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Towards an empirical and typological exploration of the sonority of nasal vowels

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Ce mémoire intitulé

Towards an empirical and typological exploration of the sonority of nasal vowels

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Résumé

Ce mémoire est une étude phonologique et phonétique visant à ordonner les voyelles nasales en fonction de leur degré en sonorité. Jusqu'à présent, la sonorité des voyelles nasales n'a pas été abordée dans la littérature phonologique et phonétique; ainsi, cette étude vise à combler cette lacune de la recherche en menant une étude typologique et expérimentale des différentes qualités des voyelles nasales. La première partie du mémoire comprend un examen du comportement et de la distribution des voyelles nasales dans les langues du monde afin d'élucider leur place dans l'échelle de sonorité. La partie typologique montre que, dans trois des langues étudiées, seules les voyelles nasales hautes subissent des processus phonologiques comme l'harmonie nasale et la réduction vocalique tandis que, dans deux des langues étudiées, seule la voyelle nasale basse subit des processus phonologiques comme le changement vocalique déplacement de la voyelle et l'attraction de l'accent. La deuxième partie est une expérience nasométrique dans laquelle l'intensité des voyelles nasales et orales est mesurée. L'analyse d'intensité permet de déterminer le niveau de sonorité de chaque voyelle nasale car l'intensité est considérée comme le corrélat physique le plus saillant de la sonorité. L'analyse statistique descriptive effectuée sur l'ensemble des données des voyelles organisées selon leur hauteur (c'est-à-dire haute, mi-haute, mi-basse ou basse) et leur type (nasal ou oral) montre que [a] est la voyelle orale la plus haute en intensité relatif. Quant aux voyelles nasales, [ĩ] est la plus élevée en intensité. Ainsi, suite à l'analyse statistique inférentielle, nous avons établi une échelle permettant de classer les voyelles orales et nasales en fonction de leur intensité.

Mots-clés : Sonorité, nasalité, voyelles nasales, intensité, voyelles orales

Abstract

This thesis is a phonological and phonetic study to classify nasal vowels according to their rank in sonority. To date, the sonority of nasal vowels has not been covered in the phonology and phonetics literature; thus, this study aims to fill that research gap through conducting a typological and experimental investigation of different qualities of nasal vowels. The first part of this thesis includes an examination of the behaviour and the distribution of nasal vowels in the world's languages to elucidate the place of nasal vowels in sonority hierarchy. The typological part of this study shows that, in three selected languages, only high nasal vowels undergo phonological processes such as nasal harmony and vowel reduction while, in two other selected languages, only the low nasal vowel undergoes phonological processes like vowel shift and attraction of stress. The second part of this study presents the findings of a nasometric experiment in which the intensity of nasal vowels and oral vowels is measured. Analysing intensity helps to determine the level of sonority of each nasal vowel, because intensity is considered the most salient physical correlate of sonority. The descriptive statistical analysis performed on the data set of vowels organized according to height (i.e., high, mid-high, mid-low, and low) and type (nasal or oral) shows that, [a] is the highest in relative intensity. As for nasal vowels, [ĩ] is the highest in intensity. Thus, according to the inferential statistical analysis, we established a scale that classifies oral and nasal vowels according to their intensity.

Keywords: Sonority, nasality, nasal vowels, intensity, oral vowels

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List of Abbreviations and Symbols

C	Consonant
V	Vowel
Ṽ	Nasal vowel
CV	Oral syllable
NV	Nasal syllable
1SG.	First person singular
3SG.	Third person singular
SPLH	Sound pressure level at high frequencies
SPL	Standard sound pressure level
QC	Québécois
UPSID	UCLA Phonological Segment Inventory Database.
V:	Long vowel

ˈV	Primary stress
/ /	Underling phonological form
[ ]	Surface phonological form
*	Ungrammatical form
dB	Decibel
V^h	Aspirated vowel

To my Parents, Amjad and Ikhlas, and to my husband, Yanal and my son, Tameem.

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Praise be to "Allah" who gave me the patience and determination to complete this research and thesis task successfully.

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1 Chapter 1 – Introduction

1.1 The Notion of Sonority

Sonority is a phonological notion that generally means the loudness of sound with regards to other sounds that have similarity in length, stress and pitch (Ladefoged, 1993). This term has been used cross-linguistically to describe the preferred choices for some types of syllable forms and associations with other syllables (Clements, 1990). In phonology, sonority is used to study syllables, and sonority scales assign the position of the phonemes within the syllable according to their sonority level. For instance, sounds with high sonority ranking are supposed to be at the center of the syllable, while the phonemes with low sonority level are found far from the center. Many versions of sonority hierarchy exist; the sonority scale which is cited more often than any other is that used by Clements (1990), which presents the following hierarchy: vowels > glides > liquids > nasals > obstruents. As for vowels, they are placed on a sonority scale according to their qualities. For example, the phonetic scale of Parker (2002) places vowels from the highest to the lowest in sonority as follows: low vowels > mid vowels > high vowels > /ə/. A more distinct classification of vowels was introduced by Parker (2008), with the following hierarchy: low vowels > mid peripheral vowels (not ə) > high peripheral vowels (not ɨ) > mid central vowels (ə) > High central vowels (ɨ).

Sonority has also been investigated phonetically, with phoneticians studying the relation between sonority and many acoustic and aerodynamic factors (cf. Parker, 2002). According to Parker (2002), the sonority exhibits strong phonetic correlates in more than one physical domain. The acoustic parameter of intensity is still the most relevant since it follows the sonority hierarchy most closely overall. Currently, linguists define sonority by relating it positively to intensity, which in turn ranks all phonemes on a phonetic scale (Parker, 2011).

Many researchers have studied the sonority of most groups of sounds theoretically and empirically, with some researchers focused on classifying the main sound classes theoretically based on their distribution in the syllable (e.g., Clements, 1990). Other researchers have studied sonority experimentally for groups of sounds through obtaining sonority levels from the values of some physical correlates (e.g., Parker, 2008; Parker, 2002). However, the class of nasal vowels was not included in these prior studies, neither theoretically nor empirically.

1.2 Nasal Vowels

Nasal vowels have considerable importance in languages of the world. That is, they are considered a carrier of phonological contrast in some languages. For instance, in French, Hindi, Lakota, and many other languages, nasal vowels are phonemic or contrastive, such that the meaning of a word can change depending on the whether a vowel is nasal or oral (Styler, 2015). In these languages, the production and perception of nasal vowels are crucial in communication and have an important linguistic function. Therefore, it is important that we can both distinguish and precisely measure the occurrence and degree of nasality of nasal vowels in speech.

