

**Perception of L3 French vowel contrasts by L1 Mandarin-L2 English
learners: a contrastive hierarchy perspective**

by

Junyu, Wu

B.A., Dalarna University, Sweden, 2014

M.A., Stockholm University, Sweden, 2017

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Supervisory Committee

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Abstract

This study looks at the L2 and L3 perception of Quebec French (QF) tense and lax vowels [y, ʏ] and /e, ε/ and rounded vowels /y-u/ and /œ-ɔ/. Inspired by the Linguistic proximity model (LPM) (Westergaard, 2021), I predict that the trilingual participants will outperform the bilingual participants as the trilingual can transfer phonological features from both the L1 and the L2 to acquire L3 contrasts.

The contrastive hierarchy theory, a representational and learning model proposed by Dresher (2009) is adopted to explain the sources of potential transfer in phonological acquisition. According to Dresher, phoneme inventories are best understood in relation to contrastive feature specifications, assigned in language-specific hierarchies. In a language-specific hierarchy, features are assigned to divide the inventory into smaller binary subsets until each phoneme is uniquely specified. The selection of the features is determined by examining the phonological processes in a given language (Dresher, 2009).

The present study provides a comparison of the perceptual performance of four groups: (1) L1 Mandarin; L2 English; L3 QF (n=22), (2) L1 English; L2 QF (n=20) and (3) QF natives (NS) (n=20), (4) naïve learners (n=20). Two learner groups are at the upper-intermediate level of QF proficiency that was measured by self-rated background questionnaire (based on instructional hours and course level). The Mandarin speakers' L2 English proficiency level was measured by IELTS (average 7.0). An ABX discrimination task (with 1500msISI) was conducted by embedding [y, ʏ] and /e, ε/ and /y-u/ and /œ-ɔ/ in CVC syllables ([bVb], [dVt], [sVz]) in a total of 120 trials.

The primary findings of the study demonstrate that 1) The L3 QF learners are able to transfer [±front] > [±round] from L1 Mandarin and [±tense] from L2 English to successfully parse L3 QF tense and lax vowels [y, ʏ] and /e, ε/. 2) The L3 QF learners, transferring [±front] > [±round] from L1 Mandarin, are able to successfully parse /y-u/ and /œ-ɔ/. 3) Lack of [±round] in the English hierarchy and the transfer of L1 phonetic roundedness cue make the L2 QF learners misparse the rounded vowels and tense and lax vowels [y, ʏ]. 4) The contrastive hierarchy theory is able to predict the ease and difficulty of acquiring these contrasts based on different types of restructuring actions. 5) The present

findings are in support of the LPM (Westergaard, 2021) and the Scalpel model (Slabakova, 2017) and reinforce the importance of developing a model in L3 phonology that takes contrastive hierarchy theory and restructuring principles into consideration.

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Dedication

I am forever grateful to my family for their unconditional support and love throughout my journey of this dissertation. This dissertation is dedicated to my beloved partner, Yi Yan. I am almost halfway through my life. I truly believe that one of the most joyful moments in my life was meeting my partner in Sweden. He has provided me with warmth and care, as well as guidance and support, shaping me into the person I am today. Since my undergraduate days at a small university, every step I've taken has been guided and planned by him. He literally changed my life.

CHAPTER ONE: INTRODUCTION

In recent years, theoretical approaches to third language acquisition have received increasing attention, with numerous studies investigating a variety of language phenomena (Flynn, Foley & Vinnitskaya, 2004; Rothman & Cabrelli Amaro, 2010; Rothman, 2011, 2015; Slabakova & Garcia Mayo, 2015; Westergaard, 2021). Unlike L2 acquisition, in L3 acquisition, there are two previous language sources, and therefore numerous scholars look into the key questions of whether both previously learned languages affect L3A, or whether one of the languages is selected as the primary source of transfer (Cabrelli Amaro & Rothman, 2010; De Angelis, 2007; Flynn et al. 2004; Rothman, 2011, 2015; Westergaard, 2021).

To address the key questions, there is a set of studies that provides a theoretical foundation for the field of L3 acquisition: Several models have been established, such as the Typological Primacy Model (TPM) (Rothman, 2011, 2015) and the Linguistic Proximity Model (LPM) (Westergaard, Mitrofanova, Mykhaylyk and Rodina, 2017; Westergaard, 2021). The Typological Primacy Model proposes that typological similarity serves as the trigger for the transfer of either the L1 or L2 into the L3 at the L3 initial stages. It proposes the idea of copying the entire grammar in the initial stages of L3A from L1 or L2 (Schwartz & Sprouse, 2021a; 2021b). Determining typological similarity is based on four factors: lexicon: phonology/phonotactics, functional morphology, and syntax. Rothman (2011) suggests that the Typological Primacy Model focusses on the wholesale transfer of abstract I-language (See section 2.3). If the L1 is more similar to the L3, then the L1 will be directly copied. If the L2 is determined to be more similar, then the L2 will be copied. On the other hand, the Linguistic Proximity Model proposes *selective* transfer¹ determined by abstract linguistic structure based on structural similarity (See section 2.3), with a focus on the selection of the parts of I-language grammars of either or both

¹ The selective transfer was first proposed by Flynn, Foley, and Vinnitskaya (2004) for the Cumulative Enhancement Model, but the difference between the LPM and the CEM is that the CEM only supports facilitative transfer. More details will be given in a background chapter (chapter 2).

previously acquired languages. Exposed to L3 input, learners are able to parse the incoming signal to construct a new L3 grammar by choosing the abstract I-language grammar of the previously acquired languages (no order of precedence). The present study is inspired by the LPM. More details will be given in the later sections in this chapter.

1.1 Terminological Notes

To facilitate the reader's understanding of several terms and concepts used in this thesis, relevant terminological clarifications are given below.

1.1.1 L3 Acquisition

The term 'L3' used in this dissertation refers to the second foreign language in monolingually-raised speakers: L1 is a speaker's first language; L2 is the second; L3 is the third. Here, it is important to make a distinction between second and foreign languages: in a second-language situation, the language is spoken mostly in natural communication environment in which learners have good opportunities to use the language, while in a foreign-language learning situation, the language is not spoken in natural communication situation, which means that the learners do not use the language often in daily communication (Ringbom, 1980). Both SL (Second Language) and FL (Foreign Language) count as an L2 for the purposes of defining L3. In China, Chinese students learn English as a foreign language: a Chinese student who was born and grew up in China where Mandarin was the only language widely spoken, and then the student took English in an instructional context at primary school (English is taught mostly in Mandarin in China). After that, the student took French as another foreign language. This is the 'L3' mentioned in the present study.

1.1.2 Grammar

To understand how learners acquire phonological properties, it is important to investigate learners' grammar of a particular language. First, we need to define grammar. It is important to note that the meaning of grammar mentioned here is different from its conventional meaning which is often the sentence structure. A grammar, according to

White (2003a), is an abstract and unconscious system of knowledge, which helps speakers to understand and produce language. One example to illustrate this could be syllabic structures. A word, such as ‘cat’, is represented and analyzed by a monosyllabic structure that contains an onset made by a consonant and a rhyme involving a nucleus (a vowel) and a coda filled by a consonant. When learners are exposed to the word ‘cat’, this word is analyzed by the abstract representations in speaker’s grammar. In this case, a monosyllabic structure is assigned to analyze the word ‘cat’/kæt/: ‘k’ is analyzed as a consonant and an onset, following a vowel ‘æ’, which is the nucleus, and finally the consonant ‘t’ the coda (See section 1.2).

1.1.3 Linguistic Competence and Performance

Many theoretical models of L3 acquisition, such as TPM or LPM, are built to explain the transfer of abstract I-language grammar. I-language grammar is considered as competence rather than performance. Here, we make a fundamental distinction between competence (I-language) and performance (E-language) to facilitate the reader’s understanding of some theories mentioned later: competence is the speaker-hearer’s linguistic knowledge of the grammar; performance is the actual use of language in concrete situations (Chomsky, 1965).

1.1.4 Transfer and Crosslinguistic Influence

The terms ‘transfer’ and ‘crosslinguistic influence’ have been variously defined over the decades. Schwartz & Sprouse (2021a; 2021b) use the term ‘transfer’ to refer to the copy of the L1 grammar that explains the initial state of the subsequent grammar. The initial state of acquisition, according to Rothman & Cabrelli Amaro (2010), is the onset of language learning after a minimum of 20 hours and a maximum of 30 hours of formal instruction. Crosslinguistic influence (CLI) is first defined as the interaction between earlier and later acquired languages in second language acquisition (Sharwood Smith, 1983; Deng, 2022). Rothman, Alonso & Puig-Mayenco (2019) restrict the use of the term ‘transfer’ to refer to representational changes at the level of linguistic competence from the L1 or the L2 in the L3, rather than linguistic performance, while CLI is limited to performance-based

interlingual influence (the actual use of language, such as political speech) that the L1 or the L2 may have on the L3 (Rothman et al, 2019). However, Westergaard (2021) proposed that “crosslinguistic influence is co-activation of structures in the mind/brain” (p. 505). Co-activation here simply means that both L1 and L2 grammar remain active to be selected for analyzing L3 structures. When L3 structures are processed, this will result in parallel activation of a number of candidate structures stored as part of the grammars of the previously acquired languages. Any grammatical structures can be selected based on the comparison of the structural similarity between L1 and L2 grammar. The structural similarity between two languages, such as a verb-object order in English and Mandarin, is what Westergaard (2017) called *linguistic proximity*. In this thesis, I have chosen to use the term ‘CLI’ for competence issues when presenting my own analyses. The term ‘transfer’ is nonetheless used when referring to the work of others who have used this term to refer to competence.

1.2 Motivation of the Thesis

As mentioned previously, with more than half the world’s population growing up multilingually, we are still uncertain about how two previously acquired languages will affect the acquisition of further languages in adults, especially in L3 phonology. Many existing models in L3 acquisition, such as the linguistic proximity model (LPM), the typological primacy model (TPM), the cumulative enhancement model (CEM) (Flynn et al, 2004), the scalpel model (Slabakova, 2017), and the L2 status factor model (Bardel & Falk, 2012, 2021) (see section 2.5), have been specifically employed to explore language phenomena in L3 largely in syntax and phonetics (Cabrelli Amaro & Rothman, 2010; Rothman, 2011, 2015; Westergaard, 2021; Zhu & Mok, 2022).

However, models in L3 phonology are somewhat understudied. In this thesis, the phonology model I adopt is contrastive hierarchy theory, a representational model proposed by Dresher (2009) (see section 2.3), which has been used in L1 and L2 acquisition (Bohn & Santos, 2018; Archibald, 2022). The contrastive hierarchy theory can elucidate how learners (L1 or L2 learners) develop their phonological system (Archibald, 2022; Bohn & Santos, 2018; Cowper & Hall, 2022; Kwon, 2021; Jakobson, 1941). I will argue

that this model allows us to measure linguistic proximity between two languages. More details about contrastive hierarchy theory will be given in Chapter 2. Using the contrastive hierarchy theory (Dresher, 2009) as a representational model, this thesis aims to contribute to our understanding of the roles the L1 and L2 play in acquiring L3 target sound and explain how L3 representations are influenced by L1 and L2 representations.

More importantly, the present study contributes to our understanding of the nature of L3 phonology. As mentioned in 1.1.4, crosslinguistic influence takes place at an abstract level, which means the level of linguistic competence. When testing existing models in L3, it is important to consider how to measure linguistic proximity representationally between two languages. In L3 phonology, there are two key questions that have been rarely addressed. The first question is how to measure the distance between two phonemic inventories. The second question is what are the processes of L3 acquisition? To discuss why those two empirical questions are foremost, we need to first address the distinction between phonetics and phonology.

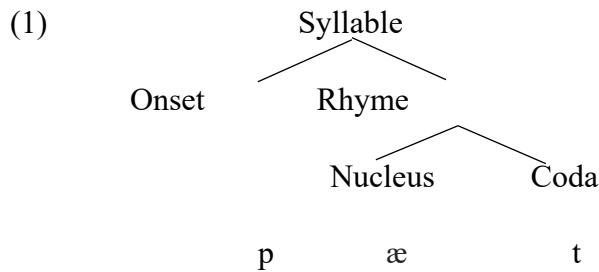
Regarding the difference between phonetic and phonology, phonetics concerns the study of speech sounds physically (acoustic or articulatory). Some phonetic features are voice onset time, duration, or formant frequencies of vowels. On the other hand, phonology is cognition not physics, and it deals with the system (grammar and structures) that provides the representation of the primary linguistic data that learners are exposed to (Archibald, 2022; Burton-Roberts, 2000; Hale & Reiss, 2000). According to Kaye (1989), “phonological segments are cognitive, a product of mind, rather than physical (acoustic or articulatory)” (Kaye, 1989. p. 19).

But what does this system look like? Here, the phonological feature comes to play a role, which helps learners identify and categorize segments in a given language. For example, phonological features, such as $[\pm\text{tense}]$, are the most basic units of phonology and the basic building blocks of speech sounds. $[\pm\text{tense}]$ is used to specify the phonemic contrasts in a given language, such as English tense and lax vowels (e.g., i $[+\text{tense}]$, ɪ $[-\text{tense}]$), so with $[\pm\text{tense}]$ in learners’ system, they are able to represent tense and lax vowels and to make a distinction between them. Referring back to the first question ‘how to measure the distance between two phonemic inventories?’, we need to compare the

abstract I-language representation of them. Contrastive hierarchy theory enables us to compare two or three systems (see section 2.3), so this can help address some classic learnability issues. For instance, when comparing two grammars, which grammar can be better used to explain the data (Archibald, 2022; Drescher, 1999; Grimshaw & Pinker, 1989). Overall, linguistic proximity can be determined in contrastive hierarchy theory.

So, why do we need to explore the mechanisms of L3 acquisition? To discuss this question, it is crucial to know how phonological representations are acquired. Let me step back to give a brief description of how syntactic representations are acquired. Fodor (1978) and Kaye (1989) use the term ‘parsing’ to describe the process of analyzing a syntactic representation. For example, a syntactic parser takes a string, such as a sentence in a language, and then analyzes its syntactic structure as an output. An example given by Kaye (1989) is *I adore stewed prunes*. When a parser is fed this sentence, it will analyze *I* as a noun phrase and then assign it the subject of the sentence, *adore stewed prunes* is a verb phrase including the main verb *adore* and its direct object *stewed prunes*. The parser² assigns structure to the syntactic string. Similarly, phonological parsing requires a physical signal as input, and then assigns a structure to the string. Let’s take a look at an example from phonology to illustrate this point. Phonological segments are combined in constituents called syllables. A syllabic parser assigns segments to the onset, nucleus, and coda. As Brunson (1989) mentioned, “syllable parsing involves the assignment of syllable structure to a sequence of segments” (p.4). This follows left to right processing of the input sequence (Brunson,1989). For instance, the internal structure of a monosyllabic string contains an onset made up by a consonant and a rhyme; the rhyme contains a nucleus, which is a vowel, and a coda filled with a consonant (Brunson, 1989). When this parser is fed a word ‘pat’, it will assign the structure of a monosyllabic string to the word, so it will analyze ‘p’ as a consonant and assign it to the onset, in the rhyme, it will assign the vowel ‘a’ to the nucleus and the consonant ‘t’ to the coda. This is how a phonological parser analyzes and represents a word.

² Bear in mind that in adults learning, this parsing procedure can be different and complex from first language acquisition as described above because adults have more than one grammar in their system, their parsing procedure might be influenced and interfered by their previously acquired languages. More details of adults’ parsing procedure will be given when describing the L3 models.



In L3 acquisition, learners know more than one language. This raises more questions that remain unanswered. A learner hears L3 input and has to discover (a) how to parse it, and (b) how to represent it. However, which structure provides the best representation for the L3 input string (Archibald, 2022)? When their grammar cannot represent an L3 input string, the grammar must change. How do they change their grammar? These are the basic L3 learnability issues that need to be addressed. Referring back to the second question ‘what are the processes of L3 acquisition?’, contrastive hierarchy theory, a representational model³ of the phonemic system can help us gain insight into the acquisition process to explore how learners organize their systems to parse and represent a new speech sound. This has never been investigated in L3 acquisition.

1.2.1. My Study and Hypotheses

The investigation into L3 acquisition in the phonological domain is sparse (Cabrelli & Wrembel, 2016). Several studies have claimed to investigate L3 phonology, but it seems that they focus predominantly on phonetic properties, such as voice onset time, duration, and formant frequencies of vowels (Gabriel, Krause & Dittmers, 2018; Llama & Lopez-Morelos, 2020; Tremblay, 2007).

However, it is vital to question how learners acquire phonological properties, such as [±front] or [±high]. For example, in the perception of the high, front, rounded vowel [y], English speakers perceive it as [u], but Brazilian Portuguese speakers hear it as [i] (Rochet, 1995). Needless to say, both English and Brazilian Portuguese do not have [y] and both

³ This model is built by the Successive Division Algorithm and the Activity Principle, which will be introduced in Chapter 2.

have [u] and [i], but why do the speakers perceive it differently? The investigation of the phonological parser can elucidate why learners choose different segments to substitute for the target sound, which is the question the present study aims to address by using the contrastive hierarchy theory as a phonological representational model.

In addition, as Archibald (2022) pointed out, numerous previous studies only focus on cross-linguistic segment-to-segment comparisons to predict the ease or difficulty of acquisition (Best, Tyler, Bohn & Munro, 2007; Flege, 1995; Flege & Bohn, 2021). For example, an L1 [i] might be compared to an L2 [ɪ]. This is considered as segment-to-segment comparisons because we only compare two sounds (e.g., [i] in the L1 and [ɪ] in the L2) that are acoustically similar. Flege (1995) makes the assumption that if two sounds are acoustically similar, this will be the most challenging for L2 learners because L2 learners would substitute an L2 [ɪ] with an L1 [i].

In contrast, the investigation of the phonological parser enables us to see inventory effects with respect to segmental behavior. As mentioned in Section 1.2, phonological features that structure the phonemic inventory are the most basic units of phonology, and they determine the segmental behaviour (Archibald, 2022). If we compare phonological features, such as [+tense, +high] versus [-tense, +high] in Quebec French, we will expect to see inventory effects, which means that all the segments specified with [+tense, +high] such as /i, y, u/ would behave differently from [-tense, +high] segments /ɪ, ʏ, ʊ/. To clarify the phrase ‘behaving differently’, let’s see one example, in Quebec French, [+tense, +high] vowels /i, y, u/ would undergo laxing harmony, while [-tense, +high] vowels /ɪ, ʏ, ʊ/ would trigger laxing harmony (Walker, 1984), so [+tense, +high] and [-tense, +high] vowels behave differently with respect to the phonological process, laxing harmony. It is indispensable to study learners’ phonological featural systems, so we will know why they choose different segments to represent the target sound in L3 and why some target sounds are easy or difficult for learners to represent.

In this thesis, I focus on perceptual L3 acquisition and aim to explore the acquisition of new segmental contrasts marked by phonological features that are present in the L1 and the L2. More specifically, the first component of the present study looks at how learners use features in the L1 to represent new segments in the L3. For example, in

Mandarin, [±front] is used to distinguish the front rounded vowel /y/ from the back rounded vowel /u/. In French, [±front] is used to distinguish the high front-back rounded vowels /y-u/, and also the mid front-back rounded vowels /œ-ɔ/ (that do not exist in either L1 Mandarin or L2 English). To parse the French /œ-ɔ/, L1 Mandarin learners need to use [±front]. My first hypothesis is that learners can parse the new segments /œ-ɔ/ because they have the necessary feature in the L1 even though they do not have /œ-ɔ/ contrasts in the L1 or L2.

The second component of the present study looks into how learners use features that are present in both the L1 and L2 to represent L3 target sounds. For instance, Mandarin has a front rounded vowel /y/ which is specified by [+front] and [+round]. English has tense and lax vowels marked by [±tense], such as /i/ [+tense], /ɪ/ [-tense]. Quebec French has [±tense] to distinguish a front rounded vowel /y/ from its lax counterpart [ɻ]: [ɻ] is not found in either Mandarin or English. For an L3 learner to parse [ɻ], the learner needs to select the features [+front] and [+round] from Mandarin and [±tense] from English. My second hypothesis is that learners are able to select features [+front, +round] from L1 and [±tense] from L2 to acquire new segmental contrasts [y, ɻ] in L3 that do not exist in their previously acquired languages. This hypothesis is inspired and developed based on the LPM that the parts of I-language grammar of either or both previously acquired languages are available to be selected for analyzing L3 target sounds.

The present study also predicts that lack of relevant features such as [±front] and [±round] in a learner's previously acquired languages would lead to misperception. For instance, English has no individual vowels that are specified for both [+front] and [+round]. Indeed, Gardner and Roeder (2022) argue that English does not have a contrastive [round] feature at all (see footnote 6). When English speakers parse the target sounds, such as /œ-ɔ/ (mid front vs back rounded vowels), they would misperceive the target sounds due to ambiguous parsing. In addition, the present study argues that some phonetic factors, such as phonetic enhancement should be taken into account to predict errors (more details about phonetic enhancement will be discussed and given in Chapter 2).

The current study focusses on perception, the cognitive operations that transform physical signals (physical properties, e.g., a speech sound) into phonological representations (e.g., phonological features) (Hickok & Poeppel, 2015). It has to be admitted that perception does not always accurately reflect an individual's actual language competence since other factors such as experimental environment could affect perceptual results to some extent. However, compared with perception, production is indeed not a perfect reflection of phonological representation as it can be influenced by multiple factors, such as articulation problems or working memory restrictions. Therefore, it is important to test perception. My general research questions are: how do learners parse and represent the L3 input by using their L1 and L2 featural systems, and what does this parsing procedure look like?

To address these questions, Mandarin (L1), English (L2), and French (L3) offer the possibility of testing my hypotheses as mentioned above. Given the different vowel systems among these three languages, acquisition of French as a third language is likely to offer needed L1-L2-L3 data to test the validity of my proposal that features of Mandarin and features of English will influence L3 French representations. In this thesis, I am particularly interested in the perception of two types of vowel contrasts in L3 French: the tense and lax vowels, [y, ʏ] (members of the same phoneme) and /e, ε,/ (separate phonemes), as well as the front and back rounded vowels, /y-u/ and /œ-ɔ/. Those segments have been selected because they are represented by the features I aim to investigate, which will be introduced in the next section. In general, the goal of this thesis is to examine learners' activation of their L1 and L2 featural systems to acquire L3 target sounds.

Let's begin with a brief description of three vowel systems to facilitate the reader's understanding of the hypotheses to be tested.

1.3 French, English, and Mandarin Vowel Inventories

We begin with a very brief description of vowel inventories in three language systems.

1.3.1 Front Rounded Vowels in Quebec French and Mandarin

In both European and Quebec French,⁴ there are a number of front and back rounded vowels, including the high, front, rounded vowel /y/ in contrast to the high, back, rounded vowel /u/ and the mid, front, rounded vowel /œ/ that contrasts with the mid, back, rounded vowel /ɔ/, as given in the tables below. [±front] is a feature to distinguish front and back rounded vowels in European and Quebec French.

Table 1 *European French Phonemic Vowel System* (Walker, 1984)

		Round	Round
High	i	y	u
High-mid	e	ø	o
		ə	
Lower-mid	ɛ	œ	ɔ
Low		a	ɑ
		a	
	front		back
		central	

Table 2 *Quebec French Phonemic Vowel System* (Walker, 1984)

		Round	Round
High	i	y	u
High-mid	e	ø	o
		ə	
Lower-mid	ɛ	œ	ɔ
Low		a	ɑ
	front	central	back

⁴ Here, I present the vowel phonemes that both varieties share. European French is addressed here because in the study of rounded vowels, participants who speak and learn Quebec or European French are considered as my target participants, but in the study of tense and lax vowels, participants who only speak and learn Quebec French are my target. It is important to understand the differences between Quebec and European French.

Similarly, in Mandarin, there is one front rounded vowel /y/ and one back rounded vowel /u/, as in Table 3. Unlike French, Mandarin only has one rounded vowel contrast /y-u/.

Table 3 *Mandarin Phonemic Vowel System* (Duanmu, 2007)

Front	Central	Back	
i y		u	High
	ə		Mid
	a		Low

However, English⁵ does not have front rounded vowels, such as /y/ and /œ/, as shown in Table 4. There are several back rounded vowels in English, such as /u/, /o/, /ʊ/. The lack of front and back rounded vowels hints that English does not have [±front] specified on rounded vowels.

Table 4 *Canadian English Phonemic Vowel System* (Gardner & Roeder, 2022)

		Front	central	Back
High	Tense	i		u
	Lax	ɪ		ʊ
Mid	Tense	e		o
	Lax	ɛ	ʌ	
Low		æ	a	

⁵ Bear in mind that there are also different varieties of the English language, such as Canadian English and American English. For example, according to Garner and Roeder (2022), a typical contemporary Canadian English system has the low back merger, which means there is no contrast among several low back vowels, such as the vowels in *lot* /lɒt/, *palm* /pɑ:m/, *thought* /θɔ:t/.

1.3.2 The L2 Acquisition of Rounded Vowels in French

Research on the L2 or L3 acquisition of French vowels by Mandarin speakers is somewhat sparse. One relevant study shows that Mandarin speakers do not have problems producing or discriminating /œ/ from /ø/ in French (Wang, Hueber, and Badin, 2014). On the other hand, research on the L2 acquisition of French vowel contrasts widely demonstrates that high /y-u/ and mid /œ-ɔ/ front vs. back rounded vowel contrasts in French are difficult for adult English-speaking learners of French in terms of discrimination (Baker and Smith, 2010; Darcy, Dekydtspotter, Sprouse, Glover, Kaden, McGuire & Scott 2012; Levy and Strange, 2008). Levy (2008; 2009) found that discrimination of /y-u/ remained at low accuracy (66%) for L1 English speakers. Darcy et al (2012) examined L1 English-L2 French learners' categorization in an AXB discrimination task, with the findings that L1 English speakers with French experience still exhibited a high error rate (37%) in the /œ-ɔ/ contrast. More importantly, Levy's studies reveal that English native speakers made two kinds of errors: Naïve learners or beginners made more errors in the perception of /i-y/ (14.5%) than /u-y/ (5%), while upper-intermediate learners mainly perceived /y/ as /u/ with an error rate (25%) without making any errors in the perception of /i-y/. This seems to imply different parsing procedures English speakers go through which will be discussed later in Chapter 3.

In L2 speech perception, it is often suggested (Brown, 1997; 1998) that the L1 acts as a filter to L2 perception, and adults initially learn the L2 through the filter of their first language (L1) phonological system, which frequently results in misperception because of the lack of the critical feature in the L1. To make it simple, the English featural system does not have the feature [±round]⁶ (Gardner & Roeder, 2022; Giegerich, 1992; Hall, 2011). This means that [±front, ±round] combination is missing in English speakers' L1 featural

⁶ The present study adopted Gardner and Roeder's Canadian English vowel hierarchy. Gardner and Roeder (2022) argued that contemporary Canadian English system does not have [±round] because there is no contrast needed to be specified by [±round] in the inventory of Canadian English vowels. We will see the entire Canadian English hierarchy in Chapter 2. Giegerich (1992) pointed out that [±round] functions at the phonemic level to a very limited extent: [±round] is not needed in English. Hall (2011) stated that [±round] can be used to enhance the phonetic specification of a particular phoneme such as a back vowel. According to Gardner and Roeder (2022), [±round] seems likely the lowest-ranked feature in dialects of English in the past, moving back and forth from a contrastive feature to a non-contrastive feature because of the development of the English vowel inventory.

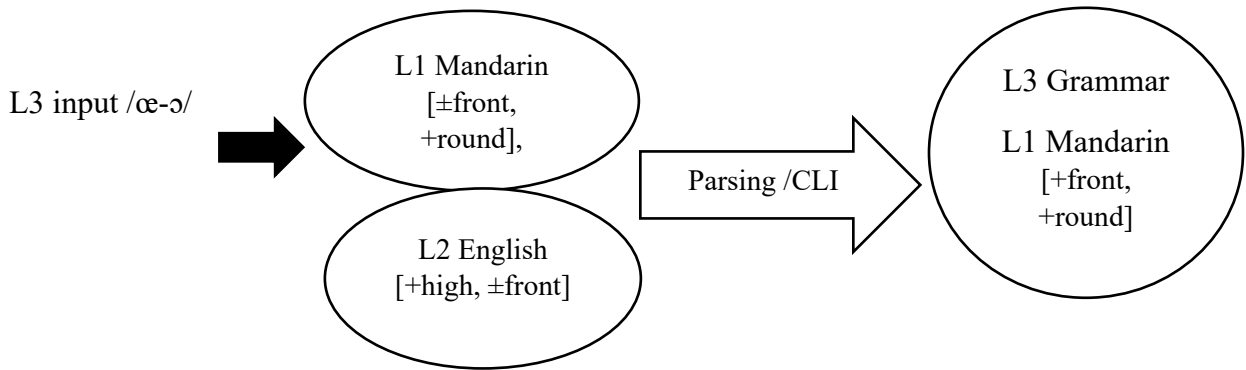
system. The absence of the feature combination [\pm front, \pm round] in English speakers' L1 featural system is the main source of errors in the acquisition of French high and mid rounded vowels⁷ (Darcy et al, 2012). Unlike English speakers, Mandarin speakers have a feature [\pm front, \pm round] to differentiate the front and back rounded vowels /y-u/ in their L1 featural system. This is essential for our present research purposes because it is hypothesized that Mandarin speakers should be able to accurately perceive the new front and back rounded vowel contrast /œ-ɔ/ using L1 features even though the phonemic contrast does not exist in their L1 or L2.

1.3.3 Hypothesis in the Perception of French Rounded Vowels

The study of French rounded vowels explores how the learners will use their L1 featural system (the contrastive feature hierarchy), when they acquire a new segmental contrast that is absent in both the L1 and L2, but the L1 has the *feature* to differentiate the new contrast. To be more specific, although the /œ-ɔ/ contrast is absent in Mandarin, Mandarin does have the features [\pm front, \pm round] to contrast the high vowels /i-y-u/. In French, [\pm front, \pm round] differentiate the high vowels /i-y-u/ and also the mid vowels /ε-œ-ɔ/. Following the Linguistic Proximity Model, my hypothesis is that L1 Mandarin-L2 English learners will be able to perceive and acquire the /œ-ɔ/ contrast in L3 French due to the presence in the L1 Mandarin feature hierarchy of the feature combination [\pm front, \pm round], as shown below. Here, the L2 English feature hierarchy is not selected because English does not have the feature [\pm round], but it is shown in Figure 1 because as the LPM postulated, finding structural similarity (features) to build a new L3 grammar is based on the parsing comparison between L1 and L2, to see which parses the L3 more successfully. By analyzing L3 input, “learners make predictions about the L3 structure by consulting previously acquired grammars” (Westergaard, et al 2017).

⁷ Here, it is argued that if [\pm front] is the missing feature, the English hierarchy will fail to distinguish /œ-ɔ/, if it is [\pm round] that is missing, then English hierarchy will fail to discriminate /œ-ε/ instead. Based on the two kinds of errors low-experienced and experienced English speakers of French made, it is hypothesized that there are two different parsing procedures English speakers go through. More details will be given in my hypotheses in Chapter 3. I assume that without relevant feature combinations, learners would encounter more complexities in parsing the target sounds.

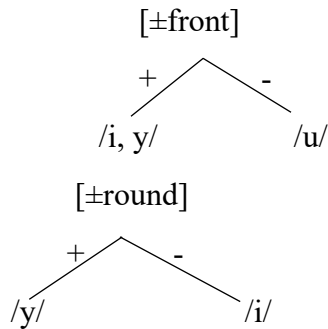
Figure 1 L3 acquisition: the selection of the features in L1



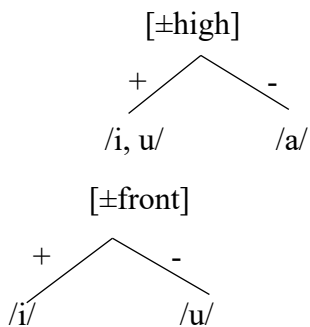
Let's illustrate this parsing procedure in a tree structure. As shown in Figure 1, when perceiving L3 input /œ-ɔ/, L1 Mandarin-L2 English learners will use the features in L1 Mandarin as in (2a) to parse /œ-ɔ/ successfully after comparing L1 and L2 featural systems, as in (2c). Partial feature trees of Mandarin, and English are given below, but more information will be given in Chapter 2.

(2) Parsing procedure: Mandarin compared to English to parse French /œ-ɔ/

a, [±front] > [±round] (Mandarin feature tree) (Wu, 2022)

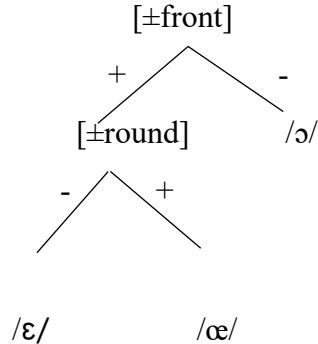


b, [±high] > [±front] (Partial Canadian English feature tree) (Gardner & Roeder, 2022)

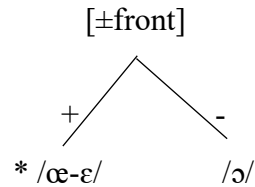


When perceiving French /œ-ɔ/, it is hypothesized that Mandarin speakers will be able to use [±front] to distinguish /ɔ/ from /œ/ and /ɛ/, so /ɔ/ will be parsed as [-front], and [±round] further distinguishes /œ/ from /ɛ/. /œ/ will be parsed as [+front, +round] as in (2c), so all the phonemes can be unambiguously parsed.

c. Mandarin speakers' parse of the L3 French input using the L1 CH⁸



d. English speakers' parse of the L2 French input using the L1 CH⁹



On the other hand, in the English feature hierarchy, the feature that is used to specify front and back rounded vowels is [±front] as in (2b), so this feature will fail to distinguish /œ-ɔ/, as in (2d). In this parsing procedure, [±front] is then used to distinguish /œ/ /ɛ/ from /ɔ/, but /œ/ /ɛ/ cannot be further specified using English feature hierarchy. The asterisk (*) means that two sounds cannot be parsed successfully. This is an example to illustrate why I predict that Mandarin speakers having a feature ranking [±front] > [±round] will perceive

⁸ According to the full hierarchy for Mandarin vowels in (21) in Chapter 2, [±front] and [±round] are contrastive in the [+high] sub-inventory, which means that the Mandarin hierarchy would parse French /œ/ /ɔ/ /ɛ/ as [-high] first then [±low]. In this case, we need to use Archibald's restructuring principle (2023): [±front] > [±round] can be redeployed under the [-high] node to parse French /œ/ /ɔ/ /ɛ/. More information about the contrastive hierarchy theory will be given in Chapter 2.

⁹ Here, if we use the example in (2b) to look at how the English hierarchy would treat mid-rounded vowels /œ-ɔ/, then we should explain why [±front] is extended to [-high] because the contrasts in the [-high] subtree are more relevant as seen in (2d). A simple way to illustrate this is again to use Archibald's restructuring principle which will be introduced shortly in Chapter 2.

high and mid French rounded vowels accurately and why L1 English-L2 French speakers without a feature ranking $[\pm\text{front}] > [\pm\text{round}]$ will make more errors when perceiving front and back rounded vowels in French, but bear in mind that because of lack of relevant features in the L1 featural system, English speakers would make different types of errors because of their L1 feature hierarchy also because of their L1 phonetic cues. The major point in this section is to illustrate why Mandarin speakers do not have problems discriminating French rounded vowels /y-u/ and /œ-ɔ/. Next, let's look at tense and lax vowels in Quebec French.

1.3.4 Tense and Lax Vowels in Quebec French, English, and Mandarin

The major difference between European and Quebec French is that the Quebec French vowel system includes lax allophonic counterparts [ɪ ʏ ʊ] of the three underlying high vowels /i, y, u/ and as in Table 5, which European French does not have.

Table 5 *Quebec French Vowels (Phonetic)* (Walker, 1984)

		front		central	back
High	Tense	i	y	ɨ	u
	Lax	ɪ	ʏ		ʊ
High-mid	Tense	e	ø		o
	Lax			ʌ	
				ɘ	
Lower-mid	Lax	ɛ	œ		ɔ
Low		æ	a		ɑ

There is contextual variation between the tense vowels /i y u/ and the lax vowels [ɪ ʏ ʊ]. When lax vowels occur in final closed syllables, as in (3), lax allophones of a high vowel in a final closed syllable trigger regressive harmonic laxing of high vowels in previous syllables, as in (3a).

(3) *Laxing Harmony* (Poliquin, 2006)

- a. minute /minyt/ → minyt → [mɪnɪt]
- b. pourrite /pʁɔɪt/ → pʁɔɪt → [pʁɔɪt]
- c. stupide /stɥpɪd/ → stɥpɪd → [stɥpɪd]

A rule of closed-syllable laxing changes tense high vowels /i, y, u/ to lax [ɪ ʏ ʊ], which suggests that there must be a feature used to mark the distinction between /i, y, u/ and [ɪ ʏ ʊ]. According to Hall (2016), Quebec French tense and lax vowels are marked by the feature [±tense]. Walker (1984) claims that [±tense] on high vowels triggers laxing harmony so [±tense] plays a more important role in Quebec French than European French. In Dresher's terms, we would say that [±tense] is phonologically active, because it triggers a rule, laxing harmony.

In addition, in Quebec French, [±tense] is also used to distinguish the mid vowels /e, ε/, which contrast phonemically, as in (4).

(4) *The /e, ε/ Contrast* (Walker, 1984).

- a. belle /bɛl/ 'beautiful' bête /bɛl/ 'bleats'
- b. bette /bɛt/ 'chard' bête /bet/ 'beast'
- c. mettre /metr/ 'put' maître /metr/ 'master'

As Walker (1984) stated, the /e, ε/ opposition is stable in Quebec French unlike European French where it has all but disappeared. The contrast /e, ε/, again, suggests that [±tense] is an active feature in this system. The difference between Quebec French and European French is crucial for our present research purposes because the study of tense and lax vowels is restricted to Quebec French only. As we will see in the following paragraphs, the contrast [y, ʏ] in Quebec French is particularly important for testing my hypotheses (see 1.2.1).

In the following below, we will view the English and Mandarin inventories again as showed in Tables 3-4 for a comparison purpose.

Similar to Quebec French, in the English vowel system, [\pm tense] is used to specify tense and lax vowels phonologically. As shown below, English has tense and lax contrasts, such as /i, ɪ/ and /u, ʊ/. Because English lacks high front rounded vowels, it is no surprise that English does not have the tense and lax contrast /y, ʏ/, which is crucial for our research. More details will be given in 1.3.2.

Table 6 *English Phonemic Vowel System* (Gardner & Roeder, 2022)

		Front	Central	Back
High	Tense	i		u
	Lax	ɪ		ʊ
Mid	Tense	e		o
	Lax	ɛ	ʌ	
Low		æ	ɑ	

On the other hand, unlike Quebec French and English, Mandarin does not have a vowel inventory which includes [\pm tense]. Table 7 presents the Mandarin vowel phoneme inventory: the high vowels /i/, /y/, and /u/, the low vowel /a/ and the mid vowel /ə/ (Duanmu, 2007; Lin, 2001; Wiese, 1997).

Table 7 *Mandarin Phonemic Vowel System* (Duanmu, 2007)

Front	Central	Back	
i y (round)		u (round)	High
	ə		Mid
	a		Low

To give a brief summary of this section in Table 8, Quebec French has [\pm tense] which is used to distinguish /e/ from /ɛ/ and /i, y, u/ from [ɪ ʏ ʊ]. Quebec French has a front rounded vowel /y/ specified by [+front, +round]. In contrast, English lacks a front rounded phoneme. Although English has [\pm tense], English lacks tense–lax contrasts on high front

rounded vowels. Finally, Mandarin does not have tense–lax contrasts but has a front rounded vowel /y/ ([+front, +round]).

Table 8 *A summary of phonological features in Quebec French, English, and Mandarin*

Languages / features	[±tense]	[±front] on rounded vowels
Quebec French	Yes	Yes
English	Yes	No
Mandarin	No	Yes

1.3.5 The L2 Acquisition of Tense and Lax Vowels

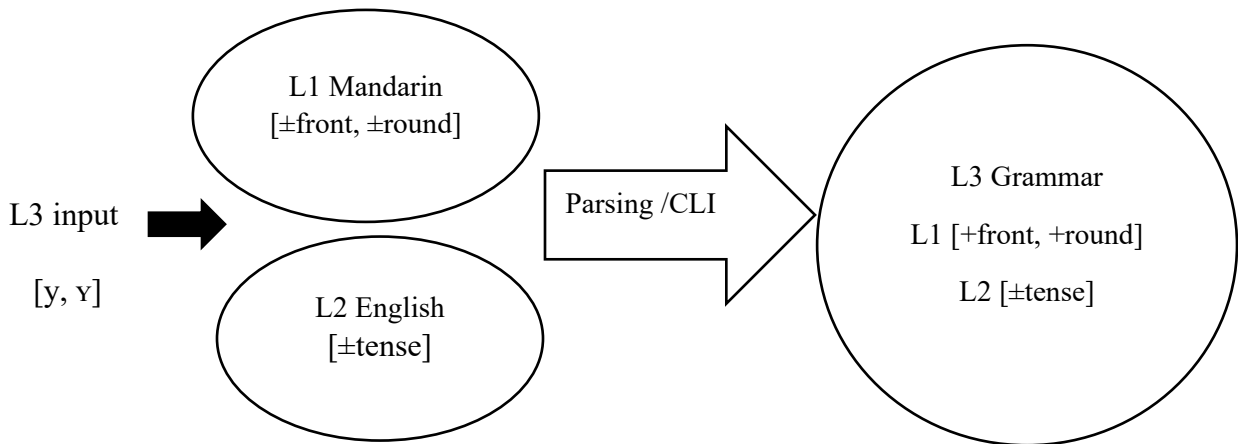
Let’s start by exploring previous research in the L2 acquisition of tense and lax vowels to understand why Mandarin speakers learning Quebec French as an L3 do not find it easy to acquire tense and lax vowels. Numerous previous studies have demonstrated that monolingual Mandarin speakers experience difficulties acquiring tense and lax contrasts, such as /i, ɪ/ in L2 English (Bohn, 1995; Sun & van Heuven, 2007; Zhang, 2002). However, once Mandarin speakers acquire [±tense] in their L2, it will be easier for them to acquire new tense and lax contrasts (/e, ε/) in L3 Quebec French than for monolingual Mandarin speakers. It is predicted that L1 Mandarin-L2 English learners will acquire the lax and tense contrasts in L3 without difficulties because of the features from both the L1 ([±front, ±round]) and the L2 ([±tense]). The present study aims to look into the roles the L1 and L2 play in the L3 acquisition of the two contrasts [y, ʏ] and /e, ε/ by L1 Mandarin-L2 English speakers to see whether they will perceive L3 Quebec French tense and lax contrasts accurately with the help of their L2 English and L1 Mandarin phonological features.

1.3.6 Hypothesis in the Perception of Quebec French Tense and Lax Vowels

To make the hypothesis more explicit, in Quebec French, there is an allophonic contrast [y, ʏ] and a phonemic contrast /ε, e/ both of which are represented by [±tense]. English also has [±tense] to distinguish tense vowels from lax vowels, such as /i, ɪ/ (Kwon, 2021), but

Mandarin does not have [\pm tense] (Duanmu, 2007). On the other hand, both Quebec French and Mandarin have [+front] specified on the rounded vowel /y/ (a combination of features [+front, +round]), but English does not. Inspired by the LPM, it is hypothesized that both the L1 and L2 features will facilitate the acquisition/parsing of the L3 structure when learning Quebec French tense and lax contrasts, / ϵ , e/ and [y, γ], as shown below.

Figure 2 *L3 acquisition: The selection of features from L1 and L2*

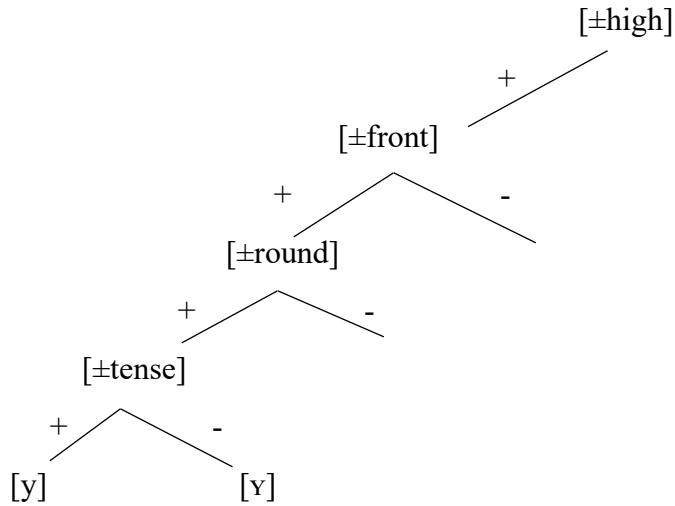


As shown in Figure 2, let's assume that L1 Mandarin-L2 English learners are exposed to L3 input (Quebec French [y, γ]). Based on the LPM, they are able to use the abstract I-language grammar of the previously acquired languages (L1 and L2 featural systems) to parse the incoming signal to build a new L3 grammar based on the best match in L1 / L2. In our case, the L1 Mandarin-L2 English learners' two featural systems are available to be selected when they are exposed to L3 Quebec French tense and lax vowels [y, γ]. In order to analyze and represent [y, γ], they should be able to select the features [+front] and [+round] from their L1 featural system and a feature [\pm tense] from L2 featural system to build their L3 grammar (L3 featural system). In other words, it is predicted that this learner will be able to accurately parse or perceive this L3 sound with the help of the L1 and L2 features.

