29.1451	5.08369	3.66215	5.16844	3.89078	7.78644	4.64611	9.94777	4.6434	3.06203	5.23785	4.72332	2.26042	2.203464	7.6836	2.81479	1.91325	6.71296	5.8073

French Medium English

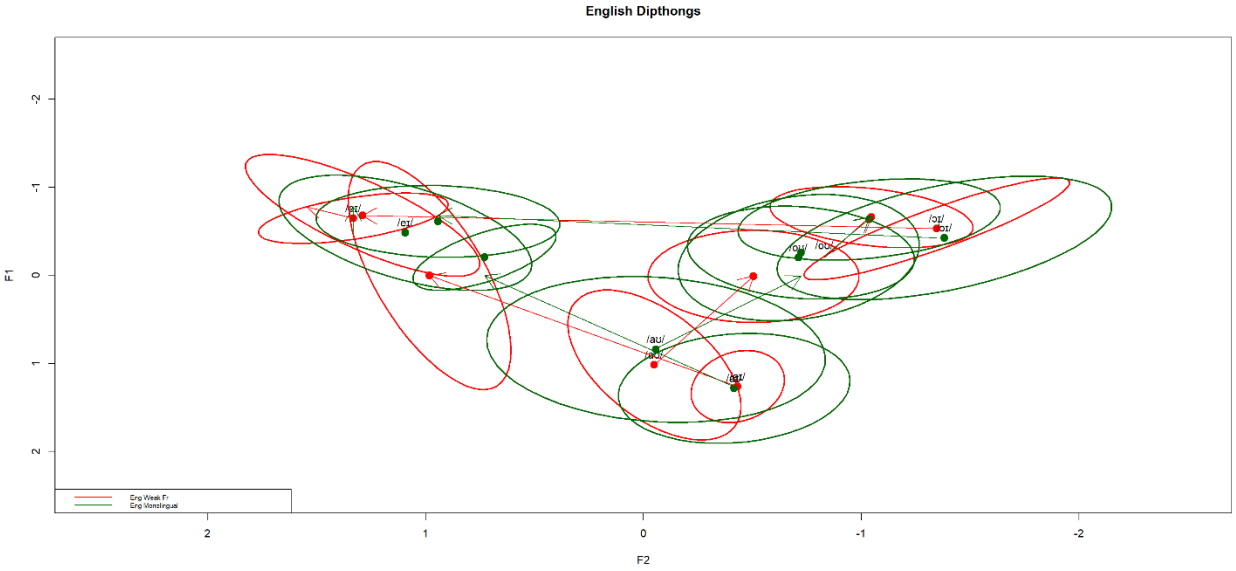
French Weak English																					
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
MT	3.29942	0.36855	5.23673	1.55177	4.13062	0.11867	5.10181	0.02211	1.71072	0.5932	2.19016	2.40722	0.73529	0.26393	2.63421	0.059541	2.28074	2.23877	1.74636	3.3285	2.00092
LD	0.86006	1.62279	0.63665	1.72321	0.99716	0.36386	0.0082	1.58407	0.50076	1.26206	2.58837	3.09133	3.38603	1.15086	0.48306	2.936611	0.96206	0.11437	3.89194	1.11609	1.46398
CC	1.74263	3.11128	3.86685	2.84498	1.23532	2.97378	0.67194	5.43665	2.85391	5.04989	0.89397	2.33001	3.43733	5.94477	1.42018	2.609353	1.42387	0.0659	2.38928	0.44592	2.53739
IA	1.92514	1.71248	0.88511	0.62454	1.80351	4.349	2.35621	1.81605	0.16434	1.10116	0.11674	0.22925	1.05224	0.28954	2.95086	2.242108	1.00699	0.95824	1.06316	0.15125	1.3399
AN	2.02111	0.80836	4.45313	0.24329	2.52186	1.48638	7.74682	3.69058	2.64305	2.45016	1.68723	1.16301	1.38751	2.6598	0.77363	2.251615	4.14525	0.50964	2.69598	2.26471	2.38015
DL	2.39129	0.1968	0.17835	1.18826	0.26436	1.10211	0.19967	3.27682	0.44479	1.56881	1.74628	2.88884	0.96108	0.24629	0.19283	1.36985	2.80369	0.61969	0.77185	1.22772	1.18197
	/pot/	/peu/	/pou/	/fée/	/pas/	/pue/	/pis/	/peur/	/sa/	/bouche/	/pipe/	/puce/	/paix/	/porc/	/tete/	/tete2/	/bon/	/banc/	/bain/	/un/	Average
	2.03994	1.30338	2.5428	1.36267	1.82547	1.7323	2.68078	2.63771	1.38626	2.00421	1.53712	2.01828	1.82658	1.7592	1.40913	1.911513	2.10377	0.7511	2.0931	1.42237	1.81738