Many studies have shown that the articulation and acoustics of nasal vowels are complicated (cf. Carignan, 2014; Delvaux, 2012; Maeda, 1993). Mainly, nasal vowels are a consequence of the coupling between the nasal cavities and the pharyngo-oral tract; when the velopharyngeal port reaches a sufficient size to let air pass through the nasal cavities during the production of a vowel, the coupling is established between the nasal cavities and the main vocal tract. This nasal coupling suggests that the acoustic spectrum of a nasal vowel is more complex than the spectrum of its oral counterpart—the former has more formants resulting from the complex articulation system—and that the effect on the acoustics depends on the degree of coupling. Thus, this coupling affects the phonetic realization of the nasal phoneme; that is, in many languages, where nasalization is contrastive, there are some articulation adjustments that aid in the lowering of the velum to produce the nasal vowel. For example, in French, the phonetic outcome of nasal vowels is somewhat different from their oral phonological counterparts. French speakers usually articulate lowered /ɛ̃/, rounded /ɔ̃/, and raised /ɑ̃/ (cf. Carignan, 2014). In brief, it is understood that the nature of nasal vowels in phonetic description is still imprecise given their complexities in the context of acoustic analysis and their articulatory changeability. Intensity and F1 of nasal vowels are the phonetic correlates that have most commonly been investigated in order to distinguish between nasal vowels; thus, in this study we will investigate nasal vowels through examining their segmental intensity.

1.3 The Goal of This Study

The general objective of this thesis is to differentiate between diverse types of nasal vowels through exploring their sonority phonologically and experimentally. For the phonological part, we examined the typology of nasal vowels. That is, we conducted a cross-linguistic study of the inventory, distribution, and behaviour of nasal vowels. Then we examined the maximum intensity of the peak point of ten types of nasal vowels and ten types of oral vowels to construct a phonetic scale for both groups of vowels. We chose to measure intensity because it is considered the most important physical correlate that displays sonority (Parker, 2008; Parker, 2002).

The experimental portion of the study was performed with a nasometer, a device that includes two microphones to record the acoustic signals produced from the nasal cavities separately from the acoustic signals of the oral cavity. Seven French participants from Montreal, Quebec were recruited to take part in this study. We recorded the speech of participants during their reading of two texts in French: a brief passage and a list of phrases containing the target oral and nasal vowels.

The general results show that there is a difference in mean of relative intensity values between the class of oral vowels and the class of nasal vowels, where the group of high nasal vowels have the greatest meam relative intensity value within nasal vowels, ranking after the group of high oral vowels that have the lowest mean of relative intensity value within the class of oral vowels. In addition, there is a significant interaction (p=0.005) between vowel height and vowel type, with the low oral vowel being the highest in mean of relative intensity for both types of vowels while the nasal counterparts are second lowest in mean of relative intensity for both types. The same applies for mid-low oral and nasal vowels, where mid-low oral vowels are second highest in mean of intensity for both types of vowels and mid-low nasal vowels are the lowest in mean of intensity for both classes.

1.4 Notational Conventions

In the linguistic representations presented throughout this thesis, certain conventions are used. Underlying forms are presented between slashes (/…/), and surface forms between square brackets ([…]). Additionally, morphemes are separated with the dash symbol (-). Ill-formed representations are preceded by an asterisk (*).

For sonority hierarchy, the phonemes are classified from highest to lowest, with the symbol (>) between them, where the phoneme on the left of this symbol is higher in sonority than the phoneme on the right. This convention also applies to intensity scales.

1.5 Organization of This Thesis

The rest of this thesis is organised as follows: Chapter 2 discusses previous theoretical and experimental research on sonority and on the acoustic basis of vowel nasality. An introduction to nasality and nasal vowels, as well as an overview of the typology of nasal vowels, is presented in Chapter 3. Chapter 4 presents the methodology of the experimental portion of the research, along with the statistical analysis. The general results and the results of the statistical analysis are discussed in Chapter 5. Then Chapter 6 discusses markedness and sonority relations, as well as the correlation between the experimental findings and the typological observations of nasal vowels. Finally, Chapter 7 includes a summary of this thesis, future work, and accomplishments.

2 Chapter 2 – Overview of Phonology and Phonetics

2.1 Introduction

This chapter involves two parts that form the cornerstone of this thesis. The first part is a phonological and phonetic overview of sonority and of the most prominent theoretical and experimental research on sonority to date. The second part discusses the acoustic nature of nasal vowels and its relation to vowel quality (i.e., height). The chapter structure is as follows: Section 2.2 introduces a literature review on sonority and its scales, influence, and phonetic parameters. Then, section 2.3 presents the relation between markedness theory and sonority. Section 2.4 is a brief survey of nasal vowels' acoustic nature relevant to vowel height. Subsection 2.5 presents a hypothesis about the phonological and phonetic behaviour of nasal vowels. Finally, section 2.6 is a summary of the chapter.

2.2 Literature Review: Sonority

The notion of sonority is a well-studied field, from both a phonological and a phonetic perspective. This section presents a brief overview of the key issues in the literature to shape the basis of this thesis. This section is organized as follows: Subsection 2.2.1 gives a general outline of sonority. Sonority scales are reviewed in subsection 2.2.2, and Subsection 2.2.3 discusses the influence of sonority on syllable structure. Finally, the acoustic parameter of sonority and intensity is examined in subsection 2.2.4.

2.2.1 Sonority

The syllable mainly refers to the entity organizing the sequence of sounds, as argued bySelkirk (1982). The syllable is divided into three main subparts according to their sonority level, with sonority level reducing at the margins (onset and coda) and increasing at the peak (nucleus). Therefore, from the phonological side, analyzing the pattern of syllable organization in a given language is a way to figure out the sonority levels for segments in the language of interest. This is because a sonority scale is built by inferring the relative sonority of each segment based on its occurrence in the syllable (Davis, 1990; Steriade, 1982). As the Sonority Sequencing Principle (SSP) states, the peak of the syllable is the segment with the highest rank on the sonority scale. As for other segments in the syllable, they are around the nucleus, where the segments rated as more sonorous are closer to the peak and the ones rated as less sonorous are more distant from it.

Consequently, many researchers have studied the influence of sonority level on syllable organization, including Sievers (1901), Jespersen (1904), Saussure (1916), Grammont (1933), Hooper (1976), Kiparsky (1979), Steriade (1982), Selkirk (1982), and Clements (1990). From a phonetic point of view, some researchers have studied various phonetic parameters to define sonority. For example, Ladefoged (1993) suggested studying perceptual salience (i.e., the property of a sound by which it is easily noticeable by the speaker and is more prominent to human perception system than another (Hickey, 2000; Kerswill & Williams, 2002; Siegel, 2010)) or loudness (i.e., a psychological term used to describe the magnitude (the strength of sound wave) of an auditory sensation (Fletcher, 1953)) of a particular sound; Goldsmith (1995) focused on the amount of airflow in the resonance chamber as a correlate of sonority; and (Butt, 1992; Ohala & Kawasaki, 1997) proposed to define sonority by considering multiple phonetic parameters. More recently, Parker (2002) examined five phonetic parameters to determine which best correlates with typical phonological sonority scales, either in a positive or negative direction. Furthermore, Parker (2011) examined maximum intensity (i.e., generally refers to the magnitude or loudness of a sound in comparison to another and technically refers to the power of a sound wave by area which is measured in Decibels (Ladefoged, 1993; Parker, 2008)) for vowels and minimum intensity for consonants to develop a sonority scale for the main classes of sounds.