To illustrate this parsing procedure in a tree structure, L1 Mandarin-L2 English learners should be able to parse Quebec French front rounded tense and lax contrasts [y, γ] using their contrastive hierarchy of the L1-Mandarin L2-English grammar, as in (5). Here,

we assume that an acquired L2 feature $[\pm\text{tense}]$ is added at the bottom of the L1 Mandarin feature hierarchy $[\pm\text{front}, \pm\text{round}]$. More explanation will be given in Chapters 2 and 3.

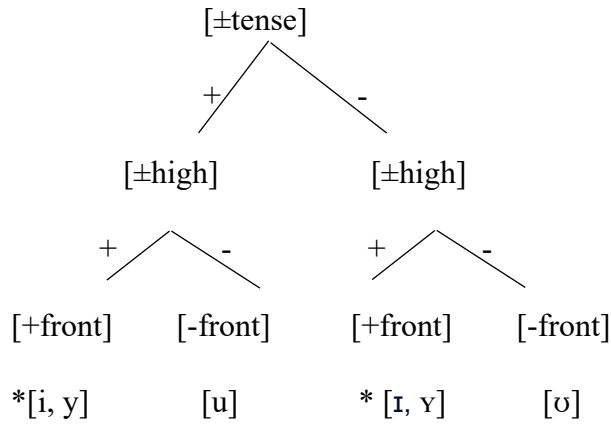
(5) the L1-Mandarin L2-English speakers' parse of L3 Quebec French tense and lax contrasts $[y, \gamma]$ using L1 Mandarin-L2 English feature hierarchy



In this parsing procedure, $[y, \gamma]$ will be categorized as $[+\text{high}]$ first, then $[+\text{front}]$ and $[+\text{round}]$ are assigned, and as in at the bottom of the tree, $[\pm\text{tense}]$ is used to specify $[y]$ as $[+\text{tense}]$ and $[\gamma]$ as $[-\text{tense}]$.

On the other hand, in English feature hierarchy, $[\pm\text{tense}]$ is ranked at the top (Gardner & Roeder, 2022), but English does not have $[\pm\text{front}, \pm\text{round}]$. This would affect English speakers' perception of tense and lax vowels $[y, \gamma]$ because they cannot parse $[y, \gamma]$ successfully, as in (6).

(6) English speakers' parse of L2 Quebec French tense and lax contrasts using the L1 CH (Gardner & Roeder, 2022)



In (6), L1 English speakers assign [±tense] first to parse [y] as [+tense] and [ʏ] as [-tense], but [±high, ±front] cannot further differentiate [i, y] and [ɪ, ʏ].

In this section, we have gone through some important background knowledge about the vowel inventories in French, English, and Mandarin, with a brief discussion of my research purposes and hypotheses.

1.4. Organization of the Thesis

This thesis consists of a total of six chapters organized as follows. In Chapter 2, empirical research is reviewed first, and then the theoretical framework of this thesis is introduced. Contrastive hierarchy theory, a phonological representational model, will be fully introduced, including the feature hierarchies for the three languages Mandarin, English and French. Relevant models in the acquisition of L2 and L3 sounds are explored and evaluated, with an overview of competing L3 learning models. Chapter 3 clarifies my hypotheses using the contrastive hierarchy theory and lays out the methodology of the current study. The results of my experimental study are presented in Chapter 4. Chapter 5 gives a contrastive hierarchy analysis of my empirical results with some discussion of the use of the contrastive hierarchy in L2-L3 phonology also the implications of my results for

previously existing models, and Chapter 6 concludes the thesis by highlighting the significance of my study and implications for further research.

CHAPTER TWO: BACKGROUND

In this chapter, first, I will review some previous studies on L3 phonology with discussions of some issues regarding methodology and research targets such as phonetic properties vs phonological properties. Then, theoretical background is given to establish the theoretical foundation of the present study.

2.1 Empirical Research

I begin with a description of some considerations relevant to, and previous studies on, L3 phonology related to the present study. It is acknowledged that investigation of phonological acquisition of a third language (L3) is a newly emerging area. Numerous scholars have agreed that L3 phonology is an understudied domain that needs to be explored (Cabrelli Amaro, 2012; Hammarberg, 1997; Wrembel, 2015c). Because of this, there are many potential considerations that need to be addressed as Cabrelli Amaro (2016) discussed. As she pointed out, methodological considerations have always been involved in the research on L3 phonology. There is a debate on the production and perception of L3 speech sounds. As Cabrelli Amaro (2016) noticed, the majority of studies in L3 phonology have focussed predominately on production with very limited research on perception. However, most influential models of second language speech are built using perception as a research method (Cabrelli Amaro, 2012). The present study takes this issue into consideration, with a focus on perception. As mentioned by Cabrelli Amaro (2012), the most important concern to the investigation on L3 phonology is to determine whether structural similarity between two languages is related to the phonological system (Cabrelli Amaro, 2012). This is also the question that the present study aims to explore and answer.

Numerous studies in L3 phonology consider Indo-European languages as target languages, such as English, German, French, Spanish, Portuguese (Cabrelli Amaro, 2013a, 2016; Cabrelli Amaro & Rothman, 2010; Gut, 2010; Missaglia, 2010). However, most of them focus on investigating phonetic properties, either on the acoustic measurements of voice onset time or vowel formants, not phonological properties (Kopečková, 2015; Lechner & Kohlberger, 2014; Llana, Cardoso, & Collins, 2010; Tremblay, 2007; 2010).

More specifically, Llama, Cardoso, and Collins (2010) measured the production of phonetic properties (voiceless stops, voice onset time) in the acquisition of Spanish as an L3 in two learner groups: L1 English L2 French; L1 French L2 English, with the finding that L2 plays a vital role in the selection of a source language. Gut (2010) investigated cross-linguistic influence on vowel reduction and speech rhythm produced by participants with different L1s in their L2 (German and English) and L3 (English or German). Measuring duration of vowel production (syllables), Gut (2010) stated that vowel reduction can be transferred to the L3. All of those studies demonstrate complex patterns of transfer between native and non-native languages in L3 speech, but they have failed to offer a full account of L3 phonological modelling (Cabrelli Amaro, 2016). They are insufficient to provide a clear representational model of the L1 or L2, and therefore they cannot look into the acquisition process to explore how learners use their grammar to parse or represent a new speech sound.

Furthermore, all of those studies (Gut, 2010; Llama, Cardoso, and Collins, 2010) utilize production as a research method. As mentioned in Section 1.3, there are many external factors, such as articulation problems that would affect production. Additionally, Cabrelli Amaro (2017) investigated to what extent L1 (L1 Spanish L2 English) and Adult L2 (L1 English L2 Spanish) phonological systems would be affected by L3 Brazilian Portuguese (BP). By testing the learners' BP production and perception to assess word-final vowel reduction, which is part of the BP phonological system only, her findings suggest that there is a difference found between groups for production but not perception. This study, again, alludes to the difference between speech production and perception systems (De Leeuw & Chang, 2023).

2.2 Theoretical Background

In order to facilitate the reader's understanding of some concepts and models mentioned later, let's start with a brief definition of some terminology and theories that are used widely in language acquisition.

2.2.1 Language Acquisition: Universal Grammar

Universal grammar (UG), proposed by Chomsky (1981, 1986), is defined as the innate language faculty that humans are born with. Before acquiring any languages, children are well equipped with principles of UG, which is the initial stage according to White (2003a). The exposure to the primary linguistic data triggers the children to set the values of parameters which form the grammar for a particular language (White, 2003a). Parameters can be regarded as a switch. For instance, when children are exposed to English, a parameter such as the head parameter would be set to the English setting head-initial corresponding to SVO (subject-verb-object), while if exposed to Japanese, children would set the head parameter to the Japanese setting head-final, yielding SOV (subject-object-verb) order. The grammar is then constructed during the process of acquisition, and eventually reaches a steady state (White, 2003a). More specifically, the relation between principles and parameters is that when an infant is exposed to a particular language, input assigned to each parameters define what principles need to be applied to construct grammatical sentences. Bear in mind that general principles are grammatical rules that are universal. Parameters (switches) account for particular languages and can be either turned on or off depending on input data. The process of constructing grammar is adapted by Archibald's (1993, p. 56)'s language learning schema as given below. The flowchart is from Deng's thesis (2022).

Input Data → Universal Grammar → Language-Specific Grammar → Speech

As shown above, language acquisition is a process where infants (guided by UG) form the grammar of a particular language (by setting parameters) based on the interaction between the input and the environment.

Chomsky (2005) elaborated his theory of language acquisition and proposed three factors that determine the nature of human I-languages, as given below.

(7) F1: Genetic endowment, or UG

F2: Experience, or Primary Linguistic Data (PLD)

F3: Principles not specific to the faculty of language

F1 is the species-specific UG which constrains all grammars including child grammars. F2 is exposure of the UG to the PLD, triggering variation in I-languages. F3 reflects biological, physical, and computational principles that interact with the language faculty (Chomsky, 2005). This view of language acquisition, according to Slabakova (2018), is different from the previous generative linguistic theory (Chomsky, 1981) in that UG is less elaborate and more minimal than the previous version.

2.2.2 Parsing to Learn

With UG as the theoretical foundation in language acquisition, Lightfoot (2020) proposes that learning is based on parsing. Parsing, according to Lightfoot, is “implemented by a person’s language faculty, initially by UG and then by an individual’s emerging I-language” (Lightfoot, 2020, p. 63). UG, according to Lightfoot’s definition, is a *toolbox*, a linguistic repository that opens for children to select structures with which to parse E-language (see section 1.1.3). Emerging I-language here means that young people grow an I-language by identifying and acquiring its parts (Lightfoot, 2006). In parsing-based learning, children have a parser to parse the E-language (PLD) they hear and discover the categories and structures allowed by UG and they then accumulate the elements of their I-language (grammar) (Lightfoot, 2020). The parsing capacity matures over time and is different among ages as the I-language develops. As a child’s I-language develops, “the parser assigns more structures to the E-language experienced and the child interprets more E-language” (Lightfoot, 2020, p.65). This is how children discover variable properties of their E-language.

In line with Lightfoot (2020), Archibald (2022) also states that “the I-language assigns structure to the E-language by selecting available structures from a minimalist, sparse UG (*toolbox*) and the emerging I-language itself” (p.8), but what does this system (I-language) look like in phonology? Dresner (2009) explored a learning algorithm in phonology that can be used to explain the growth of the I-language, which is a contrastive hierarchy model of the phonemic inventory, and crucially the successive division algorithm (see Section 2.3).

In this section, we have gone through the theories in language acquisition. To examine cross-linguistic influence, in relation to a phoneme inventory (which is what is being investigated in this thesis), we need to first understand how to measure linguistic proximity between two languages at an abstract level. In the next section, a phonological representational model that can be used to measure linguistic proximity will be introduced.

2.3. Dresher’s Representational Model: The Contrastive Hierarchy Theory

Before introducing Dresher’s model, it is essential to understand features and underspecification.

2.3.1 Features

The notion of contrast has been a central part of linguistic theory (Dresher, 2015; Jakobson, 1941, Jakobson and Lotz, 1949; Trubetzkoy, 1969,). Many phonological theories seek to account for (a) whether or not two sounds are contrastive in a given language and (b) how processes can change existing sound structures and create new structures of mental representation of speech sounds. It is commonly believed that *features* provide valuable insight into a language’s system of phonemic contrasts (Dresher, 2009).

Lahiri & Reetz (2010) demonstrate that phonological features play an active role in comprehension and production. According to their statements, the perceptual system does not capture for all the acoustic cues but “extracts the most robust cues for features” (Lahiri & Reetz, 2010. p. 50); in their words “The signal is parsed into features and not segments” (Lahiri & Reetz, 2010. p. 50). Here, *robust cues*, according to Wright (2004), are “information in the acoustic signal that allows the listener to apprehend the existence of a phonological contrast” (p.1). For example, voice onset time is a cue for distinguishing voiced and voiceless consonants in English as in /b, p/. Clements & Ridouane (2011) also propose that “humans are intrinsically predisposed to categorizing sounds and to extracting sound patterns” (p.7). In phonology, detecting new contrasts, the learner needs to select structures to parse those contrasts. Here, features come to play a role.

As mentioned in Chapter 1, phonological features are the most basic units of phonology and the basic building blocks of speech sounds. They are used to specify the phonemic contrasts in a given language. In other words, features are the phonological representation of speech sounds. Features, such as [\pm voice], make up the phonological representation of phonemes. For example, a voiced obstruent such as /d/ contrasts with a voiceless obstruent /t/. A distinctive feature [\pm voice] can be used to mark the contrast between voiced and voiceless obstruents, such as /t/ and /d/ in many languages, such as Ngizim (Mackenzie, 2013).

In addition, natural classes are captured by features. The change of a feature implies that this feature describes natural classes in an inventory. For example, in final obstruent devoicing ($[-\text{sonorant}] \rightarrow [-\text{voice}]/_ \#$), [b] becomes [p] in word final position. The change of the feature [\pm voice] indicates that [+voice] and [-voice] both describe natural classes in a given language, which also predicts that all the voiced obstruents will behave the same, undergoing a phonological process of final devoicing in word final position and becoming voiceless obstruents.

2.3.2 Underspecification

Underspecification is a theoretical device of omitting certain kinds of specifications from underlying representations in order to capture certain phonological patterns. In the 1980s, numerous researchers proposed that all predictable information had to be underspecified in underlying representations (Archangeli 1984; Kiparsky 1982; Stemberger, 1991). Predictable features are redundant (Stemberger, 1991). Redundant features are features that do not distinguish phonemes. For example, the voicing of vowels in English is redundant because vowels are always voiced, which means that there is no contrast between voiced and voiceless vowels; and therefore [+voice] would be omitted from the underlying representation of English vowels.

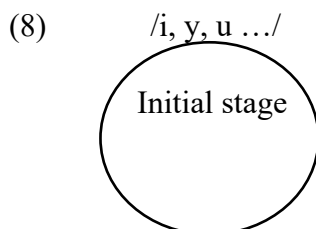
Contrastive specification only specifies features which are used to differentiate phonemes from other phonemes and redundant features are omitted (Avery & Rice, 1989). To determine the contrastive features for a language, the contrastive status of features needs

to be ordered hierarchically. As Dresher (2009) proposes, hierarchical feature ordering is the best way to determine contrastive features. As supported by Jakobson (1941), the notion of phonological contrasts is central to linguistics.

2.3.3 The Contrastive Hierarchy Theory (CHT) and the Successive Division Algorithm (SDA)

With consideration of feature theory and the notion of contrast, Dresher (1999; 2013; 2018) proposes a phonological representation model which has been used in L1 and L2 acquisition (Archibald, 2022; Bohn & Santos, 2018). This model is a theory of contrastive specification. Dresher (2009, 2015, 2018) identifies two important components of phonological feature specification: The Successive Division Algorithm (SDA) and the Activity Principle. Under Dresher’s contrastive hierarchy theory, features are specified by establishing a language-specific feature hierarchy. Establishing this hierarchy (a procedure for specifying contrasts) is based on the SDA, which will be introduced more thoroughly below. The selection of the features is determined in part by examining the phonological processes in a given language. The procedure of selection features is called the Activity Principle by Dresher (2009). Those concepts have helped to successfully identify a set of contrastive features in many languages, such as Manchu (Zhang, 1996), Ngizim (Mackenzie, 2013), Laurentian French (Hall, 2016), Xunke Oroqen (Dresher, 2018), Korean (Kwon, 2019), English (Gardner & Roeder, 2022), and Mandarin (Wu, 2021).

Dresher (2009) provides a theoretical foundation for the theory of contrastive hierarchy: features are specified by establishing a language-specific feature hierarchy by the SDA, the procedure for specifying contrasts. In this learning algorithm, an infant acquiring a language begins with no specifications and thus no way of encoding differences among segments, as shown in the example below.

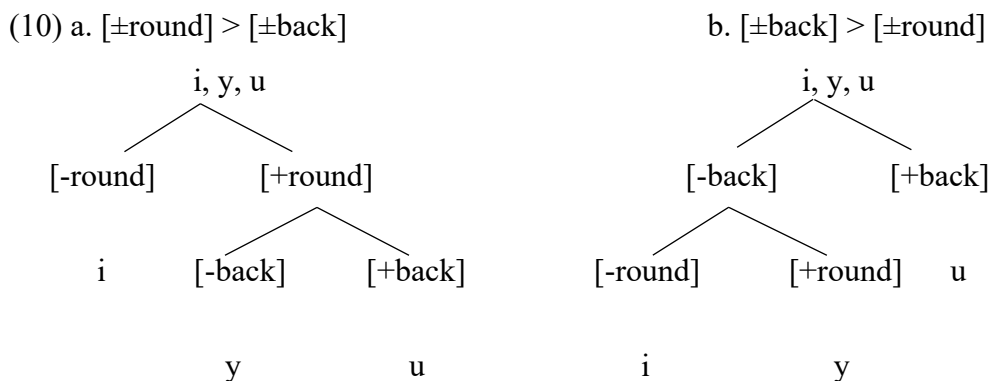


Then, after exposure to L1 input, the infant observed the differences among those segments. A distinctive feature is then assigned to divide segments into two sets: a group of segments with the positive value for this feature and a group of segments with the negative value for the feature. Here, Dresher (2009) chooses binary features [+ , -] to represent the phonological inventory. In the example given by Hall (2016), in order to divide three high vowels /i, y, u/, two possible binary features are needed: [±round] and [±back]. The infant could choose either [±round] first or [±back] to first divide the segments into two sets. This will result in two possible divisions, as in (9).

(9) /i, y, u/



After that, an additional feature will be selected in each feature specification and thus further divide the segments into subsets. This procedure will apply in turn until each phoneme is uniquely and correctly specified. This is how infants build phonological representations through parsing in the course of acquisition. In the example, if [±round] is selected first, [±back] will then be chosen to further divide /y, u/ into subsets. If [±back] is selected first, [±round] will then be chosen to uniquely specify /i, y/. There are two possible hierarchies, as given below.



The SDA, according to Hall (2007), “can be viewed as an acquisition algorithm that describes how a language learner builds phonological representations by creating

phonemic distinctions and using features to mark them” (p. 31). Dresher’s Successive Division Algorithm is given below.

(11) Successive Division Algorithm (Dresher, 2009. p.16)

- a. Begin with *no* feature specifications: assume all sounds are allophones of a single undifferentiated phoneme.
- b. If the set is found to consist of more than one contrasting member, select a feature and divide the set into as many subsets as the feature allows for.
- c. Repeat step (b) in each subset: keep dividing up the inventory into sets, applying successive features in turn, until every set has only one member.

As shown above, there can be multiple possible hierarchical organizations of features for a single surface inventory. Two questions raised here are: how can we tell which is the correct analysis? How do we determine which features are contrastive (i.e., are specified) and therefore selected for ranking, and which ones are redundant (i.e., not represented phonologically)? Here, the Activity Principle comes to play a role.

2.3.4 The Choice of Contrastive Features: The Activity Principle

Whether or not a given feature is specified in a given language is determined by examining the phonological processes in that language, the Activity Principle. It is designed to “identify the contrastive features that are relevant to phonological computation” (Dresher, 2016. p.68). For instance, if a feature, such as [\pm voice], triggers a phonological process, such as a voicing assimilation rule (e.g., English plural allophone /z/ \rightarrow /s/ / [-voice] $_$), then the feature is active and therefore the [\pm voice] feature must be included in the feature hierarchy.

Let’s return to the example in (10). In order to determine which ranking is correct, the relevant phonological process of assibilation in (14) should be taken into account: The high front vowels /i/ and /y/ trigger assibilation of coronal stops such that /d/ and /t/ become sibilant consonants before /i/ and /y/, as shown below in (13).

(13) Assibilation of /t/ and /d/ before /i/ and /y/ (Burstynsky, 1968. p.13)

- a. j'ai dit [ʒedzi]
- b. du pain [dz y pɛ̃]
- c. petit [p(ə)tsi]
- d. tête [tetsy]

(14) Phonological rule: Assibilation

$$\left[\begin{array}{l} +\text{coronal} \\ -\text{sonorant} \end{array} \right] \rightarrow [+strident] / _ \left[\begin{array}{l} -\text{consonantal} \\ -\text{back} \\ +\text{high} \end{array} \right]$$

As shown above, $[\pm\text{back}]$ is a phonologically active feature because $[-\text{back}]$ triggers the phonological process: /d/ and /t/ become sibilant consonants only before the segments /i/ and /y/ which are specified with $[-\text{back}]$ (i.e., not before /u/). The evidence from the phonological activity here shows that /i/ and /y/ must have an active phonological feature $[\pm\text{back}]$, so $[\pm\text{back}]$ should be ranked above $[\pm\text{round}]$ to make sure they are specified with $[-\text{back}]$.

Here, we would actually need to illustrate why $[\pm\text{round}]$ is selected. We choose $[\pm\text{round}]$ because it is the only feature that can distinguish /y/ from /i/ because rounding is the only difference between them. It is important to keep in mind that activity can help us choose which feature to be selected when there is more than one possible feature, but a feature does not have to be phonologically active to be specified. We need to assign enough features to distinguish all contrasting phonemes.

What we can conclude based on the analysis is that for French high vowels, $[\pm\text{back}]$ is active, and $[\pm\text{back}]$ must be chosen before $[\pm\text{round}]$ to specify /i, y/ in the contrastive hierarchy. Let us return then to the two possible representations of the vowel inventory in (10). The order in (10a) will predict the wrong alternations: /i/ cannot trigger assibilation because it is not specified with $[-\text{back}]$. This will predict incorrect surface forms, such as *[pəti]. Therefore, (10b) is the correct ranking for Laurentian French high vowels. With such a hierarchy revealing the underlying structure of Laurentian French high vowels, a

learner of Laurentian French would have to acquire the correct ranking of features, but a question raised here is why is the CH model the best model?

2.3.5 The Reasons to Adopt the Contrastive Hierarchy (CH) Model

There are many models that have been proposed for the comparison of languages, such as the Speech Learning Model (Flege, 1995; Flege & Bohn, 2021), the Perceptual Assimilation Model-L2 (Best, Tyler, Bohn & Munro, 2007), and Feature Competition Model (FCM) (Hancin-Bhatt, 1994). The Speech Learning Model (SLM) makes segment-to-segment comparisons to predict the ease or difficulty of acquisition. To be more specific, one of the major hypotheses of the SLM is that if the L2 sounds are phonetically similar to the L1, learners would equate them with L1 categories, which leads to the fact that their perception or production of L2 sounds deviate from L1 speakers. To illustrate this, Lai (2010) focused on the perception of English tense-lax vowel contrasts by Chinese learners of English, with findings that the learners tend to assimilate English tense and lax vowels into one Mandarin category. One example given in her study is that an L1 [i] in Mandarin is phonetically similar to an L2 [ɪ] in English, and therefore English lax vowel [ɪ] is categorized as /i/ in Mandarin. This example clearly reveals segment to segment comparison in that one single segment in L2 is phonetically compared to another segment in L1. However, the present study does not aim to compare a single segment in each language but to seek for inventory effects with segmental behaviour because inventory effects are a clear reflection of a phonological level.

Similarly, Perceptual Assimilation Model-L2 is used to predict the likelihood of acquiring new L2 categories when a L2 learner is acquiring a non-native language (Tyler, 2019). For instance, when each L2 phoneme in a contrast such as [r/l] in English is perceived as a different L1 category such as /ɾ/ and /l/ in Mandarin, L1 phonological categories function as a tool for discriminating L2 contrasts, so no additional learning is needed (Tyler, 2019). In contrast, if the learner does not detect an L1 category for a L2 contrast, such as [ɪ] and [i] in English, perceptual learning is needed to detect the L2 phonological contrast depending on how the L2 phonemes are assimilated to the L1 phonological system initially (Tyler, 2019). One of the recent studies that supports

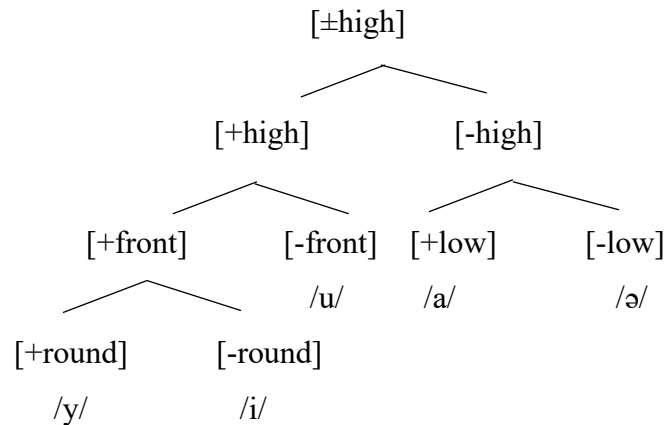
Perceptual Assimilation Model-L2 is a study on the assimilation of the English monophthongs such as /i, ɪ, ʊ, u/ by Thai learners of English (Kitikanan, 2022). It is commonly known that Thai speakers have trouble producing or discriminating English tense and lax vowels, such as /ɪ/ and /ʊ/ (Kallayanamit, 2010). In Kitikanan's (2022) study, Thai learners of English including the high-experienced and low experienced learners of English performed similarly to each other in an assimilation task by matching English lax vowels such as /ɪ/ and /ʊ/ to their L1 Thai /i/ and /u/. This study is in support of Perceptual Assimilation Model-L2 that the L1 phonological system does function as a tool for L2 learning: if there is no L1 category for an L2 contrast, learners will have more problems perceiving this contrast. Again, similar to the SLM, this model focusses on a segment-segment comparison.

Hancin-Bhatt's (1994) Feature Competition Model (FCM) is used to predict which phonological features will be transferred from the L1 to the L2 on the basis of language specific feature prominences, determined by underspecification. Phonological features that occur more frequently in a language will influence the perception of new sounds in a target language as those features are most prominent in the L1 inventory. Following this model, Smith (1997) compared features of Japanese, German, Turkish and French and proposed that the lack of the feature [distributed] is the main source of making errors in the acquisition of interdental fricatives /θ-ð/ and /s-z/ in English. Hancin-Bhatt's (1994)'s model is theoretically formulated and tends to specify an acquisition mechanism to explain inventory effects. It was a promising model of language acquisition but unfortunately her hypotheses were not fully confirmed in L2 acquisition. On the other hand, the contrastive hierarchy theory has been employed successfully in L2 & L3 acquisition (Archibald, 2023; Kwon and Starr, 2023).

As mentioned earlier, the contrastive hierarchy model takes the notion of contrast into account. This is the foundation of phonological inventories. It is important to note that “the contrastive hierarchy predicts that we should see inventory effects when it comes to segmental behaviour” (Archibald, 2022. p. 28). The feature that divides the phonemic inventory determines the segmental behaviour. For example, as in (15), in Mandarin, [+high] divides five vowels into /i, y, u/ and /ə, a/. We might, thus, expect that all the [+high]

vowels /i, y, u/ behave differently from the [-high] vowels /a, ə/, which is true in Mandarin that only high vowels undergo a rule of glide formation in which the high vowels /i, y, u/ become the glides /j, ɥ, w/ in the onset in Mandarin (Duanmu, 2007).

(15) Mandarin vowel feature hierarchy



2.4. Contrastive Hierarchy Theory in Language Acquisition

In this section, we will look into the use of the contrastive hierarchy theory in previous research. According to Dresher (2018), feature hierarchies provide answers to how learners acquire speech sounds (p.19). The set of hierarchically ordered features describes how a language learner builds phonological representations by discovering phonemic distinctions marked by contrastive features in their languages (Dresher, 2018). The developmental path is argued to be a top-to-bottom developmental path (Dresher, 2009; 2018; Jakobson, 1941). This has been shown in first language acquisition (Bohn & Santos, 2018).

2.4.1 Contrastive Hierarchy in First Language Acquisition

Using the SDA as a phonological representational model, Bohn and Santos (2018) conducted a study investigating the acquisition of stressed vowels in Brazilian Portuguese (BP) by 3 monolingual children. They focus on the acquisition of stressed vowels because the production of stressed vowels occurs early in child language acquisition (Rangel, 2002;

Miranda & Matzenauer, 2009). Their study illustrates children’s learning path in a contrastive hierarchy although children’s learning paths may vary, which is shown below.

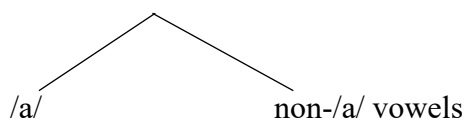
Bohn and Santos (2018) collected data from a longitudinal study of three children aged between 1;4 and 3;5 acquiring the São Paulo dialect of BP as their L1. The children were recorded in their natural environment every week for 30 minutes. To determine which vowel the child is producing, they conduct an acoustic analysis: The F1 and F2 frequencies of vowels were measured. Results indicate that three children all first acquire and produce /a/ which is used contrastively with /o/ or /i/, then /u/ and /e/ are acquired later, as shown below.

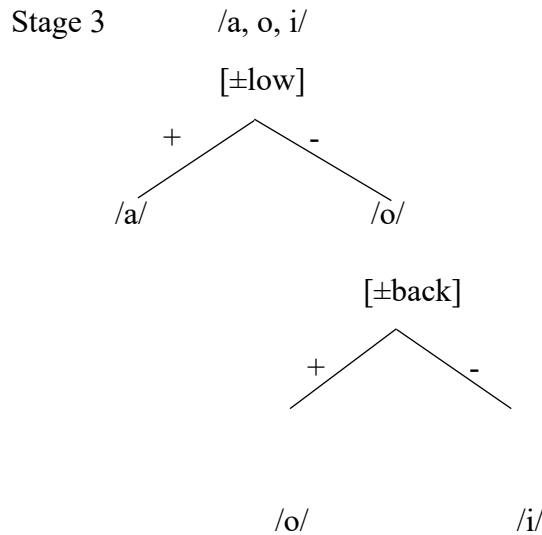
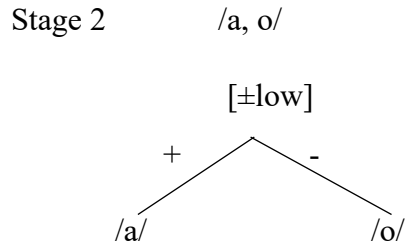
Table 9 *Summary of the Order of Vowel Acquisition* (Bohn & Santos, 2018)

Child	Order of acquisition
A.	/a/ > /o/ > /i/ > /e/ > /u/
Am.	/a/ > /o/ > /i/ > /e/
L	/a/ > /i/, /o/ > /u/ > /e/

As can be seen in the table, the three children all produce a contrastive low vowel /a/ first, and then /o/ or /i/. The order of vowel acquisition indicates that children build hierarchies to contrast phonemes in their developmental learning path. More specifically, after acquiring /a/, children have a two-way contrast between /a/ and non-/a/. Then, /o/ is acquired. In order to differentiate /a/ and /o/, [±low] is needed then, so [+low] is assigned to /a/ and [-low] is assigned to /o/ in the hierarchy, as in (16). /i/ is the third vowel they acquired. In order to make a contrast between /i/ and /a, o/, [±back] is developed and assigned to their hierarchies. This is how children start building their learning path in a contrastive hierarchy.

(16) Stage 1 /a/–non-/a/ contrast





In general, Bohn and Santos's (2018) study demonstrates that children follow a principle of contrast and the CHT explains their developmental paths (there is more than one possible path). The acquisition path does follow the hierarchical order proposed by CHT (Dresher, 2009).

2.4.2 Contrastive Hierarchy in Third Language Acquisition and the Restructuring Principles

Building on the work of Dresher, the SDA model can also account for adult language acquisition. In relation to the role of CHT in second or third language acquisition, drawing on Archibald (2020), in a case study by Benrabah (1991), 24 participants who speak L1 Arabic, L2 French, and L3 English are examined. Modern Standard Arabic has three vowels [i, a, u]; French has eleven vowel phonemes [i, y, u, e, ε, ø, œ, a, æ, o, ɔ]; English also has eleven contrastive vowels. Table 10 presents a comparison of the vocalic feature

hierarchies of the three languages. Linguistic proximity (crosslinguistic similarity) is measured by the feature hierarchy. As shown in Table 10, the feature hierarchy of French vowels seems closer to the English vowels' hierarchy than the Arabic vowels' hierarchy, and therefore the vocalic features of French vowels transfer into the L3 English and parse the vocalic contrasts in L3 English.

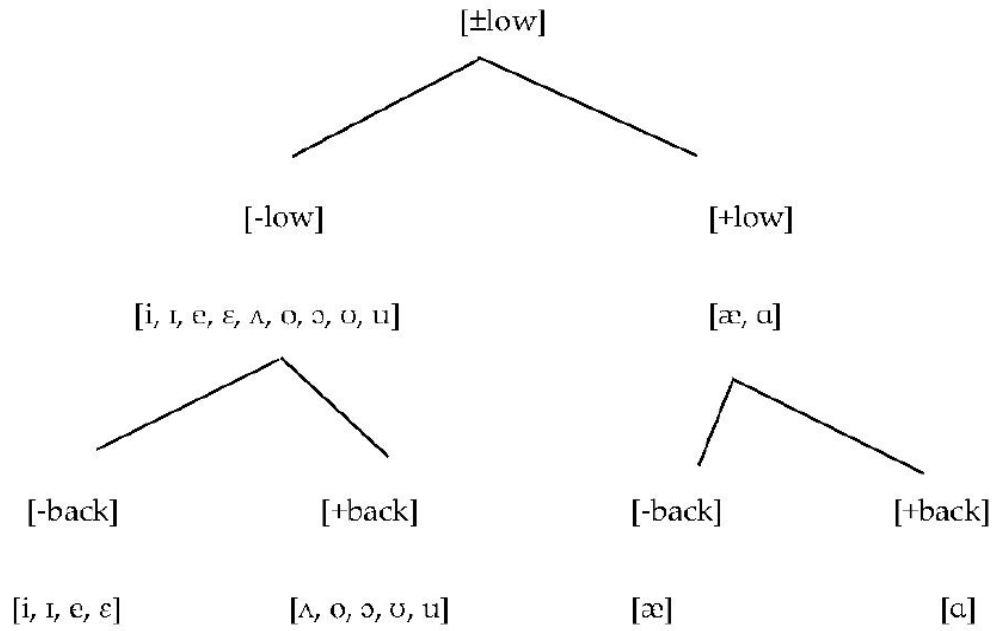
Table 10 *Vocalic Feature Hierarchies of Arabic, French, and English* (Archibald, 2020)

Arabic	[±low] > [±back]
French (Hall, 2016)	[±nasal] > [±tense] > [±low] > [±high] > [±back] > [±round]
English (Kwon, 2021)	[±tense] > [±low] > [±front] > [±high] > [±round] ¹⁰

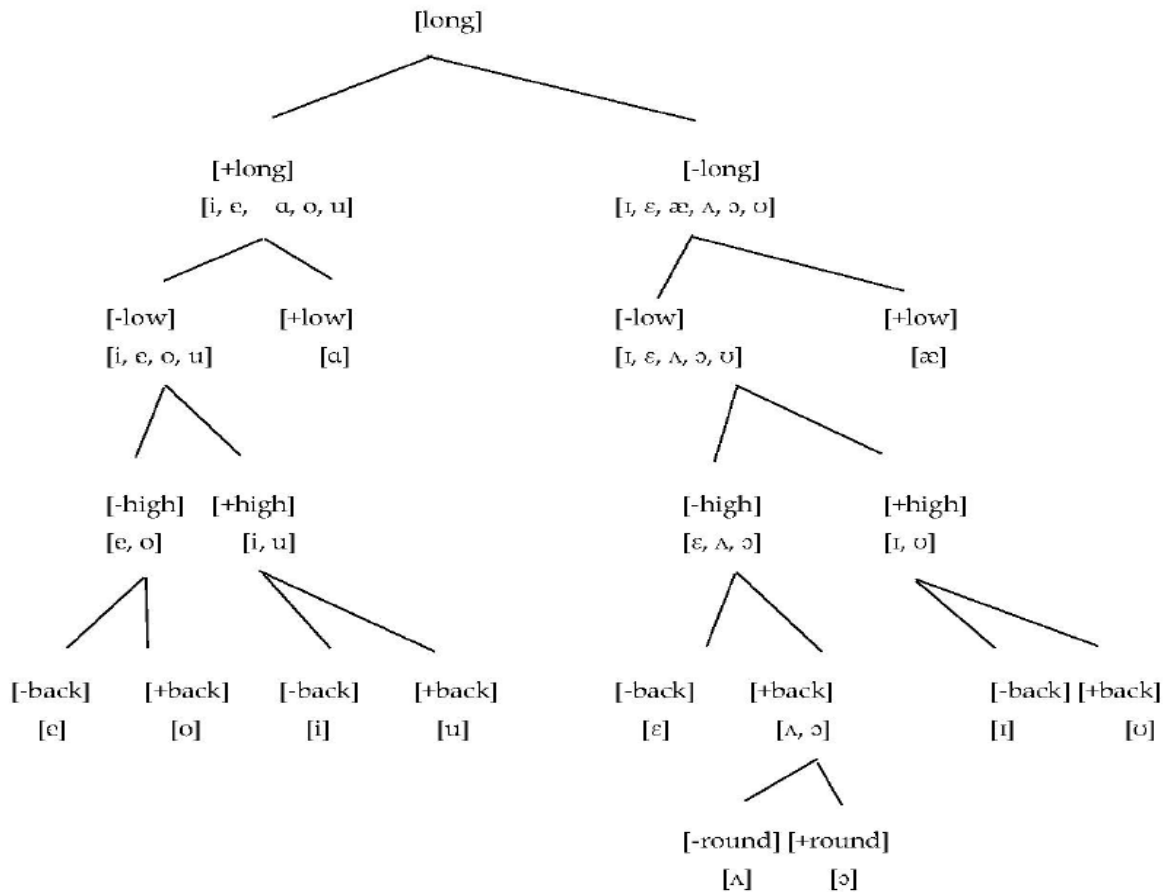
To be more specific, as mentioned by Archibald (2022), under a contrastive hierarchy model, when the learner is exposed to L3 English input that includes [i, ɪ, e, ε, æ, a, o, ɔ, ʌ, u, ʊ] they will assess whether each segment can be uniquely specified with either the Arabic feature hierarchy [±low] > [±back] or the French feature hierarchy [±tense] > [±low] > [±front] > [±high] > [±round]. It is clear that the French feature hierarchy will fare better as shown below in (17). Using the Arabic feature hierarchy to parse the English input will leave many English phonemes undifferentiated, but the French feature hierarchy is able to uniquely represent all of the English phonemes.

¹⁰ Here, Archibald uses Kwon's American English feature hierarchy, which is different from Canadian English feature hierarchy used in the present study. More can be read from Gardner & Roeder (2022).

(17) a. The Arabic contrastive hierarchy applied to English vowels (Archibald, 2022. p. 9)

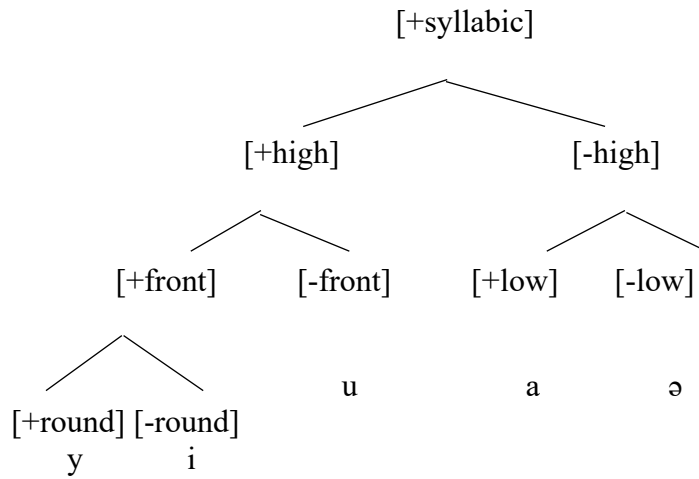


b. The French contrastive hierarchy applied to English vowels (Archibald, 2022. p. 10)

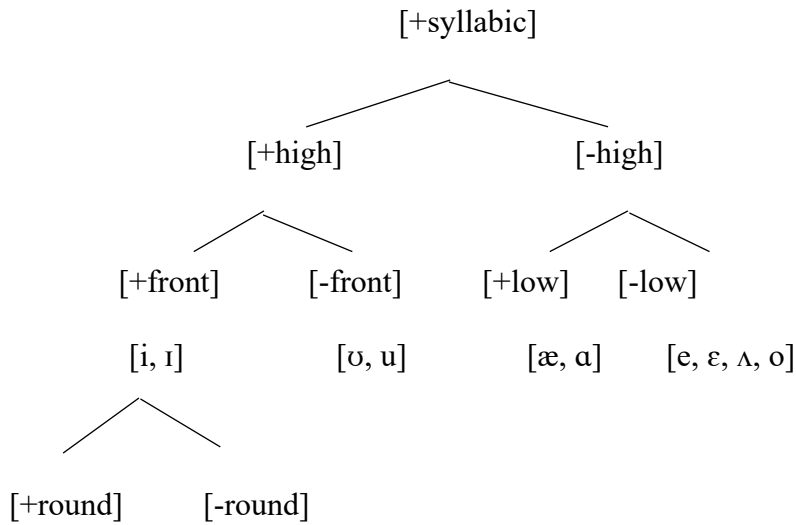


In order to parse the target sound, learners need to construct a L2 or L3 phonological grammar and establish the necessary feature for better perception. As Oxford (2015) and Archibald (2023) mentioned the most conservative change to a structure for accurate perception is to change the sister node of an existing node. With the view that grammars need to be restructured, Archibald (2023) proposes two principles of restructuring. The first one is that the features can be extended (redeployed) to another sub-inventory in order to parse target sounds. One of the examples given by Archibald is the parsing of English vowels by Mandarin speakers. To be able to parse the English vocalic input, Mandarin speakers should take restructuring actions otherwise many English vowels would be parsed ambiguously, as in (18b).

(18) a. Mandarin vowel contrastive hierarchy (Wu, 2021)

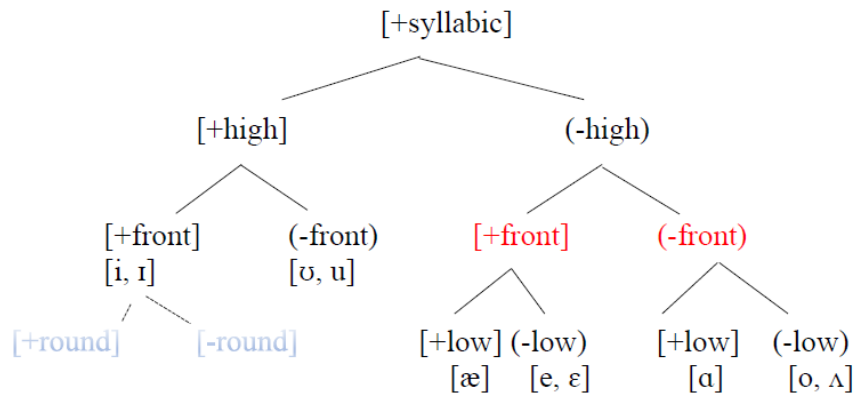


b. Use the Mandarin contrastive hierarchy to parse English vowels (Archibald, 2023, p. 13)



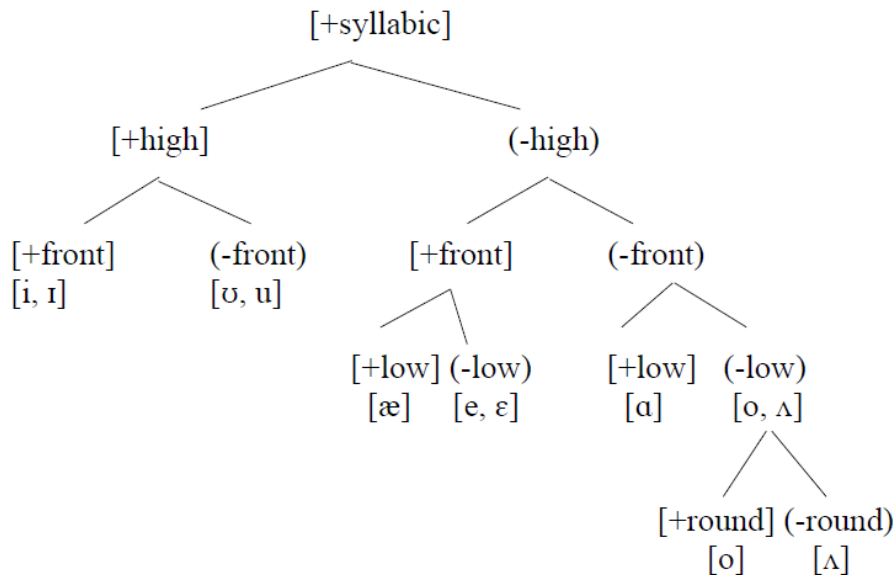
As shown in (18b), lax vowels (ɪ, ʊ, ɛ, æ, ʌ) cannot be differentiated from tense vowels. Also, [round] is not needed to parse English vowels because English vowels that differ in rounding are already differentiated by [±front]. Archibald (2023) assumes that the feature [front] can be extended to the [-high] sub-inventory, as in below. This restructuring action would allow the learner to distinguish /æ/ from /ɑ/ and /e, ɛ/ from /o, ʌ/.

(19) Restructuring [front] feature (Archibald, 2023, p. 13)



In addition, the [round] feature can also be extended to the [-low] sub-inventory, so the learner would be able to distinguish /o/ from /ʌ/, as in (20).