Annex D: L1 plots

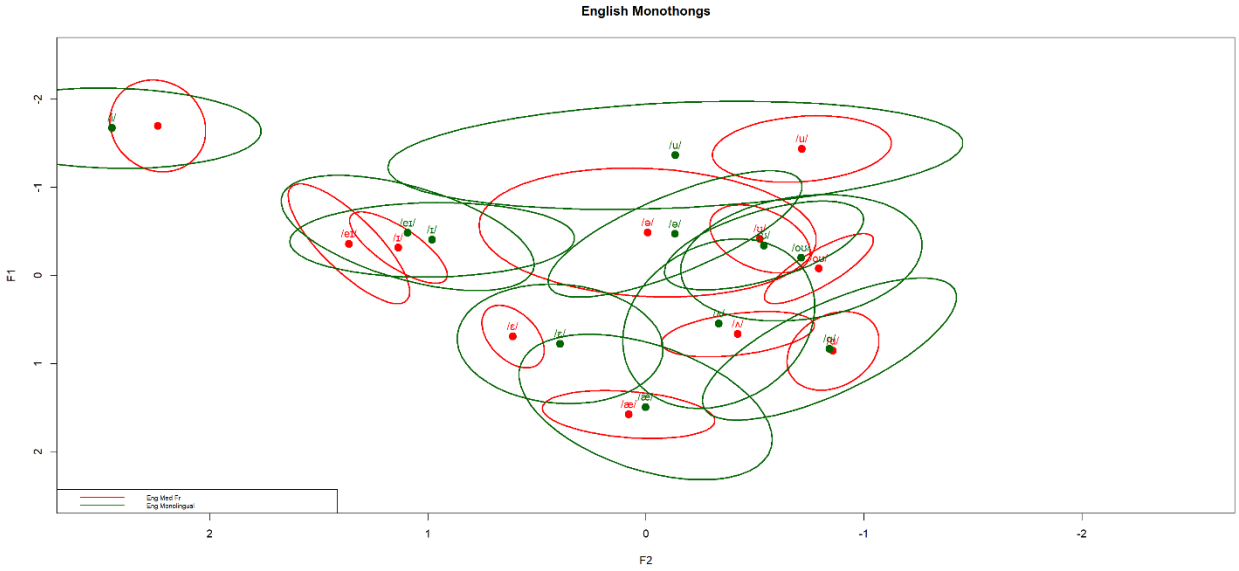
English Weak French vs English Monolinguals