2.2.2 Sonority Scales

The segments are arranged on a scale according to the degree of their relative sound from the highest level of sonority (i.e., the vowels) to the lowest level (i.e., the stops). Also, various scholars have defined sonority from different perspectives to determine if a given sonority scale is universal (Butt, 1992; Clements, 1990; Selkirk, 1984) or if it is language-specific (Davis, 1990; Steriade, 1982). Sonority scales with universal values refer to the main natural categories of sounds. For example, the universal sonority scale constructed by Clements includes five major natural categories of sounds (vowels, glides, liquids, nasals, and obstruents). These main classes are arranged from left to right, with the leftmost segments being the most sonorous, while the rightmost are the least sonorous, as in (1) below:

(1) V > G > L > N > O

Butt (1992) constructed a sonority scale that is slightly different from Clements's scale, in that he provided a scale with a different value for both voiced and voiceless obstruents. His universal sonority scale is of the following order:

(2) V > G > L > N > Voiced O > Voiceless O

Selkirk (1984) established even more divisions among the different natural classes and proposed a more detailed universal sonority scale for segments:

(3) a > e, o > i, u > r > l > m, n > s > v, z, ð > f, θ > b, d, g > p, t, k

Parker (2002) revealed a correlation between sonority and the physical property of intensity using data from English and Spanish. He suggested that the relationship between sonority level and intensity is linear, i.e., intensity values increase with sonority ranks. His study showed the consistency of sonority general levels across all languages. His sonority hierarchy organized the segments according to their phonetic results:

(4) low vowels > mid vowels > high vowels >/ə/ > glides > laterals and /r/ > flaps > trills > nasals > /h/ > voiced fricatives > voiced stops > /ǰ/ > voiceless fricatives > voiceless stops and affricates

Parker (2008) said that his intensity values of phonemes from English, Spanish, and Quechua yielded highly significant correlation with his suggested sonority indices, and he therefore introduced the following sonority scale based on both theoretical and phonetic analysis:

(5) low vowels > mid peripheral vowels (not ə) > high peripheral vowels (not ɨ) > mid central vowels (ə) > High central vowels (ɨ) > glides > rhotic approximants (ɹ) > flaps > laterals > trills > nasals > voiced fricatives > voiced affricates > voiced stops > voiceless fricatives > voiceless affricates > voiceless stops

2.2.3 Sonority Scale Constraints

Sonority principles, which entail a set of phonological constraints, require that segments with high sonority rank undergo certain phonological processes. For instance, the low vowel [a] is known to be the highest in sonority, so sonority may require that this vowel attract the stress within the syllable. This phenomenon's name is “sonority-driven stress.” In addition, more sonorous vowels are exempt from occurring in a weak position, so they may be replaced by less sonorous vowels in a process called “sonority-driven reduction.”

An example of a sonority-driven stress process is the assignment of stress in Takia language. In this language, the stress is placed by default at the rightmost syllable (e.g., [taˈma-n] ‘father’, [ifiˈni] ‘s/he hit him’, [tuˈbun] ‘her/his grandparent’). However, in Takia, sonority principles make high central, mid central (e.g., schwa), and high peripheral vowels exempt from bearing a stress whenever a high sonorous vowel occurs in another place in the same word. For instance, let us assume that stress could be placed on the default (i.e., rightmost) syllable like *[ŋa-ˈsol] ‘1sg-flee’, but this would result in a stressed high peripheral vowel when there is a more proper non-high vowel elsewhere in the word. Instead, stress is attracted away from a predetermined position on the final syllable to fall on the highest sonority syllable. That is, sonority plays a significant role, where stress attaches to the most sonorous vowel in the word (e.g., [ˈabi] ‘garden’, [ˈŋa-sol] ‘1sg-flee’). So, the stress place depends on the sonority scale relevant to Takia: a > e, o > i, u. (cf., De Lacy, 2004).

The phonological process called “sonority-driven reduction” requires that a more sonorous vowel must be removed from a weak or unstressed position. An example of this phenomenon is found in the Bulgarian language. In this language, a vowel with high sonority rank is reduced to another vowel that is lower in sonority in unstressed position (Crosswhite, 2000). According to the sonority scale of this language, more sonorous vowels like [e, a, o] are replaced by less sonorous vowels like [i, ə, u], respectively. For example, the underlying word /rogat/ becomes [rugat] ‘horned’, and /gradet/ becomes [grədet] ‘town’.

Sonority scale constraints can also impose elision, for example, when [a], a high sonorous vowel, appears in an unstressed syllable, it is elided in Lushootseed (Gouskova, 2003; Urbanczyk, 1997). The second /a/ in /ˈcacaq/ is deleted to become [ˈcacq] ‘to spear big game on salt water’; /ˈwawalis/ becomes [ˈwawlis] ‘little frog’.

The above-mentioned phenomena show that the class of oral vowels is affected by sonority forces, such that many processes occur to preserve the total sonority threshold of the syllable within the same word, such as displacement of stress from one vowel to another, vowel reduction, and vowel deletion. The above-mentioned processes targeting oral vowels have paved the way for the examination of nasal vowels in order to see which particular kinds of nasal vowels are more likely to be preferred as the nucleus of the syllable or to bear primary stress, and to see which one is more likely to undergo phonological processes.

2.2.4 Intensity: A Physical Parameter of Sonority

One of the most important research programs in linguistics dedicated to the study of sonority is the examination of its physical properties, where sonority is suggested to have strong phonetic correlates in more than one physical domain (Parker, 2008, 2011; Parker, 2002). One physical parameter that appears to be strongly correlated with the relative sonority classes (see (4) and (5)) is intensity (Parker, 2008; Parker, 2002).

Many studies have focused on intensity as a physical correlation of sonority, and various experiments have examined the relative sonority of segments through measuring intensity or its derivatives, such as acoustic energy (i.e., the vibration produced by sound waves during their travel through a medium which causes a disturbance in energy that can be heard by speaker (Jarvis, 1999; Vorländer, 2013)) and power (i.e., the ratio at which the sound energy is produced per unit time, measured in Watts (Baken & Orlikoff, 2000; Sabine, 1923)). Fant et al. (2000) aimed to study sonority through introducing a new intensity parameter, which is sound pressure level at high frequencies (SPLH). They examined the relation of speech intensity to the vocal tract filter and the voice source, as well as to the underlying aerodynamics. They chose this focus because analyzing the role of subglottal pressure and fundamental frequency (F0) in influencing intensity readings (i.e., intensity increases whenever there is an increase in F0), as well as their covariation in speech, is considered a problem of interest in phonetics. Their speech analysis proved that integrating perceptually scaled syllable prominence is appropriate for studying different parameters like intensity, duration, F0, F1, F2, and F3. Their analysis examined the syllable prominence in Swedish. They concluded that the new parameter SPLH was more associated with the notion of sonority than standard sound pressure level (SPL) (i.e., the pressure produced from variations in the air resulting from sound waves, measured in Decibels (Björklund & Sundberg, 2016; Everest & Ken, 2009; Fant, 1982)), and they presented information on the voice source spectral slope. During their study, they found that, in Swedish, high long stressed vowels like [iː], [yː], [ʉː], and [uː] exhibit low sonority level in a prominent position within the syllable.