(20) Restructuring [round] feature (Archibald, 2023, p. 13)

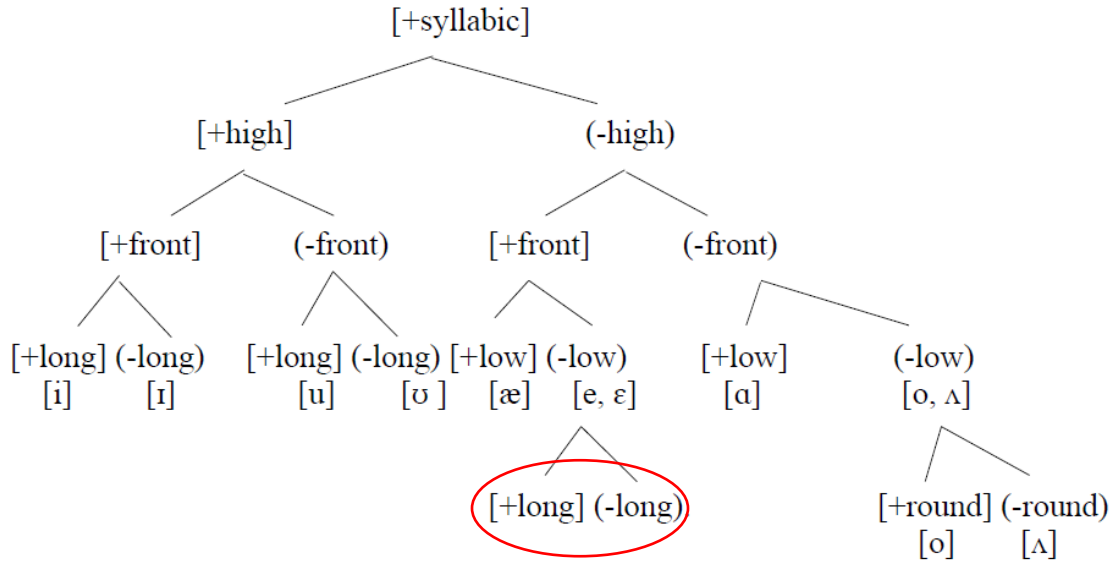


As Archibald (2023) acknowledged, “if more changes are needed, then the learner would restructure by moving a feature one level higher in the tree until the structure could successfully parse the input date” (p.15).

What if learners do not have the necessary feature to parse the target sounds? To explain this, Archibald proposed his second principle that adding a new feature starts at the bottom of the tree, and the change should be conservative and incremental. In his analysis of Mandarin learners of English acquiring [±tense] to parse English tense and lax vowels,

to acquire the [±tense] feature, Mandarin speakers of English would add the [±tense] feature dominating any pair of vowels which cannot be uniquely parsed. Here, Archibald uses [long] instead of [tense], but the two features are equivalent as applied to English (Oxford, 2015).

(21) The contrastive hierachy of the L1-Mandarin L2-English grammar (Archibald, 2023)



Archibald’s (2023) restructuring principles are crucial to the present study because learners in the present study would also need restructuring actions to parse L3 French vowels.

Overall, contrastive hierarchy theory (including the SDA) represents abstract phonological properties. It is a phonological model that can be used to measure linguistic proximity and also can account for the learning path in adult language learning. Investigating the acquisition of vowel contrasts in Quebec French from the CHT perspective, I can measure the linguistic proximity among three languages (Mandarin, English, French). For comparison purposes, this theory of model is able to predict whether the L1 or the L2 is closer to the L3 with respect to the vowel inventory. At the same time, it is able to show the ranking of features and helps me understand how learners redeploy certain features from previously acquired languages to acquire a target sound.

2.4.3 Contrastive Feature Hierarchies of the Three Languages: Mandarin, Canadian English and Quebec French

As mentioned in Chapter 1, the present study investigates L1 Mandarin-L2 English and L3 Quebec French. Table 11 presents a comparison of the vocalic feature hierarchies of the three languages (Gardner & Roeder, 2022; Hall, 2016; Wu, 2021).

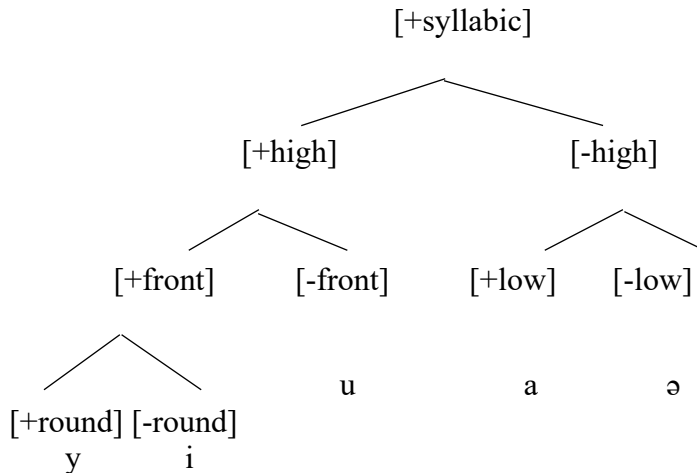
Table 11 *vocalic feature hierarchies of Mandarin, English and Quebec French*

Mandarin	[±high] > [±front] > [±round] > [±low]
Canadian English	[±tense] > [±high] > [±low] > [±front] ¹¹
Quebec French	[±nasal] > [±tense] > [±low] > [±high] > [±back] > [±round]

As shown previously in Chapter 1, Quebec French tense and lax vowels [y, ʏ] and /ε, e/ are specified by the feature [±tense]. English also has [±tense] to differentiate tense and lax vowels, such as /i, ɪ/ (Flynn, 2012), but Mandarin does not have [±tense] (Duanmu, 2007). Now, we can actually see this in the three languages' feature hierarchies.

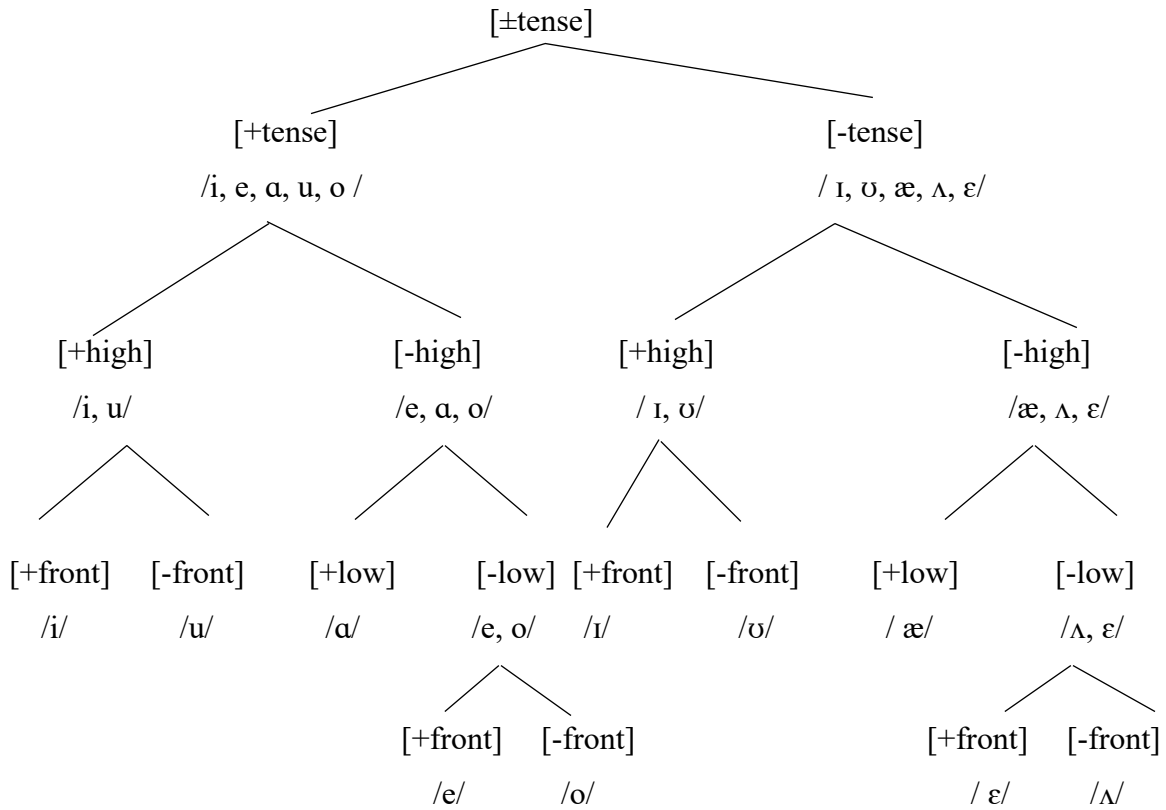
(22) Mandarin, English, Quebec French vowel feature hierarchies

a. Mandarin vowel feature hierarchy (Wu, 2021)

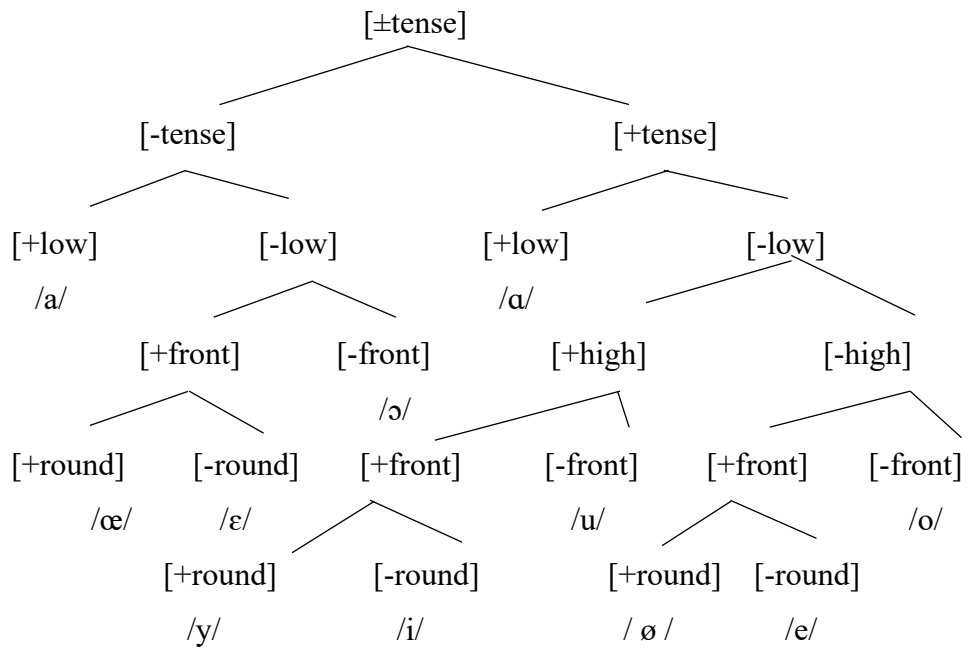


¹¹ The Canadian English feature hierarchy is used here rather than Kwon's American English feature hierarchy adapted by Archibald (2022) in his study because my participants are Canadians, speaking Canadian English.

b. Canadian English vowel feature hierarchy (Gardner & Roeder, 2022).



c. Quebec French oral vowel feature hierarchy (Hall, 2006)¹²



¹² Quebec French vowel feature hierarchy includes a [±nasal] feature ranked above [±tense] to specify the nasal vowels in Quebec French, but the present study sets aside the nasal vowels as they are not my focus.

The three feature hierarchies are constructed by examining phonological processes. For example, the selection of [+front] in Mandarin is based on frontness assimilation in which the mid vowel /ə/ becomes /e/ when adjacent to front vowels /i, y/ (Wu, 2021). In Quebec French, [±back] is selected because of assibilation (Hall, 2006; see Section 2.3.4).

As shown in (22a), the Mandarin feature hierarchy has four features [±high] > [±front] > [±low] > [±round]. In the Canadian English feature hierarchy, there are also four features: [±tense] > [±high] > [±low] > [±front], but the Canadian English feature hierarchy does not have [±round] as a contrastive feature at all. More importantly, in contemporary Canadian English system, there is no contrast between /a/ and /ɔ/ because of the low back merger, as suggested by Gardner and Roeder (2022). As presented in (22b-c), English and Quebec French both have [±tense] ranked at the top.

Bear in mind that the present study explores the acquisition of the target sounds in a third language. In L3 acquisition, numerous scholars have already proposed various models to account for various linguistic phenomena in L3A, which will be introduced, discussed and evaluated in the next section.

2.5 Theoretical Approaches to L3 Acquisition

One of the most immediate differences between L2 and L3 acquisition is that “L3 acquisition takes place when the learner has already acquired at least one L2, and the L2 has been acquired later in life than the L1” (Bardel & Falk, 2021; De Angelis, 2007; Hammarberg 2001). Compared with L2 acquisition (L2A), in L3 acquisition (L3A), both the first language (L1) and the second language (L2) potentially influence the target language (Bardel & Falk, 2021), and therefore the process of acquiring a third language is more complex since learners have two linguistic systems to choose from. As acknowledged by Cabrelli Amaro (2012), L3 acquisition is not considered as another instantiation of L2 acquisition, and therefore, it is important to not just test existing L2 models, but to build a new model of L3 acquisition. As mentioned in Chapter 1, there are a set of studies which have already provided a theoretical foundation in the field of L3 acquisition. Several models will be introduced and compared in this section with a brief discussion of the relation between those models and the present study: the Cumulative Enhancement Model

(CEM) (Flynn, 2004), the Linguistic Proximity Model (LPM) (Westergaard et al, 2017), the L2 Status Factor Model (Bardel & Falk, 2012), the Typological Primacy Model (Rothman, 2010, 2015), and the Scalpel Model (Slabakova, 2017).

2.5.1 The Cumulative Enhancement Model (CEM)

The Cumulative Enhancement Model is an L3 acquisition model proposed by Flynn (2004) that focused on morphosyntactic development. This model is considered as the first model in L3/Ln studies. Several models in L3A, such as the L2 Status Factor model (Section 2.3) and the Typological Primacy Model (Section 2.4) have been influenced by the CEM. The CEM model focusses not only the initial state, but also developmental stages, with the claim that any previously acquired structures, both from the L1 and the L2, contribute to learning an L3. Simply, it means that transfer is not a direct copy of the L1 or the L2. Transfer into the L3 will only happen when the transfer is facilitative. Facilitative influence takes place when a structure in previous languages is used in an L3 utterance, and that use is target-like in the L3. Non-facilitative influence happens when a structure in previous languages is used in an L3 utterance, but the use is not target-like and considered as an error. Overall, the CEM model predicts that non-facilitative structures will not be transferred from prior languages on learning an L3.

It is pivotal to study thoroughly the CEM model because it is the first model proposed in L3A. It gives insights to other following models. To provide evidence in support of the CEM in phonology, as mentioned by Cabrelli Amaro and Wrembel (2018), Onishi's study only finds facilitative influence from the learners' previously acquired languages, which supports the CEM. Onishi (2013; 2016) investigates the influence of experience with an L2 on the perception of L3 Japanese contrasts by L1 Korean-L2 English learners. In her study, two groups of participants were examined: L1 Korean-L2 English-L3 Japanese learners and L1 English L2 Japanese learners. The L3 Japanese contrasts Onishi tested include singleton and geminate stops (e.g. [kako], [kak:o]), long versus short vowels, word-initial voiced versus voiceless stops, word-medial voiced versus voiceless stops, intervocalic /t/ versus /d/. Some are challenging for native English speakers; some are difficult for native Korean speakers, as shown in Table 12.

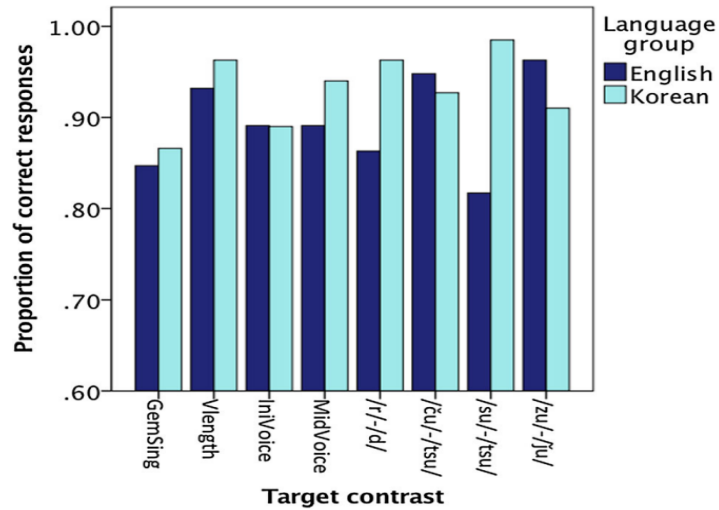
Table 12 *Cross-Linguistic Comparison of Selected Contrasts* (Onishi, 2013)

L3 Japanese contrasts	L1 Korean	L1 English
singleton and geminate stops (e.g., /kako/, /kak:o/)	Not difficult	Difficult
Short and long vowels (e.g., /ii/, /i/)	Difficult	Difficult
Word-initial stop voiceless (e.g., /bamu/, /pamu/)	Difficult	Not difficult
Word-medial stop voiceless (e.g., /maba/, /mapa/)	Difficult	Not difficult
Intervocalic /r/ and /d/	Not difficult	Difficult
Fricative and affricate /su/ /tsu/	Difficult	Not difficult

The results show that L1 Korean-L2 English learners generally perform better than L1 English-L2 Japanese learners on target contrasts in Japanese, including the contrasts that are difficult for L1 Korean speakers, such as short /long vowels, word-medial stop contrasts, and one group of fricative and affricate contrasts /su/-/tsu/ in L3 Japanese¹³.

¹³ The differences of their performance on the /su/-/tsu/ /ču/-/tsu/, and /zu/-/ju/ contrasts are significant.

Figure 3 *Proportion of correct responses* (Onishi 2016)

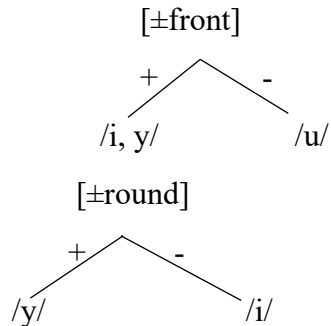


Their findings indicate that learners seem to use relevant phonological information from both their languages to perceive L3 sounds, and these learners seem to transfer only facilitative contrasts from both the L1 and L2 rather than relying only on L2 contrasts, which would lead to non-facilitative transfer to the L3.

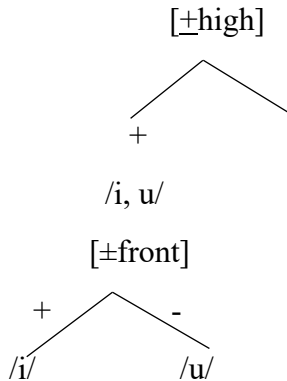
In relation to the current study, what the CEM would predict is that L1 Mandarin-L2 English learners of French would accurately perceive mid-rounded vowels /œ-ɔ/ in French because of facilitative transfer from L1 [±front, ±round], but non-facilitative influence from L2 English [±front] would not be transferred. Let's look at L1 and L2 feature hierarchies.

(23) L1 Mandarin and L2 English partial feature hierarchies

a. $[\pm\text{front}] > [\pm\text{round}]$ (Wu, 2022)



b. $[\pm\text{high}] > [\pm\text{front}]$ (Gardner & Roeder, 2022)

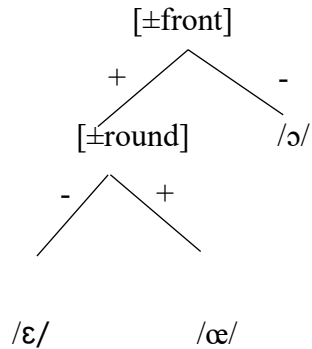


As mentioned in Chapter 1, English native speakers have difficulties perceiving front rounded vowels in French due to the lack of the feature $[\pm\text{round}]$. English only has $[\pm\text{front}]$ which would also parse $/\text{œ}/^{14}$ in French ambiguously, as in below.

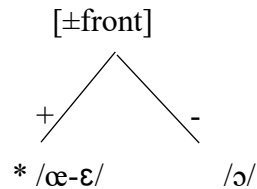
¹⁴ As mentioned earlier, prediction of errors using the contrastive hierarchy theory is rather complex. The errors are not just simply predicted based on the absence or presence of certain features. Since learners do not have relevant features, their feature hierarchy will misparse the target sounds initially, but their L1 phonetic cues also plays a role in enhancing the new sound segment acoustically from other contrasts, which eventually leads to different errors. It is hypothesized that without relevant features to parse the target sounds, both phonological features and phonetic cues will affect learners' perception. In fact, using L1 feature hierarchy, English learners will make errors in distinguishing $/y, i/$ or $/\epsilon, \text{œ}/$ first, but later their L1 phonetic cues, phonetic roundness, leads to them mis-parsing $/y, u/$ and $/\text{œ}, \text{ɔ}/$. More details are given in Chapter 3. Here, in this section, I will just use $/\text{œ}/$ as an instance to illustrate how models are utilized to predict the results in the current study.

(24) L1 Mandarin feature hierarchy vs L2 English feature hierarchy

a. Mandarin feature hierarchy parsing the L3 French input /œ/



b. English feature hierarchy parsing the L3 French input /œ/



Transferring $[\pm\text{front}]$ from L2 English is considered non-facilitative influence because it fails to facilitate parsing of /œ/. The CEM would predict that L1 Mandarin-L2 English learners of French would not transfer $[\pm\text{front}]$ from L2 English to parse target sounds. They would only transfer facilitative features [+front, +round] from L1.

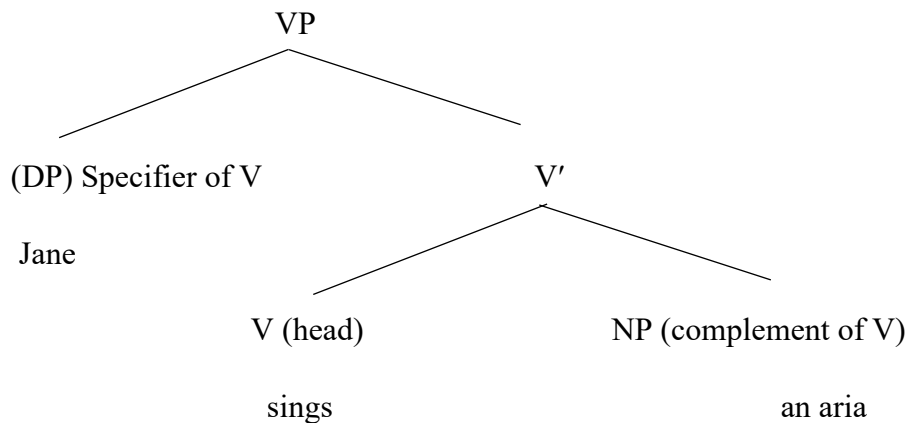
However, according to Cabrelli Amaro (2012), many studies provide evidence against the CEM, in that they document non-facilitative influence (e.g., Westergaard et al 2017). In the next section, let's look at Westergaard's Linguistic Proximity Model which predicts both facilitative and non-facilitative influences.

2.5.2 The Linguistic Proximity Model (LPM)

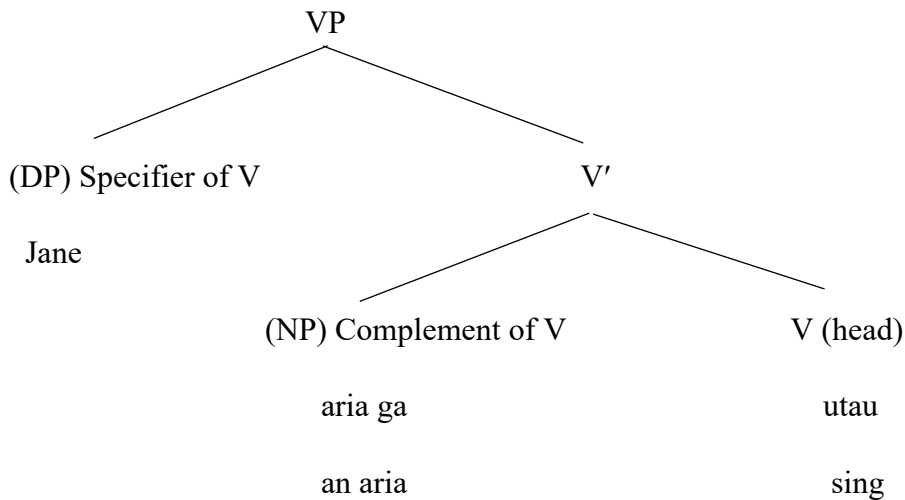
As mentioned by Westergaard, Mitrofanova, Mykhaylyk and Rodina (2017), the LPM predicts multiple sources for transfer. Westergaard (2021) uses the term *crosslinguistic influence* rather than *transfer* as she proposes crosslinguistic influence is co-activation of structures in the mind (Section 1.1.3). The source of crosslinguistic influence (CLI) with respect to a particular property is based on structural similarities between the L3 and one (or both) of the previously acquired languages. CLI takes place only if the learner is able to analyze L3 input by operating the parser on an L3 property based on the closest match in L1 / L2 or UG.

To understand how a learner parses L3 input based on parsing comparison between L1 and L2, let's take a look at one example. Assuming that a learner's first language is head-initial where heads precede their complements (e.g., English), as in (25), and his or her second language is head-final where complements precede heads (e.g., Japanese), as in (26).

(25) Head-initial



(26) Head-final



When someone learning Korean (head-final) as a third language as in (27) hears complements preceding heads, he or she is able to select a property from one previously acquired language to categorize or analyze such instances as head-final. Once the learner parses one sentence and it works, after parsing more examples, this parsing success leads to a proximity judgement of previous acquired languages. After this parsing comparison, the learner will select the Head-final structure from L2 Japanese to parse Korean.

To illustrate this, the learner is able to parse the Korean sentence in (26) by the head-final structure he or she acquired in Japanese, and the output of the parse tells the learner that that *Mimi* is a noun phrase (DP) and the subject of the sentence, *book read* is a verb phrase containing the direct object of a main verb book and the main verb read, so Korean is categorized as head-final. Bear in mind that properties from both previously acquired languages remain active in a learner's mind and can potentially influence L3 acquisition. What property is actually selected will depend on the parsing comparison.

(27) Mimi-ka chayk-ul ilk-ess-ta (Kim, 2016)

Mimi-NOM book-ACC read

'Mimi read the book.'

Furthermore, according to the LPM, language acquisition involves property-by-property learning with both facilitative and non-facilitative influence from one or both

previously acquired languages (Westergaard, et al 2017). Facilitative influence occurs when learners analyze the L3 input and find a structural similarity based on the parsing comparison: by analyzing L3 input, “learners make predictions about the L3 structure by consulting previously acquired grammars” (Westergaard, et al 2017, p. 15). Crucially, it does not have to result in a correct analysis. Non-facilitative influence happens when learners analyze L3 input incorrectly or lack sufficient L3 input, and this misjudgment of similarity leads to a misparse: they make an incorrect prediction that “a property is shared between the L3 and one of the previously acquired languages” (Westergaard, et al 2017).

To clarify this, let’s see one example given by Westergaard et al (2017) using a grammaticality judgement task.¹⁵ L2 Russian has adverb-verb word order (an adverb is placed before a verb). Similarly, English also has adverb-verb word order, but unlike Russian and English, Norwegian has verb-adverb word order (an adverb is placed after a verb but before an object), as shown in (28).

(28) **Adverb-verb** word order

English = Russian ≠ NOR

Emma **often** eats sweets ENG

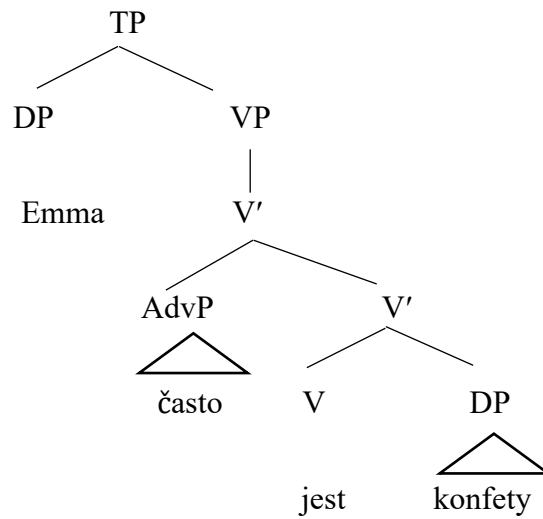
Emma **často** jest konfety RUS

Emma spiser **ofte** konfekt NOR (Westergaard et al, 2017, p. 6)

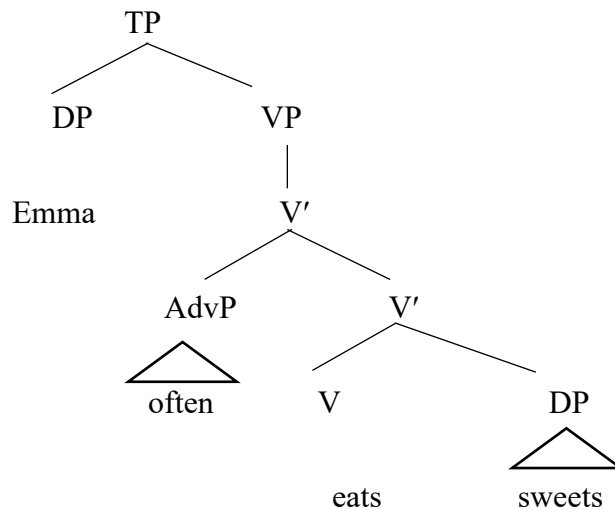
Facilitative influence takes place when L1 Nor-L2 Russian learners judge the English sentence (e.g., ‘Emma often eats sweets’) grammatical by analyzing the English sentence with the adverb-verb structure they acquired in Russian. Because of structural similarity, Russian structure as in (29) facilitates the parsing of English sentence, as can be seen in (30).

¹⁵ The grammaticality judgement task is a research method used to study language acquisition. In this task, participants hear or read a sentence and are asked to judge whether it is grammatical or not (Greenbaum, 2012).

(29) Adverb-verb word order (Russian)

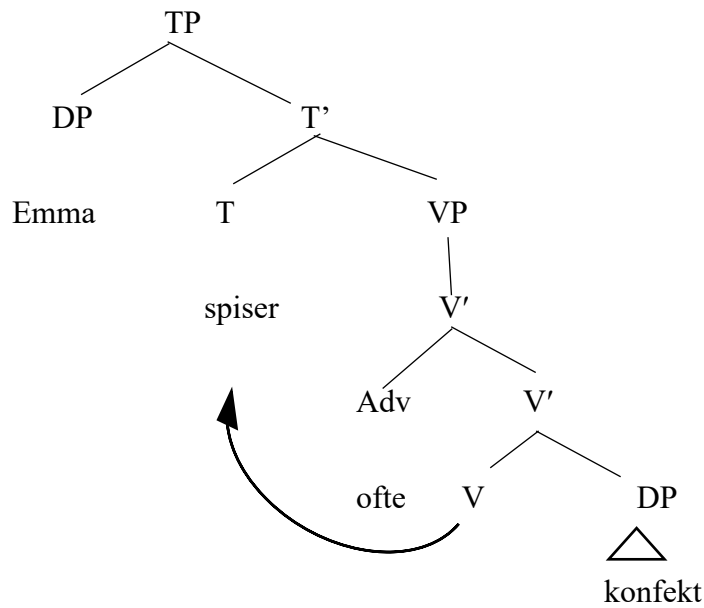


(30) Facilitative influence from Russian to perceive English

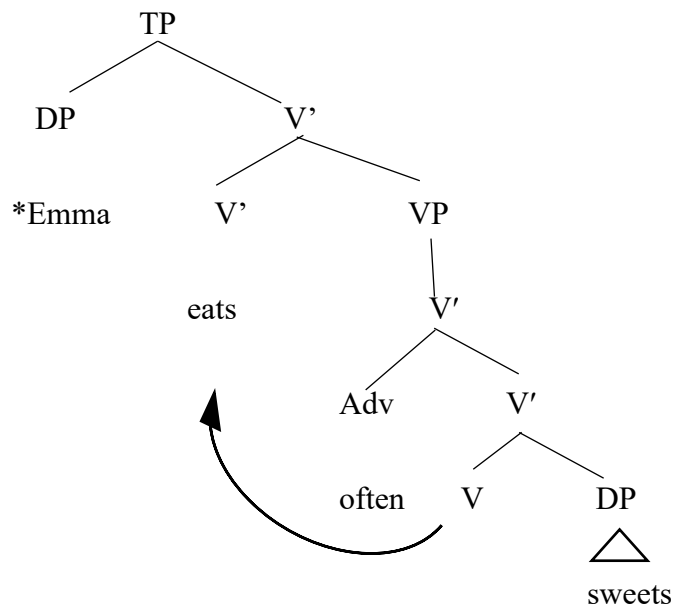


As mentioned previously, when bilingual participants misanalyse L3 input (and/or have not had sufficient L3 input) by choosing the wrong property from one of the previous language sources, non-facilitative influence happens. In relation to L1 Nor-L2 Russian learners, when they judge the English sentence ungrammatical, they compare the word order of the English sentence to the verb-adverb structure acquired in Norwegian in (31) because the English sentence does not have the word order of the structure in (32).

(31) Verb-adverb word order (Norwegian)



(32) Non-facilitative influence from Norwegian to perceive English



The LPM is a model proposed recently to explain syntactic phenomena. In L3 phonology, Wrembel, Marecka, and Kopečková's (2019) study is in support of the LPM to some extent, but they did not look into phonological features. They investigate the perception of vowel cross-linguistic similarity by L1 German-L2 English learners in an

AX discrimination task. The participants listened to minimal pairs differed in the medial vowel in three languages: 6 Polish (*bet, bat, bit, byt, but, bot*), 9 English (*bet, bat, but, beat, bit, boot, book, bot, bought*), and 9 German (*bett, bad, biet, bitt, bütt, buht, butt, bot, boot*), and they were required to indicate the degree of similarity (accuracy and reaction time) between the two vowels in two different languages. The order of comparison is Polish vs English, Polish vs German. German, English and Polish vowels tested in their study are given below. Those vowels were embedded in the words shown in the quotations above.

Table 13 *German, English and Polish Vowel Tested* (Wrembel, et al, 2019)

L1 German	L2 English	L3 Polish
/i-i/, /u-u/, /y-y/, /a-a:/	/i-i/, /u-u/	no phonemic vowel length

Their findings suggest that many L1 German-L2 English participants receive non-facilitative influences from both L1 and L2: they would rate L3-L1 pairs the same or L3-L2 pairs the same. This study demonstrates what the LPM proposed that learners would transfer from both the L1 and the L2, with non-facilitative transfer as well.

Needless to say, the LPM has played a vital role in the present study to inspire my hypotheses that L1 Mandarin-L2 English speakers should receive facilitative influences from both L1 and L2 in the perception of L3 Quebec French vowel pairs [y, ʏ], as given in Chapter 1. After viewing two models (the CEM and LPM) that allow transfer from both the L1 and the L2, let's look at two different models: the L2 Status Factor Model (L2SFM), the Typological Primacy Model (TPM), and the Scalpel Model.

2.5.3 The L2 Status Factor Model (L2SFM)

The L2 Status Factor Model (L2SFM; Bardel & Falk, 2012; 2021; Bardel & Sanchez, 2017) proposes that when a learner acquires an L3 specifically in sequential instructional contexts, their L2 has a privilege to be transferred as a primary source of transfer. This model adopts a particular neurolinguistic model, which is called the declarative/procedural memory elaborated by Paradis (1994) and Ullman (2001).

To make it explicit, this neurolinguistic approach, according to Ullman (2001), suggests that all late-learned languages (L2, L3, Ln) are sustained mostly by declarative memory (also known as explicit memory) that consists of information that can be consciously aware when people store and recall, such as an important life event. However (under this model), native language (L1 grammar) is sustained by procedural memory (also known as implicit memory), which is a type of long-term memory that helps to perform actions or skills, such as riding a bike without conscious awareness of these actions (Ullman, 2001). According to Bardel & Falk (2012), because all the late-learned languages are sustained in the same memory system, it seems that they are more likely to manifest interference from one another. In addition, in Bardel and Sanchez's (2017) revised version of the L2 status factor, they emphasized explicit knowledge of a language, the knowledge learned in a formal context and individual differences.

Building on Bardel & Falk's empirical research in L3 acquisition, Llama, Cardoso & Collins (2010) examined two factors, typology and L2 language status, in the selection of language source for phonological influence in L3 acquisition, although their study is in fact an investigation of phonetic features not phonological features. Two learner groups have Spanish as an L3 with English L1 and French L2 or French L1 English L2. Participants were asked to read word lists including voiceless stops /p, t, k/ in onset and stressed positions. In relation to typological relatedness, French and Spanish have similar VOT values ranging from 0 to 30 ms for voiceless stops, while English has a different VOT value ranging from 60 to 100 ms for voiceless sounds compared, as in Table 14.

Table 14 *L3 Phonetic Features by English, French, Spanish* (Llama et al, 2010)

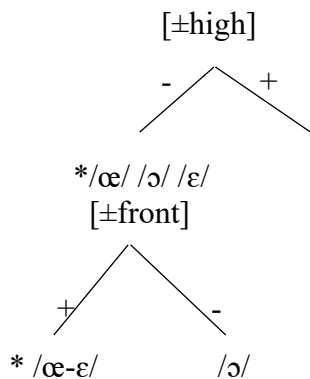
Language	VOT Value (voiceless)	Typology
French	0 to 30 ms	Similar to Spanish
Spanish	0 to 30 ms	Similar to French
English	60 to 100 ms	Different from Spanish and French

Their main findings suggest that participants have transferred VOT value from their L2s to their L3, which indicates that typology is not a prominent factor in CLI. Even though

it is a study that investigates phonetic features, it does give some support to the L2 Status Factor Model.

With respect to the present study, using the L2 Status Factor Model, it would predict that L1 Mandarin-L2 English learners of French rely mainly on L2 English when perceiving L3 target sounds, such as the mid front rounded vowel /œ/ in French. In that case, learners would use only the L2 English feature [±front] to distinguish French /œ/ from other vowels of the same height, which would lead to more errors since [±front] fails to differentiate /œ/ from /ɛ/, as shown in (33).

(33) Only English feature hierarchy parsing the L3 French input /œ/ based on L2SFM



However, my hypothesis is that L1 Mandarin-L2 English learners of French should be able to accurately perceive the contrasts in the mid vowels /ɛ-œ-ɔ/ in French because of facilitative influence from their L1, which has both [±front] and [±round]. The experimental results from the present study will allow me to test between the predictions of these models.

It is important to note that this model predicts that transfer is restricted only to the non-native (L2) grammar, instead of the L1 grammar. Several studies provide evidence against the L2SFM (Hammarberg, 2014; Barkley, 2010). For example, Bardel and Falk (2017)'s model does not really take language distance and typology into account (Bardel & Falk, 2021). In the next section, let's see a model that completely takes typology into consideration, the Typological Primacy Model (TPM).

2.5.4 The Typological Primacy Model (TPM)

The Typological Primacy Model proposes that “structural proximity between the L3 and the L1 and/or the L2 determines L3 transfer” (Rothman, 2013. p. 179). In this model, typological closeness or similarity is the trigger learners rely on to transfer the L1 or L2 into the L3: if the native language was more similar to the L3, the L1 would be copied. If the L2 was determined to be more similar, the L2 would be copied.

Transfer in this model occurs in a wholesale fashion, which entails that every property that is typologically closer to the target language will be directly transferred to the target L3. The reason for this wholesale transfer is cognitive economy, which can be understood in the phrase “human cognition economically defaults to learning paths of minimal exertion” (Rothman, 2013, p. 180). According to Rothman, when acquiring a new language, people’s cognitive processes tend to reduce the processing costs and efforts. Complete transfer takes place at the earliest moment when the parser processes enough linguistic information from the L3 input to determine which of the two languages is typologically similar to the target L3. The TPM invokes four levels of evaluation to determine the similarity to the previously acquired languages: lexicon, phonology, morphology, and syntax.

To give an example, Rothman and Cabrelli Amaro (2010) compare the initial stage of null-subject related properties¹⁶ for L3 learners of Italian and French with L1 English-L2 Spanish (French is like English, while Spanish is like Italian for null-subject properties), as shown in Table 15.

¹⁶ A null subject is the absence of an overt pronominal subject. For example, Italian is a null subject language in which the subject can be dropped in a sentence, but in Italian, the verb generally carries enough information to identify the person and number of the subject (e.g., *Faccio una torta* ‘(I) bake a cake’) The verb *faccio* is a conjugated form of *fare* that shows first person singular agreement, indicating that the null subject is ‘I’. On the other hand, English and French are not null-subject languages and require an explicit subject (e.g., *I ate an apple*; **Ate an apple*).

Table 15 *A Summary of Language Backgrounds* (Rothman, et al, 2010)

Null-subject properties	L1 English	L2 Spanish	L3 French	L3 Italian
[null subject]	No	Yes	No	Yes

The results indicated that learners transfer the syntax of Spanish for null subjects to match the syntax of the L3 Italian and the syntax of English to match the syntax of L3 French. This example demonstrates wholesale transfer because learners transfer the previously acquired language that is closer typologically to the target L3.

Furthermore, Rothman (2013) claims that the typological structural similarity is not surface but “linguistic properties that overlap cross-linguistically at the level of mental representation” (p.181). The parser in the TPM is used to determine transfer selection. When exposed to L3 input, the parser would provide “a first-pass assessment of structural proximity for the purpose of transfer selection” (p. 6). To do so, the parser analyzes the linguistic information based on a hierarchical continuum of linguistic cues (as shown below) until the parser has taken sufficient input to decide structural similarity among the languages. Bear in mind that this parser processing takes place unconsciously not dependent on surface level dis(similarity). The TPM rejects the notion that learners can consciously evaluate typological similarity.

(34) Syntactic Structure (e.g., verb-raising)



Functional Morphology (e.g., gender markers)



Phonological / Phonotactic Cues (e.g., voice onset time duration)



Lexicon (e.g., vocabulary)

More specifically, in this hierarchy structure, lexical similarity plays an important role in transfer selection. One example given by Rothman is Mongolian L1 → L2 French →L3

Turkish: with more experience with the L3. After finding enough lexical similarity between French and Turkish, the parser will stop working and make an unconscious decision on transferring French which is lexically similar to Turkish without searching for similarity at a higher level in the hierarchy, such as syntax. When there is not enough similarity at a lower level of the hierarchy (lexicon), the parser would go further up to look for cues for phonology/phonotactic and syntactic structure to assess the typological similarity to make a decision as to similarity.

If the TPM was used in the present study, we would expect to see that typological relatedness is the decisive factor for learners to transfer. If there is enough lexical similarity between Mandarin and French or English and French, the parser introduced by Rothman (2013) will stop searching and make decision for transfer selection. In our case, English and French are definitely more lexically similar (Poplack, Sankoff, and Miller, 1988), and therefore English would be the main source for transfer. L1 Mandarin-L2 English learners would be expected to perform very similarly to L1 English speakers in the perception of French vowel contrasts.

Overall, the TPM predicts that that linguistic/structural similarity will be the decisive factor when it comes to determining typological similarity. More importantly, it argues for wholesale transfer, which is the copying of one of the previously acquired grammars in the initial stages, and it allows facilitative and non-facilitative influence. It depends on the comparative perceived typology of the language patterns or a speaker's perception of typological proximity.

2.5.5 The Scalpel Model

The Scalpel Model proposed by Slabakova (2017) is a model that shares some features with the CEM and some features with the LPM. Like the LPM, the Scalpel Model argues against wholesale transfer. As Slabakova (2017) stated, “transfer is selective and works property by property” (p.3). The Scalpel Model allows for facilitative and non-facilitative transfer. Wrembel et al (2019)'s study of the perception of vowel cross-linguistic similarity (in section 2.5.2) can be evidence to support the Scalpel Model. More importantly,

Slabakova (2017) argues that “the activated grammatical possibilities of the L1-plus-L2 combined grammar act with a scalpel-like precision, rather than as a blunt object, to extract the enhancing, or facilitative, options of L1 or L2 parameter values” (p. 5). As Slabakova (2017) explained, being multilingual does not mean a learner has three or more monolingual systems stored separately in their head. Rather, Slabakova (2017) states that learners have a multilingual linguistic competence consisting of sub-grammars from the previously acquired languages, “equipped with some differentiation mechanism” (p.5). To be more specific, if an L1 and an L2 grammar have been acquired, a learner will have both the L1 and L2 in their mind. In the learner’s bilingual mind, each grammar has a tagging device for its properties or features (Bialystok, Craik, Green, & Gollan, 2009), so when L1 or L2 grammar is needed to parse the L3 target sound, because of the tagging device, both the properties or features of the L1 or the L2 or both are possible to be successfully selected. According to this view, neither the L1 or the L2 have a privileged status to be transferred, which implied that wholesale initial transfer is unessential because the scalpel function is able to successfully select the relevant features and properties when needed (Slabakova, 2017, p. 5). Needless to say, the Scalpel model incorporates several important insights from the other L3A models. In line with the CEM and the LPM, it advocates property-by-property transfer. Similar to the TPM and the LPM, it allows non-facilitative transfer. Like the LPM, it supports multiple sources for transfer and argues against wholesale transfer at the initial stage, making the same prediction as the LPM (Slabakova, 2017).