Diphthongs



English Med French vs English Monolinguals



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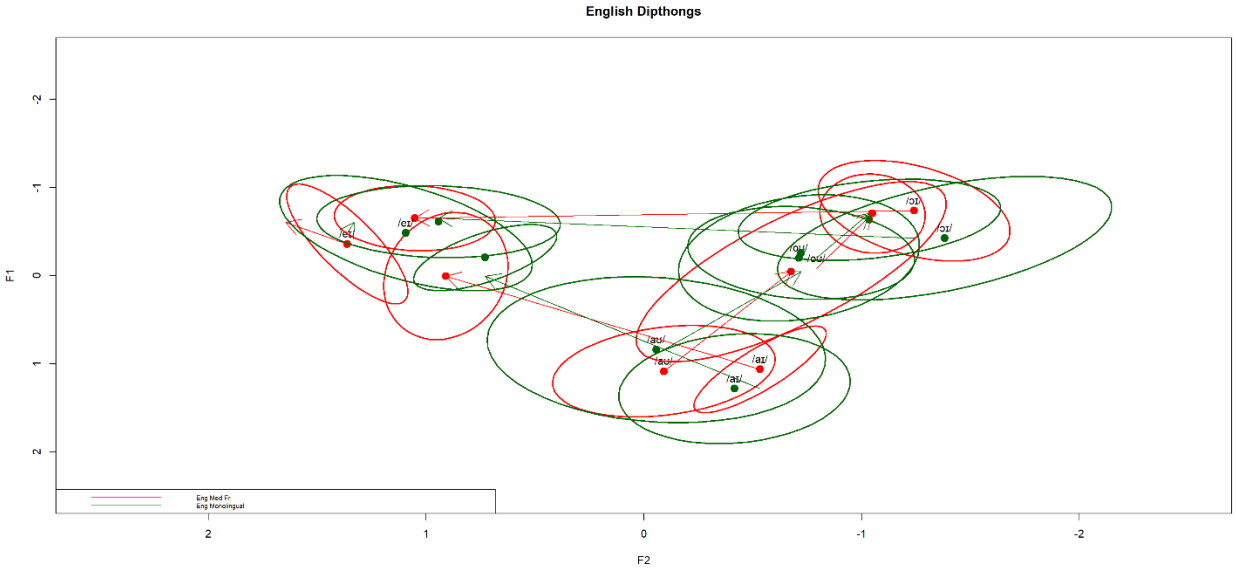
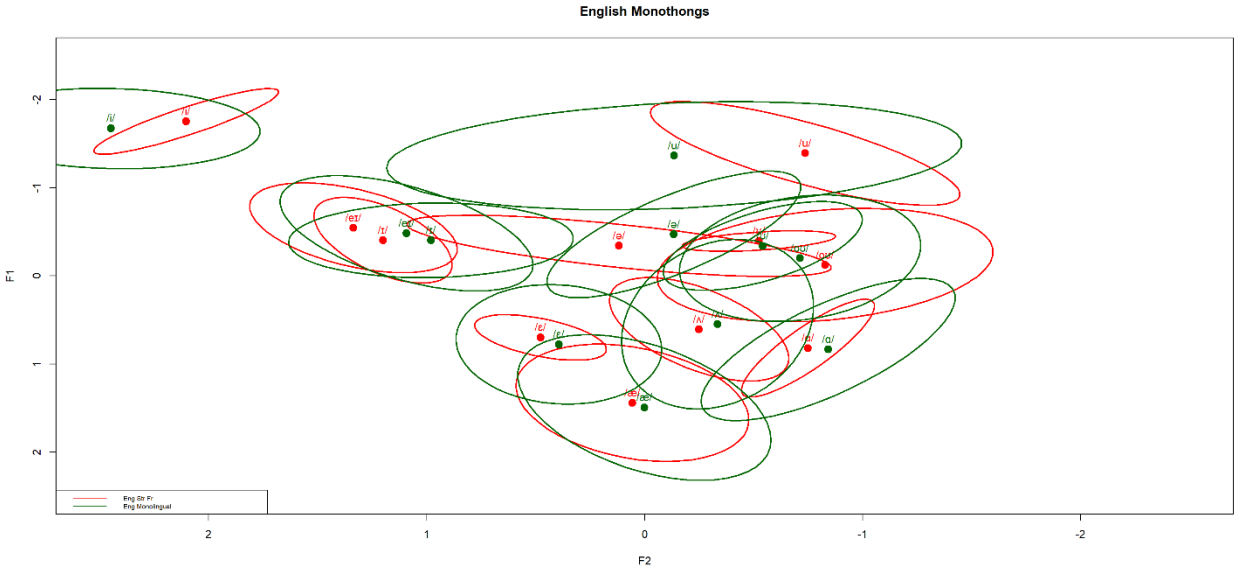
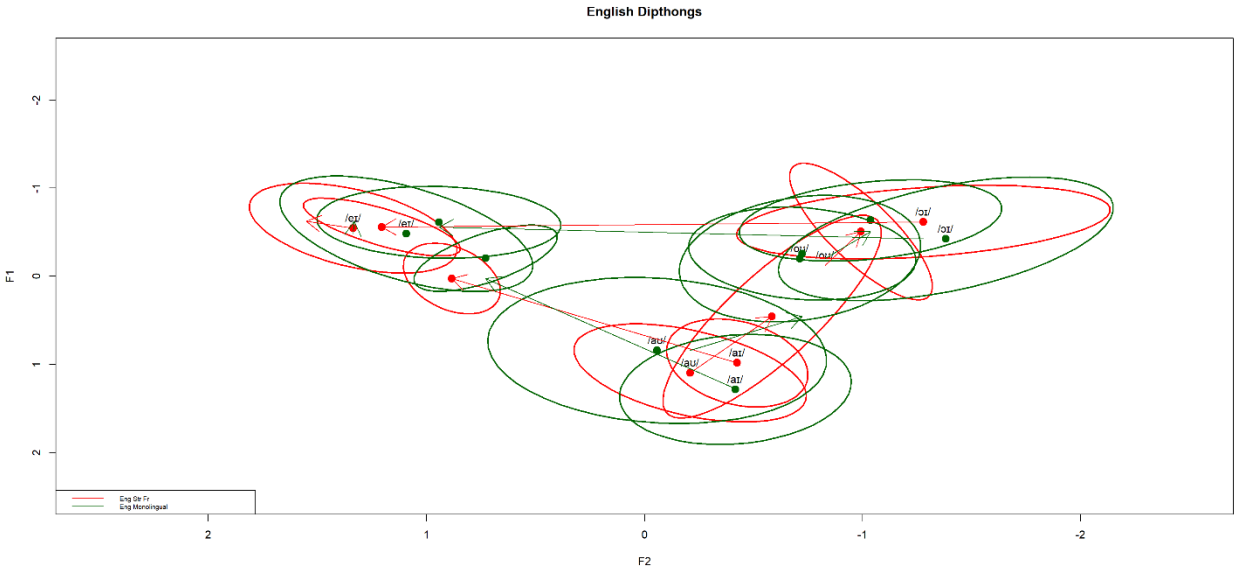