Jany et al. (2007) examined the universality of the acoustic basis like intensity and F0 for the sonority hierarchy—glides > liquids > nasals > obstruents, in four languages—Egyptian Arabic, Hindi, Mongolian, and Malayalam. They constructed a list of words made up of two syllables in which they studied the coda of the first syllable and the onset of the second syllable. Their word list for each had a low vowel as a nucleus to enable a cross-linguistic comparison of the results. They measured intensity over the entire segment for each consonant in coda and in onset position. Then they defined the acoustic sonority as a linear regression equation derived from the intensity measurements using Parker's formula (discussed below), which was created for female Spanish speakers. Jany et al. (2007) concluded that values for consonants from different classes follow language-specific patterns, while major classes, in general, such as sonorants > obstruents, follow the universal sonority hierarchy in terms of their acoustic patterns.

Gordon (2005) studied onset-sensitive stress typologically, phonetically, and phonologically in three languages: Pirahã, Banawá, and Arrernte. He based his phonetic examination of the three languages on a proposed close match between onset heaviness distinctions, the measurement of perceptual energy (i.e., the summation of loudness over time (Gordon, 2005; Nygaard & Pisoni, 1995)), and the phonological weight criteria, mostly consistent with measurements in previous studies. In addition, he indicated that perceptual considerations have justified some other typological observations, such as the rarity of onset-sensitive stress, and the greater quantity of low sonority onsets.

Furthermore, Gordon et al. (2012) performed a cross-linguistic study for four acoustic correlates of vowel sonority. They measured duration, maximum intensity, acoustic energy, and perceptual energy in five languages (Hindi, Besemah, Armenian, Javanese, and $K^{w}ak'^{w}ala$) to find an acoustic base for the position of schwa at the bottom of vocalic sonority scales. They detected a variation between languages concerning which parameter is most effective in determining the position of schwa on the sonority scale. They concluded that languages fluctuate in which parameter(s) is(are) most effective in predicting the low sonority status of schwa. Moreover, they noticed some contradictions in the sonority scale in which the schwa appears to be acoustically more intense than some high vowels. They suggested that phonological sonority in vowels may need to be quantified in more than one acoustic dimension. However, their study focused only on finding the best acoustic basis for where to place the schwa on the sonority scale. Their conclusions depended only on measuring different acoustic parameters in different languages for this only one central vowel. The aim of the current study is different from the Gordon et al. study, in that the former examines the intensity of the class of nasal vowels and the class of oral vowels to suggest a place for nasal vowels in the sonority hierarchy.

Kawai (2002) tested an automatic speech recognition analysis to estimate sonority rank by constructing a reading task of 143 utterances containing 911 phones without the speech recognition software having prior knowledge of the phone order. Kawai (2002) found that pitch (i.e., a property proportionately related to the frequency of the sound wave (Beranek et al., 1988; Campbell et al., 2014; Hirst & Looze, 2021)) and band-pass filtered power (i.e., a method of eliminating frequencies of a signal within a certain range while passing others (Gauthier et al., 2019; Shenoi, 2005)) measurements can be some of the best parameters for predicting sonority rank. Komatsu et al. (2002) aimed to prove that sonority can be quantified in a multi-dimensional perceptual space that has correlation between acoustic parameters (e.g., length, pitch, etc.) and phonological features (i.e., [voice], [sonorant], [continuant]). In examining perception of consonants in /Ca/ syllables, Komatsu et al. (2002) succeeded in modelling the consonants in a different dimensional perceptual space according to their sonority rank and presented a way to define the sonority, i.e., to define the sonority within the suprasegmental domain.

Likewise, Parker (2002) conducted an experiment for English and Spanish speakers to measure five phonetic parameters (i.e., intensity, intraoral air pressure, F1, airflow, and duration) to form a general sonority scale, where intensity is best correlated with sonority ranks. Then he proved that sonority can be defined by a linear regression equation such as the following:

sonority=5.16 + .37 × dB, where the first number refers to the intercept value while the second refers to the mean slope of a corresponding sonority rank.

By expressing sonority in equation form, Parker demonstrated that sonority is phonetically established in a specific physical correlate. In other words, defining sonority as in equation form can be easily expanded to new experimental paradigms and that its results are easily comparable across studies.

Also, Parker (2008) studied three languages—English, Spanish, and Quechua—to demonstrate that intensity is the most prominent physical correlate of sonority. He showed that the attained intensity values produce an overall mean Spearman's correlation of .91 with his proposed sonority indices. Consequently, he suggested characterizing sonority by means of a linear regression equation according to the examined intensity results for a specific language in a prosodic position such as the following:

(6) Sonority=13.9 + 0.48 * Lrel (in dB), where Lrel stands for relative sound level compared to the reference low vowel.

According to Jany et al. (2007); Parker (2008); Parker (2002), and Gordon (2005), measuring the intensity to decide the sonority level of different sounds in different languages is the most reliable physical parameter of sonority. Measuring sonority along various acoustic aspects is a more manageable task, even if it has been difficult to find a distinct acoustic parameter that anticipates all sonority groupings (cf. Parker, 2008; Parker, 2002). For this reason, the current study presumes that exploring intensity as the acoustic parameter for sonority is more appropriate than using articulatory or aerodynamic methods, which require massive effort to precisely measure physical activities of speech systems and to quantify intraoral air pressure (that is negatively correlated with sonority). The actions of carrying out an acoustic analysis of sonority are explained by a large body of literature offering various acoustic correlates of sonority, such as seen in the above mentioned studies and other studies (cf. Parker, 2008; Parker, 2002). Although most of the studies mentioned in Parker's dissertation (2002) are not supplemented by supporting acoustic evidence, Parker's phonetic examination of sonority shows that intensity properly anticipates the order of most classes of segments in sonority scales.

Moreover, Parker (2008) showed that a task based on measuring the peak intensity of vowels and the minimum intensity for consonants is suitable to form sonority hierarchies. Also (Jany et al., 2007) found a near match between Parker's intensity linear regression equation and data from consonants in four languages, except they used the root mean square (RMS) amplitude instead of intensity extremes.

Given the established practice of measuring intensity as a correlate of sonority, on one hand, and of nasometry for quantifying nasality using a split-channel device to record oral and nasal signals separately, the present study adopts the working hypothesis that the sonority of nasal vowels can be calculated on acoustic grounds. That is, measuring maximum intensity for nasal and oral vowel peaks that avoid the effect of the adjacent segments is a proper method to characterize a place for them on the sonority hierarchy.