2.5.6 Summary

In this section, five theoretical models have been introduced and discussed, as shown in Table 16. It is interesting to note that that in this chart the LPM and Scalpel are identical, and the L2SFM and the TPM are identical except they differ as to the reason for the wholesale transfer. The CEM is the only model that rejects non-facilitative transfer compared with the other models.

Table 16 *A brief summary of five models*

	The CEM	The LPM	The L2SFM	The TPM	The Scalpel Model
Property by property transfer	Yes	Yes	No	No	Yes
Wholesale transfer	No	No	Yes	Yes	No
Only allow facilitative transfer	Yes	No	No	No	No
Allow both facilitative and non-facilitative transfer	No	Yes	Yes	Yes	Yes

It would be interesting to evaluate and discuss those models after viewing the results of the present study. The discussion of each model will be given in the Discussion section.

As seen in this section, those models are used mostly in syntax but rarely in L3 phonology. To look into how they inspire L3 phonology, it is necessary to gain a basic understanding of phonological acquisition, specifically the relation between phonetics and phonology. In the next section, we will see the relation between phonetics and phonology with respect to phonetic implementation of phonological features.

2.6 Phonological Acquisition

2.6.1 Phonetics to Phonology

In previous sections, we have looked at the phonological structure represented in a contrastive feature hierarchy model and how the feature hierarchy plays a role in parsing non-native segments. As mentioned by Kwon (2021), even though an L2 learner may have the relevant features to parse the target segments, he or she may still sound different from a native speaker. The reasons could be because (1) they have a different ranking of features,

which affects the learners' perception and production and (2) phonetics also plays a role here.

Phonetics is defined as physical implementation of phonological structures (Cohn & Huffman, 2014). Avery and Idsardi (2001) proposed that phonetic gestures are organized by phonological dimensions which are phonological features in the phonological grammar. Each dimension such as [Tongue Height] or [±high] (the two features are equivalent) in their proposed model needs to be filled with a phonetic gesture such as front (palatals) or back (uvulars). Similarly, Hall (2011) proposed phonetic enhancement features, which are phonetic gestures in the contrastive hierarchy theory, which explain the interface between phonetics and phonology. The present study adopts Hall's approach because the phonetic enhancement features he proposed function particularly in contrastive feature hierarchy model, which is the phonological model employed in the current study. Next, let's look into Hall's phonetic enhancement in the CHT.

2.6.2 Phonetic Enhancement in the Contrastive Hierarchy Theory

As Hall (2011) proposed, phonetic enhancement can be used to explain cross-linguistic patterns in how phonologically underspecified segments are realized phonetically.

Phonetic enhancement theory (Stevens & Keyser, 1989) posits that there is a set of highly salient 'primary' distinctive features, such as [±tense] on /i, ɪ/ in English. They are phonological features that distinguish one phoneme from another, and then there are 'secondary' features that are redundant features but acoustically enhance the primary features. Inspired by Stevens & Keyser, Hall (2011; 2016) argues that contrastive features that are represented in the hierarchy, are primary, while non-contrastive properties function to enhance them acoustically. In other words, non-contrastive properties—redundant features—of a phoneme are used to enhance the distinctiveness of its contrastive features. Let's look at one example to illustrate this.

In Mandarin, [±front] is ranked higher than [±round] ([front]>[round]). As mentioned earlier, /i/ and /y/ trigger frontness assimilation in Mandarin (Duanmu, 2007), which implies that /i/ and /y/ must have a contrastive feature [+front], so both of them are specified

with [+front], and then [±round] is the only feature that differentiates them, so it is assigned lower to differentiate /i/ and /y/. In the ranking below, /i/ and /y/ are specified with [+front, -round] and [+front, +round]. There is no other feature needed to distinguish them, meaning that they do not need to have any phonetic enhancement features to enhance their contrastiveness, unlike /u/, which is without a contrastive counterpart under the [-front] node as in Table 17.

(35) Mandarin feature hierarchy

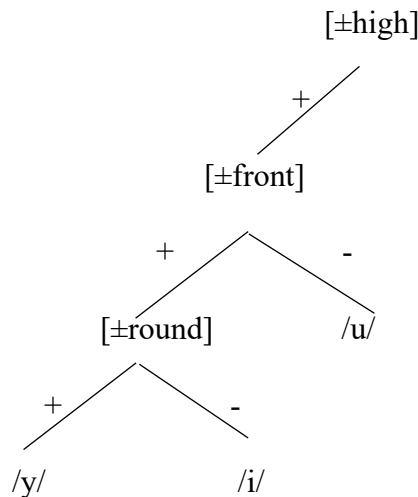


Table 17 *Phonological features in Mandarin*

+high	+front	-front
	-round /i/ +round /y/	/u/

In Mandarin, [-front] is also a phonologically active because it triggers backness assimilation (Duanmu, 2017), which means that /u/ also needs to be contrastively back. An example of a redundant feature used for phonetic enhancement is rounding on /u/: /u/ is not contrastively [+round], but redundant rounding enhances [-front] because both rounding and contrastive backness have the effect of lowering F2. Keep in mind that redundant rounding is a phonetic property, so it is not represented in the contrastive feature hierarchy, so /y/ is both phonologically and phonetically round, but /u/ is only phonetically round.

As Hall (2011) mentioned, in line with the contrastive hierarchy theory, if phonological representations include only contrastive features, those predicable properties

of sounds such as roundness in Mandarin /u/ should be filled in the transition from phonology to phonetics, so he proposes his view of the phonology-phonetics interface from aspects of the contrastive hierarchy theory and enhancement theory as shown below.

(36) Elements of a theory of contrast and enhancement (Hall, 2011, p. 19).

- a. Phonological feature specifications are assigned by the Successive Division Algorithm.
- b. Only these contrastive feature specifications are phonologically active.
- c. In phonetic implementation, redundant properties of segments tend to be filled in in ways that enhance the auditory impression of their contrastive features.
- d. Phonetic enhancement is variable across languages, speakers, and contexts, and distinctness of phonemes is sometimes reduced by other factors, such as articulatory overlap (Stevens & Keyser, 2010, §4).

Using /u/ in Mandarin as an example, Hall’s phonology-phonetics interface is illustrated in Table 18. Because of backness assimilation, /u/ is specified with [-front]. Redundant rounding phonetically enhances [-front]. The arrows indicate the relation between phonetics and phonology.

Table 18

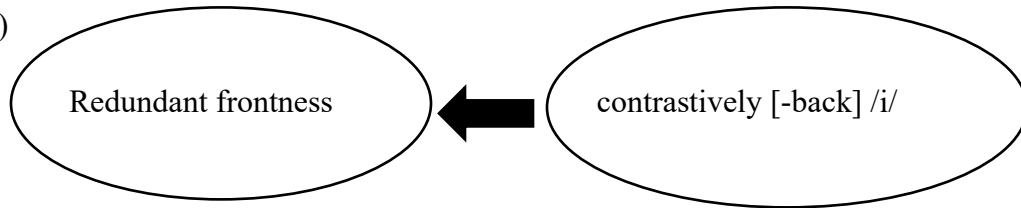
Phonological processes	Phonological features	Phonetic enhancement
Backness assimilation ➡	[-front] ➡	Redundant rounding

There are several ways to enhance a particular feature (Hall, 2011), as discussed below. The following principles are taken from Hall (2011. p. 20).

- a. A contrastive feature can be enhanced by increasing its articulatory and acoustic effect. For example, a contrastively [-back] vowel such as /i/ can be acoustically enhanced by frontness in which the tongue body is pushed toward the hard palate. The arrows describe the relation between contrastive features and phonetic enhancement features.

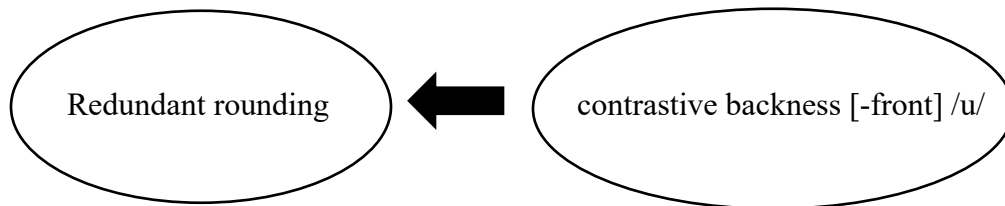
(37)

(a)



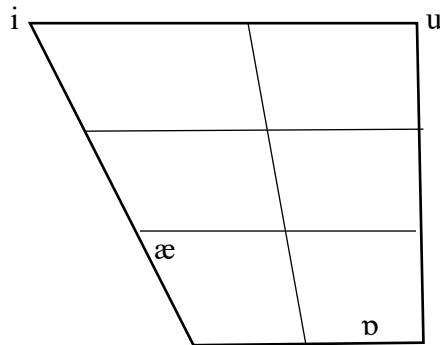
b. A feature can be enhanced by the addition of phonetic articulation (physical action) with a similar acoustic/auditory effect. Contrastive backness can be acoustically enhanced by redundant rounding because both have the effect of lowering F2 (Hall, 2011. p. 20). (b) is an example of the back vowel /u/ in Mandarin.

(b)



c. A feature can be enhanced by phonetic articulation that facilitates the forms of enhancement described in (a) and (b). As Hall explained, “a contrastively [-back] or [+back] vowel can be enhanced by being realized as high, because the upper part of the vowel space permits a wider range of variation in F2 (tongue advancement): [i] is more front than [æ], and [u] is more back than [ʊ]” (Hall, 2011. p. 20), as given below.

(c)



Hall (2011) stated that the ranking of constative features makes restrictions on the underspecification of inventories and limits the phonetic properties of individual segments.

As shown in (35), the feature hierarchy imposes restrictions on the phonetic properties of each segment in Mandarin. Because of the ordering of the features, /i/ and /y/ are contrastively specified for both [+front] and [±round], and so neither of these properties can be deployed as an enhancement of the other; the place and rounding of these vowels are fully determined by their phonological feature specifications. /u/, on the other hand, has no phonological specification for [±round], and so its phonetic implementation can use rounding as an enhancement of its specification for [-front]. Further, as Hall (2011) mentioned earlier, phonetic enhancement is variable across languages, which means that the phonetic enhancement of [-front] in Mandarin might not be found in English or French. In this section, we have gone through a detailed explanation of phonetic enhancements from a theoretical approach. Next, let's look at briefly phonetic enhancement from an applied approach.

2.6.3 Phonetic Enhancement and Cues

In previous sections, we have introduced phonetic enhancement and its relation to phonology. Broadly speaking, phonetic enhancements are acoustic cues used to increase the contrastiveness between two sounds. *Cues*, according to Wright (2004), are acoustic information used to perceptually distinguish phonological contrasts in linguistic input. According to (Grenon, Kubota & Sheppard, 2019), English speakers rely on formant cues to perceive the difference between /i-ɪ/ in English. *Formants* are acoustic energy with a particular frequency in the sound wave, showing a resonance in the vocal tract and mostly being used to identify a vowel sound (Wood, 2005). However, recognizing phonological contrasts in the L2 input can be difficult for learners because they rely on cues used in their first language to perceive phonemes (Flege & Hillenbrand, 1984). L2 learners of English may inaccurately perceive and categorize cues that are not present in their L1 or not attend to them at all. Turning to a segmental example, a naive speaker of Japanese learning English may use vowel length cues from Japanese to perceive the /i-ɪ/ tense (long duration) and lax contrasts (short duration) in English rather than using the English spectral or formant cues. Needless to say, learners are sensitive to different cues because of their different language backgrounds. Japanese speakers are sensitized to rely on duration

differences from their L1 when perceiving English tense and lax vowels rather than spectral cues as English speakers do (Grenon et al, 2019), so duration is an important cue used in vowel discrimination for Japanese speakers (Harmon Idemaru & Kapatsinski, 2019). Since languages differ in relation to cue ranking, it is important to keep in mind that phonetic enhancement features (secondary cues) from the L1 could affect learners' perception of the target sounds in L2 or L3 to a large extent.

Referring back to Kwon's statement at the beginning of this section, we need to recognize that the ranking of features in addition to phonetics (redundant features in a contrastive feature hierarchy) can both affect learners' performance of the target sounds. As Archibald (2023) stated, the learner detects phonetic variation in the input, analyzes the phonetic variation in the perception system and makes a decision to represent such variation with feature values. The role L1 phonetic enhancement features play here is to help enhance the contrastiveness of the phonetic implementation of a contrastive feature, making a phoneme more distinct from others in the inventory. Speaking of phonemes, the present study investigates both phonemes and allophones. It is necessary to make a clear distinction between them before moving to the next chapter.

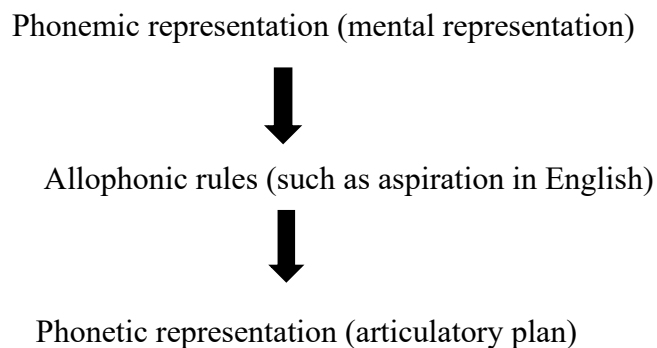
2.7. Phonemes and Allophones

As noted in Chapter 1, the present study examines four pairs of target sounds which are the tense and lax vowels /e, ε/ and [y, ʏ]; the front and back rounded vowels /y, u/ and /œ-ɔ/. [y, ʏ] is an allophonic contrast, and thus different from the other phonemic contrasts. There are two levels of representation: the phonemic level and the phonetic (or allophonic level). Phonemic representation is defined as "the phonological form of linguistic expression represented in the mental lexicon" (van der Hulst, 2016. p. 6). To put it simply, how a speech sound is represented in the mind. An example given by Anderson (2018) is that the word *clean* is represented phonemically like /klin/ in our mind.

In contrast, the phonetic representation is an articulatory plan (van der Hulst, 2016), which means how speech sounds are articulated and pronounced. For instance, *clean* /klin/ is stored in our mind, but English speakers actually say [k^hʎi:n] (Anderson, 2018). In other

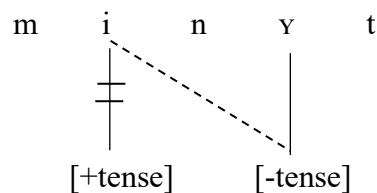
words, when a given phoneme is spoken, it gets pronounced as the particular allophone conditioned by the surrounding context. Referring back to the word *clean*, when pronouncing *clean*, the underlyingly voiced /l/ becomes a voiceless [ɫ] following the voiceless [k^h] because of assimilation. /k/ is pronounced as [k^h] because voiceless stops in English are aspirated when they are word-initial (Wissing, 2005).

At the phonemic level, there are no details about allophonic variation. The relation between phonemic and phonetic representations can be categorized as three levels in below. The flowchart is adapted from van der Hulst (2016).



Turning back to the present study, the contrast between [y] and [ɥ] in Quebec French is allophonic, which means that these vowels are not distinct at the phonemic level, but [y] and [ɥ] are involved in a phonological process where lax allophones of a high vowel, such as [ɥ] in a final closed syllable trigger regressive harmonic laxing of high vowels in previous syllables (/minyt/, [minɥt]) as shown in (38). [ɥ] spreads [-tense] to /i/ which is specified for [+tense], so /i/ receives [-tense] and becomes a lax vowel [ɪ]. In addition, [±tense] still needs to be represented in learners' contrastive hierarchy because of the phonemic contrast between tense and lax mid vowels in Quebec French.

(38) Feature spreading in regressive laxing harmony



From an acquisition approach, phonological processes have a vital role to play in acquiring a target sound. As Archibald (2022) stated, the Activity Principle and the

Contrastive Hierarchy determine available sources to the learner to construct the L3 feature hierarchy. The Activity Principle means that the L3 learner needs to be exposed to the features triggering phonological processes in the L3, such as [-tense] in laxing harmony. This phonological process of laxing changes high vowels from [+tense] to [-tense]. Such a phonological process is a cue to help the learner realize that [\pm tense] is an active feature in Quebec French, and to make a contrast, [\pm tense] is needed to categorize tense high vowels.

In this chapter, there are several concepts that have been introduced and discussed. They are important theoretical foundations of the current study. It is important to understand that the contrastive hierarchy theory, a learning and representational model, has been developed and elaborated by numerous scholars (Archibald, 2022; Hall, 2011; Kwon and Starr, 2023; Purnell, Raimy, and Salmons, 2019). Also, there are previous studies that have been conducted in language acquisition using this model (Archibald, 2020; Bohn and Santos 2018). It is a powerful model that enables us to compare two or three feature hierarchies and helps us gain insight into the acquisition process in L3A.

In the next chapter, let's look at the research questions the present study aims to address and explore the hypotheses based on the feature hierarchies of three languages. The research methods will also be introduced.

CHAPTER THREE: METHOD

In this chapter, my hypotheses will be introduced and elucidated in the contrastive hierarchy theory, followed by my research questions. Then, my research design and research procedure are given.

3.1 Hypotheses

In this section, I will present hypotheses and predict likely errors using the contrastive hierarchy theory. My general hypothesis is that feature hierarchies drawn from the L1 and/or the L2 can be used to parse new L3 phonemic contrasts. My hypotheses 1 and 2 are specific applications of this general hypothesis. Let's look at them one by one.

3.1.1. Hypothesis 1: The Selection of [±front] > [±round] in L1 and [±tense] in L2

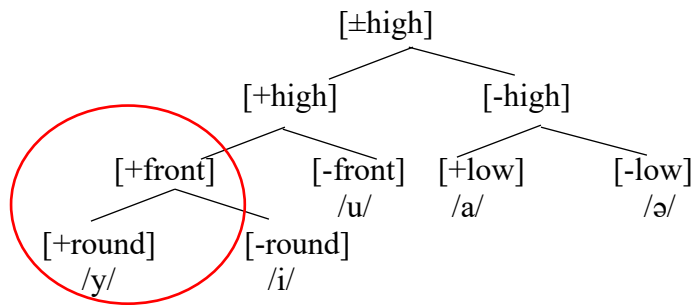
The contrastive hierarchy is the repository that can be accessed by learners (Archibald, 2023; Kwon & Starr, 2023), and language learners' L1 and L2 phonological feature hierarchies heavily influence the structure of their integrated I-language. Integrated I-language, according to Archibald (2023), means that both L1 and L2 are stored in a common accessible location. L3 learners do not have to choose whether to transfer L1 or L2 because any previous I-grammar is available to be selected for transfer.

As mentioned previously, Mandarin and English do not have the tense/lax contrast [y, ʏ], and Mandarin does not even have tense and lax contrasts, but Mandarin and English have the necessary features ([±front] > [±round] from Mandarin and [±tense] from English) to parse [y, ʏ]. This would help L1-Mandarin-L2 English learners establish their L1-L2 integrated grammar to parse [y, ʏ].

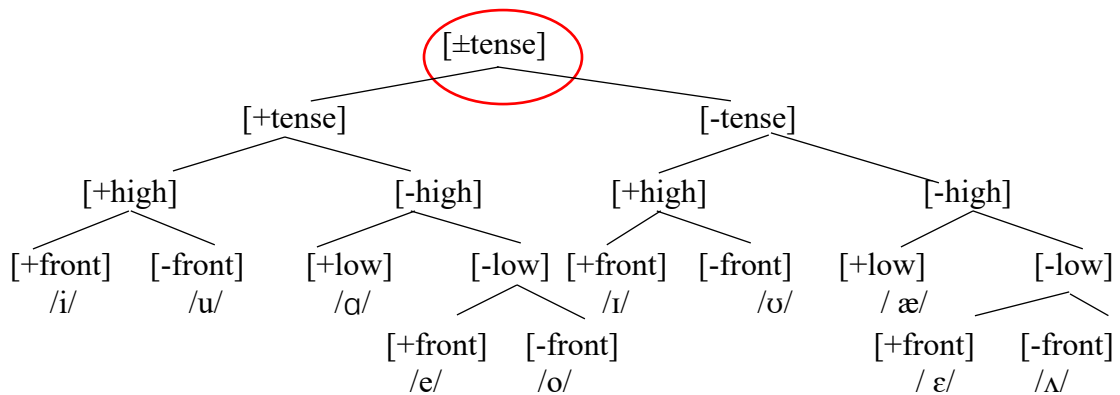
Hypothesis 1: L1-Mandarin L2-English learners will select the L1 phonological ranking [±front] > [±round] (used to distinguish /y/ from /u/ or /i/), and the L2 English [±tense] feature (used to distinguish tense and lax contrasts, such as /i/ from /ɪ/) to parse the L3 tense and lax vowels allophonic contrast [y, ʏ]: [ʏ] is not found in either Mandarin or English.

Let's illustrate hypothesis 1 by looking at what is transferred from the Mandarin and English feature hierarchies. Given the linguistic proximity model, which states that learners are able to select the necessary structures from their previously acquired languages to parse L3 target sounds, the sources of potential transfer are shown in (38-39). Mandarin has $[\pm\text{front}] > [\pm\text{round}]$ used to distinguish /y/ from /i/. In English, $[\pm\text{tense}]$ is used to differentiate tense from lax vowels.

(38) Mandarin vowel feature hierarchy (Wu, 2022)

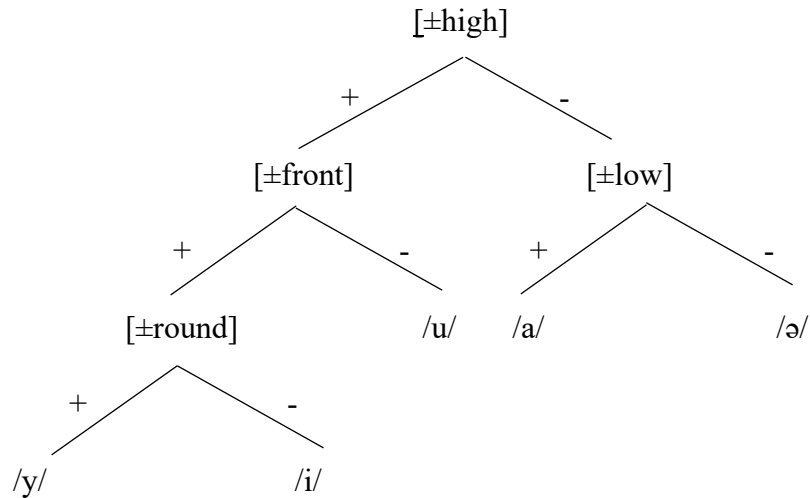


(39) Canadian English vowel feature hierarchy (Gardner & Roeder, 2022)



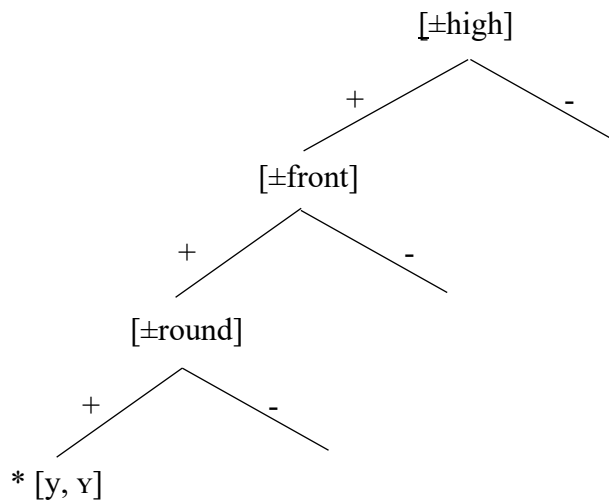
To understand how L1-Mandarin L2-English learners will parse [y, ʏ], let's step back to look at how Mandarin monolingual speakers will parse tense and lax vowels first. The contrastive hierarchy of Mandarin is displayed in (40) and represents monolingual Mandarin speakers' grammar. I will elucidate how perceptual difficulties can be predicted for a monolingual Mandarin speaker.

(40) Mandarin feature hierachy (Wu, 2021)



As can be seen in (41), [±front] > [±round] in Mandarin is able to parse [y] in Quebec French, but Mandarin does not have contrasts between tense and lax vowels, and therefore the [±tense] feature is not needed, which hints that Mandarin monolingual speakers are likely to conflate tense and lax vowels in Quebec French.

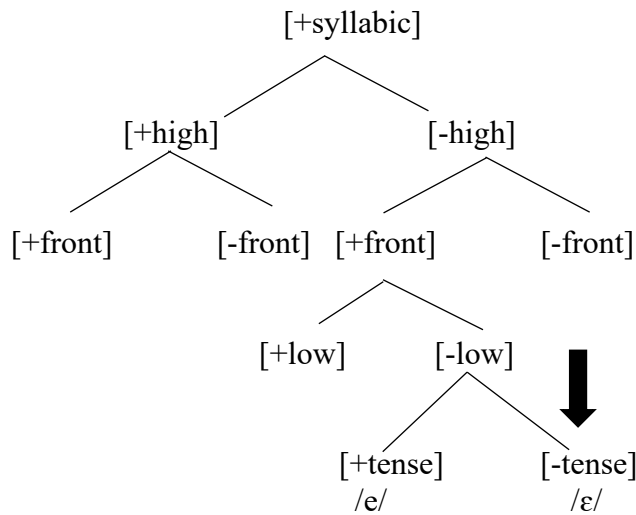
(41) Mandarin feature hierarchy parsing [y, ʏ] in Quebec French



The node containing more than one vowel suggests that [y, ʏ] cannot be distinguished, which means that Mandarin monolingual speakers cannot parse the [y]/ [ʏ] contrast successfully. To be more specific, although [y, ʏ] are allophones in Quebec French, [±tense] is active on high vowels. On the other hand, Mandarin monolingual speakers do not have [±tense] active on /y/ in Mandarin, and therefore [y, ʏ] are indistinguishable.

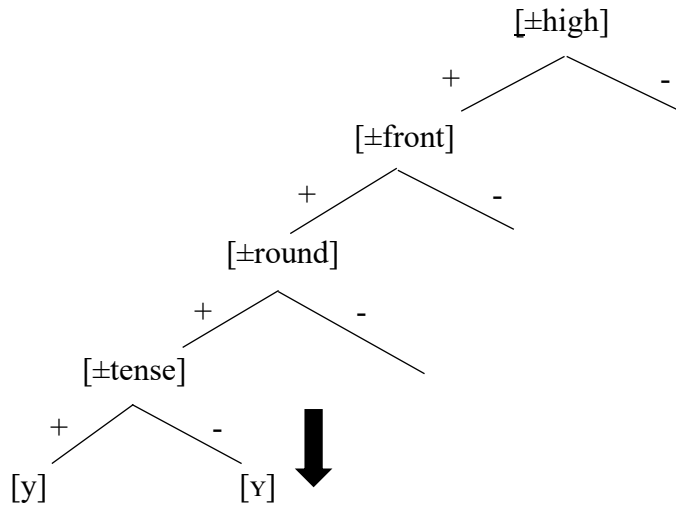
Mandarin speakers who have English as an L2 would construct an L1-L2 integrated grammar and establish the necessary features ([±front] > [±round] from L1 Mandarin; [±tense] from L2 English) for better perception. As Oxford (2015) and Archibald (2023) mentioned, the most conservative change to a structure is to change the sister node of an existing node. As stated in Chapter 2, Archibald (2023) proposed restructuring principles that restructuring starts at the bottom of the tree, and the change should be conservative and incremental. Archibald’s analysis of L1 Mandarin speakers acquiring [±tense] to parse L2 English tense and lax vowels contextualize his restructuring principles: Mandarin speakers of English will add the [±tense] feature dominating any pair of vowels which cannot be uniquely parsed as in (42).

(42) The contrastive hierachy of the L1-Mandarin L2-English grammar (Archibald, 2023)



In line with Archibald’s restructuring principles, L1 Mandarin-L2 English learners will be able to parse Quebec French front rounded tense and lax contrasts [y, ʏ] using their contrastive hierachy of the L1-Mandarin L2-English intergrated grammar, as in (43). In this parsing procedure, [y, ʏ] will be categorized as [+high] first, then [+front] and [+round] are assigned, and as in at the bottom of the tree, [±tense] is used to specify [y] as [+tense] and [ʏ] as [-tense].

(43) The contrastive hierarchy of the L1-Mandarin L2-English grammar parsing L3 Quebec French tense and lax contrasts [y, ʏ]



3.1.2. Hypothesis 1: The Selection of [±tense] in L2

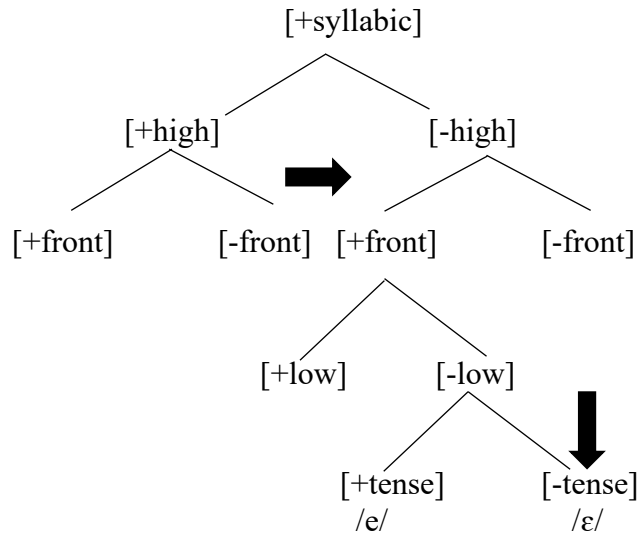
The present study also investigates the mid tense and lax vowels /e, ε/ which are separate phonemes in Quebec French. English has the mid tense and lax vowels as well. However, such a contrast does not exist in Mandarin, and therefore the mid lax vowel /ε/ in English consistently presents perceptual difficulty to L1 Mandarin speakers even at the high-intermediate level of English proficiency (Yu, 2012).

Hypothesis 1: with the help of L2 English, Mandarin speakers will be able to parse /e, ε/ in L3 Quebec French. However, they will have to conquer more difficulties compared with acquiring [y, ʏ] because of the complexity in the development of their L1-L2 grammar: they need two restructuring actions ‘extending’ and ‘adding’ to develop their L1-L2 grammar.

To contextualize the complexity, let’s refer back to restructuring principles by Archibald (2023). Restructuring principles include two restructuring actions: (1) extending an existing node to another sister node; (2) adding a new feature dominating any pair of vowels which cannot be uniquely parsed as in (44). To make it simple, I call them extending and adding in my thesis. The complexity is that in order to parse /e, ε/, Mandarin speakers

need to establish their L1-L2 grammar by extending (the right arrow) and adding (the down arrow) in (44): they need to extend $[\pm\text{front}]$ to the $[-\text{high}]$ sub inventory. Then, they add $[\pm\text{tense}]$ ($[\pm\text{long}]$) to parse $/e, \epsilon/$.

(44) The contrastive hierarchy of the L1-Mandarin L2-English grammar (Archibald, 2023)



The differences between phonemes and allophones need to be discussed in terms of perception. When using the L1 or L2 feature hierarchy to parse the L3 input, the learner needs to consider the environmental variation asking whether it is predictable or not (Archibald, 2022). For instance, assume a scenario where an L1 Mandarin-L2 English speaker is learning L3 Quebec French tense/lax contrasts. In English, these contrasts are unpredictable because they are phonemic contrasts that appear in the same phonetic context (such as $/i/$ in *beet* contrasting with its lax counterpart $/i/$ in *bit*), while in Quebec French, they are predictable ($[i]$ and $[ɪ]$ are allophones of $/i/$). $[\pm\text{tense}]$ is predictable for the high vowels because the tense and lax allophones occur in different contexts, such as *béni* $[beni]$ and *élite* $[elit]$, so learners are able to make predication about the use of tense and lax vowels based on the phonetic environment (e.g., closed or open syllables). In other words, there are no minimal pairs. In relation to the present project, the current project examines the perception of both the allophonic contrast $[y, ʏ]$ and the phonemic contrast $/\epsilon, e/$ marked by $[\pm\text{tense}]$ and intends to answer the question of how the L3 learner perceives allophonic tense and lax contrasts. Next, let's look at my hypothesis 2.

3.1.3. Hypothesis 2: The Selection of [±front] > [±round] or [±round] in L1

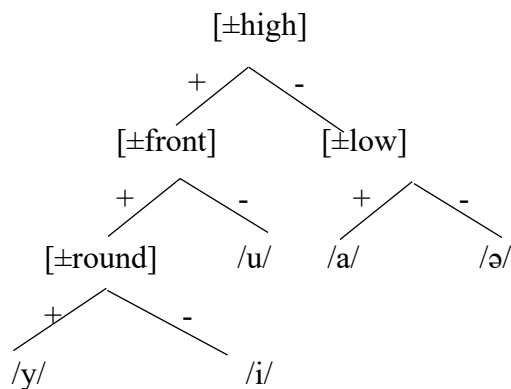
As mentioned in Chapter 1, the mid rounded vowel contrast /œ-ɔ/ parsed by [±front]> [±round] in Quebec French does not exist in either Mandarin or English. Although Mandarin does not have this phonemic contrast, the Mandarin feature hierarchy has the necessary feature ranking [±front]> [±round] to parse the L3 target sounds.

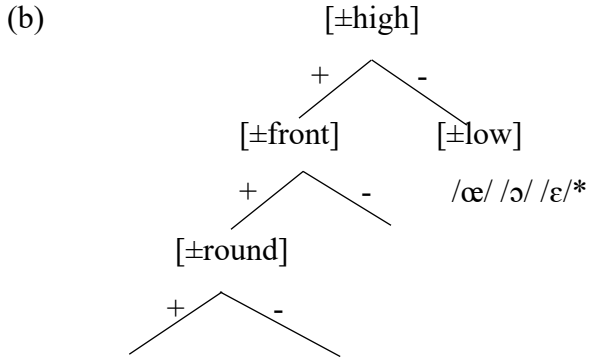
Hypothesis 2: Mandarin speakers are able to select the L1 phonological ranking [±front] > [±round] to parse /œ-ɔ/ (not found in Mandarin or English) and /y-u/ in French successfully.

To be able to parse French mid rounded vowels, Mandarin speakers will take the restructuring actions proposed by Archibald (2023). As shown in (45a), the Mandarin feature hierarchy is [high]> [front] > [low] > [round] in which [front] > [round] is ranked below the [+high] node. As in (45b), when parsing French vowels, without any restructuring actions, /œ-ɔ-ε/ are analyzed as [-high] vowels, but they cannot be further differentiated by [±low] because they do not contrast in height.

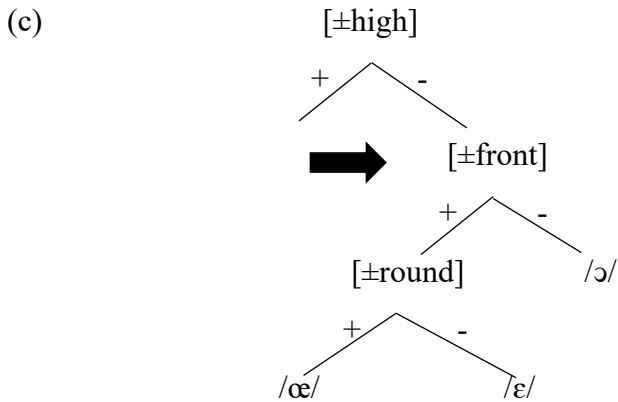
(45) Mandarin speakers' parse of the French mid-rounded vowels using [±front]> [±round]

(a) Mandarin feature hierarchy



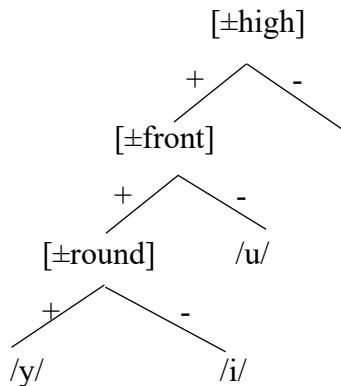


Following Archibald’s restructuring principle, $[\pm\text{front}] > [\pm\text{round}]$ can be extended to the $[-\text{high}]$ sub-inventory. This restructuring action and the resulting hierarchy would allow the learner to parse /œ/, /ɔ/, and /ɛ/ as in (45c).



With respect to the rounded-vowels /y-u/ in French, Mandarin speakers are able to parse them with $[\pm\text{front}] > [\pm\text{round}]$ without any restructuring actions, as shown in in (46).

(46) Mandarin speakers’ parse of the French front-rounded vowels using $[\pm\text{front}] > [\pm\text{round}]$



In this section, my hypotheses are presented and elucidated by using the contrastive hierarchy theory. My first hypothesis (H1) is that L1-Mandarin L2-English learners will use their L1-L2 integrated grammar: the L1 phonological features $[\pm\text{front}] > [\pm\text{round}]$ and/or the L2 English $[\pm\text{tense}]$ feature to parse the L3 Quebec French tense and lax vowels allophonic contrast $[y, \gamma]$ and mid-tense and lax vowels $/e, \epsilon/$ but $/e, \epsilon/$ can be more challenging than $[y, \gamma]$ because of the complexity of the restructuring actions. My second hypothesis (H2) is that Mandarin speakers will use the L1 phonological feature ranking $[\pm\text{front}] > [\pm\text{round}]$ to parse the $/\text{œ-ɔ}/$ contrast that does not exist in their L1 and $/y-u/$ contrast in French. With the features from the L1 and L2, it is predicted that Mandarin speakers will not have problems discerning these target contrasts.

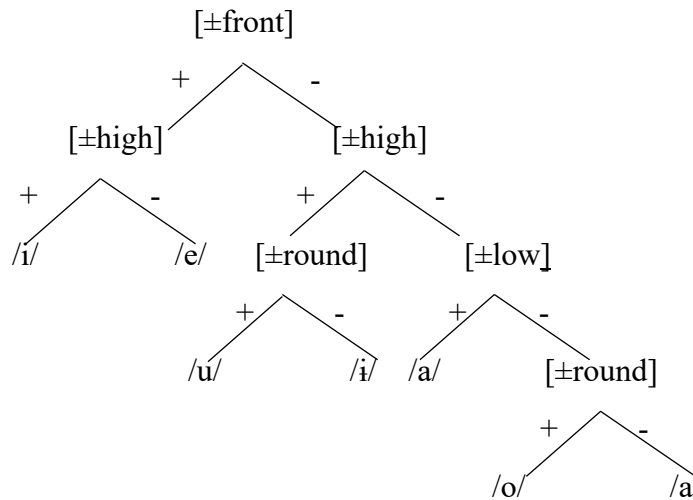
As shown in previous sections, the contrastive hierarchy theory is a substantive model that can be used to predict learners' behaviour with respect to the target sounds. However, it is also important to explore how the contrastive hierarchy theory is used to predict errors. That is to say, how do learners perceive the target sounds without the relevant features or a target like feature ranking in their previously acquired languages.

3.1.4. Lack of Relevant Features or Feature Rankings

In this section, we will look at how the learners whose L1s do not have $[\pm\text{front}] > [\pm\text{round}]$ or $[\pm\text{round}]$ perceive rounded vowels in French. Those learners are Korean, English and Brazilian Portuguese speakers. It is hypothesized that the lack of $[+\text{front}] > [\pm\text{round}]$ or $[\pm\text{round}]$ will lead to parsing ambiguity.

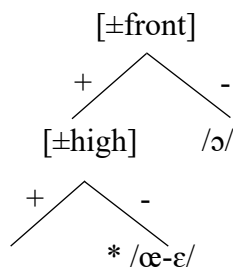
Firstly, let's look at L1 Korean speakers parsing the L2 French vowel contrast $/\text{œ-ɔ}/$. Kwon (2019) conducted a contrastive hierarchy analysis of Korean vowels by looking at a mid vowel and a low vowel merging in Modern Korean. The Korean vowel contrastive hierarchy is given below. It has $[\pm\text{front}]$ ranked at the top, then $[\pm\text{high}] > [\pm\text{low}] > [\pm\text{round}]$. Overall, the Korean vowel feature hierarchy does not have a $[\pm\text{round}]$ contrast anywhere in the $[+\text{front}]$ sub-inventory.

(47) Korean vowel contrastive hierarchy (Kwon, 2019)



It is argued that the lack of the feature ranking $[\pm\text{front}] > [\pm\text{round}]$ is the reason why they cannot parse rounded vowels in French. As Oh (2023) posited, L1 Korean speakers cannot parse the rounded vowel /œ/ in French successfully and will assimilate /ε/-/œ/ into one category as evidenced by Oh (2023)’s study that Korean speakers rated /ε/-/œ/ as one category with 95% rating scores in a perceptual assimilation task.¹⁷ Let’s see why they assimilate those vowels into one category using the contrastive hierarchy theory. Using the Korean feature hierarchy in (48), we can see that $[\pm\text{front}]$ is used to distinguish /œ/ and /ε/ from /ɔ/, but again /œ/ and /ε/ cannot be further specified because they are not contrastive in tongue height features: they are both [-high].

(48) Korean speakers’ parse of the /œ/ contrast using the L1 CH

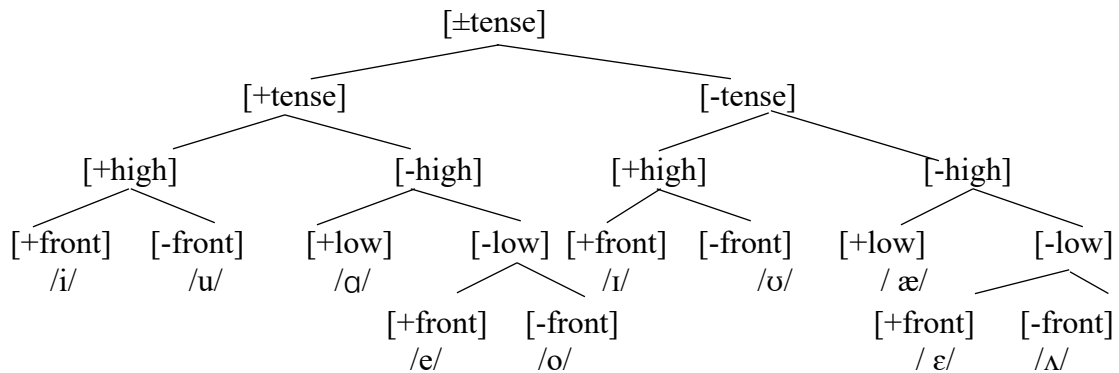


¹⁷ During the task, participants are asked to assimilate different vowel rounds in the target language to their native vowel phonemes.

To summarize, the Koreans have trouble discriminating the French vowels /œ-ɛ/.¹⁸ The reason is that the Korean feature hierarchy does not have a [±round] contrast anywhere in the [+front] sub-inventory. In other words, it is possible to conclude that the lack of [±front] > [±round] causes problems in the perception of rounded vowels in French.

Next, let's see why English speakers have trouble perceiving rounded vowels in French (Levy, 2009). The lack of [±round] causes parsing confusion, which can be seen in English speakers acquiring French rounded vowels. As shown in (49), the Canadian English vowel feature hierarchy does not have [±round]. English speakers without [±round] will be unable to assign distinct representations to rounded vowels in French, such as /y/ or /œ/: L1 English speakers parsed the /y-i/ contrast with an error rate of 25% in a discrimination task (Smith & Baker, 2010).

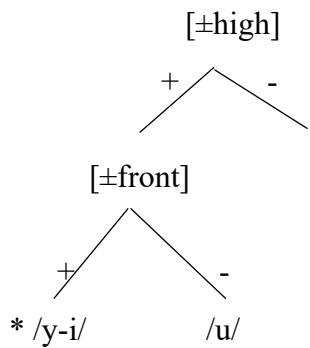
(49) English vowel feature hierarchy (Gardner & Roeder, 2022).



To illustrate this further, the English vowel feature hierarchy does not have [±round], so English speakers would parse the /y/ as /i/. In this parsing procedure, [±high] is first assigned, which separates /i, y, u/ from the non-high vowels but does nothing to distinguish them from one another. [±front] is then used to distinguish /y/ /i/ from /u/, but /y/ and /i/ cannot be further differentiated using the English vowel feature hierarchy.

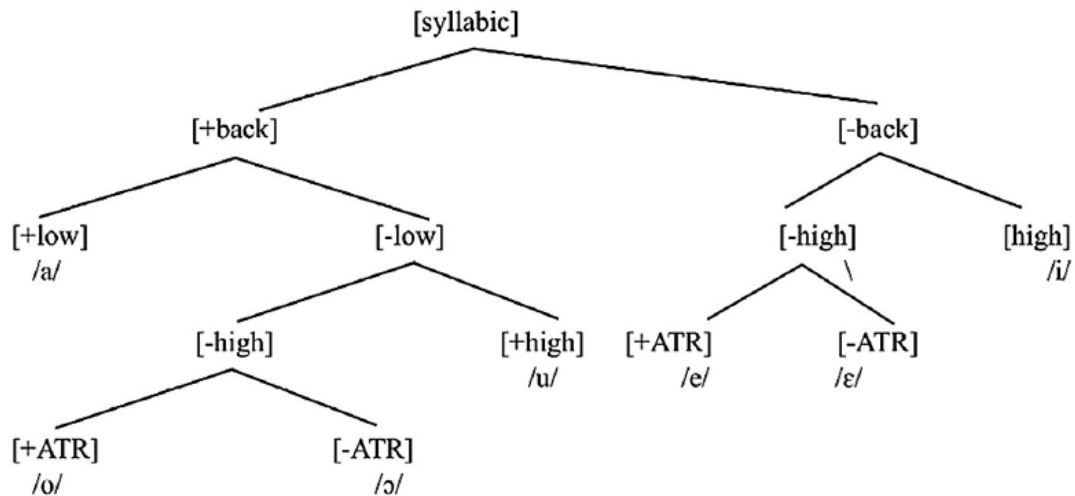
¹⁸ Some may argue that they can extend their [±round] feature to the [+front] class as L1 Mandarin speakers do, but it takes time for learners to restructure their feature hierarchies.