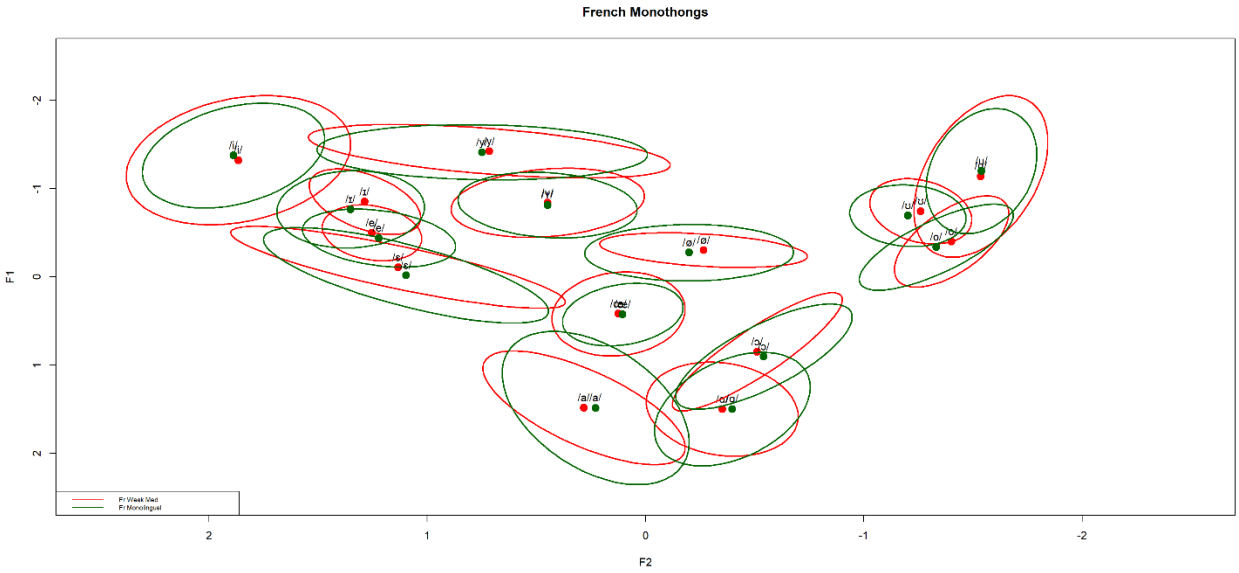
English Strong French vs English Monolinguals