2.3 Markedness and Sonority Relations

Markedness is a term that is considered one of the most important and well-established theories in phonology. The way of describing this concept has changed noticeably since the work of pioneers like Trubetzkoy (1931, 1939) and Jakobson (1941). Thus, different explanations of this concept have been suggested depending on one's different theoretical tendencies. Markedness can refer to different things like frequencies of occurrences from typological perspectives, or structural complexity within phonological representations (Moravcsik & Wirth, 1986). In its most basic form, markedness typically refers to which elements are usually outputs, triggers, and undergoers of particular phonological processes. Under such an approach, the less marked element is the output of a phonological process (in certain neutralization processes), is not the trigger for alternation, and undergoes phonological processes; whereas the more marked element is rarely the output of a phonological process, is always the trigger for alternation, and do not undergo phonological processes.

Markedness can refer to typological criteria (though it is not acceptable by all markedness accounts); for example, a cross-linguistic overview of sound inventories shows that few languages have fricatives like /θ, ð/, as opposed to /s, z/. Moreover, with respect to the feature [voice], cross-linguistic studies show that voiceless stops occur more frequently and imply voiced stops in an inventory (Moravcsik & Wirth, 1986).

Some accounts see structural complexity as a criterion of markedness in that, simple structures (e.g., singleton onsets) are less marked than complex structures (e.g., complex onsets) (Coupé et al., 2009; Givón, 1991; Vennemann, 1989; Watts & Rose, 2020). Thus, complex structures are eliminated through phonological processes that are forms of markedness reduction to avoid multiple markedness violations (an idea rejected by de Lacy (2006)). An example of reducing sructural complextiy can be seen in Polish, in which complex onsets must assimilate in [voicing]. For instance, the word /psdura/ 'nonsense' must agree in voicing with the last consonant of the onset cluster regardless of the underlying feature of the other two consonants, which becomes [bzdura] 'nonsense' (cf. Lombardi, 1999, for more examples and discussion about voicing assimiliation in complex onsets).

Markedness relations are usually expressed by markedness hierarchies (i.e., scales that organize features or values relative to other features or values (de Lacy, 2006)). One well-known example is the hierarchy for major place of articulation (PoA) which is presented in (7), based on the work of Lombardi (1995, 1998) and others.

(7) Major place of articulation markedness hierarchy
dorsal > labial > coronal > glottal

The PoA hierarchy shows that dorsals are more marked than others in the same hierarchy, in that dorsals can never be less marked than coronals (de Lacy, 2006). There are other markedness hierarchies for voice, sonority, and tone. Table 1 represents the sonority-based hierarchy that was suggested by de Lacy (2006) for vowels in head position, arranged from the less marked (i.e., the highest in sonority) segment leftmost and the more marked (i.e., the lowest in sonority) segment rightmost.

Table 1: Vowel markedness scale

Quality	Low	Mid-low peripheral	Mid-high peripheral	High peripheral	Mid central	High central
Example vowel	a	ɛ	e	i	ə	ɨ

Some markedness hierarchies vary depending on their environment (e.g., the sonority hierarchy varies depending on the prosodic context). Vowel markedness varies according to the prosodic context (de Lacy, 2006). Many vowels can be unmarked relative to others, and thus be seen as the output of epenthesis and neutralization. Thus, it has been suggested that vocalic phenomena can be classified according to their relative sonority. However, many markedness hierarchies that are pertinent to consonants do not vary with prosodic context. For example, most coronals are less marked than dorsals in nearly every environment. For the sonority of vowels, the least marked vowel in a prosodic head (e.g., the nucleus that holds the primary stress of the prosodic word) is [a], while the least marked vowel in a prosodic non-head (e.g., any other nucleus that does not hold the primary stress of the prosodic word) is high central [ɨ, ʉ]. An added difficulty is that prosodic contexts may overlap. For example, the least marked vowel in syllable nuclei is the highly sonorous [a]. However, the least marked vowel in unstressed syllables is the low sonority [ɨ, ʉ]. Thus, unstressed syllables and nuclei can have two differing requirements placed on them. As syllable nuclei, they should be highly sonorous, while as syllable non-nuclei, they should have low sonority. Languages differ as to which requirement occurs and to what extent; therefore, any sonority level can be the least marked in intersecting in prosodic head and prosodic non-head environments (De Lacy, 2004; de Lacy, 2006). Despite such variation and conflict in vowel sonority, there are vowel-related hierarchies that are not affected by prosodic context. For example, nasal vowels are more marked than oral vowels regardless of prosodic environment. There are also markedness relations with respect to backness and roundness that do not vary in different prosodic contexts. These hierarchies have a significant effect on epenthesis and neutralization (de Lacy, 2006).

Since there are some conflict and variation in the sonority hierarchy for vowels, more classifications were done between vowels based on their phonological behaviour and on their physical correlates like airflow, intensity, and intraoral air pressure. For instance, Parker (2002) presented compelling evidence that among such factors as duration, intensity, intraoral air pressure, F1, and airflow, sonority is best demonstrated by intensity. Parker's results confirm with remarkable precision the vocalic sonority hierarchy proposed by de Lacy (2002, 2006) (see Table 1). Thus, studying the phonological behaviour of nasal vowels, on the one hand, and measuring their intensity, on the other hand, seems to be an effective method for classifying nasal vowels on the sonority hierarchy. This seems particularly fitting because vocalic phenomena in general depend on prominence or lack thereof, and some subsets of nasal vowels are favoured in prominent positions, in comparison to other subsets of nasal vowels. Considering the results presented by Parker (2002) concerning the link between sonority and intensity, the present study suggest that the behaviour of nasal vowels may adapt to a sonority-based hierarchy. The next section discusses the phonetic nature of nasal vowels and how it may affect on their intensity measurement.

2.4 Phonetics of Nasal Vowels

This section presents a concise discussion of the acoustic nature of nasal vowels and of the influence of their complex articulation and degree of height on acoustical measurements like intensity and formants. Subsection 2.4.1 reviews the acoustic bases of nasal vowels. The relation between vowel height and velum positions is presented in subsection 2.4.2. Finally, the relation between nasality and vowel height is discussed in subsection 2.4.3.

2.4.1 Acoustic Bases of Nasality

Nasal vowels are articulatorily, perceptually, and acoustically complex sounds. Their articulation involves three separate resonators: the pharyngeal cavity, nasal cavities, and the oral cavity, which makes it the most complex resonant system in human speech (Delvaux, 2012). Due to this complex system, figuring out nasal vowels' acoustic features has attracted the interest of many researchers (Bjuggren, 1964; Delattre, 1954; House & Stevens, 1956; Maeda, 1982a, 1982b, 1984; Stevens et al., 1987).