(50) English speakers' parse of /y/ using the L1 CH



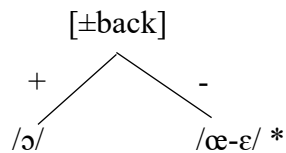
Similarly, Brazilian Portuguese learners have difficulties parsing French front and mid rounded vowels (Alcantara, 1998; 2021). The reason once again is because of the lack of the [±round]. The Brazilian Portuguese (BP) vowel feature hierarchy does not have [±round] (Bohn, 2015), as shown in (51). Bohn (2015) examined BP vowels using the contrastive hierarchy theory, with the ranking [±back] > [±low] > [±high] > [±ATR].

(51) BP vowel feature hierarchy (Bohn, 2015)



In the acquisition of French by BP speakers, Alcantara (2021) reported the following order of acquisition of rounded vowels, inferred from accuracy rates in advanced learners: [y] (67.95% accurate) > [ø] (60.98%) > [œ] (43.90%), so it is clear that mid rounded vowels are difficult to acquire for L1 Brazilian speakers. The possible parsing process is given in (52).

(52) Brazilian speakers' parse of the /œ-ɔ/ contrast using the L1 CH



In (52), [±back] is used to distinguish /œ/ /ɛ/ from /ɔ/, but /œ/ and /ɛ/ cannot be further differentiated using the Brazilian Portuguese vowel feature hierarchy, as the other features—[±low], [±high], [±ATR]—do not distinguish them. Again, by looking at how Brazilian speakers acquire French rounded vowels, we are able to conclude that the lack of the feature [±round] leads to difficulty in the acquisition of rounded vowels in French.

In this section, by looking at several examples of parsing procedures from different L1 subjects, it is clear that the presence and ranking of the contrastive features in previously acquired languages predict errors in the learners' acquisition of the target sounds. Lack of relevant features and rankings result in parsing ambiguity. However, in phonological acquisition, phonetics and phonology often interact with each other, and therefore L1 phonetic enhancement features should also be taken into account. The present study selected the rounded vowel contrasts /y, u/ and /œ, ɔ/ as target sounds based on previous research (Desmeules-Trudel & Joanisse, 2020; Smith & Baker, 2010). It is essential to discuss the reason.

3.1.5. The Selection of the Target Sounds in the Present Study

Based on previous studies on L1 English acquisition of L2 French rounded vowels, there are two types of errors English speakers make when perceiving a French rounded vowel /y/. Levy & Strange (2008) investigate the perception of multiple vowel pairs by L1 English-L2 French learners (European French) at different proficiency levels including naïve learners (L1 English speakers who have had no exposure to French) and L1 English-L2 French learners at the advanced level of French proficiency. In their studies, naïve learners (inexperienced learners) made two different types of errors: they misparse /y/ as /i/ (15.4% error rates) or /u/ (24% error rates). However, English speakers at the advanced level of

French proficiency have notably more difficulties discriminating /y-u/ (29% error rates) than /i-y/ (3% error rates). A summary of their results is given in Table 22.

Furthermore, Levy (2009) expanded previous studies examining the perception of French vowels by three groups of learners: naïve learners (L1 English) and L1 English-L2 French learners at the intermediate and advanced levels of French proficiency. Levy's research, again, points to a similar result: Naïve, intermediate and advanced learners of French perceive the high front rounded vowel /y/ differently: Naïve learners mainly perceive /y/ as /i/ with 10% error rates, while intermediate learners mainly perceive /y/ as /u/ with an error rate of 9%, but sometimes discern /y-i/ ambiguously; advanced level learners of French do not make any errors in the perception of /i-y/ but with an error rate of 6% in the perception of /y-u/ (See Table 22).

Moreover, in relation to the acquisition of Quebec French rounded vowels by English speakers, there are also studies showing that English speakers make two types of errors when perceiving /y/. Smith and Baker (2010) investigate the perception of Quebec French high vowels /i-u/, /i-y/, /y-u/ by English speakers who have lived in Quebec for two years and have learned Quebec French for an average of 5 years. Their findings indicate that English speakers (intermediate and advanced level learners) perceive /i-y/ with an accuracy of around 75% (an error rate 25%) and /y-u/ with an accuracy of about 65% (an error rate 35%). In line with Levy & Strange (2008) and Smith and Baker (2010), Desmeules-Trudel & Joanisse' (2020) study of L1 English-L2 Quebec French learners (advanced level)' perception of rounded vowels specifically reveals that /y-u/ is the most difficult contrast to distinguish compared with other contrasts, such as /y-a/ even when reducing the ISI to 500ms (a phonetic level), with a low accuracy of 45.8% (an error rate 54.2%). To summarize, it is evident that /y-i/ and /y-u/ are both challenging for English learners of Quebec French especially intermediate level learners.

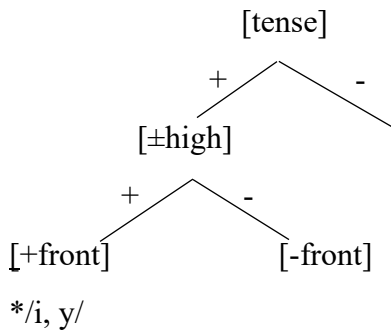
Table 19 is a summary of all the results from the previous research presented above. It is clear that naïve and intermediate level learners of French have problems discriminating both /y-i/ and /y-u/, especially English learners of Quebec French, but advanced learners have a major issue to distinguish /y/ from /u/.

Table 19 *A Summary of Previous Studies on the Acquisition of /y/ in European French (EF) and Quebec French (QF) by English Speakers* (Desmeules-Trudel & Joanisse, 2020; Levy & Strange, 2008; Levy; 2009; Smith & Baker, 2010)

Error rates	Naïve		Intermediate		Advanced		French
High rounded vowels	/y-i/	/y-u/	/y-i/	/y-u/	/y-i/	/y-u/	EF
Levy & Strange (2008)	15.4%	24%	Not tested	Not tested	3%	29%	
Levy (2009)	10%	5%	1%	9%	0%	6%	
Smith & Baker (2010)	Not tested	Not tested	25%	31%	20%	36%	QF
Desmeules-Trudel & Joanisse' (2020)	Not tested	Not tested	Not tested	Not tested	Not tested	54%	

With previous research as a foundation, given the error rates in the discrimination of /y-u/ and /y-i/ in the Table above, it suggests that L1 English-L2 French learners make more errors in distinguishing /y/ from /u/ in their later developmental path. There are two possible causes that lead to two different types of errors. In relation to the misparsing of /y/ as /i/, as discussed previously, English speakers parse /y/ using their L1 feature hierarchy, which leads to the result that /i/ and /y/ cannot be further distinguished as can be seen in (53).

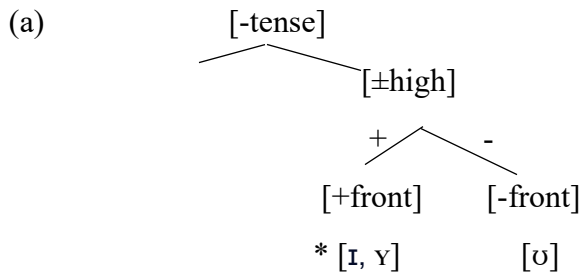
(53) English learners' possible paring /y/ using the L1 CH.



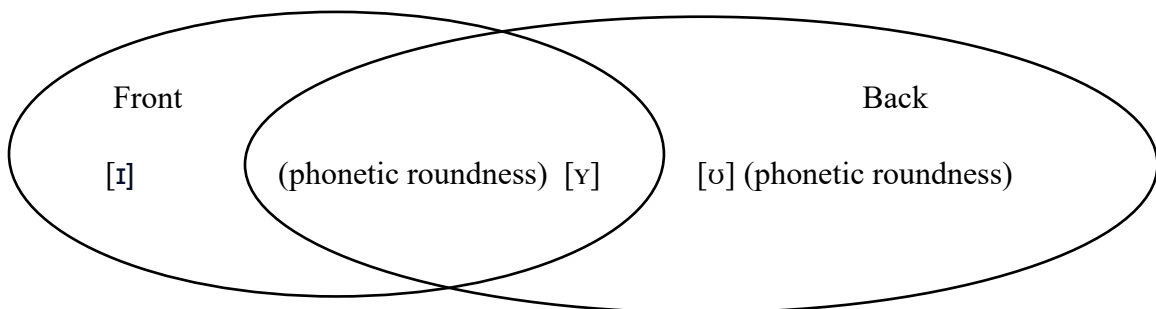
With respect to the misparsing of /y/ as /u/, both /y/ and /u/ have phonetic roundness which is the acoustic information English speakers rely on to perceptually distinguish /u/ from /i/ in their L1 (Hall, 2011; Keyser & Stevens, 2006; Stevens & Keyser, 2010). In addition, French /y/ is acoustically similar to English /u/ based on the acoustic measurement of vowel formants (F2) (Turner, 2023). It seems possible to assume that the transfer of L1 phonetic roundness cue is the cause that leads to the misparsing of /y/ as /u/.

As mentioned earlier, English learners of French will parse /y/ ambiguously as /u/ or /i/. This would also affect their perception of tense and lax vowels [y, ʏ] because they could parse [ʏ] as [ɪ] or [ʊ], as shown in (54).

(54) Two possible errors



(b)



In (54a), L1 English speakers choose [-tense] > [±high] > [±front] to parse [ʏ], so [ʏ] and [ɪ] cannot be further differentiated. In (54b), L1 English speakers will interpret phonetic roundness as being a property of back vowels and this might lead them categorize /y/ and /u/ as one category, which happens very often to intermediate level learners of French. In this way of thinking, it is possible that when parsing [y, ʏ], they will parse them as [i, ʊ] or [u, ɪ].

The present study will not further address the situations that lead to different types of errors or the developmental stages. English learners may follow from phonological parsing to phonetic parsing as the interface between phonetics and phonology is complex and deserves more in-depth analysis and exploration, but it is important to note that when predicting errors we need to take L1 phonetic enhancement into consideration. More possible explanations will be discussed in Chapter 5. The main point here is that there are two types of errors made by English speakers learning French as an L2. L1 phonetic enhancement causes errors in the perception of /y-u/ especially for intermediate level learners. This is also the reason why the present study selected the rounded vowels /y-u/ and /œ, ɔ/ as both contrasts are likely to be misperceived by intermediate level learners of Quebec French (QF) who are the participants recruited in the present study.

In this section, we have looked into previous studies and gain an understanding of the role L1 phonetic enhancement plays in making errors. It is necessary to conclude that lack of relevant features or feature rankings and L1 phonetic enhancement both affect learners' perception of the target sounds. In the next section, the research questions will be introduced.

3.2 Research Aim and Research Questions

In this section, the type of participants recruited in the present study, the specific aim and the research questions are introduced.

The current project investigates crosslinguistic effects in the acquisition of L2/L3 Quebec French. I recruited four groups of participants including two experimental groups and two control groups: Two control groups include Naïve (first exposure) learners of

French (L1 Mandarin-L2 English speakers without learning French as an L3) and French native speakers. According to Carroll (2013), first exposure learners are learners without previous experience of learning the target language. Each of these participants has no significant exposure to French, compared with the L1-Mandarin L2-English L3 European French or Quebec French group. The two experimental groups include L1 Mandarin L2 English-L3 Quebec French learners; L1 English-L2 Quebec French learners. The experimental groups and control groups are shown in Table 20.

Table 20 *Participant groups*

Experimental groups	Control groups
L1 Mandarin-L2 English -L3 Quebec or European French	French native group
L1 English -L2 Quebec or European French	Naive (first exposure) learners of French (L1 Mandarin-L2 English)

My research aim, inspired by the Linguistic Proximity Model, is to examine whether Chinese learners of English are able to restructure (extend or add) features from the L1 Mandarin and the L2 English to acquire L3 target sounds in French. Using the contrastive hierarchy theory as a learning and representational model, I want to explore (1) what they transfer, and (2) after they transfer, how they restructure their feature hierarchy in order to acquire L3 target sounds.

In more concrete terms, I aim to look at L1 English and L1 Mandarin speakers learning Quebec or European French as an L2 or L3. I predict that the trilingual participants will outperform the bilingual participants because the trilingual participants can transfer phonological features from both the L1 and the L2 to acquire an L3 contrast.

The following are my research questions for the first component of the project to answer how they restructure their feature hierarchy in order to acquire L3 target sounds.

- A. Do L1 Chinese-L2-English-L3 Quebec French learners demonstrate facilitative influence from L1 Mandarin ([+front, +round]) and L2 English ([±tense]) in the

perception of the allophonic contrast [y, ʏ] and the phonemic contrast /ɛ, e / in L3 Quebec French? If they do, then

- B. Do L1 Mandarin-L2 English L3 Quebec French learners perceive the contrasts better than L1 English-L2 Quebec French learners?
- C. What are the differences between the perception of allophonic and phonemic contrasts?

My first hypothesis (H1) is that L1-Mandarin L2-English learners will be able to use their L1-L2 integrated grammar: the L1 phonological features [±front] > [±round] and/or the L2 English [±tense] feature to parse the L3 Quebec French tense and lax vowels allophonic contrast [y, ʏ] and mid-tense and lax vowels /e, ε/.

With the help of L2 English [±tense], Mandarin speakers will be able to parse /e, ε/ in L3 Quebec French. However, they will have to conquer more difficulties compared with acquiring [y, ʏ] because of the complexity in the development of their L1-L2 grammar: they need two restructuring actions ‘extending’ and ‘adding’ to develop their L1-L2 grammar to develop their L1-L2 grammar.

On the other hand, L1 English-L2 Quebec French speakers will perceive less accurately than L1 Chinese-L2-English learners in the perception of the allophonic contrast [y, ʏ] because the lack of [±front, ±round] in their L1 and the influence of L1 phonetic enhancement feature.

With reference to the mid vowel contrast /e, ε/, it is hypothesized that the L1 Mandarin L2-English-L3 Quebec French learners will perform similarly to the L1 English-L2 Quebec French learners because the L1 Mandarin L2-English-L3 Quebec French learners have the necessary feature [±tense] from their L2 English to parse /e-ε/. L1 English-L2 Quebec French speakers have a tense and lax distinction in mid vowels in their L1 English, so they should perceive accurately on /e-ε/.

The following are my research questions for the second component of the study to explore what learners can transfer when perceiving L3 target sounds.

A. Do L1 Chinese-L2-English Quebec French learners demonstrate facilitative influence from the ranking $[\pm\text{front}] > [\pm\text{round}]$ in the L1 feature hierarchy in the perception of the rounded contrasts /y/-/u/ and /œ-ɔ/ in L3 Quebec French? If they do, then

B. Do L1 Chinese-L2 English L3 Quebec French learners perceive the contrasts better than L1 English-L2 French learners?

The second component aims to test how learners restructure their feature ranking to parse the target sound. My second hypothesis (H2) is that Mandarin speakers will use the L1 phonological feature ranking $[\pm\text{front}] > [\pm\text{round}]$ to parse the /œ-ɔ/ contrast that does not exist in their L1 and /y-u/ contrast in French. On the other hand, the L1 English-L2 French learners will perceive the contrasts worse than the L1 Chinese-L2-English learners due to the fact that L1 phonetic enhancement feature will lead to misperception.

3.3 Study Design

In this section, some potential issues of recruitment are addressed first, followed by an introduction of the solution I adopted, a self-background questionnaire. Then, the discrimination task used in the present study is introduced. Finally, recruitment procedure and participants' information are given.

3.3.1 Potential Issues

There are several potential concerns which need to be addressed here when recruiting participants. First of all, in the experimental groups, the participants' proficiency level of French needs to be controlled. Furthermore, the participants' proficiency levels in French and English should be at least at intermediate level because the present study does not investigate the L3 acquisition in the initial state.

There are always debates about the relation between proficiency level and pronunciation: whether a certain level of proficiency is correlated with learners' pronunciation. To address this, the present study utilized IELTS or TOEFL, standard English tests that includes listening and speaking assessments to judge participants'

proficiency level. The French class participants took also included listening and speaking assessments.

There are also issues about participant selection. For the participants in my first study, their instructors were required to have taught Quebec French rather than European French because only Quebec French has the allophonic contrast [y], [ʏ]. Secondly, the L1 Chinese-L2-English learners need to be international students or adult learners who speak English as a second language rather than bilingual children who acquire two languages simultaneously because my target participants are Mandarin speakers learning English as a second foreign language. In my second study, it is essential to ascertain that L1 English and L2 French learners are not native bilingual speakers who are fluent and native in both English and French, otherwise they would achieve a similar performance as native French speakers do.

To solve all of those potential issues to ensure that the target participants are identified, a self-background questionnaire was employed in the present study to select participants.

3.3.2 Self-rated Background Questionnaire

As pointed out by Bryman (2008), questionnaires are an efficient use of research time. At the same time, they are very versatile, so they can be applied in different kinds of research with a variety of participants who are comfortable taking them. It has to be admitted that participants are variable in terms of their personalities and experiences. Some are good at taking tests or assessments; some are not (Zhang & Zhan, 2020). An example given by Ockey and Gokturk (2019) is that students with little experience in completing multiple-choice items may not be able to demonstrate their language ability on a multiple-choice standardized test designed to determine if students have enough language ability to study in a foreign country. Using self-rated background questionnaire, all the participants are comfortable to provide information about their previous language background, so the present study could gather the information quickly whether they are native bilinguals, monolinguals, or late L2 learners.

In addition, Sabourin, Leclerc, Lapierre, Burkholder and Brien (2016) mentioned that a language background questionnaire (LBQ) is able to assess and evaluate a participant's language background. To test the validity of LBQ, they conducted a study with a group of participants (81 in total) with four variables, AoA (including the age of first exposure (Ao1E) to the L2 and the age of immersion in the L2 (AoI), or the age of instruction in the L2), proficiency, and manner of acquisition (a naturalistic environment or instructional environment). Those participants included L1 French speakers, L1 English speakers, and non-L1 English or French speakers. They were classified as monolinguals, bilinguals, and late L2 learners. Then, they were grouped together and did the LBQ. The LBQ is able to quickly predict and confirm that participants are monolinguals, bilinguals or late L2 learners. This means that the LBQ is able to accurately predict participants' language history. More importantly, after a three-month interval, it was found that there is no significant difference between their test and retest results, which implies that the results can be replicated. This, again, indicates that the LBQ is both reliable and valid.

Back to the present study, to ensure that target participants were recruited, a self-background questionnaire was employed. This required each participant to report information about their language history, use, and proficiency levels before taking the actual task. Let's see what information participants are required to fill in the questionnaire.

Firstly, course levels and hours of instruction on the ACTFL scales were used to help determine the proficiency level of French. The ACTFL provides definitions, especially at the lower levels of proficiency in foreign language learning. It is used particularly in academia to test learners' proficiency level. The ACTFL Proficiency scales describe five major levels of proficiency: Distinguished, Superior, Advanced, Intermediate, and Novice. The description of each major level is representative of a specific range of abilities in terms of four skills, reading, writing, speaking, listening. According to Language Testing International's report,¹⁹ each proficiency level is associated with specific instructional hours, as shown below. In addition, the present study mainly recruited participants who

¹⁹ It is acknowledged that the effects of instructional hours on school outcomes are debatable and arguable due to the variations in student learning, teaching sources and education systems (Woessmann, 2010; Skirbekk, 2006).

have taken French intensive 120 and 170 at UVic, which are courses designed for intermediate level learners.

Table 21 *ACTEFL Proficiency level and instructional hours*

Length of Instruction	Proficiency level
8 weeks (240 hours)	Intermediate
16 weeks (480 hours)	Intermediate-advanced
24 weeks (720 hours)	Advanced-superior

Participants' proficiency level of English was measured by standardized English tests, such as IELTS or TOEFL. The reason is that almost all the international students, especially Chinese students would take IELTS or TOEFL to study at an English-speaking country, such as Canada. IELTS or TOEFL would be more consistent and effective to access their English ability, including speaking, listening, speaking and writing. Further, IELTS and TOEFL scores are also classified and converted to English proficiency levels by the CEFR (Common European Framework of Reference for Languages), as given below.

Table 22 *English proficiency levels*

CEFR	TOEFL	IELTS
Beginner	n/a	n/a
Elementary	n/a	n/a
Intermediate	42-71	4.0-5.0
Upper-intermediate	72-94	5.5-6.0
Advanced	95-120	6.5-7.5
Proficient	n/a	8.0-9.0

On the other hand, instructional hours were not taken into account because all the Chinese students started learning English around age 6 in a formal and explicit context, meaning that most of them should have more than 720 instructional hours. However, English is taught in Mandarin in China, with a focus only on its writing component and a concern about test-taking skills (You, 2004). Hence, most of Mandarin speakers cannot be

considered as advanced learners even though they have more than 720 instructional hours, so we need to take other assessments, such as IELTS or TOEFL into account.

In addition to instructional hours and course levels, all the participants were also asked to conduct a self-assessment of their L2 and L3 proficiency levels with a five-point scale related to some standard, as shown below. Their scores were coded with five fluency levels based on the ACTFL. The self-assessment rate was adapted from Sabourin, Leclerc, Lapierre, Burkholder and Brien’s (2016) language background questionnaire (LBQ) as they claimed participants are generally accurate when self-assessing their proficiency levels.

The Self-assessment form used in the present study

Other than your mother tongue, what language(s) do you know? How well do you know each in terms of speaking, listening, reading and writing? (To rate proficiency level, please take a look at the table below)

Second language 1:

Name of the language: _____ Years of learning: _____

How well I know the language in terms of the following skills:

speaking _____, listening _____, reading _____ and writing _____

(Give a number from 1 to 5 where 1 means “novice” and 5 “distinguished”.)

1	Novice	You can express simple information (writing and speaking), using familiar words or phrases. You can understand key words and simple phrases in a familiar context (reading and listening).
2	Intermediate	You can express familiar topics related to everyday life with non-native learners of the language. You can understand speech related to familiar everyday topics that conveys basic information.
3	Advanced	You can understand the main idea and most supporting details in connected discourse or narrative essays on a variety of general

		interest topics. You speak skillfully with accuracy and can deal with unfamiliar topics.
4	Superior	You can understand texts from many genres dealing with a wide range of abstract subjects both familiar and unfamiliar. You can use complex grammatical structures to support your opinions and arguments.
5	Distinguished	You are able to discuss global issues or highly complex concepts and give a speech with accuracy and efficiency and adapt your language to suit the situation and audience. You can understand a wide variety of forms, styles and registers of speech on highly specialized topics.

Besides that, the self-rated background questionnaire in the present study also adapted Sabourin et al.'s (2016) LBQ to include various information, such as age of L2 acquisition (AoA), manner of acquisition (MoA), the length of residence (LOR), as shown below also in Appendix 1.

The following information was included in the self-background questionnaire:

Gender	Age	LOR	Origin, Education dialect	LoE English	LoF French	AoA	MoA	Instructional hours (French)	IELTS or TOEFL
Their length of residence (LOR in Canada and any other countries they have lived in)									
Their length of learning English or French (LoE & LoF)									
Their average age of onset (AOA) for learning English or French									
The manner of acquisition (MoA): naturalistic exposure or instructional contexts									

3.3.3 Discrimination Task

3.3.3.1. Task Design

The research method used in this study was an ABX discrimination task, where a listener has to match a token X to either token A or B, and then indicate the answer by

pressing a button labeled A or B. A discrimination task was chosen because it is a task designed for testing listeners' discrimination capabilities of different phonemic categories and allophones (Strang & Shafer, 2008). This meets the research aim in the present study as it aims to test different learners' perception of phonological contrasts. In my study, pseudo words were used because the environmental context needed to be controlled: both tense and lax vowels would occur in the same contexts in these pseudo words. This cannot happen in real French words given the properties of allophony [y, ʏ] (i.e., there are no minimal pairs).

A set of nonsense French words was constructed by embedding [y, ʏ] and /ɛ, e/, and /y-u/ and /œ-ɔ/ in different consonantal contexts in CVC syllables, including /bVb/, /tVd/, and /sVz/. The selection of those consonantal contexts was based on previous studies. According to Gottfried (1984), French vowels spoken in labial and coronal consonant contexts (specifically /p-p/, /b-b/, /t-t/²⁰) are discriminated significantly better than isolated vowels. Some of them such as /t-t/ or /pp/ were not chosen because target sounds in those contexts were real words. In addition, as Fernandez, Feijóo, Balsa & Barros (1998) demonstrated, fricative noise (/s-z/) improves the recognition of the vowels, which is why the fricative context was also chosen. Those contexts were chosen because participants could have difficulty in the perception task due to the consonantal contexts as this could affect the accuracy of the results. Unrelated distractors (/i/-/u/ in the first study and /i/-/ɛ/ in the second study), were included in order to distract participants' attention because participants might be able to feel concentration drop if they heard similar sounds for a long time, which would lead them to make more errors due to lack of concentration. This would affect the accuracy of the results.

In addition to this, two native Quebec French speakers also helped to check the list of nonsense French words selected in the present study to make certain that there are not real words involved as some consonantal contexts with the target sounds ([y, ʏ] and /ɛ, e/, and /y/-/u/ and /œ-ɔ/) embedded result in real words in French.

²⁰ Consonantal contexts such as /tyd/ do not include affrication of the /t/

3.3.3.2. Stimuli

Stimuli were recorded by two native Quebec French speakers in a sound-isolated recording booth. One speaker's voice was used for the X token, whereas the other was used for the two different A and B tokens. Using a different voice is to ensure that what the task measures is phonological categorization rather than a lower-level acoustic-phonetic comparison (Strange & Shafer, 2008). If all three items in an ABX trial were of one voice, even if the X was a different token than the A or B it matches, the acoustic similarities of the same vocal tract are such that one could argue that participants pay pure attention to phonetic detail in comparison rather than phonological categorization (Strange & Shafer, 2008). The speakers must have some linguistics background, understanding the purpose of the task because pronouncing allophonic contrasts in the same contexts requires training and knowledge. The two speakers read the target words at the end of the carrier phrase "Je dis le mot..." ("I say the word...") three times. Reading three times guaranteed that I would be able to choose the one with clear acoustic cues. The carrier phrase served to ensure intonational uniformity. Recordings were normalized for amplitude and spliced into separate sound files using Praat.

In the first component of the current study, stimuli were arranged in four different pairings for [y] and [ɣ] and /ɛ, e/: BAA, ABB, ABA, and BAB. Four orders in the testing (BAA, ABB, ABA, BAB) were needed to balance the order of stimuli so all four possible orders of stimuli were present with balance of options (AB) (X=A or B) and balance of sounds (BA / AB) (X=B) (Strange & Shafer, 2008). The randomization was set such that the same pair in both 'minimal pairings' ABB and ABA, for example, would not occur in the same block (there were four blocks in total). This yielded a total of 48 trials (one trial being a sequence of three non-words). Distractor contrasts including the vowels /i/-/u/ were added randomly into those trials. In total, we had 62 trials. In the second component of the present study, stimuli were arranged in four different pairings for /y/-/u/ and /œ-ɔ/: BAA, ABB, ABA, and BAB, which resulted in the same number of trials as in the first study. Distractor contrasts (/i/-/ɛ/) were added randomly. In total, there were 124 trials for participants to perceive in the experiment. Those trials were divided into four blocks. Each block contained 31 trials.

The inter-stimulus interval (ISI) was 1500ms, which invoked a phonemic level of perception (based on Werker & Logan's (1985) categorization). Although the contrasts the present study looks at, such as [y] [ʏ], are allophonic in the L3, the feature [±tense] that is used to specify them is phonologically active in the L3. The current project aims to look at whether learners acquire the feature [±tense] phonologically, which is why an ISI of 1500 ms was chosen. Participants had 2200 ms to make their response before the next trial was initiated, following the practice of many previous studies (Darcy et al., 2012; Turner, Horwitz, & Souza, 1994).

The effect of inter-stimulus interval (ISI) needs to be considered because the duration of inter-stimulus interval could affect the accuracy of the perception results (Cowan & Morse, 1979; Pisoni, 1973; van Hoesen & Schouten, 1992). To understand this, it is necessary to understand what listeners do in the ABX task. In the ABX task, listeners need to indicate whether stimulus X is identical to stimulus A or B. To do so, they need to try to remember the auditory traces (acoustic information). When X is presented, they try to match the sound of X with the auditory traces of A and B, but it has been proposed by Gerrits (2001) that with a long ISI, "there will be a decay of the auditory trace in short term memory, which will encourage listeners to base discrimination on phonemic representations in long term memory" (p. 5). Numerous studies report that discrimination results indicate that a longer ISI has an increasing effect of labelling phonemes (Cowan & Morse, 1979; Pisoni, 1973; van Hoesen & Schouten, 1992). Werker & Logan (1985) showed different performances among English NSs exposed to the Hindi /t-/ ʈ / contrast in an AX task by reducing the inter-stimulus interval. They categorized 1500ms as tapping into a phonemic level of perception. In their research, English NSs were unable to discriminate the contrast at 1500 ms ISI. Interestingly, reducing to 500ms triggered accurate perception, which is categorized as a phonetic level of perception.

Finally, all items were pseudo-randomized by the program PsychoPy for presentation to participants. Then, the program was stored on the website Pavlovia.org, a platform for conducting online PsychoPy experiments that helps researchers control their experiments, data, and results.

3.3.4 Participants

3.3.4.1 Recruitment Procedure

A total of 93 participants voluntarily took part in the current study, including 29 Chinese speakers learning Quebec French as their L3, 24 English speakers learning Quebec French as their L2, 20 Chinese speakers without learning Quebec French, and 20 Quebec French natives.

They were provided via email with the consent forms and self-background questionnaires. Then, they completed and returned it, with the electronically signed consent forms, to the researcher via email. Their self-background questionnaires were evaluated based on the course level, their English scores, and their other language background. That the participants matched the criteria was confirmed via email.

Eventually, there were total 82 participants who met the criteria and were selected, including 22 Chinese participants learning Quebec French as an L3: 20 English participants, 20 Chinese participants without learning Quebec French, and 20 Quebec French natives. After completing the task, each participant was offered a \$10 (CAD) gift card to compensate them for their time participating in the study. Some participants did not match the criteria because of their language background. For example, some English participants reported that they are bilingual speakers learning English and Quebec French since they were born. This means that they are likely to achieve similar performance as native speakers of Quebec French. Some participants are at French beginner level (course level), which did not meet the level the present study requires. In addition, some English participants also took Mandarin as an additional language, which does not meet the requirement in the present study. Learning Mandarin as an additional language implies that those English participants might have acquired [±front] > [±round] from Mandarin, which means that they are more likely to achieve a similar performance as Mandarin participants.

3.3.4.2. Participants' Information

More specifically, L1 Mandarin-L2-English-L3 Quebec French learners were recruited from Tangram Culture Academy language school²¹. The instructor at Tangram Culture Academy also helped recruit some previous students studying at McGill University in Québec. In the Tangram Culture Academy language school, they have French classes teaching both Chinese international high school students and Chinese adults. Some instructors speak Quebec French and some speak European French, meaning that both varieties are explicitly taught in class, which was confirmed with the instructors. Twenty native speakers of Quebec French and twenty L1 English L2 Quebec French learners were recruited from French departments at the University of Victoria (UVic) through recruitment email sent by their French secretary and also UVic French classes (French 120 & 170). Specifically, twenty L1 English-L2 Quebec French participants are students taking Intensive French 120 and Intensive French 170 designed particularly for French intermediate learners at UVic. The Course instructor is from Quebec and stated that she teaches and speaks Quebec French in class. She also helped with recruitment by allowing the researcher to recruit in her class. Naïve learners of French were recruited from Tangram Culture Academy language school and UVic. Participants' details are given below. Here, only experimental groups' details are provided since they are target groups in the present study. Some major information is presented, including participants' gender, age, length of learning English and French, their length of residence in Canada, IELTS scores, proficient level, and original city they come from in China. The control groups' information and other detailed information are given in Appendix 2.

²¹ Tangram Culture Academy language school is a Victoria-based Chinese language and culture institute but offers various courses including French. Their French instructors are native speakers of European French or Quebec French.

Table 23 *Participant information (Mandarin speakers)*

Their length of residence (LOR in Canada)

Their length of learning English / French (LOE & LOF)

No.	Gender	Age	LOR (years)	City	Education	LO (E) (years)	LO (F) (years)	IELTS	Quebec French
P1	M	21	3	Suzhou	Undergraduate	10	1	6.5	Intermediate
P2	F	20	3.5 s	Xi'an	Undergraduate	15	3.5	6.5	Intermediate
P3	M	25	7	Nanjing	Undergraduate	10	1	7.0	Intermediate
P4	F	18	5	Beijing	High school	7	5	7.0	Upper-intermediate
P5	F	30	5	Beijing	Undergraduate	15	2	6.5	Intermediate
P6	F	20	10	Shanghai	Undergraduate	14	5	6.5	Upper-intermediate
P7	F	20	6	Suzhou	Undergraduate	10	2	7.0	Intermediate
P8	F	18	5	Tianjin	High school	6	3.5	7.0	Intermediate
P9	F	24	12	Shanghai	Undergraduate	12	4	7.5	Upper-intermediate
P10	F	22	5	Yangzhou	Undergraduate	10	1	7.0	Intermediate
P11	M	19	2	Beijing	Undergraduate	10	4	TOEFL 113 (7.5)	Intermediate
P12	F	22	6	Changzhou	Undergraduate	10	1.5	6.5	Intermediate
P13	M	17	10	Guangzhou	Montessori Academy	11	3	7.0	Intermediate
P14	M	23	5	Nanchang	Undergraduate	12	5	7.0	Intermediate
P15	F	22	4	Zhejiang	Undergraduate	11	2	6.5	Upper intermediate
P16	M	24	6	Hangzhou	Undergraduate	18	1	7.0	Upper-intermediate
P17	F	22	5	Beijing	Undergraduate	12	8	7.0	Advanced
P18	F	18	5	Nanjing	Undergraduate	12	3	6.5	Intermediate
P19	F	20	2	Zhejiang	Undergraduate	15	2	7.5	Intermediate
P20	M	23	5	Qingdao	Undergraduate	10	4	7.0	Upper-intermediate
P21	M	19	1	Shandong	Undergraduate	18	1	7.5	Intermediate
P22	M	22	12	Shenyang	Undergraduate	13	8	7.5	Advanced

As shown in Table 24, a total of twenty-two L1 Mandarin-L2 English-L3 Quebec French learners in Canada participated in this study. Almost all the Chinese participants are undergraduate students who are used to or currently taking French courses (online or in person) at Tangram Culture Academy (TCA). They are international students who came to Canada for high school and higher education. In order to get into a university in Canada, all of them took IELTS or TOEFL as a proof of English proficiency. Many of them were also enrolled in French classes at McGill and UVic (Intensive French 120 & 170) after getting into university for full participation in Quebec society. Besides that, there are a small number of participants who are high school students in Grade 12 taking French classes at TCA. They are Chinese students coming to Canada for high school. In general, the average IELTS score of all the participants is 7.0. Participants' length of residence in Canada ranges from 1 year to 12 years, with a mode of 6 years. The average length of learning English is 10 years, and the average length of learning Quebec French is 3 years. All of them claimed that Mandarin Chinese is their mother language, and they have learned English as an L2 and Quebec French as an L3. Because of the variety of French courses they took, many of them claimed that they know both European and Quebec French. Next, let's look at English participants' information.

Table 24 *Participant information (English speakers)*

Their length of learning English / French

No.	Gender	Age	Education	LO (F) (years)	Quebec French
P1	M	25	Undergraduate	8	Advanced
P2	F	22	Undergraduate	7	Intermediate
P3	F	22	Undergraduate	15	Upper-Intermediate
P4	F	20	Undergraduate	7	Intermediate
P5	F	20	Undergraduate	8	Intermediate
P6	F	19	Undergraduate	10	Advanced
P7	F	26	Undergraduate	1	Intermediate
P8	F	30	Undergraduate	2	Intermediate

P9	F	22	Undergraduate	2	Intermediate
P10	F	20	Undergraduate	4	Intermediate
P11	M	25	Undergraduate	10	Upper-Intermediate
P12	M	19	Undergraduate	2	Intermediate
P13	M	30	Undergraduate	4	Intermediate
P14	F	24	Undergraduate	1	Intermediate
P15	M	27	Undergraduate	2	Intermediate
P16	M	29	Undergraduate	2	Intermediate
P17	F	26	Undergraduate	1	Intermediate
P18	M	30	Undergraduate	4	Intermediate
P19	F	20	Undergraduate	8	Upper-Intermediate
P20	F	25	Undergraduate	18	Advanced

As can be seen in Table 26, a total of twenty English participants learning Quebec French learners as an L2 took part in the current study. All of them were recruited from French department at UVic: As mentioned earlier, many of them were recruited from Intensive French 120 and 170 taught by a French instructor from Quebec. Almost all of them are undergraduate students at UVic French department. There are also few participants just took French classes but not program-students. All of the participants reported that they took Quebec French as their L2, but they know both European and Quebec French. Their average length of learning Quebec French is 3-5 years.

To summarize, in the present study, four target groups were recruited and tested: (1) experimental groups are L1 Chinese-L2-English learners who learned Quebec French as a L3 and (2) L1 English-L2 Quebec French learners, and (3) naive French learners (L1 Mandarin and L2 English speakers) and (4) native speakers of Quebec French function as a control group: L1 Chinese-L2-English-L3 Quebec French learners (N=22), L1 English-

L2 Quebec French learners (N=20), and naive French learners (N=20), and native speakers of Quebec French (N=20).

3.3.4.3. Training Session

The present study conducted an online experiment, which means that participants completed the discrimination task on Pavlovia, without too much interaction with the researcher. Although participants did receive a detailed instructional email before taking the task, to ensure that all the participants were familiar with online environmental setting, they were required to take a short training session before taking the actual discrimination task. This training session was set before the discrimination task. It took about 1-2 minutes depending on participants' understanding of the instructions.

The procedure is described by the following steps: When participants clicked the link sent via email to participate in the research, an instructional page was presented first on their screen. There was no time limit for them to read the instructional page. After reading the instructional page carefully, they just pressed 'space' on their keyboard to continue. Then, they encountered a short training session involving three trails for them to practice before taking the actual task. In each trail, they listened to a recording of a sequence of three pseudo words, such as [bib], [byb], and [bib], but on their screen, they could not see the vowels, only the surrounding consonants, such as bVb displayed on their screen. Then, they were required to match the third pseudo word (X), to either the first pseudo word (A) or the second pseudo word (B) they heard, and then indicated their answer by pressing 'A' or 'B' on their keyboard. Their results in the training session were not taken into account. After this short training session, another instructional page was shown to ask them whether they were ready to take the actual task. If not, they could retake the training session or contact the researcher for questions. If they were ready to take the actual task, they could press 'space' on their keyboard to continue.

In the actual discrimination task, similar to the training session, participants listened to tense and lax vowels [y, ʏ] and /ɛ, e/ and rounded vowels /y/-/u/ and /œ-ɔ/ embedded in pseudo words ([bVb], [dVt], [sVz]) in 124 trails. Then, they were asked to identify X as

either A or B by pressing ‘A’ or ‘B’ on their keyboard. As mentioned earlier, 124 trials were divided into four blocks. After each block, there was a short break time. The length of break time depended on participants’ needs. When there was a short break time coming, participants saw an instructional page that informed them about break time. Then, they took a break. There was no time limit for break time. Once they were ready to continue the task, they could press ‘space’ on their keyboard to continue.

3.4. Statistics

Both descriptive and inferential statistics were used. Participants’ results were downloaded, recorded into Excel, and categorized based on participants’ groups including L1-Mandarin-L2 English, L1 English, naïve learners, and native French. Their results were coded as correct and incorrect: one point for a correct answer; 0 points for an incorrect answer. Excel was used to calculate the raw accuracy rates. Then, linear mixed effects models (LMMs) were run in R v. 3.6.1 with a random effect for Participant. Linear mixed models allow both fixed and random effects. It assumes that groups are independent, but each group also has individual differences. The best model fit was decided based on Akaike information criterion (AIC). According to Wagenmakers and Farrell (2004), the best fit model is the one with the lowest AIC value. For all other inferential statistics, a significance level of $p = .05$ was used. All post-hoc pairwise comparisons were run by `emmeans` function in R to calculate significant differences between each group.

3.5. Validity and reliability

In order to ensure that my research method was reliable, a pilot study was conducted before the actual experiment to test the feasibility of the experimental design. Similar target populations were recruited in my pilot study, including eleven native Mandarin speakers at the intermediate to advanced levels of Quebec French proficiency, and seven native Quebec French speakers. The ABX discrimination task was employed to investigate their perception of Quebec French tense and lax vowels /e-ɛ/ and [y, ʏ] (Wu, 2022), with a similar result to the present study, thus demonstrating the reliability of the method.

However, my pilot study also helped identify certain weaknesses in my design, especially in the nature of the stimuli and the statistics used. Unlike my pilot study which used one speaker to record stimuli, in the present study, stimuli were recorded by two native Quebec French speakers to improve the validity of the ABX discrimination task (see Section 3.3.3.2). The linear mixed effect model was utilized in the present study, as it was more suitable for this data set (See Section 4.1). More details are given in the next chapter.

To ensure both reliability and validity, the selection of stimuli was based on previous research (Gottfried, 1984). The design of the task including the inter-stimulus interval (ISI) (1500 ms) and the balance of the order of stimuli (four pairs) (see Section 3.3.3.2) was all used to ensure the validity of the present study.

There are previous studies that have been conducted using the same population and the same experimental method (Darcy et al, 2012; Nichols, 2014). This ensures the reliability of the current study. Darcy et al' study looked at the perception of French rounded vowels by L1 English-L2 French learners using pseudo words and the ABX discrimination task, with the finding that L1 English speakers have difficulties perceiving high and mid rounded vowels, which is similar to the present study. Nichols (2014) using the AX discrimination task investigated the perception of Quebec French tense and lax allophonic contrasts by L1 English-L2 Quebec French learners. Her findings suggest that English speakers even at the advanced level of QF proficiency cannot perceive tense and lax allophonic contrasts accurately, which is again similar to the findings in the present study. Numerous studies (Levy, 2009; Baker and Smith, 2010; Darcy et al, 2012; Desmeules & Joanisse, 2020). tested the same population using different experimental methods, but their results are all similar to the present study.

In the next chapter, the results from these statistical analyses are reported with a detailed introduction of the statistical model employed in the present study.

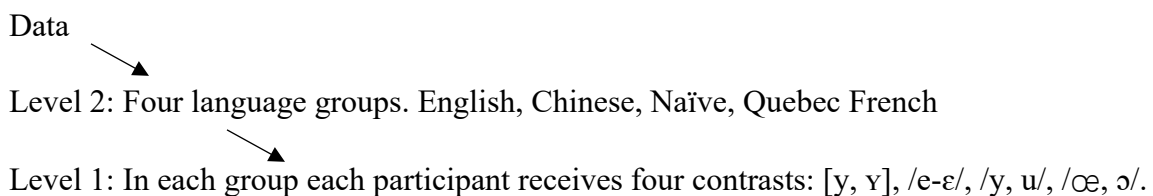
CHAPTER FOUR: RESULTS

This chapter is organized into four sections. Before the statistical analyses, a preliminary analysis section is given to illustrate why the linear mixed effect model is the best choice to explain my data. After that, an overall summary of the results is presented, including descriptive analyses and a model summary. In Section 4.3 and 4.4, the effects of language background and contrastive segments are reported based on descriptive and statistical analyses of the L1 controls and learners' accuracy rates.

4.1 Preliminary Analyses

The present study set two independent variables, (language background and contrastive segments, which are categorical variables), and one dependent variable, (accuracy rate) which is a continuous variable. It is essential to present a brief preliminary analysis to explain why a linear mixed effect model is employed to analyze my data. First, let's look at the type of data collected for statistical analysis.

The data collected in the present study have a hierarchical structure, so the linear mixed effect model is appropriate. Linear mixed effect models (LMMs) (See Section 3.4) are designed for multilevel analyses addressing hierarchical data (Garson, 2013). Garson (2013) uses employee relations as an example to explain when and why to use LMMs: employee data are at level 1, agency data are at level 2, and department data are at level 3. In this example, employee data is nested in agency data, and agency data is nested in department data. This is a hierarchical structure. The data in the present study also has a hierarchical structure, as given below.



As shown above, nested data exist: level 1 (contrast) data is nested within level 2 (language groups). Because of multilevel data, the present study is able to conduct two

analyses: an analysis on the perception of the same contrast by participants from different language groups; and an analysis on the perception of different contrasts by the participants from the same language group. However, the data in the second analysis violate the independence assumption (Winter, 2013) as the different accuracy rates from the same subject cannot be regarded as independent²² from each other, which leads to the second reason why the linear mixed effect model is chosen.

The linear mixed effect model can deal with non-independent data at the analysis stage by adding a random effect (unknown factors such as individual differences) for the subject (Winter, 2013), which is why this model is chosen. It is well known that “the independence assumption is by far the most important assumption of all statistical tests” (Winter, 2013). To understand independence, let’s use level 2 data referred to above as an example.

In this case, the level 2 data are accuracy of the perception of the same contrast (e.g. [Y] vs [y]) by participants with different language backgrounds, so each accuracy score comes from a different subject as shown below. Each accuracy score is independent from the others.