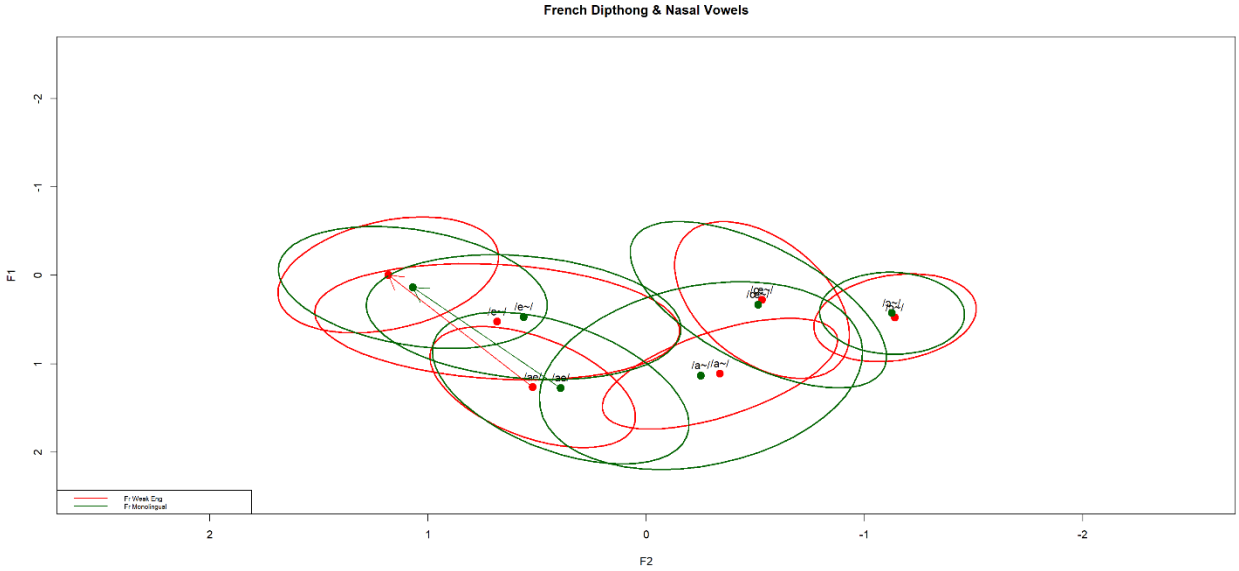
Diphthong



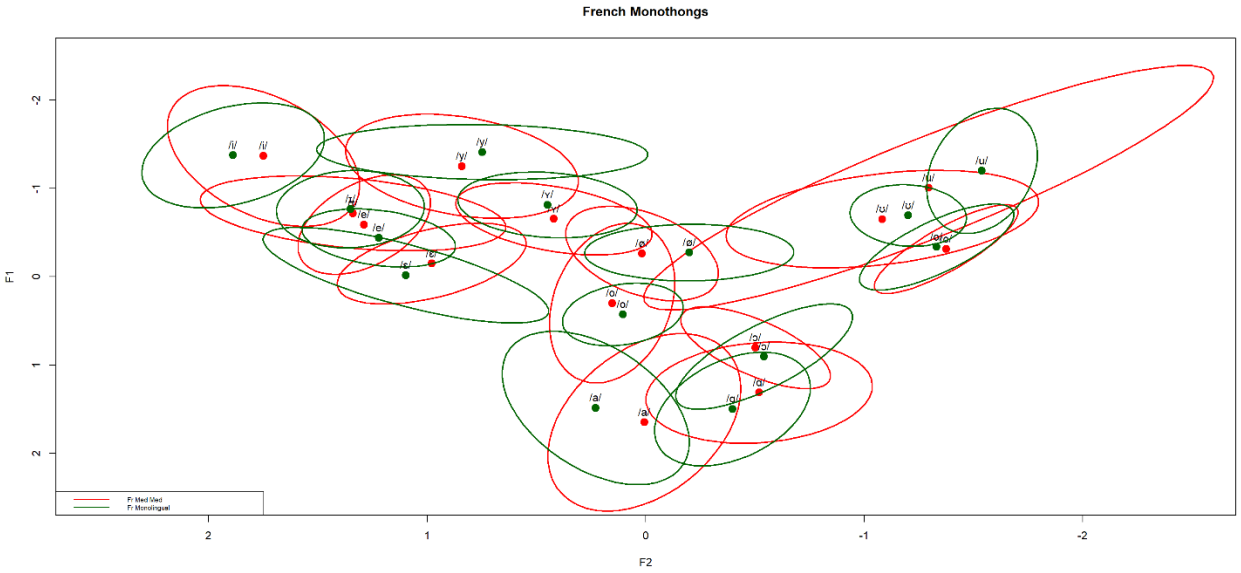
French weak English vs French Monolingual