Maeda (1982a) suggested a port model such that as a result of an expansion in the velopharyngeal port area, there is a reduction of the same amount in the oral passage area which is controlled by the shape of the pharyngo-oral tract suitable for an oral vowel. Therefore, the opening size of the velopharyngeal port can increase from zero to a fully open oral passage area. According to Maeda (1993), this port model suggests that there are two extreme configurations, a pharyngo-oral tract for an oral vowel, and a pharyngo-nasal tract which is employed when the passage to the oral cavity is fully obstructed. Nasal vowels are produced between these two extremes. The port model produced by Maeda (1993) describes the process of vowel nasalization as a transfer function from the extreme oral configuration of the pharyngo-oral tract to the extreme nasal configuration of the pharyngo-nasal tract. At the former configuration, the velopharyngeal port is closed (i.e., nasal coupling=0) during vowel production, the vocal tract system has only vowel formants (i.e., only poles), and two nasal pole-zero pairs are collapsed upon each other at their respective frequencies, known as the critical resonances of the nasal tract. At the other extreme configuration, the nasal antiformants cancel out certain oral formants such that only the formant structure of what is essentially a nasal consonant remains.

Delvaux (2012) concluded that a nasal vowel includes a large number of formants whose frequency is either intermediate between a resonance of the pharynx and mouth system and another resonance of the pharynx and nose system, or the product of the separation of pole-zero pairs from one of the two systems. The nasal vowel also features a series of spectral zeros or anti-formants from these pole-zeros pairs, which reduce acoustic energy to their own frequency, i.e., they can weaken or even cancel one of the formants of the overall system.

Thus, the acoustic complexity of nasal vowels is due to two factors. On the one hand, the spectrum of the nasal vowel is richer than that of the corresponding oral vowel because it has a greater number of elements in each frequency range. In addition to the oral formants, which are shifted in the frequency domain compared to the oral vowel, a number of pole-zero pairs are introduced at different frequencies, and the interaction between these various elements can be complex. On the other hand, it is difficult to predict the precise acoustic properties of a nasal vowel, since these are sensitive to multiple factors, such as the degree of coupling and the oral configuration of the vowel, as well as to the anatomical properties of the nasal cavities of each individual speaker (Delvaux, 2002). In addition, nasalization does not equally affect the oral configuration of different types of vowels, but there are factors that play a role during vowel nasalization such as vowel height. The next subsection describes the effect of role of velum movement on vowel height and nasalization.

2.4.2 Velum Movements and Vowel Height

Velum positions are contrastive for oral and nasal sounds. For instance, velum height varies for oral and nasal sounds, in that the velum is low for nasal sounds, which enables the airflow to pass through the nasal cavity, and high for oral sounds, which block air from passing through the nasal cavity. However, there are certain variations in velum height that cannot be considered contrastive articulatory gestures. For example, within the class of oral vowels, the velum is often raised for high vowels and lowered for low vowels (Bell-Berti, 1980; Fritzell, 1969).

Bell-Berti et al. (1979) confirmed that, for obstruents, the velum position is the highest, while it is lowered a bit for high vowels, then lowered still more for low vowels. In their study, Bell-Berti et al. (1979) examined the height of the velum in meta-linguistic CVCCVC expressions, in which each expression had a nasal consonant at the middle. They stated that, for words that have low vowels, the height of the velum was lower, whereas for words that have high vowels, the velum's position was higher. Bell-Berti (1980) used a fiberoptic camera imbedded all the way through the nasal passage to trace velum movement for an English speaker saying metalinguistic words that do not have a nasal vowel, like /itsa/ and /ista/. Similarly, she concluded that velum position was lower for low vowels.

Velum position varies according to the produced sound. It is lowest for nasal consonants, higher for low vowels, even higher for high vowels, and highest for obstruent consonants. Velum position for nasal vowels varies with the vowel height, just as is the case for oral vowels, even though velum positions are considerably lower for nasal vowels than for oral vowels (Henderson, 1984).

In addition, early acoustic modelling studies have shown the influence of velum movements and positions on vowel articulations. For example, House and Stevens (1956) indicated in their study that, for a small opening size of velopharyngeal port (VP), acoustic coupling is expected to happen more with high than with low vowels. Moreover, Maeda (1993) reported that the interaction of the nasal formants and anti-formants with oral tract vowel formants explained the different effects on different vowels that result from the same changes in the VP size. Thus, vowel nasalization produces antiformants that may have an effect on the inherent formant structure of a given vowel, and the effect varies according to the quality of vowels, which may affect their intensity in comparison to oral vowels.

2.4.3 Vowel Height and Nasality

As discussed in the above subsection, the position of the velum, the articulator which adjusts the VP opening, has a particular relation with the height of vowels. For nasal vowels, the production of high nasal vowels involves slight opening of the VP to have a sufficient nasal coupling, while the articulation of low nasal vowels requires much more opening of the VP to achieve the same degree of nasal coupling (Maeda, 1993).

Moreover, acoustic effects of the nasal coupling depend on the height of the vowel. For example, when French vowels [i], [y], and [u] are nasalized (their first formant frequency (F1) below 400 Hz), the lowest resonance is F1, and the nasal pole-zero pairs appear above it, so the weakening of F1 would not occur for these vowels. On the other hand, when non-high vowels are nasalized, the F1 frequency is above 400 Hz, thus the F1 peak can be affected by the first anti-formant (i.e., the F1weakens) (Maeda, 1993).

Finally, from a perceptual approach, the same degree of lowering of the soft palate may or may not lead to the perception of nasalization, depending in particular on the identity of the vowel. A velar opening of 0.4 cm^2 is sufficient for a vowel /i/ to be perceived as nasalized, while a velum opening of 1.6 cm^2 is necessary for the vowel /a/ to be perceived as nasalized (Maeda, 1993). Thus, high nasal vowels are rapidly assumed to be more nasal than are low nasal vowels (Hawkins & Stevens, 1985).

2.5 Hypothesis

The above subsections discussed the notion of sonority and its principles and scales, along with examples about the class of oral vowels. Then, the subsequent subsections discussed the nature of nasal vowels and the influence of their complex articulation and degree of height on acoustical measurements like intensity. Based on the above discussion of the sonority relations and the articulatory and acoustic nature of nasal vowels with relation to their degree of height, we hypothesize that the degree of height and nasality will affect on the intensity readings of nasal vowels. Thus, high nasal vowels will display higher intensity levels than mid and low nasal vowels. In addition, typologically, phonological processes will target nasal vowels that differ in height from oral vowels. As a result, we expect that high nasal vowels will be the target of phonological processes in the studied languages and, thus, higher in sonority than mid and low nasal vowels.

2.6 Summary

This chapter has presented the findings of previous theoretical and experimental studies on sonority and acoustic consequences of vowel quality. The first part of this chapter explored research on different angles of sonority through studying and classifying various phonemes according to their sonority rank from highest to lowest. The second part of this chapter presented a brief description of nasal vowels' acoustic nature, focussing on the issue of vowel height and acoustic consequences. The outline of these two parts offers this thesis its line of reasoning towards clearer investigation of nasal vowels' sonority. Hence, this thesis intends to fill the research gap in the existing literature and to examine the nasal vowels typologically and experimentally in order to determine their place on the sonority hierarchy.