Subject	Language background	Accuracy
Participant 1	L1 English-L2 Quebec French	70%
Participant 2	L1 Mandarin-L2 English-L2 Quebec French	80%
Participant 3	Quebec French natives	90%
Participant 4	Naïve learners	60%

However, in the level 1 data referred to above, each person was tested on four different contrasts with potentially different scores, so different accuracy scores are inter-dependent rather than independent. A linear mixed effect model deals with this situation by adding a random effect for the subject. On the other hand, ANOVA model is not utilized in the present study because it cannot resolve non-independence issue.

²² One subject makes four accuracy rates, and four accuracy rates rely on one subject’s French proficiency and perception ability. Hence, the four accuracy rates have an inter-dependent not independent relationship.

Linear mixed effect models are an extension of linear regression models. The present study has tested the data based on the linear regression assumptions (Poole and O' Farrell, 1971) (as given in Appendix 3) to ensure that the data collected in the present study meet all the assumptions.

In the present study, statistical analyses were run in R v. 3.6.1. A regression model (the model built on my data) was used to identify the relationship between the independent and dependant variables, which will be shown in a model summary. Under this model, the emmeans function was used to conduct a post-hoc test for pairwise comparison that drives the significant effects in the data. Now, let's look at overall results.

4.2 Overall Results

In the present study, there are two control groups, Quebec French natives (QF natives or the L1 controls) and naïve learners (L1 Mandarin-L2 English learners without learning French as an L3). The two experimental groups include the L3 Quebec French learners (the L3 QF) and the L2 Quebec French learners (the L2 QF). The density plot shown in Figure 8 indicates the distribution of the overall results of the four groups, which is the participants' overall perceptual results of all the target contrasts tested in the current study. Table 26 gives the information about the descriptive statistics including means, standard deviations, and medians.

4.2.1 Overall Descriptive Statistics

Figure 4 Density plot of the overall results

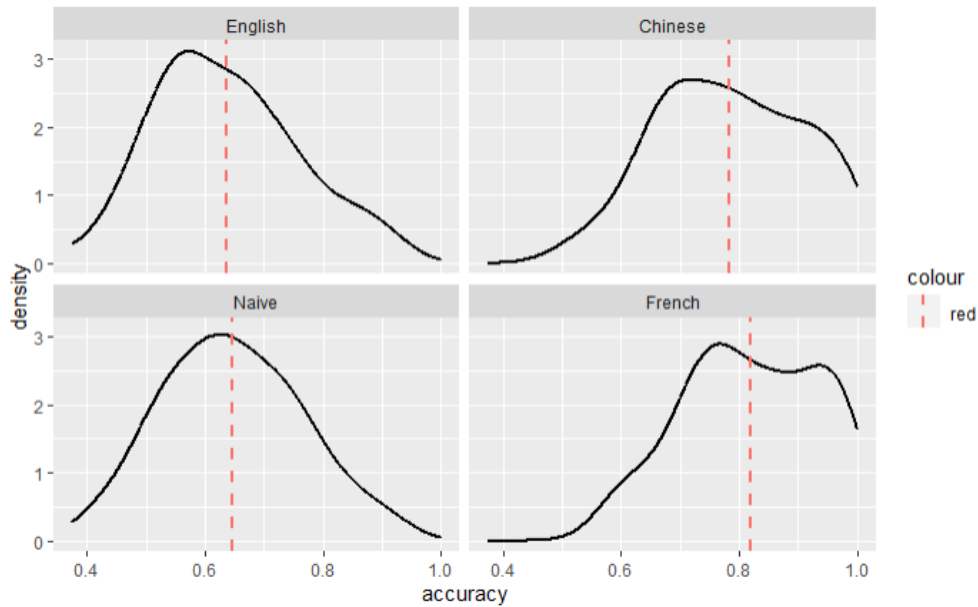


Table 25 Descriptive statistics

Groups	Mean	Median	Standard Deviation
QF natives	81.9	83.3	11.54
L3 QF group	78.4	79.1	12.37
L2 QF group	63.5	62.5	12.14
Naïve	64.6	62.5	11.82

In general, a similar distribution could be observed for the L3 QF group and the QF natives. Both groups have similar means (81.9 and 78.4 respectively). The peaks of the density curves reflect that most participants in both groups achieve high scores close to 80% in the perception of all the tested contrasts in the present study.

On the other hand, the L2 QF and naïve groups also pattern in a similar fashion. Their means are greater than their medians, as can be seen in Table 26. Again, both groups' means are similar (63.5 and 64.6 each). The peaks of density curves indicate that most participants in these two groups receive scores around 60%, which is lower than the L3 QF group and QF natives.

4.2.2 The Selection of Models

Before conducting statistical analyses, it is important to find the best model to explain the overall results. In this section, we compare three linear mixed effects models. The model LMM1 includes ‘language’ (language background) as a fixed effect factor, the model LMM2 includes ‘contrastive segments’ as a fixed effect factor, and the third model, LMM3, includes both fixed effect factors. The purpose is to select the best model to explain the overall results. The AIC and BIC values (See Section 3.4) are used as criteria for model selection. A lower AIC or BIC value indicates a better fit (Stone, 1977). In the table below, the model, LMM3, is the best fit (AIC = -554.65; BIC = -520.71). As can be seen, both the difference between LMM3 and LMM1 and the difference between LMM3 and LMM2 are statistically significant (p-values < .01), which indicates that when taking both factors into account, the model LMM3 improves significantly.

Table 26 *Model comparison*

Model	AIC	BIC	p-value
LMM3 (Language + Contrast segment)	-554.65	-520.71	
LMM1 (Language)	-425.73	-403.05	<0.01*
LMM2 (Contrast segment)	-493.34	-470.65	<0.01*

4.2.3 A Model Summary

The model LMM3 including two fixed effect factors “language background” and “contrastive segments” (they are fixed effect factors because language background and contrastive segments remain constant without change) and “subject” as a random effect is, therefore, the model that was used to test overall effects on accuracy rates.

Before looking into the model summary, in order to facilitate the reader’s understanding, some statistical terminology is first provided.

R-squared values range from 0 to 1. If R-squared is quite high, such as 0.92, it will be possible for us to interpret this as 92% of the variation that is found in a dataset being explained by a model. For instance, we have one variable ‘language background’, so the R-squared reflects how much of my data is accounted for by differences between language

backgrounds. As Ozili (2023) explained, most studies in social science or humanities do not aim to predict human behaviour but to assess whether predictors have a significant effect on the dependent variable, and therefore an R-squared that is between 0.10 and 0.50 (or between 10 percent and 50 percent when expressed in percentage) is acceptable in social science research.

Residual standard error scores range from 0 to 1. The value that is close to 0 means small. Small residual standard error (residual score) means that random effects (such as individual differences) are small and do not affect accuracy rates.

Finally, the p-value of a model is used to determine the correlation (or relationship) between two or more variables (such as language background and accuracy rate). If the p-value is less than the significance level (0.05) then it means that fixed effect factors have significant effects on accuracy rates.

Table 27 *Model summary*

R-squared	0.63
P-value	<0.01*

Table 28 *Effect summary*

Random Effects	
Groups	SD
Subject	0.04
Residual	0.09

The results in Tables 28-29 show a significant effect on accuracy ($p < .01$), with $R^2 = 0.63$, suggesting that 63% of variation is predicted by the fixed factors and random effects. The model's small residual score at 0.09 indicates that random effects are relatively small. This demonstrates that both language background and contrastive segments affect accuracy rates, and random effects are small. Now, let's look at the effects of language background and contrastive segments in particular.

4.3 The Effect of Language Background

The results of the effect of language background are discussed in this section. First, a descriptive analysis of the variants perceived for each target sound is presented, in order to detail the rates of accuracy and the non-target realizations observed. Then, a summary of the model is given to report the effect of the language background. Finally, a pairwise comparison is shown.

We begin by reporting the results for two tense and lax vowel contrasts [y, ʏ] and /e-ε/, which are followed by the two rounded vowel contrasts /y, u/ and /œ, ɔ/. It is hypothesized that language background would affect participants' accuracy rates. In order to examine the statistical significance of the difference and whether language background as a categorical variable has an effect on accuracy rate, I ran a linear regression model that includes 'language' (language background) as a fixed effect factor. A post-hoc pairwise comparison is then conducted under this model by using the emmeans function in R to determine whether the difference between groups is significant.

4.3.1. *The Results for Tense and Lax Allophone Vowels [y, ʏ]*

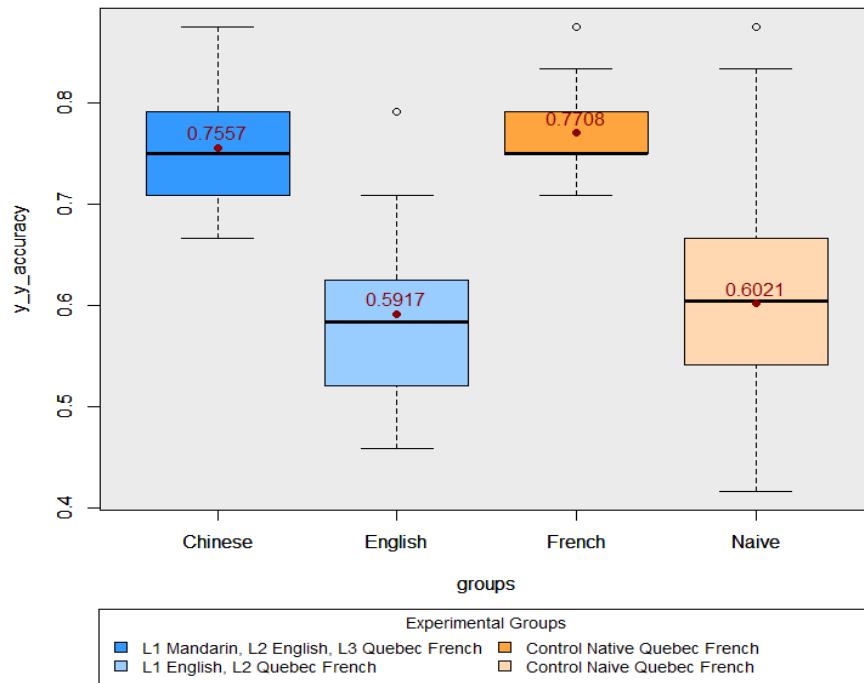
4.3.1.1 Descriptive Statistics

In general, the QF natives and the L3 QF group' results are more similar statistically than the other two groups as evidenced by comparing the mean, median, variance, range and the distribution of the results. The mean, the average of the accuracy, is calculated using the mean function in R. The mean of the results of tense and lax allophonic contrasts are displayed in Table 30 and Figure 5. The L1 Mandarin-L2 English learners of Quebec French (L3 QF or Chinese) and the native Quebec French speakers perform above 76% accuracy: the L3 QF learners 75% versus QF speakers 77%. On the other hand, the other two groups achieve similar accuracy: L1 English L2 Quebec French learners (L2 QF or English) perform at 59% accuracy, and naïve learners achieve a 60% accuracy rate.

Table 29 *Descriptive statistics*

Groups	Mean	Median	Standard Deviation
QF natives	77.08	75	4.78
L3 QF group	75.57	75	6.2
L2 QF group	59.17	58.34	8.4
Naïve	60.21	60.42	12.05

Figure 5 *The perception of tense and lax allophonic vowels across the four groups*



The median is shown by the bold lines across each box in Figure 5, and is also reported in Table 30. Similarly, the medians in the L1 Mandarin-L2 English learners of Quebec French (L3 QF) and the native Quebec French speakers' groups are around 75%, while the other two groups have similar medians around 60%.

The standard deviation given in Table 30 reflects that a small variance (4.78) is found in QF natives' results. In learner groups, the L3 QF group has a smaller variance (6.2)

compared to the other two groups (8.4, 12.05). This is also reflected in the interquartile ranges²³ in Figure 5. In Figure 5, QF natives' result is less dispersed as the box for QF natives is relatively shorter compared with the other three groups, which means that a less variance is found in QF natives' results. Compared with the L2 QF and naïve groups, the L3 QF group's result is less dispersed given a short box length. This again suggests that a small variance is found in the L3 QF group.

The range of the accuracy scores is shown from the lowest value to the highest value in each group. QF natives have a range between 72% to 83%, which is the smallest range among the other three learner groups. The L3 QF group's result is ranged between 67% to 88%, which is smaller than the L2 QF group's range (between 45% to 72%). In contrast, naïve group has a large range between 42% to 82%.

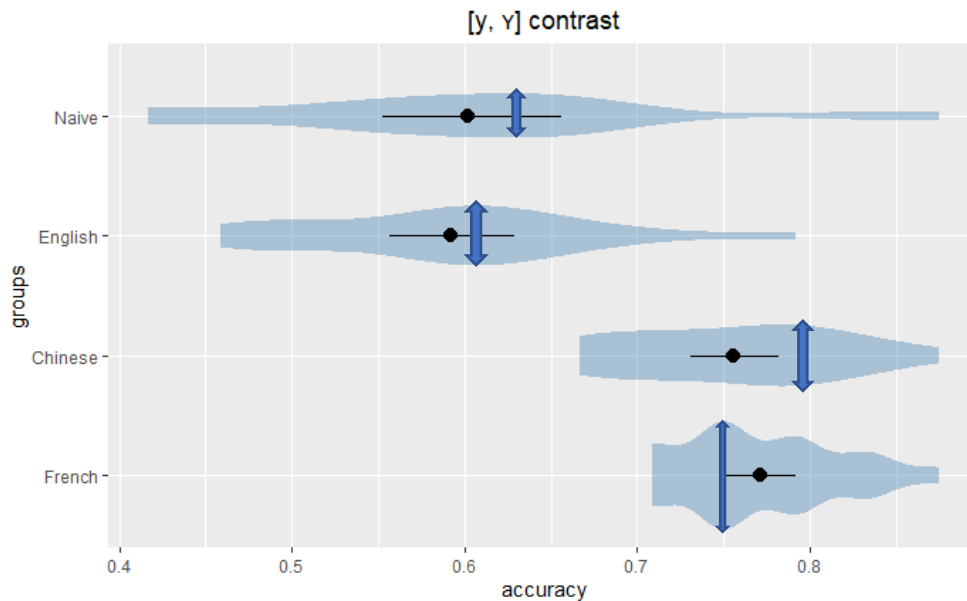
In addition, some outliers that are dots above the boxes in the native, the L2 QF and naïve groups were removed from the dataset²⁴. Overall, Figure 5 demonstrates that the L3 group's result is closer to the NS group on the perception of [y, γ] compared to the other two groups. Next, let's look at details in the distribution of their results.

The violin plot in Figure 6 is able to show clearly the distribution of the results to ensure that the results are accurate and reliable.

²³ The box lengths in each group reflects how the results are dispersed between each group. The longer the box, the more dispersed the result. The shorter, the less dispersed the results.

²⁴ Outliers are frequently encountered while collecting data, and they are "extreme values that abnormally lie outside the overall results, which affects the reliability of the study" (Kwak & Kim, 2017, p. 407). One method is "to remove outliers as a means of trimming the data" (Kwak & Kim, 2017, p. 410).

Figure 6 *The perception of tense and lax allophonic vowels across four groups*



In Figure 6, both the L3 QF group (Chinese) and QF natives' results are densely and consistently distributed. More specifically, in native Quebec French group, the wider sections (the blue double arrow) of the violin plot are at 0.75, revealing that most participants in this group receive a score of 75%. The L3 Quebec French group's results are distributed evenly, with a wider section around 0.8, representing that most L3 QF participants receive a score of around 80%. The distribution of the results as another strong evidence demonstrates that both QF natives and the L3 QF group behave indistinguishably on the perception of [y, ʏ]. In contrast, the L2 Quebec French group (English) and naïve group' results are distributed widely and dispersedly, and the wider section of the L2 QF group is around 60 %, reflecting that more participants are scored around 60%. Now, let's look at statistical analyses of the results.

4.3.1.2 The Model Summary

In this section, a model summary is given to evaluate whether the linear regression model best fits the results in the present study, and to see whether there are other factors that might affect accuracy rates.

As shown in Table 31, the R-squared value is 0.52 (52%), which is considered high in social science and humanities according to Ozili (2023). This means that the variation

in my dataset can be well explained by the linear regression model used to examine the effect of language background in the perception of [y, γ]. The residual standard error is very small (close to 0), which implies that random effects are small. P-value (<.01) again indicates that there is significant relationship between ‘language’ and accuracy rate, so ‘language’ has an effect on the perceptual accuracy rate.

Table 30 *Model summary*

Residual standard error	0.08
R-squared	0.52
P-value	<0.01*

4.3.1.3 Pairwise Comparison

Before presenting the results of pairwise comparison, it is essential to clarify the interpretation of the effect size because effect size is reported in pairwise comparison. Effect size informs how meaningful the relationship between variables or the difference between groups is. It indicates the practical significance of a research outcome. A large effect size means that research finding is practically significant, while a small effect size indicates limited practical applications. According to Lakens (2013), a commonly used interpretation is to refer to effect sizes as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) based on benchmarks suggested by Cohen (1988) as can be in Table 32. When we compare two groups to see how substantially different they are, the effect size is a quantification of the difference between the two group means: large effect sizes mean the difference is large and important, while small effect sizes mean the difference is small and unimportant.²⁵ The effect size calculated in the present follows Cohen’s interpretation.

Table 31 *Cohen’s d*

Relative size	Effect size
Small	0.2
Medium	0.5
Large	0.8

²⁵ As Sullivan & Feinn (2012) mentioned, “a *P* value can inform the reader whether an effect exists, but the *P* value will not reveal the size of the effect” (p. 279). When effect size is less than 0.2, we can interpret that “the difference is negligible, even if it is statistically significant” (McLeod, 2019; Sullivan & Feinn, 2012).

Table 32 *Pairwise comparison in tense and lax allophonic contrasts*

Groups		Estimate ²⁶	St. Error	P-value (p< 0.05)	Effect size (d)
QF native	L3 QF	0.02	0.03	0.93	0.18
QF native	L2 QF	0.18	0.03	0.01*	2.17
QF native	Naïve	0.17	0.03	0.01*	2.04
L3 QF	L2 QF	0.16	0.03	0.01*	1.98
L3 QF	Naïve	0.15	0.03	0.01*	1.86
L2 QF	Naïve	-0.01	0.03	0.98	0.13

Table 33 was generated using the emmeans function under the regression model built on the data. The statistical results demonstrate that there is no significant difference between the L3 QF group and the Quebec French natives on the perception of tense and lax allophonic contrasts [y, ʏ] (p = .93; effect size =0.18). The results of the L2 (59%) and L3 (75%) QF groups, however, are significantly different (p <.01; effect size =1.98). There is also a significant difference between the L3 QF group and the naïve learner group (p <.01; effect size =1.86). Overall, the statistical results indicate that the L3 QF learners perceive [y, ʏ] indistinguishably from Quebec French natives, but English and Chinese learners of Quebec French behave significantly differently when perceiving [y, ʏ].

4.3.2 *The Results for Tense and Lax Phonemic Vowels /e-ɛ/*

4.3.2.1 **Descriptive Statistics**

It is evident that the tense and lax mid vowels /e-ɛ/ are challenging for all participants. The perceptual results of the tense and lax mid vowels displayed in table 35 reveal that the L3 QF group and the QF natives perform similarly to each other on /e-ɛ/, with accuracy above 65%. Similarly, the L2 QF group and the naïve group achieve 58% accuracy, as given below.

²⁶ Estimate values here are to show how different two groups are (mean difference).

Table 33 *Descriptive statistics*

Groups	Mean	Median	Standard Deviation
QF natives	69.58	70.83	8.35
L3 QF group	65.15	66.67	7.67
L2 QF group	58.33	58.54	6.76
Naïve	58.33	58.54	8.23

Figure 7 *The perception of mid-tense and lax vowels across four groups*

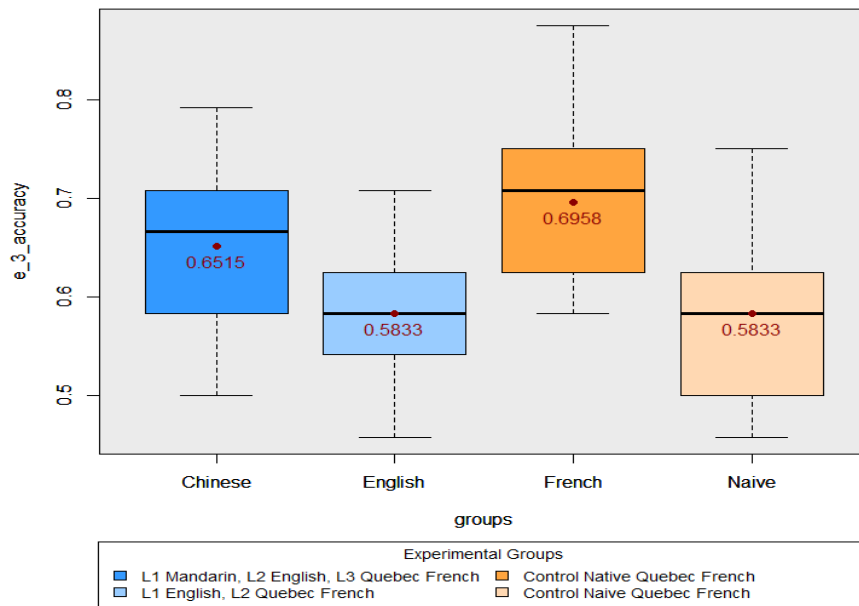
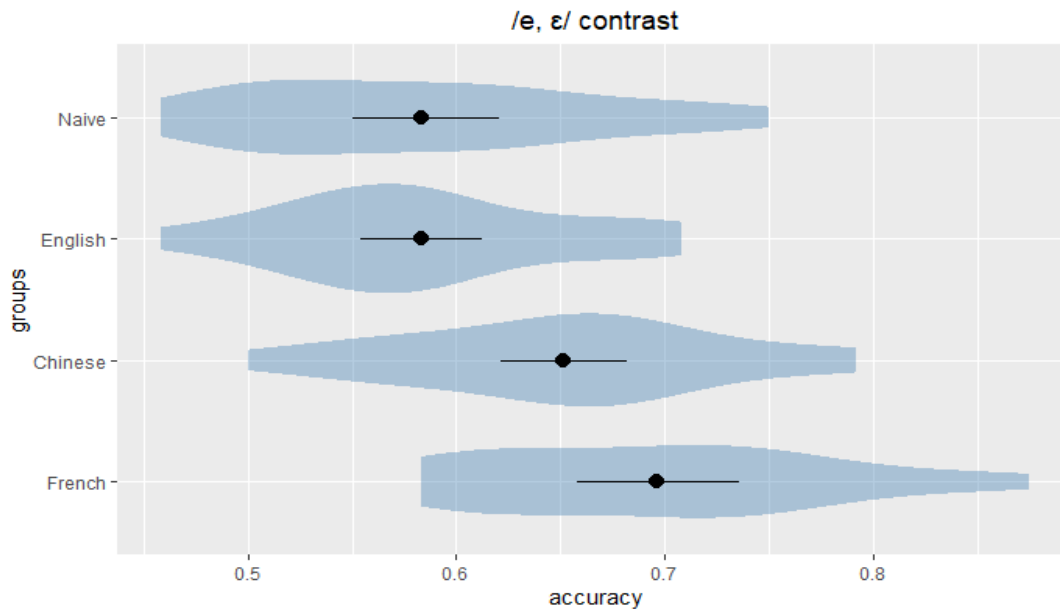


Figure 7 clearly shows that all the participants achieve low accuracy rates on /e-ε/. The L3 QF French group achieve an accuracy of 65%, which is quite low compared with the other tense and lax contrast which was [y, ʏ]. Surprisingly, the L1 control group, Quebec French natives, also have a low accuracy at 69.5% (almost 70%), which suggests that /e-ε/ in pseudo words are also difficult for native speakers of Quebec French to perceive. In contrast with [y, ʏ], in the perception of the mid tense and lax contrast /e-ε/, the L3 QF and L2 QF French groups both perform poorly, below 70% accuracy: the L3 QF group 65% versus the L2 QF group 58%. Naïve learners achieve 58% accuracy, which is the same as the L2 QF French group.

The median, marked bold lines across each box in Figure 7 and also reported in Table 34, illustrates that the L1 control and the L3 QF group's results are closer to each other with 66% versus 70% compared to the other two groups. On the other hand, the L2 QF group and naïve group' results are identical with the median of 58%, which is the same as their mean. This suggests that the L2 QF and naïve groups' results have a symmetrical distribution, indicating that both groups perform evenly on the perception of /e-ε/.

The distribution and range of their results are given in violin plots below. In general, the distributions of the data in all the groups are wide and dispersed. This means that there is a large variance in participants' performance in each group (also see standard deviation in Table 34: 8.35, 7.67, 6.76, 8.23). To be more specific, although the L3 QF group (Chinese) and QF natives (French) show similar performance on the perception of /e-ε/ according to their average scores, the ranges of their results are quite different. As can be seen their violin plots, QF French natives' results range (from the smallest value to the greatest value) is from 0.58 to 0.87, which reflects that all the participants' scores are within a range from 58% to 87%. However, the L3 QF group's results range is from 0.5 to 0.79, representing that participants' overall scores are within a range from 50% to 79%. The L2 QF group and naïve learners perform worse than the other two groups with a range from 0.5 to 0.7 above. The distribution and range, again, reveal that all the participants including QF natives have difficulties perceiving /e-ε/, with a large variance showing that participants' performance is heterogeneous.

Figure 8 *The perception of mid-tense and lax vowels across four groups*



4.3.2.2 The Model Summary

In this section, a model summary is given to evaluate the model and to see whether there are other factors that might affect accuracy rates.

Table 34 *Model effect summary*

Residual standard error	0.08
R-squared	0.28
P-value	<0.01*

In Table 35, the R-squared value is 0.28 (28%), suggesting that 28 % of variation is predicted by the fixed factors and random effects. The low residual standard error (0.08) implies that random effects are relatively small, and the predictor (language background) in this model has an effect on accuracy rate. The p-value ($p < .01$) indicates that there is a significant relationship between ‘language’ and accuracy, so ‘language’ has an effect on accuracy rate.

However, it seems that even with the help of L1 Mandarin and L2 English, the L3 QF learners still have difficulties perceiving /e-ε/. In addition, all the participants including native speakers of QF do not perform well on this contrast demonstrating a large variance.

The higher the variance, the more heterogeneous the data is. This means that the overall results of /e-ε/ are not consistent, so it is hard to make a strong conclusion.

4.3.2.3 Pairwise Comparison

Table 35 *Pairwise comparison in tense and lax mid contrasts*

Groups		Estimate	St. Error	p-value (p< 0.05)	Effect size (d)
QF native	L3 QF	0.04	0.02	0.26	0.57
QF native	L2 QF	0.11	0.02	0.01*	1.45
QF native	Naïve	0.11	0.02	0.01*	1.45
L3 QF	L2 QF	0.07	0.02	0.03*	0.88
L3 QF	Naïve	0.07	0.02	0.03*	0.88
L2 QF	Naïve	0.00	0.02	1.00	0.00

As can be seen in Table 36, there is no significant difference between the L3 QF group and the Quebec French natives ($p = .26$; effect size = 0.57). The results of the L2 (58%) and L3 (65%) QF groups are significantly different ($p = .03$; effect size = 0.88). The difference between the L3 QF group and the naïve learner group ($p = .03$; effect size = 0.88) is also statistically significant. The statistical results reflect that the L3 QF learners and the native Quebec French speakers perform indistinguishably from each other on tense and lax mid vowels /e-ε/, but the L2 QF learners perform at a level close to chance. More importantly, the L2 and L3 QF learners perform significantly differently on /e-ε/.

To summarize, these two sections (4.3.1 & 4.3.2) demonstrate that the L3 QF learners and the native Quebec French speakers perform similarly to each other on the two contrasts [y, ʏ] and /e-ε/, while the L2 QF learners perform significantly worse than the L3 QF learners. However, the perceptual results of two contrasts are not homogeneous as the perception of the tense and lax allophonic contrast [y, ʏ] is definitely better with a smaller variance than the tense and lax mid contrast /e-ε/ on average. More reasons to explain their differential performance will be discussed in the next chapter.

4.3.3. The Results for High Rounded Vowels /y, u/

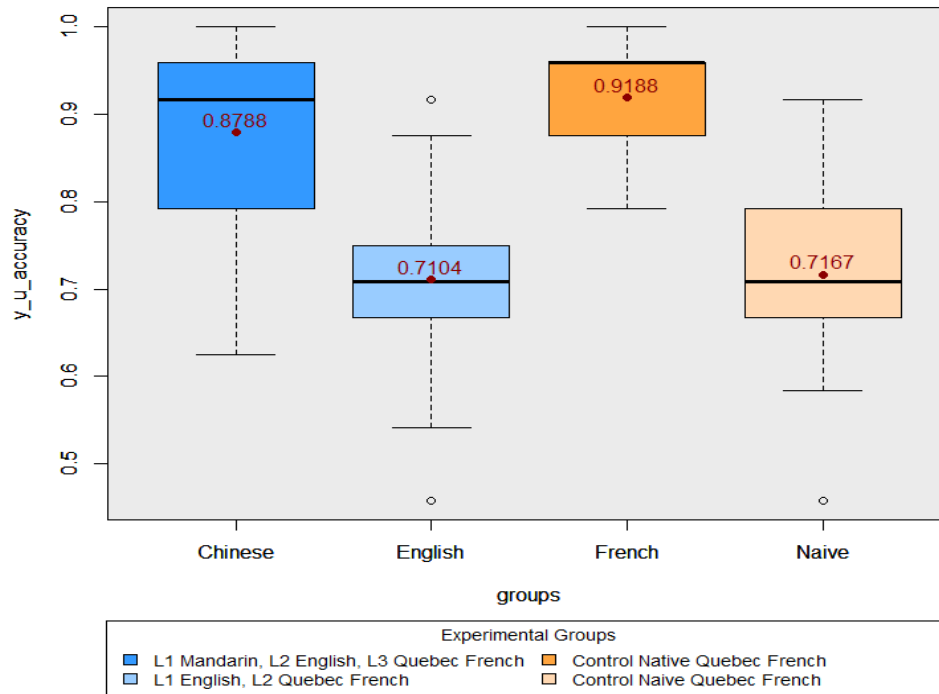
4.3.3.1 Descriptive Statistics

Recall from Section 1.5.2 that Mandarin and French both have high rounded vowels /y, u/ specified by a featural ranking $[\pm\text{front}] > [\pm\text{round}]$, so my hypothesis predicts that /y, u/ will be easy for Mandarin speakers to perceive because they have the relevant featural ranking to parse /y, u/. Let's look at how Mandarin speakers perceive French high rounded vowels /y, u/.

Table 36 *Descriptive statistics*

Groups	Mean	Median	Standard Deviation
QF natives	91.88	95.83	6.69
L3 QF group	87.88	91.67	10.9
L2 QF group	71.04	70.84	10.7
Naïve	71.67	70.84	10.4

Figure 9 *The perception of high rounded vowels across four groups*



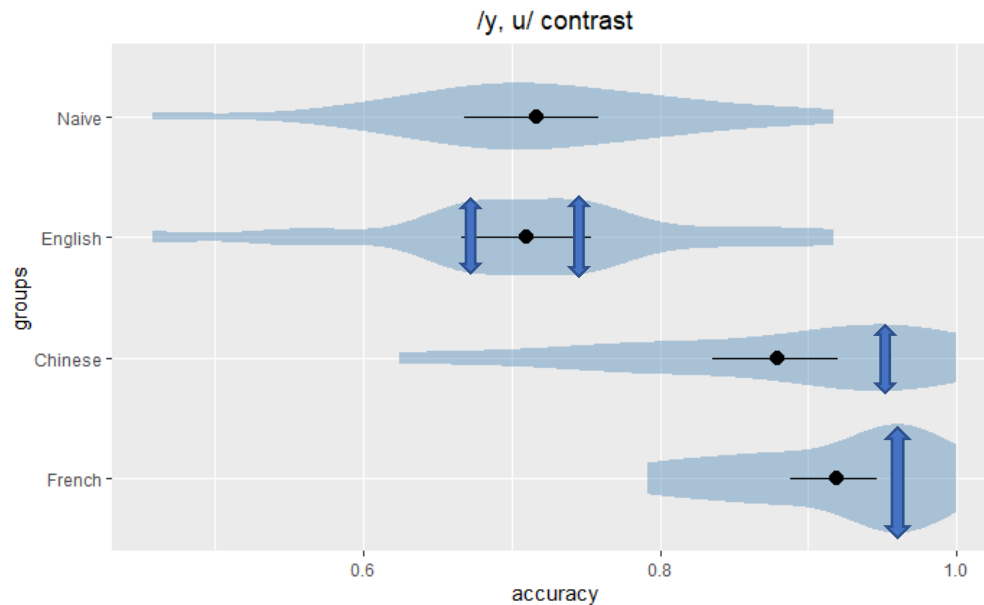
Overall, some similarities in performance between the L3 QF group and the QF native group can be observed in Table 37 and Figure 9, but there is still a difference between the QF natives and the learner groups. First, let's look at the means. Both the QF natives and the L3 QF group achieve higher average accuracy rates than the other two groups, with accuracy rates of 87% and 91%. In contrast, the L2 QF group's accuracy rate is lower than the L3 QF group, with a 71% accuracy rate. Naïve learners behave the same as the L2 QF group with a 71% accuracy rate.

The median indicates that both the L2 QF and naïve groups perform evenly on the perception of /y, u/ given the median of the L2 QF and naïve groups (70.84%) is very close to their mean (71%). In contrast, the L1 control (96%) and L3 QF groups (92%) have similar median around 90%.

Besides that, it is observed in Figure 9 that there is a larger range in the results for the learner groups compared to the QF natives. This means high variability in the learner groups' results while the QF natives have a range between 80% to 100%, which is the smallest range among the other three learner groups. The L3 QF group's result ranges from 62% to 100%, which is similar to the L2 QF group's range between 53% to 88%, and the naïve group has a range between 58% and 92%. In addition, the standard deviations shown in Table 38 also support that high variability is found in the learner groups as all learner groups have standard deviation around 10.

Now, let's look at the distribution of their results in violin plots to understand their overall performance.

Figure 10 *The perception of high rounded vowels across four groups*



In Figure 10, the wider section at 0.95 in the QF natives group indicates that most participants receive a 95% accuracy rate on /y, u/. The L3 QF group (Chinese) have a wider section around 95%, revealing that most participants in the L3 QF group also achieve a 95% score. The distribution of both the L3 QF group and the NS group demonstrates that both groups perform identically as reflected by their wider sections. On the other hand, for the L2 QF group (English), the wider sections of their violin plot are at 0.68 and 0.75, which means that most participants in this group receive scores of 68% and 75%, which is very different from the L3 QF and NS groups.

4.3.3.2 The Model Summary

Recall from the previous two sections that the model effect is determined by calculating an R-squared value with an acceptable range between 0.10 and 0.50. As shown in Table 38, the R-squared value is 0.49 (49%). This shows that 49% of the variation in my dataset can be well explained by this model, and a small residual standard error indicates that the random effects are small, so the predictor in this model has an effect on accuracy rate. The p-value ($p < .01$) demonstrates that the relationship between 'language' and

accuracy rate is statistically significant, so it is possible to make a strong claim that language background has an effect on accuracy rate.

Table 37 *Model effect summary*

Residual standard error	0.10
R-squared	0.49
P-value	<0.01*

4.3.3.3 Pairwise Comparison

Table 38 *Pairwise comparison in high rounded vowels*

Groups		Estimate	St. Error	P-value (p<0.05)	Effect size (d)
QF native	L3 QF	0.04	0.03	0.56	0.41
QF native	L2 QF	0.20	0.03	0.01*	2.11
QF native	Naïve	0.20	0.03	0.01*	2.05
L3 QF	L2 QF	0.17	0.03	0.01*	1.71
L3 QF	Naïve	0.16	0.03	0.01*	1.64
L2 QF	Naïve	-0.01	0.03	1.00	0.06

The results of pairwise comparison in Table 39 express that statistically, the L3 QF group and QF natives are not significantly different ($p = .56$; effect size = 0.41). The L3 QF group and the L2 QF group, however, are significantly different ($p < .01$; effect size = 1.71). Additionally, the L3 QF group and naïve learners are significantly different ($p < .01$; effect size = 1.64). Based on the statistical results, it is possible to conclude that the L3 group's behaviour is indistinguishable from the NS group on /y, u/ while the L3 groups' behaviour is significantly different from the L2 group on /y, u/.

4.3.4 The Results of The Mid Rounded Vowels /œ, ɔ/

4.3.4.1. Descriptive Statistics

The mid rounded vowels /œ, ɔ/ do not exist in the Mandarin vowel system, but Mandarin has the necessary feature hierarchy [\pm front] > [\pm round] to parse them, so my hypothesis predicts that the mid rounded vowels will be parsed successfully by the L3 QF learners.

Let's see learners' performance on the mid rounded vowels. In Table 40, it is clear that QF natives and the L3 QF group are closer in terms of mean, median and standard deviation compared to the other two groups.

Table 39 *Descriptive statistics*

Groups	Mean	Median	Standard Deviation
QF natives	89.17	91.6	8.45
L3 QF group	85.04	87.5	9.24
L2 QF group	65.62	66.7	16.4
Naïve	68.3	70.8	11.4

Figure 11 *The perception of mid rounded vowels across four groups*

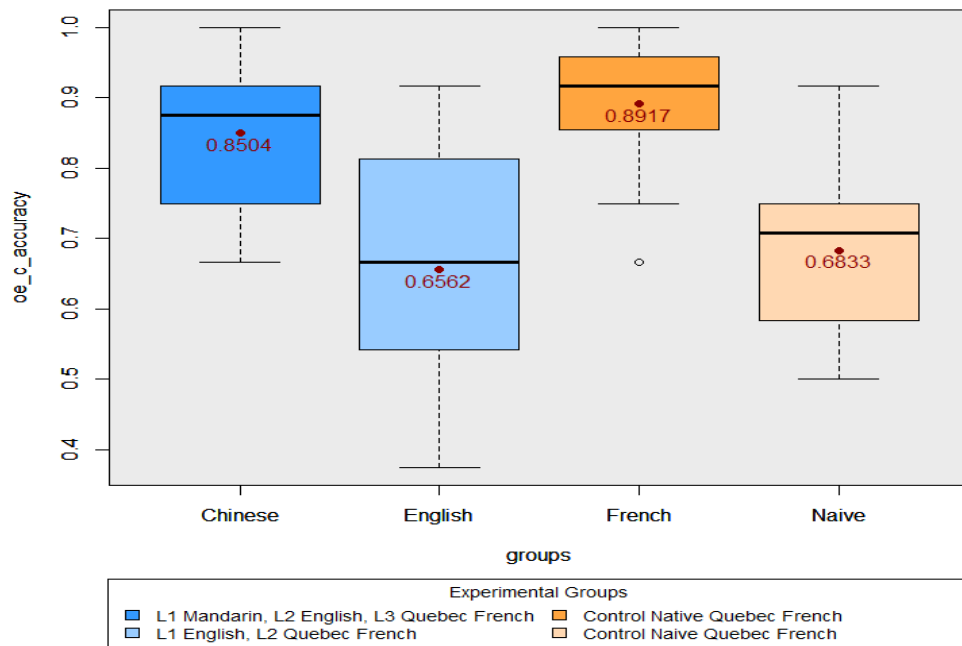
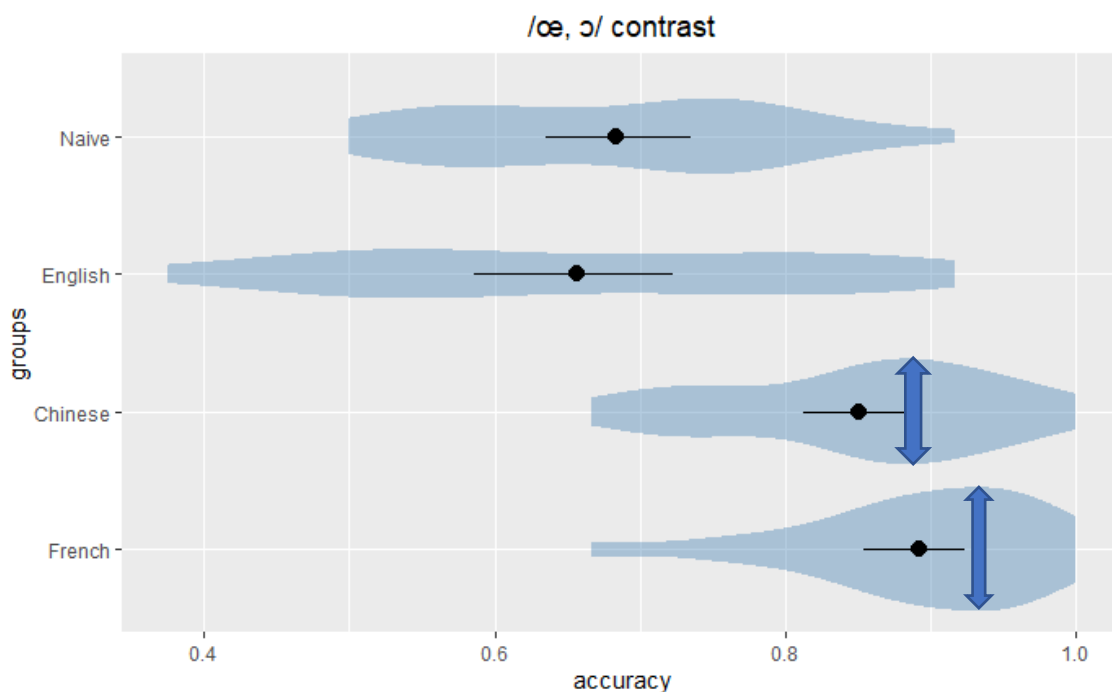


Figure 11 displays a comparison of the means. Similar to the results of the high rounded vowels, the L3 QF group and the QF natives perform closely on /œ, ɔ/ with accuracy rates 85% and 89%. The L2 QF learners achieve a lower average accuracy 65% when compared to both the L3 QF groups and the L1 controls. Naïve learners perceive slightly better than the L2 QF group, with a 68% accuracy.

In relation to the range of participants' results shown in Figure 11, QF natives have the smallest range between 75% and 100% among the other three groups. In the learner groups, the L3 QF group has a smaller range between 68% and 100% compared to the two groups: the L2 QF group (38% to 90%) and naïve group (51% to 90%).

Figure 12 presents the distribution of their results. The L2 QF group (English)'s result is distributed widely and dispersed, showing a large variance in their performance. On the contrary, the distribution of the L3 QF group (Chinese) and QF natives are dense, which means a small variance in their performance. The wider section of the L3 QF group's violin plot is at about 0.9, indicating that most participants receive a 90% accuracy rate. Similarly, the NS group has a high wider section at around 0.93, which reveals that most QF native speakers achieve a 93% accuracy rate. Overall, the distribution of the results demonstrates that both the L3 QF group and QF natives' performance on /œ, ɔ/ are more consistent, i.e., with low variability. However, the L2 QF group's performance is very different from those two groups with high variability. The distribution of their results is further strong evidence to prove that the L3 group's behaviour is indistinguishable from the NS group on /œ, ɔ/.

Figure 12 *The perception of mid rounded vowels across four groups*



4.3.4.2 The Model Summary

A model summary is provided to evaluate the model and to examine the effect of language background to accuracy rates.

Table 40 *Model effect summary*

Residual standard error	0.12
R-squared	0.44
P-value	< 0.01*

An R-squared value at 0.44 (44%) is high, and a small residual standard error (close to 0) indicates that the random effects are small and language background is a predictor of the accuracy rates. Again, the P-value of this model is <.01, so we can state that the relationship between language background and accuracy rates is significant, and it is reasonable to conclude that language background has an effect on accuracy rate.

4.3.4.3 Pairwise Comparison

Table 41 *Pairwise comparison in mid rounded vowels*

Groups	Estimate	St. Error	P-value (p<0.05)	Effect size (d)
QF native L3 QF	0.02	0.03	0.93	0.35
QF native L2 QF	0.18	0.03	0.01*	2.00
QF native Naïve	0.17	0.03	0.01*	1.77
L3 QF L2 QF	0.16	0.03	0.01*	1.65
L3 QF Naïve	0.15	0.03	0.001*	1.42
L2 QF Naïve	-0.01	0.03	0.98	0.23

The results shown in Table 42 reveal that a statistically significant difference is not found ($p = .93$; effect size = 0.35) between the L3 QF group and QF natives. The L3 QF group and the L2 QF group's results, again, are significantly different ($p < .01$; effect size = 1.65). The L3 QF group and naïve learners are also significantly different ($p < .01$; effect size = 1.42). The statistical results reflect that the L3 QF groups and the L1 controls behave similarly to each other on /œ, ɔ/, while the L2 and L3 QF groups perform significantly differently on /œ, ɔ/.

Overall, it is possible to summarize that the L3 QF learners do not have difficulties perceiving rounded vowels, even the mid rounded vowels that do not exist in their previously acquired languages.

4.3.5 Summary

In this section, several linear regression models taking ‘language’ as a fixed effect factor were run to test the effect of language background on accuracy rate. Then, a pairwise comparison test was conducted to test the statistical difference in the means among each group. Overall, among learner groups, the L3 QF group perform significantly differently from the L2 QF group on all the contrasts, but the L3 group’s performance is indistinguishable from the NS group, which is expected based on my hypothesis that Mandarin speakers will be able to use features from their previous acquired languages, L1 Mandarin and L2 English, to parse the target sounds successfully. The model summaries demonstrate that language background does have an effect on accuracy rate.