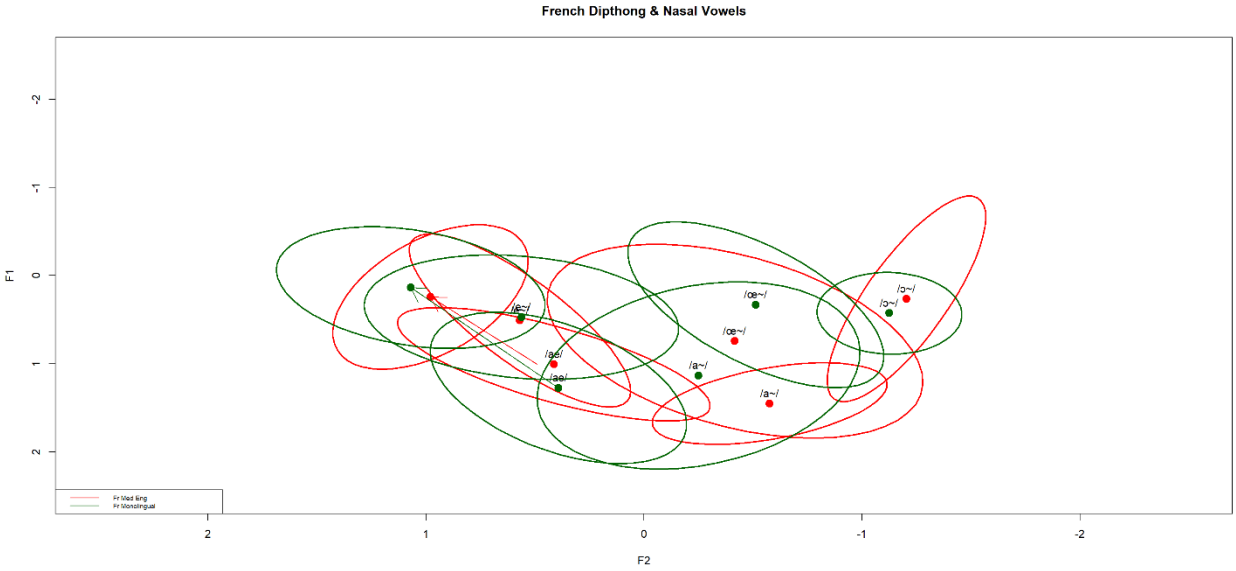
Nasal Vowels & Diphthongs



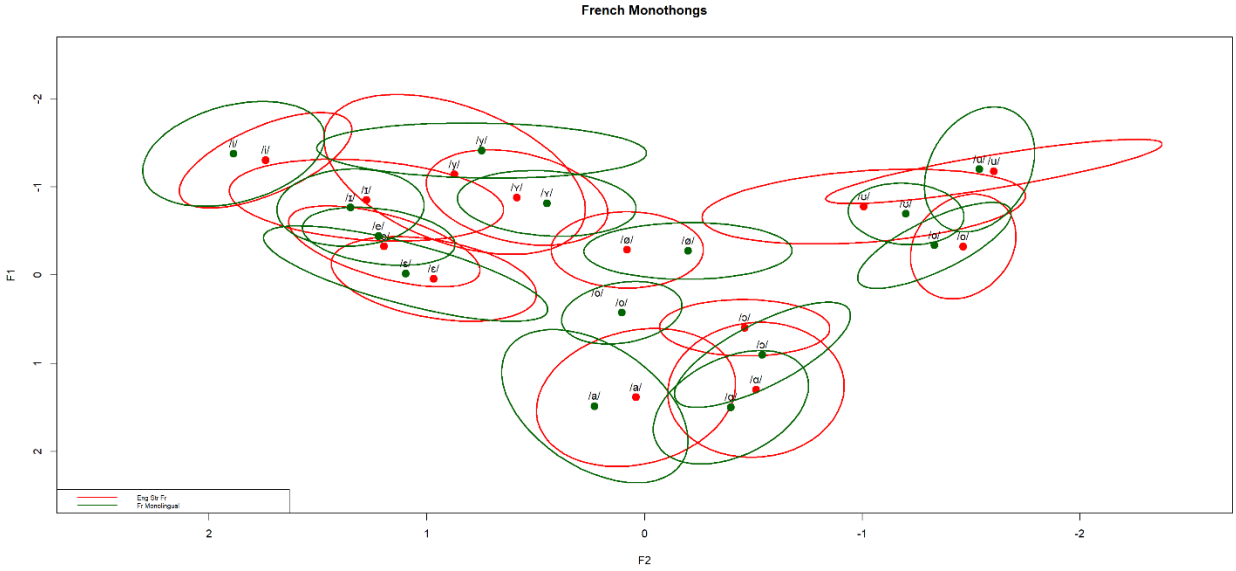
French Med English vs French Monolinguals



Nasal Vowels & Diphthongs



French Strong English vs French Monolinguals



Nasals Vowels & Diphthongs