3 Chapter 3 – Typology of Nasal Vowels

This chapter reviews languages in which subsets of nasal vowels undergo one or more phonological phenomena which may be considered as evidence of its sonority rank in these languages. First, a brief introduction on nasal vowels and a statement of the purpose of the research are presented in section 3.1. Then section 3.2 outlines phonological phenomena that target various nasal vowels, with examples from languages that show these phenomena. Finally, the chapter concludes with a summary in section 3.3 of the phonological phenomena.

3.1 Introduction

The feature [nasal] is present in almost all languages. Only 10 (~1%) of the languages listed in the expanded UPSID database (Maddieson, 1984, 1991) have no nasal consonants, and four of these languages do not have any phonemic nasal or nasalized segments. Few languages (around 20%) have phonemic nasal vowels (Maddieson, 1984, 1991). Languages can either have fewer nasal vowels than oral vowel counterparts or an equal number of oral vowels and nasal vowels. No case has been observed where the number of nasal vowels exceeds that of oral vowels (Ruhlen, 1975). Regarding frequency, the most common nasal vowels in the world are /ĩ/ (13%), /ɑ̃/ (13%) and /ũ/ (12%). The nasal vowels /ɛ̃/ (5%), /õ/ (5%), /ɔ̃/ (4%), /ẽ/ (2%), and /œ̃/ (0.9%)are the least common in the world's languages (cf. Maddieson, 1984, 1991).

The research on the phonology of nasal vowels is often typological in nature, in that researchers cross-linguistically study the inventories, behaviour, and distribution of nasal vowels with respect to those of oral vowels. Many studies have been conducted on the phonology of nasal vowels to examine them from diverse angles. For instance, some studies have explored nasal vowel inventories in different languages and have provided detailed overviews of the relevant historical and synchronic processes (e.g., Beddor, 1983; Beddor, 1993; Ruhlen, 1973; Schourup, 1972). Other studies have examined how speakers' linguistic background may influence the perception of contrast between oral and nasal vowels (e.g., Beddor & Strange, 1982), and of nasal vowel height (cf. Beddor et al., 1986). Although there are many cross-linguistic studies conducted on nasal vowels, it is still not obvious which types of nasal vowels are least marked (as defined in markedness theory, for instance; de Lacy (2002)).

To find any difference in phonological behaviour between different types of nasal vowels, the UPSID database, created by Maddieson (1984), was used to search for languages that have nasal vowels in their vocalic system. The result of the search for nasalized vowels showed that 102 languages (22.62%) of all languages in UPSID had nasalized vowels, in addition to some references that discuss the grammar and phonology of each language. Next, each available resource of these 102 languages was examined to verify whether nasal vowels were phonemic in the vocalic system of the examined languages. This criterion was essential because the goal of this study is to classify nasal vowels on the sonority scale, thus, nasal vowels should be contrastive with oral vowels (i.e., they are not derived or resulting from a phonological process targeting an oral vowel). The search results of all resources of the 102 languages showed that 31 languages had contrastive nasal vowels. Unfortunately, not all of resources for the 31 languages were accessible or available, thus, the number of languages was reduced to be 21 languages. More than 21 resources about these languages were examined thoroughly, in which 6 languages clearly showed a change in phonological behaviour between different subsets of nasal vowels. Some of these 6 languages exhibited phonological processes that targeted only nasal vowels while others showed phonological processes that targeted certain subsets of oral and nasal vowels. However, for the present study, these six languages were the only ones that could serve the purpose of this thesis and shed light on the sonority of nasal vowels.

Thus, the next section reviews phonological phenomena, such as nasal harmony, nasal vowel reduction, nasal vowels in restricted or limited positions, and the placement of stress on nasal vowels to determine which nasal vowel can be considered more sonorous than the other types of nasal vowels. For instance, certain phonological processes target only high nasal vowels; for example, in the Mòbà dialect of Yoruba, nasal harmony affects only high vowels (Ajiboye, 2017). Additionally, in the standard Yoruba language, a process of vowel reduction in a weak position targets only high oral and nasal vowels (Akinbiyi, 2007). On the other hand, the low nasal vowel can be singled out for a phonological process of optional shift; for instance, in the Colombian language Tucano, only low oral and nasal vowels optionally shift to a high central vowel (Waterhouse, 1967).

3.1.1 Purpose of the Research

Many cross-linguistic studies have examined the distribution and behaviour of oral vowels (see Chapter 2). In addition, they examined which type of oral vowels is the target of different phonological phenomena in contrast to other qualities of oral vowels. Moreover, oral vowels of different qualities have been classified along a hierarchy according to their phonological behaviour, which is ruled by sonority principles. For example, in languages such as Abelam, Gujarati, Kara, Kobon, Yimas, an oral vowel like [a] is conditioned by sonority principles to attract the primary stress—a phenomenon known as sonority-driven stress patterns (cf. de Lacy, 2002).

Building on what is known about the behaviour of oral vowels in the world's languages, the purpose of this thesis is to argue that the behaviour and distribution of nasal vowels in a relevant language may reflect their sonority levels. To achieve this goal, this chapter aims to explore which subset of nasal vowels in the world's languages is affected by phonological processes with respect to other nasal vowels, and how these phenomena may aid in elucidating their sonority rank. To figure out the sonority levels of distinct types of nasal vowels, we can examine their distribution and behaviour in the language's system through studying the phonological constraints that are imposed on one type of nasal vowel but not on another. For example, discovering that one type of nasal vowel occurs in a stressed position, occurs as the peak of a syllable, attracts the stress, or is reduced to another segment in an unstressed position in contrast with other qualities of nasal vowels may show that this nasal vowel has a high sonority rank with respect to other nasal vowels in the studied language.

For the goal of this study, we pose some questions about the potential phonological behaviour of nasal vowels in the studied languages:

I. Will the subset of nasal vowels targeted by phonological processes be the same subset corresponding to oral vowels? That to say, will the low nasal vowel be the target of phonological processes as its oral counterpart?
II. Will the sonority rank of nasal vowels, according to their quality (i.e., height), be similar to the sonority rank of oral vowels?

3.2 Phonological Phenomena Targeting Nasal Vowels

This section presents different phenomena that affect certain kinds of nasal vowels in contrast with other qualities of nasal vowels. Subsection 3.2.1 presents nasal harmony, with examples from a language that shows this phenomenon. Subsection 3.2.2 discusses the phonological phenomenon of nasal vowel reduction. Then an observation of the employment of nasal vowels in restricted or limited positions is presented in subsection 3.2.3. The placement of stress on nasal vowels is discussed in subsection 3.2.4. All tones have been removed in the examples for the sake of legibility.