With respect to the contrasts, the perception of the rounded vowels contrasts is better than the tense and lax contrasts. More specifically, tense and lax mid vowels /e-ɛ/ are challenging for all the participants including QF natives. The next step in my analysis consists of determining whether the different contrasts have an effect on accuracy rate. More importantly, we aim to examine whether there is significant difference in the means for each contrast.

4.4. The Effect of Contrastive Segments

4.4.1 The Perception of all the Contrasts by the L3 Quebec French Learners

4.4.1.1 Statistical Analysis

In this section, the goal is to examine the statistical significance of the difference between the perception of each contrast by the participants from the same group to answer the research question, what are the differences between the perception of allophonic [y, ʏ] and phonemic contrasts /e, ɛ/ by learners?

Additionally, the present study aims to investigate inventory effect, which means that the segments specified with the same feature (such as /œ-ɔ/ and /y, u/ specified with [+round]) should behave the same. To put it simply, if the learner has no problem

discriminating /y, u/, it is hypothesized that they would also be able to perceive /œ-ɔ/ successfully.

The independent variable is contrastive segments which are the four different contrasts, and the dependent variable is accuracy rate. I ran a linear mixed effect model that includes ‘contrastive segments’ as a fixed effect factor and ‘subject’ as a random effect. This model is used to determine whether ‘contrastive segment’ has an effect on accuracy and whether a random effect would affect accuracy. A post-hoc pairwise comparison is again conducted under this model by using the emmeans function in R to determine the significant differences for each contrast. Bear in mind that only two experimental groups, the L3 and L2 Quebec French learners’ results are analyzed as we are only interested in learners’ performance on the target contrasts.

In each sub-section, a descriptive statistical analysis including mean, median, standard deviation is given first, followed by a summary of the model, and finally, a pairwise comparison is shown.

Table 42 *Descriptive statistics in the L3 QF learner group*

Groups	Mean	Median	Standard Deviation
/y, u/	87.87	91.67	10.9
/œ, ɔ/	85.04	87.5	9.24
[y, ʏ]	75.57	75	6.2
/e-ɛ/	65.15	66.67	7.67

Table 43 shows that the L3 Quebec French group perform better on the two rounded vowel contrasts /œ, ɔ/ and /y, u/ than the tense and lax vowels /e-ɛ/ and [y, ʏ], with accuracy rates of 85% and 87%, compared to 65% and 75%. Similarly, the medians in the two rounded contrasts (91.67% and 87.5%) are closer and higher compared to the other two contrasts (75% and 66.67%). In addition, the tense and lax vowel contrasts have smaller standard deviation (6.2, 7.67) compared to the two rounded vowels (10.9, 9.24), suggesting that the results of the two rounded vowels have a larger variance compared to the two tense and lax vowels.

4.4.1.2 The Model Summary

In this section, effect and model summaries are given to evaluate the model and the effect of contrastive segments.

Table 43 *Effect summary*

Random Effects	
Groups	SD
Subject	0.02
Residual	0.08

Table 44 presents the random effect of ‘subject’. A small residual score (see Section 4.1.1.4) at 0.08 indicates that random effects are small. Standard deviation at 0.02 is also small, representing that there is a small variance within-group, so the L3 QF learners’ performance on all the contrasts is consistent. To be more specific, this means that almost all twenty-two L3 QF learners achieve high accuracy on the two rounded vowel contrasts /œ-ɔ/ and /y, u/, but low accuracy on the two tense and lax vowel contrasts /e, ε/ and [y, ʏ]. In addition, the random effects are small, which implies that the fixed effect has a large effect on accuracy.

Table 44 *Model summary*

Contrast segment	p-value	R-squared
	<0.01*	0.55

A R-squared value at 0.55 (55%) means that 55% of the variation that is found in my dataset can be explained by the model run in the present study. Given the model’s p-value (<.01), it is possible to state that there is significant relationship between contrastive segments and accuracy rate, so the effect of contrasts is significant in the L3 QF group’s perceptual results. In other words, contrasts do have an effect on accuracy.

4.4.1.3 Pairwise Comparison

Table 45 *Pairwise comparison in L3 QF learner group*

Contrast	Estimate	SE	p-value (p<0.05)	Effect Size (d)
e, ε – œ, ɔ	-0.20	0.03	0.01*	2.37
e, ε – y, u	-0.23	0.03	0.01*	2.71
e, ε – y, γ	-0.10	0.03	0.01*	1.24
œ, ɔ – y, u	-0.01	0.03	0.68	0.33
œ, ɔ – y, γ	0.10	0.03	0.02*	1.13
y, u – y, γ	0.12	0.03	0.01*	1.47

The emmeans function in R was used to conduct a post-hoc analysis for pairwise comparison to test whether there is significant difference between each contrast pair. As shown in Table 46, in the contrast group /œ-ɔ/ and /y, u/, p-value is .68 which is statistically insignificant with a small effect size 0.33 according to Cohen’s d’s interpretation. It is possible to conclude that the difference between the performance on the two contrasts is not significant. On the other hand, for the contrast pair /e, ε/ and [y, γ], the p-value is .01, and the effect size at 1.24 is large, revealing that the difference between the performances on them is statistically significant. In addition, except the contrasts /œ-ɔ/ and /y, u/, all the other contrast groups are significantly different. This is also reflected in estimate which is the mean difference. Overall, the statistical results reflect that the L3 QF learners perceive /œ-ɔ/ indistinguishably from /y, u/, but their perceptions of the other contrasts are all significantly different from each other.

4.4.2 The Perception of all the Contrasts by the L2 Quebec French Learners

4.4.2.1 Statistical Analysis

Following the same procedure, a linear mixed effect model that includes ‘contrastive segments’ as a fixed effect factor and ‘subject’ as a random effect is run to examine the L2 QF learners’ performance. The means, medians, standard deviations of four contrasts are given in Table 47.

Table 46 *Descriptive statistics in L2 QF learner group*

Groups	Mean	Median	Standard Deviation
/y, u/	71.04	70.84	10.69
/œ, ɔ/	65.63	66.67	16.44
[y, ʏ]	59.17	58.33	8.40
/e-ɛ/	58.34	58.33	6.75

Similar to the L3 QF learners, the L2 QF learners perceive the rounded vowels better than the tense and lax vowels as displayed in Table 48, but their means and medians are lower than the L3 QF learners in general. In particular, the L2 Quebec French group perform better on the /y, u/ contrast than on the other contrasts, with a 71% accuracy rate and median 70.84. On the other hand, they perform poorly on the mid tense and lax contrasts /e, ɛ/ with only a 58% accuracy rate and median 66.67. Standard deviation shows that there is a smaller variance (8.4, 6.75) in the perception of the two tense and lax vowels compared to the two rounded vowels (10.69, 16.44).

4.4.2.2 The Model Summary

Table 47 *Effect summary*

Random Effects	
Groups	SD
Subject	0.05
Residual	0.10

In Table 48, a small standard deviation (0.05) and residual scores (0.10) mean that random effects are relatively small, indicating that there is a small variance within-group, so we can conclude that the L2 QF subjects perform consistently on all the contrasts. Again, a small random effect suggests that a fixed effect has a large effect on accuracy rate.

Table 48 *Model summary*

Contrast segment	p-value	R-squared
	0.004*	0.32

The R-squared value of 0.32 is high, which means that the model fits well to test the effect of contrastive segments. The P-value (.004) reveals that the relationship between contrastive segments and accuracy is statistically significant. It is reasonable to interpret that the fixed effect factor ‘contrastive segments’ significantly affects the L2 QF group’ accuracy rates.

4.4.3.2 Pairwise Comparison

Table 49 *Pairwise comparison in L2 QF learner group*

Contrast	Estimate	SE	P-value (p<0.05)	Effect Size (d)
e, ε – œ, ɔ	-0.07	0.03	0.19	0.72
e, ε – y, u	-0.13	0.03	0.01*	1.25
e, ε – y, γ	-0.008	0.03	0.99	0.08
œ, ɔ – y, u	-0.05	0.03	0.34	0.53
œ, ɔ – y, γ	0.06	0.03	0.20	0.63
y, u – y, γ	0.12	0.03	0.03*	1.17

A post-hoc test is then conducted for pairwise comparison to determine the significant difference in the means among each contrast. As shown in Table 50, between the contrasts /œ-ɔ/ and /y, u/, the p-value is 0.34. This means that the difference between the performance on the two contrasts is statistically insignificant. Similarly, between the contrast pairs /e, ε/ and [y, γ], the p-value is 0.99, showing that the difference in means between the perception of /e, ε/ and [y, γ] is not statistically significant. The statistical results indicate that in general, the difference between each group is relatively not very large. This can also be seen in estimate, the mean difference between the two contrasts.

4.4.3. Summary

In this section, two linear mixed effect models taking ‘contrastive segments’ as a fixed effect factor and ‘subject’ as a random effect factor were run to test the effect of

contrasts on accuracy. Again, a post-hoc pairwise comparison was run after that to test the statistical difference in the means for each contrast.

Overall, the L2 and L3 Quebec French groups perform better on the two rounded vowel contrasts /œ, ɔ/ and /y, u/ than on the tense and lax vowels /e-ɛ/ and [y, ʏ]. There is no significant difference in the perception of the rounded vowels /œ-ɔ/ and /y-u/, but a significant difference is found in the perception of /e, ɛ/ and [y, ʏ]. For both the L2 and L3 QF learners, among all the contrasts, they achieve a high accuracy rate for the high rounded vowels /y, u/. Similar to the L3 QF learners, for the L2 QF learners, the mid tense and lax vowels /e, ɛ/ are the most challenging target contrast. Finally, the model and effect summaries demonstrate that contrastive segments as a fixed effect factor have an effect on accuracy rate with small random effects.

In this chapter, we have looked into how target sounds are perceived by all the participants. These results show that the L3 group's behaviour is indistinguishable from the NS group on all the contrasts while the L3 groups' behaviour is significantly different from the L2 group on all the four contrasts. Furthermore, we see that for the L3 QF group the /œ-ɔ/ and /y, u/ contrasts are significantly easier to discriminate than the /e, ɛ/ and [y, ʏ] contrast. These are the data we need to explain, and in the following chapter we turn to such an explanation.

CHAPTER FIVE: DISCUSSION

In this chapter, I will first present a summary of my results as they relate to my hypotheses. Then, I situate my findings in relation to previous studies. After that, I will turn to the role of contrastive hierarchy theories in explaining these results. Finally, the relation between the results and previously proposed L3 learning models will be discussed.

5.1 Summary and Hypothesis Evaluation

In an ABX discrimination task, the participants accurately perceived contrasts between front and back rounded vowels /y, u/ and /œ, ɔ/, and between tense and lax vowels, including both the allophonic difference between [y, ʏ] and the phonological contrast between /e-ɛ/ in pseudo words. The results of the experiment are summarized below, with a particular focus on how the results address the experiment's hypotheses. First, the hypotheses are explored by addressing the following research questions.

RQ1: Do L1 Chinese-L2-English-L3 Quebec French learners demonstrate facilitative influence from L1 Mandarin ([+front, +round]) and L2 English ([±tense]) in the perception of the allophonic contrast [y, ʏ] and the phonemic contrast /ɛ, e / in L3 Quebec French? If they do, then

RQ2: Do L1 Mandarin-L2 English L3 Quebec French learners perceive the contrasts better than L1 English-L2 Quebec French learners?

Hypothesis 1 predicts that the L1 Mandarin-L2 English learners of Quebec French (L3 QF) perceive tense and lax contrasts [y, ʏ] more accurately than L1 English-L2 Quebec French learners because the L3 QF learners have the necessary features from the L1 ([±front] > [±round]) and L2 ([±tense]) that help them parse [y, ʏ] successfully. In relation to /e-ɛ/, it is predicted that the L3 QF learners should perform similarly to the L2 QF learners because the L3 QF learners have a necessary feature [±tense] from their L2 English to parse /e-ɛ/. The L2 QF learners have a tense and lax distinction in mid vowels in their L1 English. In other words, the groups will behave differently because of their language background. This prediction is confirmed. Both linear regression and linear mixed effect

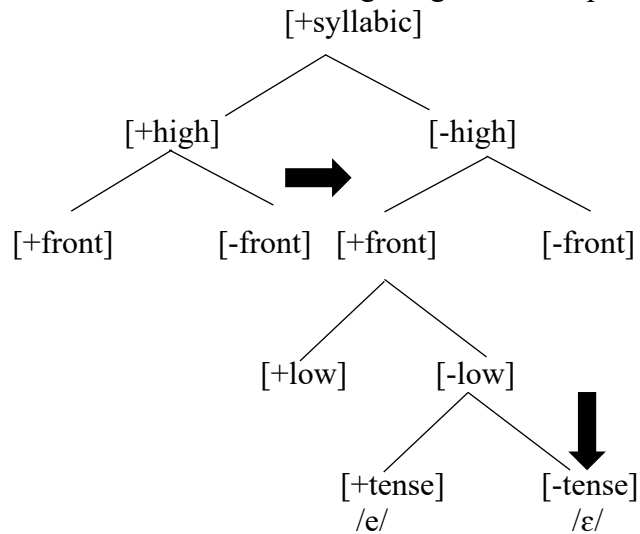
models reveal that language background has a significant effect on the accuracy rate. The L3 QF groups' behaviour is significantly different from the L2 QF group on both [y, ʏ] and /e-ɛ/. More importantly, the L3 QF learners' performance is not significantly different from the NS group on [y, ʏ] and /e-ɛ/, but the performance of the L2 QF group and the NS group is significantly different. These results indicate that language background is a predictor of learners' accuracy rates.

The L2 QF learners achieved an accuracy on /e-ɛ/ at 58%, which is slightly lower compared to the L3 QF learners (65%), but their means are close. In fact, all the participants including QF natives did not achieve high accuracy in the perception of /e-ɛ/. This will be discussed later in Section 5.2.2.

RQ3: What are the differences between the perception of allophonic and phonemic contrasts?

In Hypothesis 1, it is also predicted that /e, ɛ/ is challenging for the L3 QF group to perceive, and therefore the L3 QF group would perform worse on /e-ɛ/ than [y, ʏ] because of the parsing complexity of /e, ɛ/. This prediction is confirmed. The results showed that the L3 QF learners performed significantly better on [y, ʏ] than /e-ɛ/. One postulated reason of this difficulty is that to successfully parse /e, ɛ/ requires more restructuring actions. To parse [y, ʏ], the L3 QF learners need to use [±tense] in their L1-L2 interlanguage grammar, but parsing /e, ɛ/ requires more restructuring actions. They need to extend [±front] to the [-high] sub inventory and then add [±tense] as in (58).

(58) Possible L1-Mandarin L2-English grammar to parse /e, ε/



RQ4: Do L1 Chinese-L2-English Quebec French learners demonstrate facilitative influence from the ranking $[\pm\text{front}] > [\pm\text{round}]$ in the L1 feature hierarchy in the perception of rounded contrasts /y/-/u/ and /œ-ɔ/ in L3 Quebec French? If they do, then

RQ5: Do L1 Chinese-L2 English L3 Quebec French learners perceive the contrasts better than L1 English-L2 French learners?

With respect to the perception of high and mid rounded contrasts, Hypothesis 2 predicts that the L3 QF learners would differ significantly from the L2 QF learners with higher accuracy rates even though /œ-ɔ/ are absent in both Mandarin and English because the L3 QF learners have the feature ranking ($[\pm\text{front}] > [\pm\text{round}]$) used to parse /y, u/ and /œ, ɔ/ in French, while the L2 QF learners do not have such features. This prediction is confirmed. More specifically, the L3 QF learners behaved significantly differently from the L2 QF learners, but they performed indistinguishably to the NS group on high and mid rounded vowels without significant difference. Again, statistical results demonstrate that in the perception of high and mid rounded contrasts, language background has a significant effect on accuracy rates.

To sum up, L3 QF and L2 QF participants perceived the target sounds significantly differently. In contrast, the L3 QF participants demonstrate similar performance to the native controls. Statistical results prove that language background affects accuracy rates. It is possible to conclude that with the help of L1 Mandarin ($[\pm\text{front}] > [\pm\text{round}]$) and L2

English ([±tense]), L3 Quebec French learners can clearly acquire the target sounds to a native like level.

5.2 Comparison with Previous Studies

5.2.1 Cross-linguistic Influence

The findings of the present study provide strong evidence that both previously acquired languages influence L3 acquisition. Findings of previous studies focusing on adverb-verb order in L3 English (Westergaard, et al, 2017) as well as in phonetics on vowel lengthening in L3 Polish (Wrembel, et al, 2019) support that L3 learners can be affected negatively or positively by both L1 and L2 when perceiving L3 target input. More importantly, L3 learners are able to choose a property from either the L1 or the L2 to parse L3 input (Westergaard, 2021). Inspired by the LPM proposed by Westergaard, the current study contributes a novel finding that L3 learners are able to select phonological features from both L1 and L2 to represent L3 target sounds. With the contrastive hierarchy theory, the present study is able to present parsing procedures of the L3 target sounds with new data in the acquisition of tense and lax vowels and rounded vowels in Quebec French, which are discussed in the next section.

5.2.2 Acquisition of Tense and Lax Vowels

The L2-L3 perception results of tense and lax vowels are consistent with previous work on L3 Quebec French. In relation to tense and lax allophonic contrasts, L1 English-L2 Quebec French learners have difficulties perceiving [y, ʏ] (Nichols, 2014; Wu, 2022). In Nichols's (2014) study, in an AX discrimination task, L1 English learners at the high intermediate level of L2 QF proficiency only achieved a 66.2% accuracy rate of discriminating [y, ʏ]. L1 English-L2 Quebec French learners in the present study shows a similar rate of 59%. In Wu's (2022) study, L1 Mandarin-L2 English learners of L3 Quebec French and Quebec French speakers performed similarly on [y, ʏ] and /ɛ, e/ contrasts with no significant difference in an ABX discrimination task: both groups performed above 94% accuracy: Mandarin speakers 94% versus QF natives 97%. This is partially confirmed in the present

study, in that both the L3 QF group and QF natives performed similarly on the two contrasts, but with low accuracy above 76%. The possible reason is discussed in the next paragraph.

Furthermore, the present study provides new data concerning some possible experimental issues in previous studies. Previous work (Nichols, 2014; Wu, 2022) on the perception of [y, ʏ] or /ɛ, e/ utilizes a discrimination task without controlling for inter-stimulus interval (ISI) or the number of speakers. This would make their results inaccurate to some extent. In Nichols's study, the inter-stimulus interval varied unpredictably, so it is difficult to know whether or not inter-stimulus interval affects accuracy rates. Recall from Section 3.3.3 that English speakers are unable to perceive the Hindi /t-/ʈ/ contrast in 1500ms ISI, but reducing to 500ms triggered accurate perception (Werker & Logan, 1985). For Wu's (2022) study, with only one speaker who read the stimuli, it can be questioned whether the L1 Mandarin-L2 English learners of Quebec French attended to the acoustic similarities of the same vocal tract or to the phonological categorization. Additionally, both studies included limited L1 controls (<10) and L2 and L3 learners (<10), and therefore it is difficult to know whether a larger group of participants would behave the same. The present study takes those possible issues into account with a large sample size (>20), which again strongly reinforces that L1 Mandarin-L2 English learners of L3 Quebec French (L3 QF learners) outperform the L1-L2 Quebec French learners (L2 QF learners) because the L3 QF learners transfer phonological features from both the L1 Mandarin and the L2 English to acquire an L3 tense and lax contrasts.

The results of the present study reveal that QF natives did not achieve high accuracy on all the contrasts. The most unexpected one is that tense and lax contrasts are perceived with low accuracy rates by all the participants, including Quebec French natives, which is important to discuss further. Recall from Chapter 1 that in Quebec French, [±tense] is used to distinguish the tense and lax allophones of the high vowels, such as [y, ʏ], and also the phonemically contrastive mid vowels /e, ɛ/, as in *maître* [metr] 'master' and *mettre* [metr] 'to put', while European French does not have either lax allophones for high vowels nor a robust contrast between /e, ɛ/. One possible reason why all the participants did not achieve high accuracy is because participants did not get much input of the tense and lax distinction. In relation to this, Kircher (2012) conducted a study to investigate the attitudes young

Quebec francophones, anglophones, French-English bilinguals and allophones hold towards Quebec French compared to European French, using interviews and questionnaires. His findings showed that all four mother tongue groups indicate more favourable attitudes towards European French. More importantly, Lamontagne (2014), analyzing the production of Quebec French vowels, reported that the /e, ε/ distinction is disfavoured in older Quebec French speakers' production. All of these, again, seem to suggest that QF natives do not get enough input of tense and lax distinction, such as /e, ε/ distinction. Needless to say, the quantity of input definitely affects one's language development, and therefore not getting much input could be a possible reason why all the learner groups and QF natives in the present study could not perceive such contrasts accurately.

5.2.3 Acquisition of Rounded Vowels

Investigations of the tense and lax contrasts in Quebec French from L2 or L3 acquisition approach are somewhat few and far between. However, there are numerous previous studies focusing on the L2 acquisition of French rounded vowels.

The L2 perception results of rounded vowels reported here are consistent with previous studies on European and Quebec French. Research on the L2 acquisition of French vowel contrasts widely demonstrates that high /y-u/ and mid /œ-ɔ/ front vs. back rounded vowel contrasts in French are particularly difficult for adult English-speaking learners of French (Levy, 2009; Baker and Smith, 2010; Darcy et al, 2012; Desmeules & Joannisse, 2020). Levy (2009) using an AXB discrimination task investigated the perception of the /y/-/u/ contrast in pseudo words by L1-English learners of French at the high intermediate level of French proficiency. The accuracy rate is 70%, which is similar to the accuracy of /y-u/ in the present study: 71%. Darcy et al (2012) revealed that in an ABX task with a 500 ms ISI, learners' performance on the /y/-/u/ contrast was more accurate than on the /œ/-/ɔ/ contrast. In Darcy et al's study, the accuracy rates of /y-u/ are 85% for intermediate learners; 89% for advanced learners, which is better than the accuracy of 71% in the present study. Accuracy rates of /œ-ɔ/ are 62.6 % for intermediate learners and 67%

for advanced learners in Darcy's research. The present study shows a similar rate of 66% for /œ-ɔ/. In line with Darcy, L2 learners' performance on /y-u/ is better than /œ-ɔ/ in the present study. One study by Smith & Baker (2010) looks at L1 English acquisition of L2 Quebec French, using an AX discrimination task without controlling inter-stimuli. Their results reflected that both advanced and intermediate levels achieved relatively low accuracy of discriminating /y-u/ around 65%, which is again similar to the current study (71%). Another study related to /y-u/ in Quebec French was conducted by Desmeules-Trudel & Joanisse (2020). Desmeules-Trudel & Joanisse focused on the perception of Quebec French /y-u/ by 64 Canadian-English speakers using an AX discrimination task with a 500ms ISI. Their findings suggest that /y-u/ is the most difficult contrast to distinguish compared with /y-e/ or /y-a/ (above 90%), with a low accuracy of 45.8%. It is interesting to note that reducing ISI to 500ms actually causes more difficulties to the perception of /y-u/ in their study. A low accuracy of /y-u/ with a short ISI indicates that the misperception of /y-u/ occurs at a phonetic level as ISI 500ms is categorized as a phonetic level according to (Werker & Logan, 1985). This would be consistent with the hypothesis (see Section 2.6) that English speakers rely on their L1 phonetic-cue, L1 phonetic roundness to discriminate /y-u/ and not on phonological features.

The L3 perception of rounded vowels by Mandarin speakers are somehow neglected in L3 acquisition. One relevant study was conducted by Wang, Hueber and Badin (2014) with a focus on the production and perception of French vowels by L1 Mandarin-L2 English learners. It is found that Mandarin speakers improve significantly ($p < .001$) in producing /œ/ in French after a short training session. After the training session, Mandarin speakers also participated in a perception test and achieved 86% accuracy rates. The present study's results are similar to theirs with accuracy rates of 85%. The present study, again, supports this statement that L1 Mandarin-L2 English learners of Quebec French do not have problems perceiving /œ-ɔ/.

5.3 The Role of Contrastive Hierarchy Theory

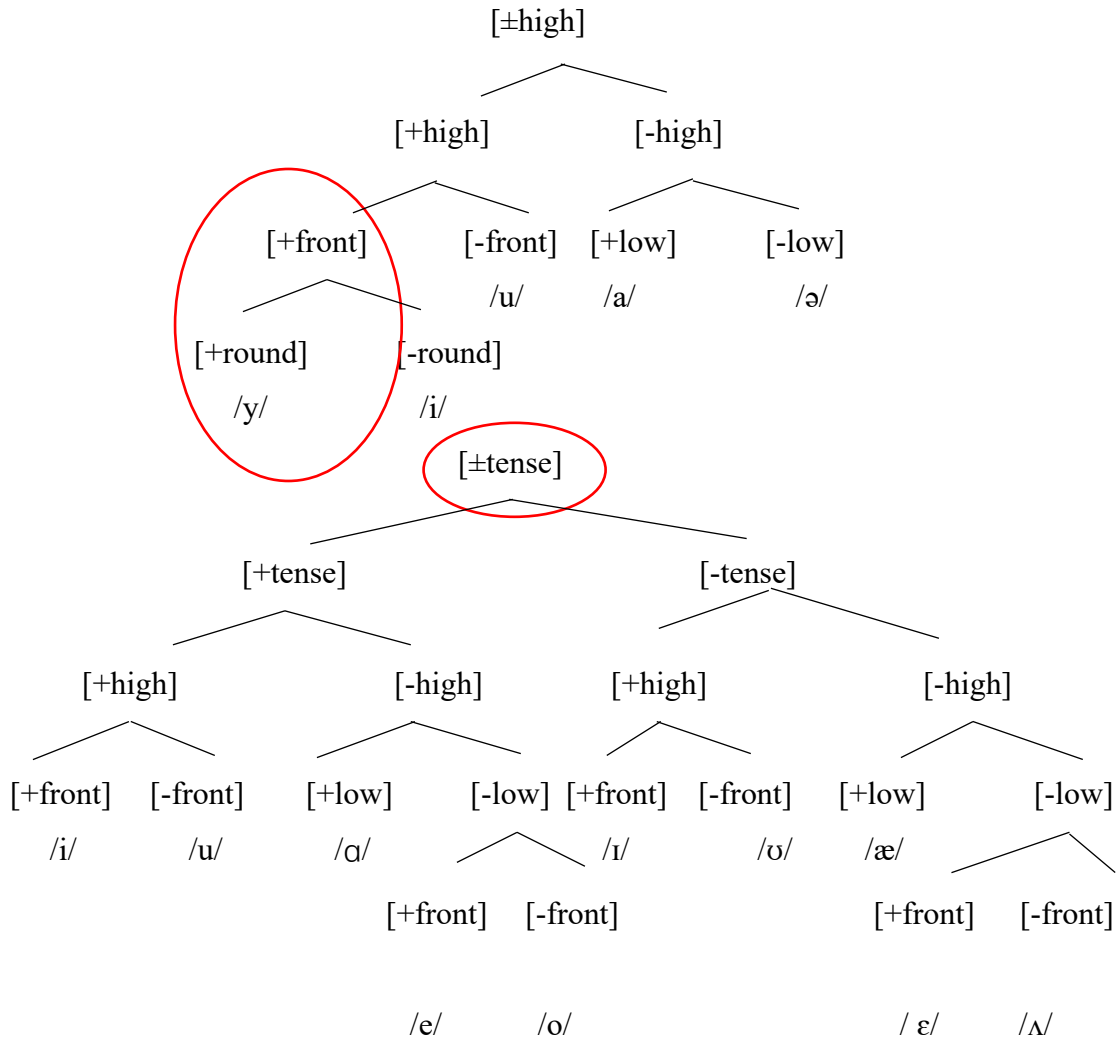
Using a contrastive hierarchy theory as a representational model of the phonemic system, the current study was able to explore the acquisition process and explain learners' possible parsing procedures and facilitative influence based on the results.

5.3.1 Facilitative Influence and Parsing Procedure

In terms of perceiving tense and lax vowels, it is well known that L1 Mandarin-L2 English learners struggle to achieve accurate perception of contrasts such as /i-ɪ/ and /u-ʊ/ which are marked by [±tense] because [±tense] is absent in their L1 and they rely on duration as a cue instead of spectral cues (which can be re-weighted). This indeed indicates that Mandarin speakers should experience difficulty acquiring any tense and lax contrasts (Bohn, 1995; Zhang, 2002). However, given the results of the present study that the L3 QF (L1 Mandarin-L2 English-L3 Quebec French) learners' performance is indistinguishable from the NS group on [y, ʏ] and /e-ɛ/, it is possible to confirm that after achieving proficiency in English as their L2 (average IELTS 7.0), L3 QF learners do receive facilitative influence from both their L1 and L2 to parse the L3 tense and lax contrasts. Although it can be questioned how the L3 QF learners have acquired [±tense] (this will not be further addressed in the present study), their performance on tense and lax vowels in L3 QF suggests that it is possible to acquire [±tense], and the participants in the present study have acquired it.

The contrastive hierarchy theory is used to explain possible sources of potential cross-linguistic influence. The possible facilitative influences the L3 QF learners received are [±front] > [±round] in L1 Mandarin and [±tense] in L2 English: [±front] > [±round] used to distinguish /y/ from /i/ and /u/. Then, [±tense] is used to differentiate tense [y] from lax vowels [ʏ], as shown below.

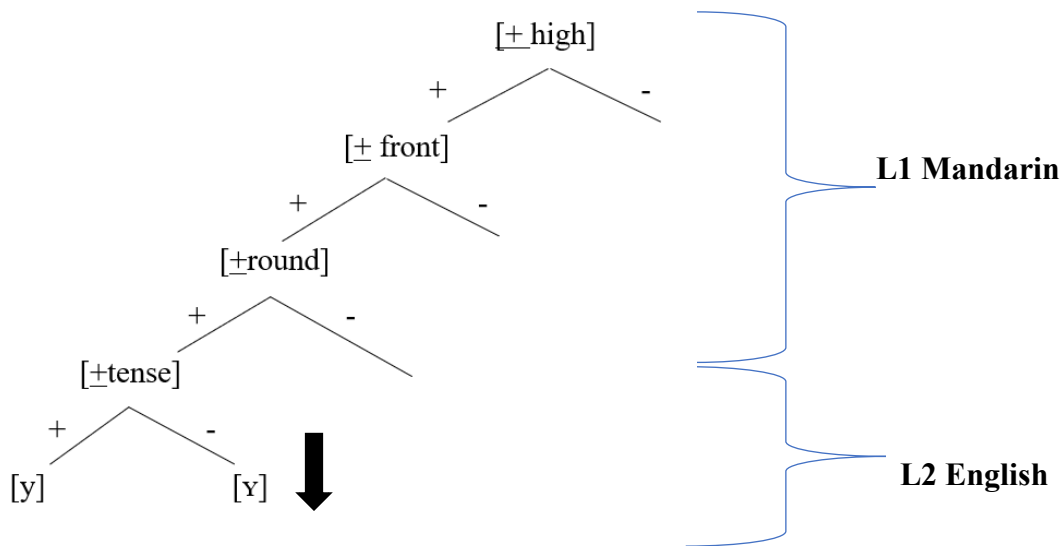
(60) Facilitative influence from Mandarin and English feature hierarchies



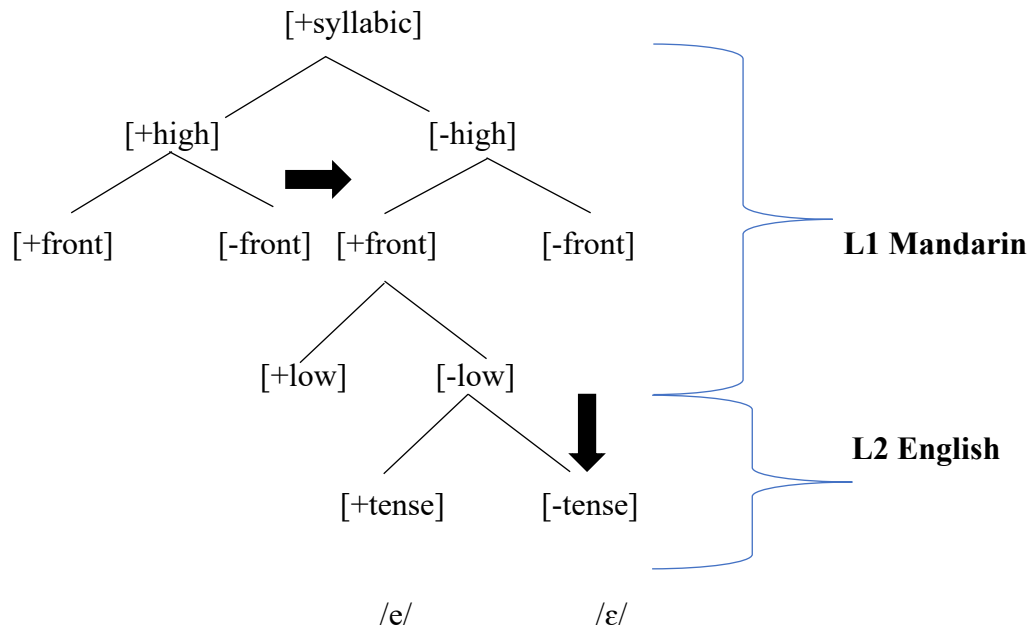
It is important to elucidate the parsing procedures by using the contrastive hierarchy theory. Here, several possible parsing procedures are illustrated in a contrastive hierarchy of L1-Mandarin L2-English grammars. As Westergaard et al (2017) and Westergaard (2021) proposed, both L1 and L2 grammar remain active be selected for analyzing L3 structures. Natvig (2021) proposed an intergrated mutilingual sound systems based on hybrid representation of an intergrated set of phonological contrastive features. Archibald (2022) mentioned the idea of integrated I-grammar that both L1 and L2 store in a common accessible location for learners to select (See Section 3.1.1), and he proposed the restructuring principles that learners are able to redeploy contrastive features from their L1 feature hierarchy to distinguish new contrasts in the L2 (See Section 2.4). Again, Kwon (2021) elucidated a possible parsing procedure using the contrastive hierarchy theory with

the conclusion that L1 Mandarin speakers can develop a new feature $[\pm\text{tense}]$ at the bottom of their L1 contrastive hierarchy to parse tense and lax vowels in the L2 English (See Section 3.1). Following Westergaard (2021), Archibald (2023) and Kwon and Starr (2023), I propose a possible L1-Mandarin L2-English grammar using the contrastive hierarchy theory. In order to parse $[y, \gamma]$ and $/e-\epsilon/$, the L3 QF learners need to construct a L1-L2 integrated phonological grammar and utilize the necessary features from both the L1 and L2 for better perception. As introduced in Section 3.1, there are restructuring activities ‘adding’ and ‘extending’ learners use to restructure their phonological grammar. A possible parsing procedure by L1-Mandarin L2-English grammars is presented below.

(61) Possible L1-Mandarin L2-English grammar



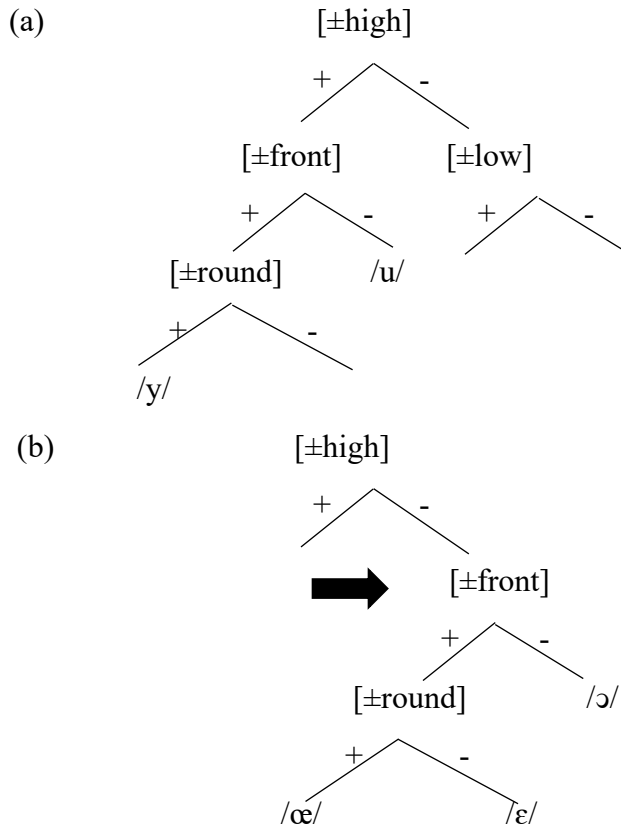
(62) Possible L1-Mandarin L2-English grammar



In this parsing procedure, [y, ʏ] are parsed as [+high] first, then [+front] and [+round] are assigned to differentiate [y, ʏ] from other high vowels such as /i/ and /u/, and at the bottom of the tree, [±tense] is used to specify [y] as [+tense] and [ʏ] as [-tense]. To parse /e, ε/, Mandarin speakers need to establish their L1-L2 grammar by extending (the right arrow) and adding (the down arrow): they need to extend [±front] to the [-high] sub inventory. Then, they add [±tense] to parse /e, ε/.

With respect to the rounded vowel contrasts /œ-ɔ/ and /y-u/ in Quebec French, the results of the present study (85% for /œ-ɔ/ and 88% for /y-u/) provide strong evidence that the L3 QF learners receive facilitative influence [±front] > [±round] from L1 Mandarin to help them parse /y-u/ and /œ-ɔ/ that does not exist in either Mandarin or English. A possible parsing procedure is given below. To parse /y-u/, the L3 QF learners do not need to adjust their grammar, while to parse /œ-ɔ/, [±front] > [±round] needs to be extended to the [-high] sub inventory.

(63) Possible parsing procedures



Possible facilitative influence and proposed parsing procedures in the present study are supported by numerous empirical studies providing evidence that redeploying existing features is possible for L3 learners. Archibald (2005) argued that a learner's phonological knowledge can be redeployed to help in L2 acquisition. In other words, learners can take features available in the L1 and create new structures in the L2. More specifically, according to Kwon & Starr (2023) and Archibald (2023), the contrastive hierarchy features are the repository that can be accessed by learners. In L3 acquisition, learners have an integrated repository in which both the L1 and L2 are available for learners to select to parse the new structures in an L3. In line with their theories, the present study posits that the L3 QF learners are able to select contrastive features or rankings from both L1 and L2 to represent L3 target sounds. In addition, it is possible to conclude that the L3 QF learners achieved significantly better on both tense and lax (76% for [y, ʏ]; 65% for /e, ɛ/) vowel contrasts and rounded vowel contrasts (above 85% for /y-u/ and /œ-ɔ/) than the L2 QF

leaners (59 % for [y, ʏ]; 58% for /e, ε/; 71% for /y-u/; 66% for /œ-ɔ/) because they receive facilitative influence that are contrastive features from both L1 Mandarin and L2 English.

5.3.2. The Prediction of the Ease and Difficulty

As noted in the previous section, the L3 QF learners achieved the highest accuracy rate with /y, u/ (88%), followed by /œ, ɔ/ (85%), and then [y, ʏ] (76%). /e, ε/, on the other hand, is perceived poorly with the lowest accuracy rate (65%). Statistical results reveal that there is a significance difference in the perception of [y, ʏ] and /e-ε/ ($p = .006$), /œ, ɔ/ and [y, ʏ] ($p = .002$), and /y, u/ and [y, ʏ] ($p < .01$), although the difference between /œ, ɔ/ and /y, u/ is not significant ($p = .68$). Given the results, it seems that the contrastive hierarchy theory is able to predict the ease and difficulty based on different restructuring activities.

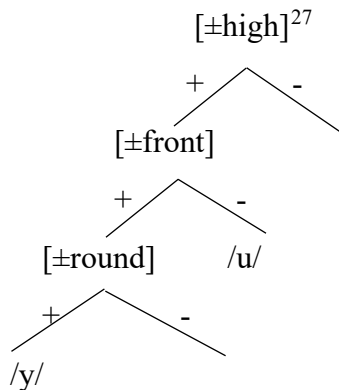
Before looking at the prediction of ease and difficulty, it is important to understand some previous background in language learning, which establishes a theoretical foundation for my predictions. First, let's look at some classic learnability questions. Some questions which have been explored for decades are: what will tell the learner that the grammar is inadequate, and what actions will the learner take when the grammar is inadequate (Dresher, 1999; Archibald, 2022). A short answer to the first question is that the learner discovers their current grammar is inadequate when structures in the input data cannot be parsed (Fodor, 1988; Archibald, 2022; Lightfoot, 2020) and the learner makes errors in perception. A possible answer to the second question is that driven by the errors made when parsing the input, the learner will tend to update (change) their grammar to parse the structure in the input data (Kivinen, 2003; Magri, 2016). As Magri (2016) explained, a learner will maintain a current grammar to parse the target sound, but this grammar is updated (changed) when it makes an error on the current input data.

However, as Dresher (1990) proposed, when a learner's current grammar cannot parse a target form, it is difficult to reliably know "what parameters or constraints must be reset to yield a correct target form" (p. 28), so the learner is uncertain about "which parameter setting to 'credit' for a successful prediction and which to 'blame' for an unsuccessful prediction" (Nazarov & Jarosz, 2021, p. 2). When the learner encounters parsing failure, they need to revise and restructure their grammar (Archibald, 2023).

To understand the change in the grammar from a contrastive hierarchy theory approach, it is acknowledged that there are two restructuring actions that learners could take when parsing target sounds unsuccessfully: (1) Extending an existing node to another sister node (two nodes are dominated by the same node), or (2) adding a new feature dominating any pair of vowels which cannot be uniquely parsed. However, when the learner has relevant features in their multilingual integrated I-grammar, restructuring actions are not required even though the learner is parsing a new contrast in the input. On the other hand, sometimes, learners need to take more than one restructuring action to parse the target sound when their feature hierarchy keeps making parsing errors on the input data. Let's illustrate this step by step.

Based on the results, it is assumed that in the process of learning Quebec French vowels, Mandarin speakers would encounter four different situations. The first one is that they maintain their current feature hierarchy without any changes because their current feature hierarchy is able to parse the target contrast successfully. One such contrast is /y-u/ in French: To parse /y-u/, Mandarin speakers just simply use $[\pm\text{front}] > [\pm\text{round}]$ from their L1 Mandarin feature hierarchy, and no restructuring actions are required as shown in (64a). This explains the high accuracy in the perception of /y, u/ (88%).

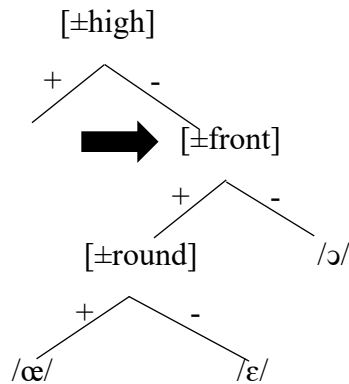
(64) (a) Mandarin speakers' parse of the French front rounded vowels /y-u/ using $[\pm\text{front}] > [\pm\text{round}]$



²⁷ $[\pm\text{high}]$ is not presented from earlier trees because it does not distinguish the target vowels /y/ and /u/. The presence of $[\pm\text{high}]$ here is to illustrate redeployment process.

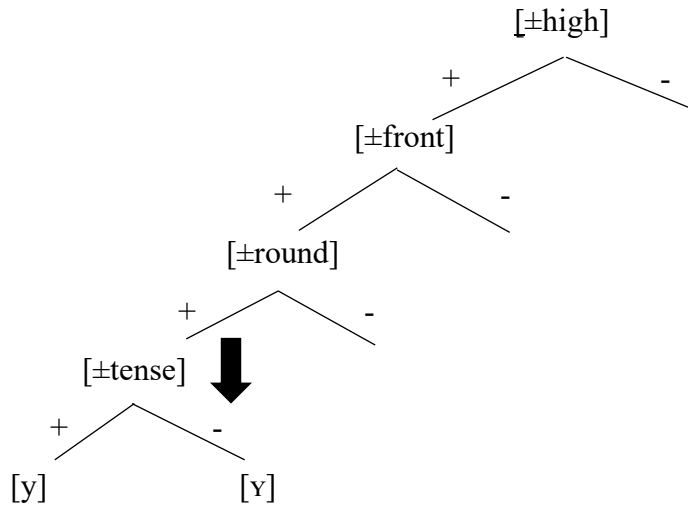
When Mandarin speakers' current feature hierarchy cannot parse the target contrast, some change should be made. There are two restructuring actions available for them to choose between. Here, I argue that extending is easier than adding because extending is a conservative change that only applies to the contrastive sister nodes dominated by the same node (see Section 2.4.2), and learners only need to use their existing features without developing any new features as “the learners are conservative and proceed incrementally so as to avoid having to retreat from an unjustified overgeneralization” (Archibald, 2023). Now, back to learning Quebec French, the second situation is that Mandarin speakers have to change their feature hierarchy by extending $[\pm\text{front}] > [\pm\text{round}]$ to another sister node to parse the mid-rounded vowels /œ, ɔ/ in Quebec French in (64b). As extending is easier than adding, in the present study, the L3 QF learners achieved higher accuracy in the perception of /œ, ɔ/ (85%) compared to [y, ʏ] (76%) ($p < .002$).

(b). Mandarin speakers' parse of the French mid-rounded vowels by extending $[\pm\text{front}] > [\pm\text{round}]$



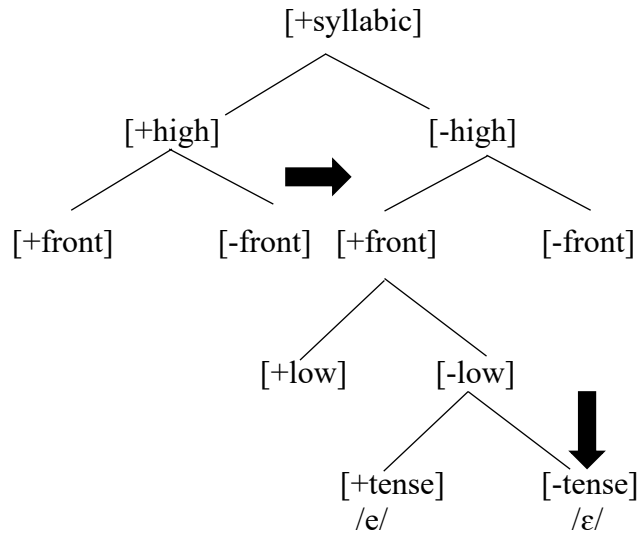
To parse [y, ʏ], Mandarin speakers make one change by adding $[\pm\text{tense}]$ at the bottom of their L1 feature hierarchy to develop their integrated grammar to parse tense and lax vowels in Quebec French as in (64c). This change, according to Kwon and Starr (2023), will take a while to motivate them change their current grammar.

(c). Mandarin speakers' parse of L3 Quebec French tense and lax contrasts [y, ʏ] by adding [±tense]



Finally, as mentioned in Section 3.1.5, to parse mid tense and lax vowels, Mandarin speakers have to make two changes in their feature hierarchy to parse /e, ε/, extending [±front] to the [-high] sub inventory and then adding [±tense] as in (64d). This is considered as the most difficulty situation they have to deal with, which is why /e, ε/ is perceived less accurately by the L3 QF learners. Additionally, the two changes may not take place at the same time. Initially, the learner fails to parse the target sound and updates their current feature hierarchy by extending. After that, making more errors on the current input motivates them to develop a new feature by adding. Keep in mind that the path can be different depending on learners' individual differences. Some learners may choose extending first and then adding, but to successfully parse /e, ε/, they need to extend first and then add.

(d) Mandarin speakers' parse of the French mid tense and lax vowels /e, ε/ by extending [±front] and adding [±tense].



To summarize, when Mandarin speakers cannot parse the target sound successfully, restructuring actions are considered. There are four possible situations Mandarin speakers encounter when parsing Quebec French vowel contrasts in Table 51. In the case in which Mandarin speakers do not have the necessary feature to parse the target sound, they will have to add a new feature. When their existing features can parse the target sound, they will utilize such features or conduct some adjustment (extending or both extending and adding). The prediction of the ease and difficulty is given below.

Table 50 *Restructuring actions*

Tested contrasts	Condition	Restructuring actions	Level of difficulty
1 /y, u/	Have necessary features	Not necessary	Easy
2 /œ, ɔ/	Have necessary features but need adjustment	Extending	Moderate
3 [y, ʏ]	Without necessary features	Adding	Somewhat difficult
4 /e, ε/	Have some necessary features but need adjustment, and also miss other necessary features	Extending and adding	Difficult

In this section, based on the results, we have looked into the prediction of the ease and difficulty using the contrastive hierarchy theory approach, and have gained an understanding of how the change of the contrastive features or feature rankings in previously acquired languages would influence the learner’s perception of the target sounds. Next, let’s look at error prediction with a consideration of phonetic enhancement.

5.3.3 Error Prediction and Phonetic Enhancement Features

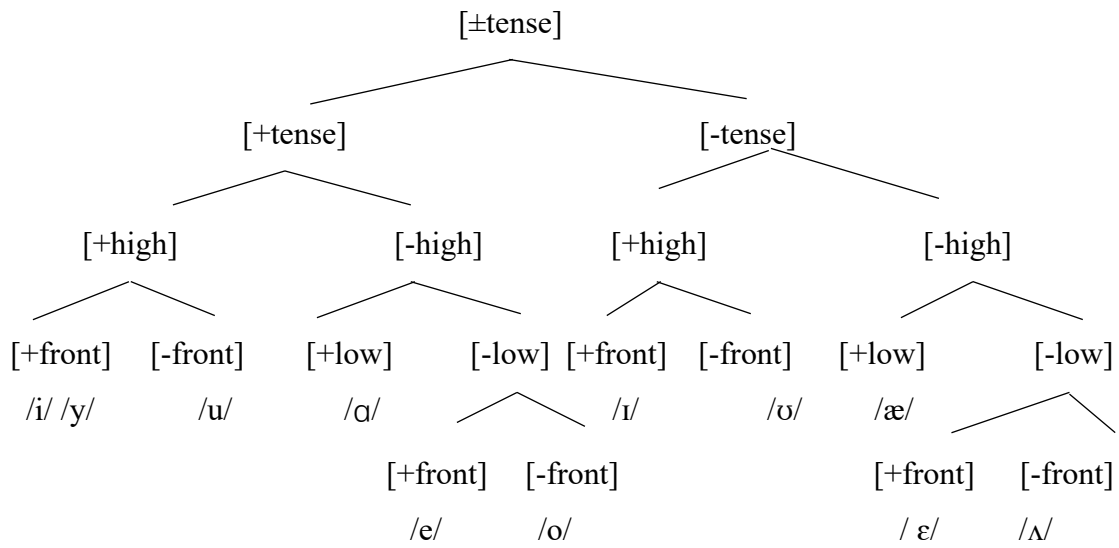
Previous studies (Kwon, 2021; Archibald, 2022;2023) demonstrate that the contrastive feature hierarchy plays a vital role in the acquisition process, as the presence or absence of contrastive features would affect learners’ performance on perceiving the target sounds in L2 or L3. The present study emphasizes the importance of the presence of contrastive features and featural rankings: having [±front] > [±round] will help Mandarin speakers parse mid-rounded vowels that do not exist in their previously acquired languages. However, to predict errors, it seems that there are still other factors that need to be taken into consideration as discussed in Section 3.1.5. For example, the L2 perception results for the rounded vowels seem to suggest that it is important to consider the role of phonetic enhancement: phonetic cues that are used to enhance contrastive features (see Section 2.6).

In this section, I will provide a discussion of some assumptions related to the role that L1 phonetic enhancement plays in the prediction of errors. Although the present study does not examine the perception of /i-y/ versus /y-u/ by English speakers, numerous previous studies demonstrate that English speakers learning French in fact make two different types of errors: (1) the misparsing of /y/ as /i/ (naïve learners and intermediate level learners) or (2) the misparsing of /y/ as /u/ (intermediate and advanced level learners) (Levy, 2009; Smith & Baker, 2010) (see Section 3.1.6). Needless to say, due to the lack of a target-like hierarchy, the learners need to conduct restructuring actions, and they may elaborate their nodes in different orders. Previous studies (Levy, 2009; Smith & Baker 2010) suggest that the learner's current feature hierarchy (lack of relevant features) and L1 phonetic enhancement may cause different types of errors in a learner's developmental path. One assumption is that the L1 phonetic enhancement plays a role in causing errors in their later developmental stage given the fact that intermediate and advanced level learners make more errors in distinguishing /y/ from /u/ (Smith & Baker, 2010; Desmeules-Trudel & Joanisse 2020).

It is assumed that the two different types of errors made by English speakers is indicative of two distinct parsing procedures at different times in their developmental path. The first stage is what I will call *phonological parsing* where English speakers use their feature hierarchy to parse French rounded vowels. This leads to the misparsing of /y/ as /i/. The second stage is what I will call *phonetic parsing*. As both /y/ and /u/ have phonetic roundness (which is the acoustic information English speakers rely on to perceive back vowels in English (Hall, 2001; Keyser & Stevens, 2006; Stevens & Keyser, 2010) the L1 English speakers will interpret phonetic roundness as being a property of back vowels. This leads to the misparsing of /y/ as /u/. Now, let's illustrate these two types of errors caused by feature ranking and L1 phonetic enhancement step by step using the contrastive hierarchy theory.

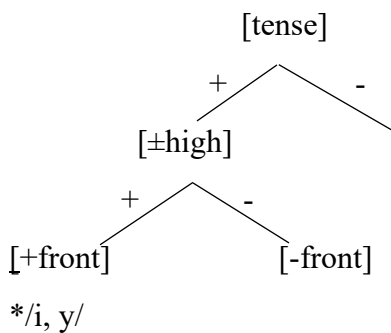
As shown in (64), the English feature hierarchy suggests that English speakers should have difficulties in distinguishing /i/ from /y/ as both /i/ and /y/ are [+tense, + high, +front].

(64) English feature hierarchy



Recall from Section 3.1.6 that Levy and Strange (2008) conducted a study on the perception of the French vowels /y-u/ and /y-i/ by naïve learners (L1 English) and L1 English-L2 French learners at the advanced level of French proficiency. Naïve learners made more errors in the perception of /i-y/ (15.4%) compared to advanced level learners (3%). This implies phonological parsing, which is illustrated in (65).

(65) Using the English feature hierarchy to parse /y/



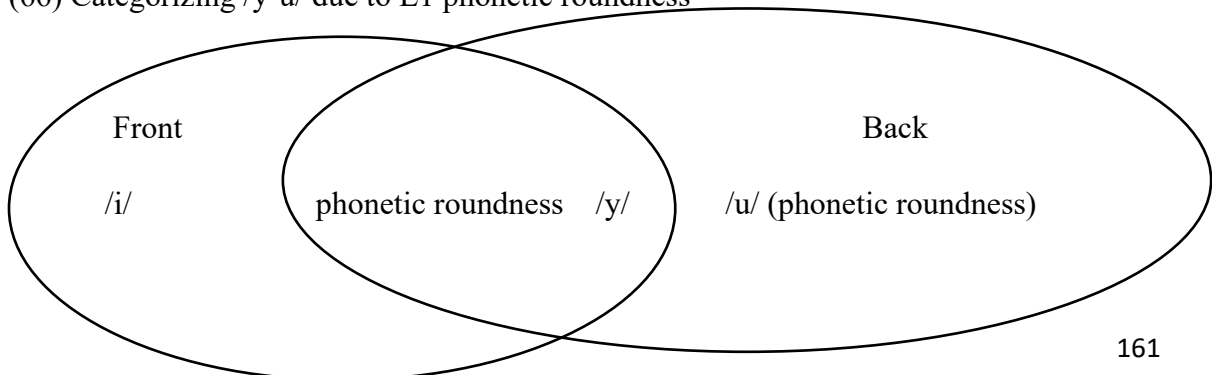
As can be seen in (65), when perceiving French /y/, naïve learners will parse /y/ using their L1 feature hierarchy, which leads to the result that /i/ and /y/ cannot be further distinguished. In (65), given the L1 English feature hierarchy, /y/ is firstly assigned [+tense] and then [+high], and finally [+front] is used to further specify /y/, but the lack of [±round] is unable to differentiate /i, y/. This type of error is caused by the lack of relevant features. However, experienced learners (intermediate and advanced levels) make more errors in

discriminating /y, u/ (an error rate of 33%) (Smith & Baker, 2010) compared to an error rate of 3% for /y, i/ (Levy, 2008). This suggests that roundness affects English speakers' perception of /y/ to a large extent since both /y/ and /u/ exhibit phonetic roundness, but the English feature hierarchy does not have a contrastive feature [\pm round]. This suggests that phonetic roundness (which is English speakers' L1 phonetic enhancement feature) plays a role here.

To illustrate how L1 phonetic enhancement leads to the misparsing of /y/ as /u/, let's recall the explanation of phonetic cues in Section 2.6. First, L2 learners may inaccurately categorize cues that are not found in their L1 or use their L1 phonetic cues to perceive a target sound. This can create difficulty in their perception. In English, as Gardner & Roeder (2022) stated, phonetic roundness is a phonetic cue (secondary cue) that English speakers use to distinguish front and back vowels.

I argue that L1 English speakers transfer their L1 phonetic enhancement cue and thus attend to the roundness of [y] in the input which results in their parsing [y] as /u/ given that they are acoustically similar with respect to phonetic roundness (Turner, 2023). This stage is phonetic parsing. Desmeules-Trudel & Joanisse' (2020) study of L1 English-L2 Quebec French learners' perception of rounded vowels specifically revealed that /y-u/ is the most difficult contrast to distinguish compared with other contrasts, such as /y-i/ (Smith & Baker, 2010) even when reducing the ISI to 500ms, which is categorized as a phonetic level of perception (see Section 3.3.3.2). This is strong evidence to support the claim that the misperception of /y-u/ is largely based on phonetic roundness in L1 English and not on phonological featural rankings. This seems to suggest that if learners do not have relevant features or feature rankings, learners may inaccurately perceive the target sounds and categorize them based on their L1 phonetic enhancement features that are phonetic cues used to enhance contrasts in L1.

(66) Categorizing /y-u/ due to L1 phonetic roundness



However, there are many questions about the two parsing procedures. I will leave it to future research to explore what might cause the shift from phonological to phonetic parsing, and what the implications would be for the discrimination of all the other contrasts discussed in this thesis.

To summarize, in Section 5.3, the contrastive hierarchy theory is used to show facilitative influence from L1 Mandarin and L2 English. However, to predict errors, phonetic enhancement features also need to be taken into account. It appears as if there might be two possible procedures: phonological parsing and phonetic parsing.

5.4 The Relation of the Data to Existing L3 Learning Models

In the present study, theoretical triangulation was employed to examine the broad claims of several L3 learning models, including the Cumulative Enhancement Model (CEM) (Flynn, 2004), the Linguistic Proximity Model (LPM) (Westergaard, 2021), the L2 Status Factor Model (Bardel & Falk, 2012), the Typological Primacy Model (TPM) (Rothman, 2011, 2015), and the Scalpel Model (Slabakova, 2017) measured against a new phonological data set. At the same time, the present study triangulates by investigating the extent to which these different models can be used to explain the specific results of the present study. In the following paragraphs, there will be a discussion of the results in relation to these learning models.

The results of the present study do not support the TPM (Rothman, 2011) that would make predictions relying on typological proximity decided by the parser used to consider the strong proximity shared by L1 Mandarin or L2 English and L3 Quebec French. The parser would search shared properties following a cue hierarchy (i.e., lexicon, phonology/phonotactics, functional morphology, syntactic structure), analyze the language input and determine the typological closeness. Based on the TPM's predication, English has a higher chance than Mandarin to be parsed as typologically closer to L3 Quebec French because of shared properties, such as the lexicon. For instance, *content* 'satisfied or happy' is a shared lexical item between English and Quebec French, and there are many cognates between English and French (Peters, Velghe, & Van Rompaey, 2019). Thus, the

entire grammar of English should be transferred into L3 Quebec French. Following this prediction, the L3 QF learners should perceive the target sounds indistinguishably from the L2 QF learners as the L3 QF learners would use the entire L2 English grammar to parse the target sounds in L3 QF. However, the L3 groups' behaviour is significantly different from the L2 group on all the target sounds in the present study ($p < .05$). This argues against the prediction made based on the TPM. In addition, the L2 Status Factor Model is not discussed further as it makes the same predication as the TPM: the L3 QF learners would use their L2 English grammar to represent the target sounds because the L2 has a privileged status to be transferred compared with the L1 according to the L2 Status Factor Model.

The findings in the present study are in line with the LPM (Westergaard, 2021) and the Scalpel model (Slabakova, 2017) as the Scalpel model shares all important claims with the LPM. The LPM predicts that learners are able to select structures from all the previously acquired grammar by property-by property selection. Both L1 and L2 grammars are able for learners to select. Facilitative influence from both L1 ([±front] > [±round]) and L2 ([±tense]) is found to have a significant influence on the results. This strongly suggests that cross-linguistic influence is, as Westergaard stated, property-by-property from an integrated L1 and L2 I-grammar. However, non-facilitative influence is not found in the L3 QF group, which leads to our next discussion associated with the Cumulative Enhancement Model (CEM) (Flynn, 2004).

The present study seems to support the CEM to some extent, but there is a reason non-facilitative influence is not found in the L3 QF group. Also, non-facilitative influence is found in the L2 QF group. Firstly, let's explore the reason. As mentioned previously, existing learning models are built largely based on syntactic phenomena in which there are always two or three shared structures between L1 and L2. For example, a subject-verb-object order is shared by Mandarin and English, so the learning of L2 English word order can be facilitated by the similar word order from the L1. On the other hand, when L1 and L2 differ, their structures compete and learning is difficult, resulting in a non-facilitative influence. For instance, the word order in Japanese (SOV) is different from that in English (SVO). This would possibly lead to a non-facilitative influence from L1 Japanese when learning the word-order in L2 English. In the present study, L1 Mandarin and L2 English

do not have competing structures because the English feature hierarchy does not have a feature ranking like $[\pm\text{round}] > [\pm\text{front}]$ to compete with $[\pm\text{front}] > [\pm\text{round}]$ in Mandarin. This might be the reason why non-facilitative transfer is not found in the L3 QF learner group. In addition, non-facilitative influence is found in the L2 QF learner group: because of the lack of $[\pm\text{round}]$ in the English hierarchy, the bilingual L1 English-L2 Quebec French learners cannot differentiate /i/ from /y/, and they rely on their L1 phonetic roundness to parse target sounds in QF, which leads to them mis-parsing [y, ʏ], /y-u/ and /œ-ɔ/. Therefore, it is evident that the present study does not support the CEM.

In this section, the existing learning models have been discussed and evaluated with respect to the current study. My findings are in support of the LPM (Westergaard, 2021) and the Scalpel model (Slabakova, 2017) but argues against the TPM (Rothman, 2011), the L2 Status Factor Model (Bardel & Falk, 2012), and the CEM (Flynn, 2004). Next, I will present the conclusions of the present study, pointing out the important contributions, and the future implications and limitations of the current study.

CHAPTER SIX: CONCLUSION

This chapter is organized into several sections. First, the research findings are summarized, followed by a discussion of the contributions of the work, and the chapter is finally concluded by discussing future research and limitations.

6.1 Summary of Research Findings

The present study aims to add to our understanding of multilingual phonological acquisition by exploring the L2 and L3 perception of Quebec French (QF) tense and lax vowels [y, ʏ] and /e, ε/ and rounded vowels /y-u/ and /œ-ɔ/. Inspired by the LPM, it is predicted that the trilingual participants will outperform the bilingual participants because the trilingual can transfer phonological features from both the L1 and the L2 to acquire L3 contrasts. Specifically, the present study aims to explain the sources of potential transfer using the contrastive hierarchy theory, a representational and learning model proposed by Dresher (2009). Several questions guide the research:

RQ1: Do L1 Chinese-L2-English-L3 Quebec French learners demonstrate facilitative influence from L1 Mandarin ([+front, +round]) and L2 English ([±tense]) in the perception of the allophonic contrast [y, ʏ] and the phonemic contrast /ε, e / in L3 Quebec French? If they do, then

RQ2: Do L1 Mandarin-L2 English L3 Quebec French learners perceive the contrasts better than L1 English-L2 Quebec French learners?

RQ3: What are the differences between the perception of allophonic and phonemic contrasts?

RQ4: Do L1 Chinese-L2-English Quebec French learners demonstrate facilitative influence from the ranking [±front] > [±round] in the L1 feature hierarchy in the perception of rounded contrasts /y/-/u/ and /œ-ɔ/ in L3 Quebec French? If they do, then

RQ5: Do L1 Chinese-L2 English L3 Quebec French learners perceive the contrasts better than L1 English-L2 French learners?

In this section, these questions are revisited in light of the results.

Research questions 1 to 3 examine whether the L3 QF learners are able to transfer $[\pm\text{front}] > [\pm\text{round}]$ from L1 Mandarin and $[\pm\text{tense}]$ from L2 English to successfully parse L3 QF tense and lax vowels $[y, \gamma]$ and $/e, \epsilon/$. Compared with the L3 QF learners, the L2 QF learners do not have the necessary feature $[\pm\text{round}]$ in their L1 English, and therefore they parse $[y, \gamma]$ ambiguously.

The results of the perception task reveal that the L3 QF group's behaviour is not significantly different from the NS group on the perception of tense and lax vowel contrasts in L3 QF while the L3 groups' behaviour is significantly different from the L2 QF group on the contrasts $[y, \gamma]$ and $/e-\epsilon/$ ($p = .000 < .05$). The L3 QF learners achieve higher accuracy (76% for $[y, \gamma]$ and 65% for $/e-\epsilon/$) than the L2 QF learners (59% for $[y, \gamma]$; 58% for $/e-\epsilon/$). This reinforces that the L3 QF learners, transferring $[\pm\text{front}] > [\pm\text{round}]$ from L1 Mandarin and $[\pm\text{tense}]$ from L2 English, are able to successfully parse the target sounds in L3 QF.

Research questions 4 and 5 explore whether the L3 QF learners can parse the L3 QF rounded vowels $/\text{œ}, \text{ɔ}/$ and $/y, u/$ by using $[\pm\text{front}] > [\pm\text{round}]$ from L1 Mandarin, even though the $/\text{œ}, \text{ɔ}/$ contrast does not exist in either their L1 or their L2. Again, the lack of $[\pm\text{round}]$ in the English hierarchy, and the transfer of L1 phonetic roundedness cue make the L2 QF learners misparse the rounded vowels in L2 QF.

The results of the present study indicate that there is no significant difference found between the L3 QF group and the NS group's performance on $/\text{œ}, \text{ɔ}/$ and $/y, u/$. However, a significant difference is found between the L2 and L3 QF groups ($p < .01$). This, again, shows that the L3 QF learners, transferring $[\pm\text{front}] > [\pm\text{round}]$ from L1 Mandarin, are able to successfully parse $/y-u/$ and $/\text{œ}-\text{ɔ}/$. Overall, it is possible to conclude that L1 Mandarin-L2 English learners of L3 Quebec French outperform L1 English-L2 Quebec French learners because of transferring phonological features from both the L1 and the L2.

In the next section, the contribution of the findings from this study is discussed with respect to the field of L3 phonetics and phonology.

6.2 Contributions

6.2.1 Theoretical Contributions

The findings from the thesis provide some vital theoretical contributions with respect to the previously proposed learning models in L3 acquisition, the role of the contrastive hierarchy theory, and the prediction of ease and difficulty in L3 phonology. In particular, the current study provides further evidence that L3 learners are able to select properties from both the L1 and L2 to represent a L3 speech sound, and a non-facilitative influence occurs when learners do not have the necessary features to represent the target sound. As mentioned in the previous section, this finding contrasts with the prediction of several learning models in L3 acquisition, including the Cumulative Enhancement Model (CEM) (Flynn, 2004) which would hypothesize only facilitative transfer in L3 acquisition, the L2 Status Factor Model (Bardel & Falk, 2012), and the Typological Primacy Model (TPM) (Rothman, 2011, 2015). On the other hand, the findings in the present study are in support of the LPM (Westergaard, 2021) and the Scalpel model (Slabakova, 2017) with predictions that learners are able to select structures from either L1 or L2 by property-by property selection. However, the results in the present study have demonstrated that both L1 and L2 properties can be selected at the same time to parse the target sounds, which is a novel finding. As introduced in Chapter 2, all the learning models proposed in L3 acquisition are utilized mostly to explain syntactic phenomena, and therefore the results of the present study provide evidence supporting the need for an L3 phonology model that could account for multiple potential sources of transfer.

To formulate this kind of model, there are some important suggestions drawn from the results in the present study. First, we must have a representational model of the phonological sound systems to show learners' previously acquired languages. Here, the contrastive hierarchy theory plays an essential role in explaining how L3 representations are influenced by L1 and L2 representations. The contrastive hierarchy theory, as introduced previously, has helped to successfully identify a unique set of contrastive features in many languages, including Manchu (Zhang, 1996); Aymara, Hausa, and Ngizim (Mackenzie, 2013); Laurentian French (Hall, 2016); Xunke Oroqen (Dresher, 2018); Korean (Kwon, 2019) and Mandarin (Wu, 2022). It is a powerful model that has much to

offer in L2 and L3 phonology. Furthermore, Archibald (2022, 2023) has proposed restructuring principles using the contrastive hierarchy theory, which are adopted in the present study to predict the ease or difficulty of acquiring the target sounds in the L2 or L3. It is necessary to propose a new model in L3 phonology that involves the contrastive hierarchy theory and restructuring principles. This requires some further investigation.

6.2.2 Empirical Contributions

Along with making contributions to our understanding of what are the sources of potential transfer in L3 phonology and providing great insights into how the effect of language background affects learners' accuracy, the thesis makes several empirical contributions. First, as mentioned previously, numerous studies demonstrate that L3 learners are able to choose a property from either the L1 or the L2 to parse L3 input (Rothman, 2011; Westergaard, 2021). The current study contributes a novel finding that both L1 and L2 properties can be chosen to parse L3 input. Specially, both $[\pm\text{front}] > [\pm\text{round}]$ from L1 Mandarin and $[\pm\text{tense}]$ from L2 English can be used to parse $[\gamma, \gamma]$.

Secondly, previous research in L3 phonology has predominately focused on phonetic properties, either on the acoustic measurements of voice onset time or vowel formants not phonological properties (Kopečková, 2015; Llama, Cardoso, & Collins, 2010; Lechner & Kohlberger, 2014;). They are insufficient to provide a clear representational model of the L1 or L2, and therefore they cannot explore how learners use their L1 or L2 grammar to parse or represent a new speech sound. The present study, on the other hand, utilizing the contrastive hierarchy theory as a representational model, is able to display specific parsing procedures and the acquisition process in L3 phonology.

More importantly, using the contrastive hierarchy theory and Archibald's restructuring principles, the present study provides important insight into our understanding of the ease and difficulty of parsing the four contrasts $[\gamma, \gamma]$, $/e, \epsilon/$, $/y, u/$, and $/\text{œ}, \text{ɔ}/$. As predicted, the complexity of restructuring actions affects learners' accuracy to a large extent. For example, parsing $/e, \epsilon/$ is particularly challenging compared with other contrasts for the L3 QF learners as they have to conduct both extending and adding

restructuring actions. The prediction of difficulty in the current study can help us answer questions, such as why are some contrasts more difficult than others? Is the presence or absence of certain contrastive features the most important factor to predict the ease and difficulty of acquiring target sounds? The current study adds more evidence to demonstrate that the presence of a contrastive feature is important, but the most important concern is to understand how learners redeploy their previously acquired contrastive features to help in L3 acquisition. As Archibald (2005) argued, a learner's phonological knowledge can be redeployed to help in L2 acquisition. As shown in the present study, Archibald's redeployments theory in L3 phonology illustrated by his restructuring principles have the predictive power of testing the ease or difficulty in L3 phonology.

In relation to integrated grammar (Archibald, 2023; Natvig, 2021; Kwon, 2021; López, 2020), the present study has proposed a possible L1-Mandarin-L2-English intergrated grammar using the contrastive hierachy theory. This can help us understand particularly how learners use their L1-L2 integrated grammar to parse the target sounds in L3; what L1-L2 integrated grammar looks at. Although integrated grammar is such a huge and complex topic (Archibald, 2022; López, 2020; Lightfoot, 2020; Rothman, 2011; Westergaard, 2021), the contrastive hierarchy theory can be used to show and describe it.

With respect to error prediction, the present study reinforces the importance of the relation between phonetics and phonology in L3 phonology and provides insight into the developmental path. The L2 QF learners' results reveal that if learners do not have the necessary features to parse the target sound, there are two possible parsing procedures for them, which are phonological parsing followed by phonetic parsing. Two different parsing procedures lead to two different types of errors. However, my claim is somewhat speculative as it would be important to explore the cause of the shift from phonological to phonetic parsing, and I will leave this to be investigated in the future.

Another unexpected contribution is the finding that all the participants including QF natives did not achieve high accuracy on discriminating tense and lax vowels in Quebec French. The reason as discussed is possibly because of limited input. No previous studies in L2/L3 acquisition have reported this, which merits a comprehensive investigation to examine specifically QF tense and lax vowels in Quebec.

6.3 Limitations and Future Research

Although the results of the present study contribute to our understanding of multilingual phonological acquisition, the present study focusses on L1 Mandarin-L2 English-L3 Quebec French learners and L1 English-L2 Quebec French learners. While some generalizations can be made through the results of the present study, it is interesting to explore to what extent these generalizations may hold for other languages. Therefore, future work will need to investigate more language combinations to gain a deep understanding of the interaction between the L1, the L2 and the L3, with a focus on the contrastive hierarchy theory. Some possible studies could consist of examining multiple L1s or L2s acquiring the same target language (e.g., L1 or L2 German, L1 or L2 Swedish, or L1 or L2 Japanese learners acquiring French). These studies could help us better examine the possible sources of transfer, the role of the contrastive hierarchy theory and how learners' previously acquired language systems influence their L3 outcome. French would be a useful target language to examine because it has an inventory with a particular type of vowel that is both front and rounded. Needless to say, there are many languages that do not have a front-rounded vowel. This would make it possible to investigate specifically how learners would acquire a front-rounded vowel by restructuring their existing feature hierarchies.

The present study focusses on two types of rounded vowels in Quebec French which are /y, u/ and /œ, ɔ/. These two types of rounded vowels also exist in European French. As shown in the present study, Mandarin speakers did not have any problems discriminating /y, u/ and /œ, ɔ/ in Quebec French, and they achieved significantly higher accuracy ($p < 0.0001$) than English speakers. This is due to the help of $[\pm\text{front}] > [\pm\text{round}]$ in L1 Mandarin. However, in European French or Quebec French, there are other rounded contrasts as well, such as /ø/ and /o/. Future work should examine all the rounded contrasts in European or Quebec French to reinforce the statement supported by numerous scholars (Brown, 1997; Archibald, 2005) that once learners have a particular feature, they should be able to parse all the contrasts specified by this feature, although there can be individual variation in the paths chosen.

The present study also focusses on tense and lax contrasts in Quebec French though there is some question as to whether or not they are used frequently in Quebec nowadays. As stated previously, while QF natives and the L3 QF learners performed indistinguishably on these two contrasts, all of the participants achieved low accuracy due to some factors, such as limited input. It is necessary to investigate other languages having tense and lax contrasts specifically [y, ʏ]. Future work could investigate tense and lax contrasts in other languages, such as Swedish and German, to provide a better understanding of the L1-L2 influences on the L3.

Given that the present study only includes upper-intermediate learners of Quebec French, it is important to inquire to what extent the findings are applicable to learners at different proficiency levels. Future work should include participants at different proficiency levels to examine whether beginner learners would achieve a similar result. More importantly, involving participants at different proficiency levels could show learners' developmental path of acquiring certain target sounds, such as the acquisition of /y-i/ and /y-u/ in German by English speakers. Hopefully, this type of developmental path can be confirmed with additional research.

An interesting finding in the present study is that L3 QF learners perceived the four contrasts significantly differently due to different restructuring actions required. As mentioned early, there are four different conditions: (1) no restructuring actions needed, (2) extending, (3) adding and (4) both adding and extending. They can be used to predict the ease and difficulty of acquiring target sounds. It is expected that further research can be conducted to reinforce this finding.

Despite some of the advantages of the present study, it has some limitations as well. One of these limitations is the selection of consonantal contexts in pseudo words. As mentioned earlier, /t/ and /d/ are assimilated to [ts] and [dz] before /i/ and /y/ in Quebec French (Baker, 2010), which means that the selection of the coronal consonant contexts /t-d/ might be particularly challenging for Quebec French natives to discriminate as high-front vowels do not occur in /t-d/ in real words. In the present study, QF natives achieve high accuracy in the perception of /y/, but the selection of /t-d/ in pseudo words could have affected their accuracy to some extent.

An additional limitation is that the present study conducted an online experiment to collect data due to the COVID-19 pandemic, which may not have been sufficient to accurately examine participants' performance because it is difficult to manipulate the experimental environment and to provide clarifications for participants immediately. Some potential participants may not be familiar with online environments, and therefore they might decide not to participate in the experiment. Because of using an online experiment, the present study also had to limit the time for participants to take the online perception task, which resulted in the limitation in the number of trials in the discrimination task. The limitation of this could be solved simply by conducting a lab experiment, so participants are able to perceive more trials in the task. In addition, in future work, production could be considered since the present study only focusses on perception. The results of a production task would allow us to explore interactions between speech perception and production.

A third limitation of the study concerns the sample size of the present study. In the present study, there are around twenty participants ($n = 20$) in each group, which is not a large sample size. This could affect the conclusions to some extent. A large sample size allows us to draw a strong conclusion based on the study. In future work, it would be ideal to recruit a greater number of participants, so the generalizability of results will be greater.

Another possible limitation is that the L3 learners' high accuracy could be the result of the L3 group being better at learning a foreign language because QF is their second rather than their first foreign language, so their improvement could be caused by experience and domain-general cognition rather than formal linguistic properties. However, the present study including research method and theoretical frameworks is all based on previous research (Darcy, et al, 2012; Cabrelli, 2012; 2018; Westergaard, 2021). There are numerous studies using a L2-L3 comparison (Onishi, 2013; 2016; Wu, 2022). Additionally, the argument that the participants' perception is guided by the specific features / contrasts present in the existing grammar is based on a triangulation of previous theoretical frameworks, which suggests a valid and reasonable approach. However, for comparison purposes, it would be informative and ideal to conduct a study in which participants whose L1 lacked [\pm round], and whose L2 lacked [\pm tense] learned an L3 which made a high, front, round tense/lax distinction.

The last limitation is related to the experimental method. For example, data from single word discrimination task may not generalize to the perception (or indeed production) of natural discourse. We recognize that L2-L3 learners may perceive non-native contrasts differently under different listening conditions. Sometimes a sentence-level task may add contextual cues that aid processing, while other times the complexity may interfere with processing. Therefore, as Levitt and List (2007) point out, laboratory experimentation is necessary in order to control for the factors that might be influencing more complex tasks. This basic science work will help us to understand how the real-world context works. In relation to the current study, the question I am investigating is exactly like the issues that learners face in natural discourse situations. For example, some speakers have difficulty producing and comprehending contrasts between tense and lax vowels, some between rounded and unrounded vowels. The ABX discrimination task used in the present study is designed to help us understand the factors which influence learners' perception of certain vowels in the real world and why.

6.4 Summary

In summary, the thesis contributes to our understanding of multilingual phonological acquisition using the contrastive hierarchy theory as a phonological representational model. My findings demonstrate that the trilingual participants outperform the bilingual participants because the trilingual can transfer phonological features from both the L1 and the L2 to acquire L3 contrasts. Moreover, by examining the acquisition of the four contrasts /y-u/ and /œ-ɔ/, [y, ʏ] and /e-ɛ/, the results reveal the ease and difficulty of acquiring these contrasts based on different types of restructuring actions. In addition, my findings are in support of the LPM (Westergaard, 2021) and the Scalpel model (Slabakova, 2017) and reinforce the importance of developing a model in L3 phonology that takes contrastive hierarchy theory and restructuring principles into consideration.

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Appendices

Appendix 1. Questionnaire on the Language Background of the Participants

1. What is your mother tongue (your first language)?
2. What is the language you grew up speaking, if different from (1)?
3. What is the name of the hometown you grew up in and in which country?
4. How many years did you live in this town?
5. Could you name other places where you have lived for more than 3 months at a time?
6. How long did you live at each of these places?
7. Other than your mother tongue, what language(s) do you know? How well do you know each in terms of speaking, listening, reading and writing? (To rate proficiency level, please take a look at the table below)

Second language 1:

Name of the language: _____ Years of learning: _____

How well I know the language in terms of the following skills:

speaking _____, listening _____, reading _____ and writing _____

(Give a number from 1 to 5 where 1 means “poor” and 5 “fluent”.)

Second language 2:

Name of the language: _____ Years of learning: _____

How well I know the language in terms of the following skills:

speaking _____, listening _____, reading _____ and writing _____

(Give a number from 1 to 5 where 1 means “poor” and 5 “fluent”.)

Second language 3:

Name of the language: _____ Years of learning: _____

How well I know the language in terms of the following skills:

speaking _____, listening _____, reading _____ and writing _____

(Give a number from 1 to 5 where 1 means “poor” and 5 “fluent”.)

1	Novice	You can express simple information (writing and speaking), using familiar words or phrases. You can understand key words and simple phrases in a familiar context (reading and listening).
2	Intermediate	You can express familiar topics related to everyday life with non-native learners of the language. You can understand speech related to familiar everyday topics that conveys basic information.
3	Advanced	You can understand the main idea and most supporting details in connected discourse or narrative essays on a variety of general interest topics. You speak skillfully with accuracy and can deal with unfamiliar topics.
4	Superior	You can understand texts from many genres dealing with a wide range of abstract subjects both familiar and unfamiliar. You can use complex grammatical structures to support your opinions and arguments.
5	Distinguished	You are able to discuss global issues or highly complex concepts and give a speech with accuracy and efficiency

		and adapt your language to suit the situation and audience. You can understand a wide variety of forms, styles and registers of speech on highly specialized topics.
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8. If English is your second language, please complete the following:
 1. Have you taken any English proficiency test?
 2. What test(s) have you taken?
 3. What and when were the latest scores from the test(s)?

9. If French (**please choose: Quebec French? Or European French?**) is your second / third language, please complete the following:
 1. Have you taken any proficiency test?
 2. What test(s) have you taken?
 3. What and when were the latest scores from the test(s)?
 4. What course level you are currently taking? Instructional hours in total?

Appendix 2. Participants' Information

Naïve learners' information (L1 Mandarin-L2 English without learning French) is given below. A large number of them are newcomers in Canada, such as international students or new immigrants from China.

	Gender	Age	City	Education	LO (E)	IELTS	Other languages
P1	F	17	Zhejiang	Undergraduate	9 years	6.0	Romanian
P2	F	38	Jiangsu	Bachelor degree	5 years	5.0	Romanian
P3	F	30	Kunming	Master degree	10 years	7.5	Japanese
P4	M	33	Kunming	Bachelor degree	12 years	7.0	Tai
P5	M	30	Chongqing	Bachelor degree	6 years	CET-460	No
P6	F	31	Yunnan	Bachelor degree	10 years	TOEFL 68	No
P7	F	29	Changsha	Master degree	20 years	7.5	Spanish
P8	M	22	Changsha	Undergraduate	15 years	7.5	No
P9	M	30	Beijing	Master degree	10 years	6.5	Japanese
P10	F	27	Henan	Master degree	16 years	8.0	Finish
P11	M	24	Beijing	Diploma	12 years	4.0	Japanese
P12	M	30	Beijing	Master degree	10 years	6.5	Japanese
P13	F	25	Xinjiang	Bachelor degree	11 years	5.0	No
P14	M	37	Wuhan	Master degree	8 years	7.5	No
P15	F	21	Tianjin	Undergraduate	15 years	6.5	Korean
P16	F	18	Harbin	Undergraduate	8 years	8.5	No
P17	F	17	Beijing	High school	10 years	6.0	No
P18	F	20	Zhejiang	Undergraduate	15 years	6.5	Korean

P19	F	29	Guang Dong	Bachelor degree	16 years	5.5	No
P20	F	24	Guangzhou	Undergraduate	15 years	7.5	Japanese

Native Quebec French speakers' information is given below. Some participants did not fill their education background because they said they just got certificate from college and did not want to provide specific details. Many of the participants are from Quebec and have been living there since they were born. Some of them were born in Quebec and then moved to Victoria for their undergraduate and graduate studies. They are the students in French department at UVic.

No.	Gender	Age	Education	Place grow up & the place living
P1	M	22	Undergraduate	Quebec / Victoria
P2	F	40	PhD	Ontario / Victoria
P3	M	25	Graduate	Quebec / Victoria
P4	F	28	Graduate	Quebec / Victoria
P5	F	45		Saskatchewan / Victoria
P6	F	35	Master degree	Victoria / Ontario
P7	F	26	Graduate	Quebec / Victoria
P8	F	30		Quebec / Quebec
P9	F	37		Quebec / Quebec
P10	F	35	Master degree	Quebec / Quebec
P11	F	41		Quebec / Quebec
P12	F	26	Master degree	Quebec / Quebec
P13	F	45		China / Quebec
P14	F	30	Master degree	Quebec / Spain

P15	M	36	Bachelor degree	Quebec / Victoria
P16	M	48		Quebec / Quebec
P17	M	40		Quebec / Quebec
P18	M	38	Bachelor degree	Quebec / Quebec
P19	F	34	Bachelor degree	Quebec / Victoria
P20	F	23	Graduate	Quebec / Victoria

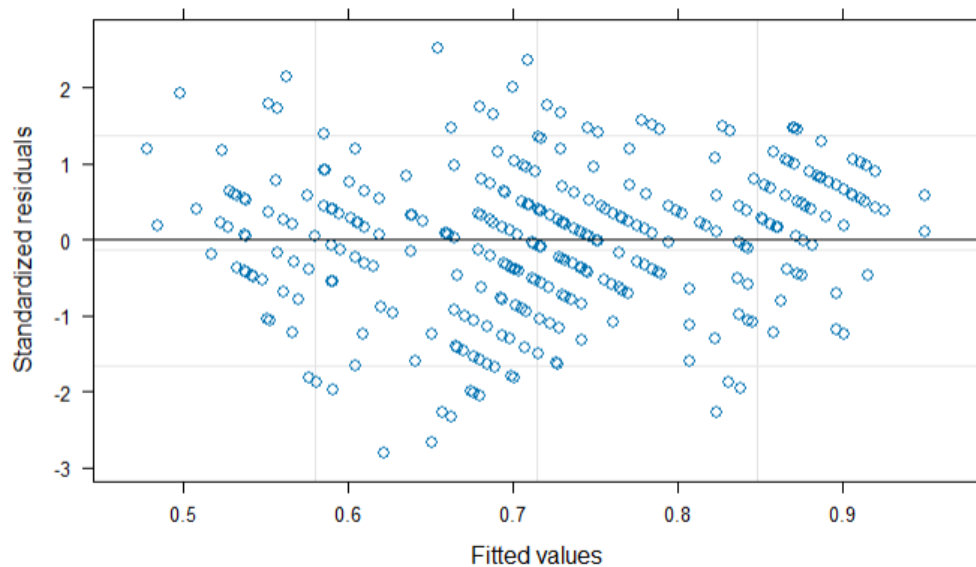
Appendix 3. Linear Assumptions

Linear regression makes several assumptions about the data (Poole and O' Farrell, 1971) such as:

1. Linearity of the data: The relationship between the predictor (x) and the outcome (y) is assumed to be linear.
2. Normality of residuals: The residual errors are assumed to be normally distributed.
3. Homogeneity of residuals variance: The residuals are assumed to have a constant variance (homoscedasticity)
4. Independence: Observations are independent of each other.

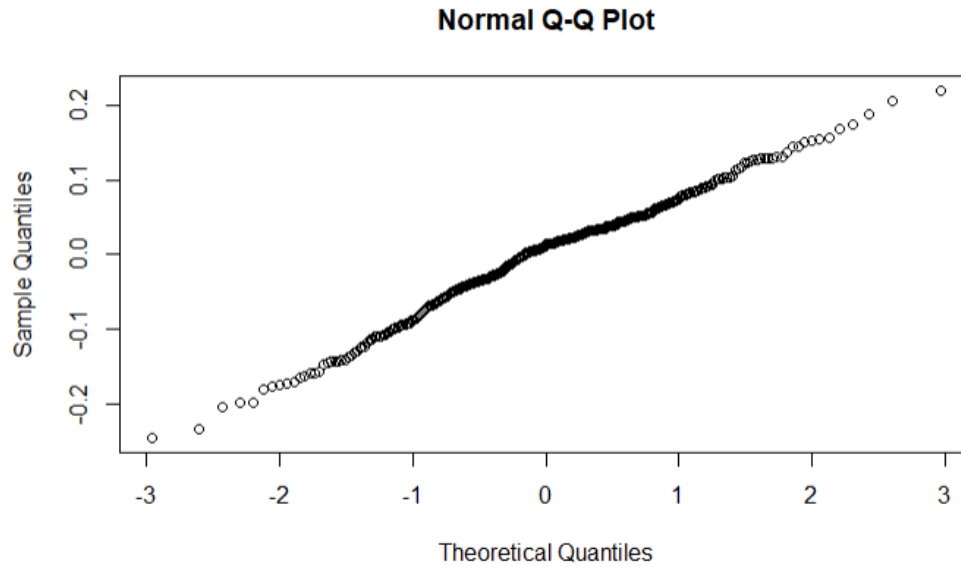
I should check the model I built on my data whether or not it meets these assumptions.

1. Linearity of the data



I tested my data by plotting residuals vs fitted values and then generate this plot. This plot is used to check the linear relationship assumptions. If the plot shows a horizontal line, it is an indication for a linear relationship. As shown above, there is a horizontal line, without distinct patterns, which is an indication for a linear relationship.

2. Normality of residuals



I tested my data in the model I built by generating this Normal Q-Q plot, which is used to examine whether the residuals are normally distributed. It's good if residuals points follow the straight dashed line. As shown in my plot, residual points follow a straight dashed line.

3 Homogeneity of residuals variance

```
Levene's Test for Homogeneity of Variance (center = mean)
  Df F value Pr(>F)
group 3  0.1892 0.9037
324
```

Levene's test is used to assess the equality of variance between different samples. The null hypothesis for Levene's test is that the variance among groups is equal.

From the above result, we can observe that p-value = 0.9037 which is greater than our significance level of 0.05. So, we do have not enough evidence to reject the null hypothesis. So, the variance across the samples is equal at 0.05 significance level. This means that the residuals variance is homogenous.

4. Independence

As present in Chapter 4, level 2 data are independent as each accuracy rate comes from a different subject. Level 2 data violate the independence assumption. Different accuracy rates from the same subject cannot be regarded as independent from each other. This is why the Linear mixed effect model was chosen.