3.2.1 Nasal Harmony

Nasal harmony refers to phonological patterns in which the nasality feature spreads in a long-distance fashion. This means that nasal harmony can spread the feature of nasality to a series of segments or to a non-adjacent segment, and it usually occurs in the same word or in adjacent words (cf. Walker, 2011). For example, in the Mòbà dialect of Yoruba which is spoken in Southwestern Nigeria, nasal harmony has a particularity with a subset of nasal vowels (Ajiboye, 2017).

Mòbà displays the same vocalic system as the standard Yoruba language. Thus, Mòbà and standard Yoruba have seven oral vowels, /i, e, ɛ, a, u, o, ɔ/, and three nasal vowels, /ĩ, ũ, ã/. However, in Mòbà, the phonological phenomenon of nasal harmony occurs differently than in standard Yoruba. That is, nasal harmony in standard Yoruba targets all types of vowels evenly (Ajiboye, 2017). In Mòbà, nasal vowels of different heights spread the nasality trait regressively, affecting all segments before them, except in the case of the low oral vowel that blocks the spread of nasal harmony. According to Ajiboye's study, this dialect displays two variants of high nasal vowels: phonemic/underlying high nasal vowels and derived high nasal vowels. For instance, the phonemic high nasal vowel [ĩ] at the end of the underlying form of the word /urĩ/ 'iron' spreads the nasality feature to the high back oral vowel [u] and /r/, thus they become nasalized from the spread of nasal harmony in surface form of the word [ũr̃ĩ] 'iron'. Also, the underlying form of the word /idũ/ 'bed bug', where [ũ] is the phonemic nasal vowel that spreads the nasal harmony to the first high vowel [i]. Thus, a derived high nasal vowel is found in the surface form of the word [ĩdũ] 'bed bug'. However, the low nasal vowel is only phonemic, where the nasality of the low nasal vowel [ã] in /agã/ 'a kind of cult' is blocked by the first vowel in the same word and thus pronounced faithfully, while it is spread to the high oral vowel /i/ and /y/ in the word /iyã/ to become [ĩỹã] 'pounded yam' and to /u/ and /y/ in the word /uyã/ to become [ũỹã] 'famine' (cf. Ajiboye, 2017, for more examples).

While the above examples are all monomorphemic, nasal harmony is also found in polymorphemic words, which help in figuring out the derived nasal vowel. Table 1 below presents examples of polymorphemic words with nasal roots to show how the underlying high nasal vowels in the root spread nasality to the added nominalizing prefix [u]. It is worth noting that the nominalizing prefix is oral when the root to which it attaches is oral, and it is nasal when the root to which it attaches is nasal.

Table 2: Nasal roots spreading nasality to prefixes [u]

Nasal root	Gloss	Prefix[u]-Nasal root	Gloss
r̃ĩ	'walk'	ũ-r̃ĩ	'walk'
ỹĩ	'praise'	ũ-ỹĩ	'praise'
nĩ	'have'	ũ-nĩ	'possession'

Thus, the Mòbà dialect of Yoruba displays a difference in behaviour between different subsets of nasal vowels, where high nasal vowels have a less limited distribution in the word than do low nasal vowels, such that two variants of high nasal vowels (derived and underlying) exist in this dialect while just one variant of low nasal vowels (underlying) is present. Thus, high oral undergo a structurally conditioned phonological process of nasal harmony to output high nasal vowels which indicates that high nasal vowels are less marked than the low nasal vowel in this language (cf. de Lacy, 2006, for discussion about valid markedness diagnostics). As a result, this phenomenon suggests that high nasal vowels are more sonorous than the low nasal vowel.

3.2.2 Nasal Vowel Reduction

Vowel reduction is a well-known phonological phenomenon targeting vowels, causing these vowels to undergo qualitative changes when they are in unstressed or weak positions. For example, certain vowels might have changes in stress, sonority, duration, loudness, articulation, or position in the word. Other phonological processes may be considered as a form of reduction, such as vowel shift, and denasalization. Although denasalization might hypothetically be considered as a valid diagnostic (cf. Huffman & Krakow, 1993; Van Hoecke, 1994, for discussion about denaslization in French), in the present study, the 21 examined languages do not exhibit this process. This subsection presents phonological processes which affect nasal vowels in the Yoruba, Tucano, and Ikaan languages respectively, along with examples from these three languages illustrating which nasal vowel is influenced.

3.2.2.1 Standard Yoruba Language

Standard Yoruba is one of several languages spoken in Southwestern Nigeria (Akinbiyi, 2007). As mentioned in subsection 3.2.1, standard Yoruba has seven oral vowels /i, e, ɛ, a, u, o, ɔ/, and three nasal vowels, /ĩ, ũ, ã/. Standard Yoruba syllables have an alternation between high (i.e., oral, and nasal) vowels and syllabic nasals (see table 3). According to Akinbiyi (2007), this alternation between high oral and nasal vowels to syllabic nasals is employed in weak environments (i.e., unstressed syllables) as a way of reducing the sonority threshold The production of syllabic nasals comes from the deletion of (a) a nasal syllable (NV) like the syllable /mi/ in the word /mi ol ɔ/ becomes [ŋ ol ɔ] 'I didn't/wont go'; (b) a high nasal vowel like /ũ/ in the word /oũɟɛ/ which becomes [oɲɟɛ] 'food'; (c) an oral syllable (CV) like the syllable /ri/ in the word /rirɔ/, which becomes [nrɔ], or (d) a high oral vowel like /i/ in the expression /mo fe i ʃadura kã/ which becomes [mo fe n ʃadura kã] ' I want to say a prayer' (Akinbiyi, 2007). The following examples in Table 3 show the resulting form of syllabic nasals reduced from the underlying high nasal vowels.[1]

Table 3: The reduction of high nasal vowels to syllabic nasals

High nasal vowel as underlying form	Syllabic nasal as surface form	Gloss
oũɟɛ	oɲɟɛ	'food'
oũg͡bɛ	oŋ͡mg͡bɛ	'thirst'
mĩ ko ta	ŋ ko ta/ŋ o ta	'I don't sell'

[1] The first two examples are from Akinbiyi, A. (2007). *Category Change as Vowel Reduction: High Vowels in Yoruba.* Rutgers University. In fact, they are the only examples of high nasal vowel reduction. The third example is found in Oyelaran, Ọ. O. (1970). *Yoruba Phonology*. Stanford University. https://books.google.ca/books?id=g6ZEAQAAIAAJ . Oyelaran was the first among Yoruba scholars to suggest that syllabic nasals are only derived from high nasal vowels.

We can conclude that, in the standard Yoruba language, only high oral and nasal vowels undergo a reduction process in unstressed or weak positions. This process is seen as sonority reduction in weak positions to maintain the normal sonority threshold for the whole word Akinbiyi (2007). That is, the nucleus of the syllable has the highest level of sonority, and the degree of sonority drops on the margins; thus, a margin must not have a vowel with a high sonority level, in order to maintain the sonority threshold of the syllable. The behaviour of high nasal vowels in this language suggests a high sonority rank in that a vowel with a high sonority level is not allowed to occur in an unstressed position.

3.2.2.2 The Tucano Language

Tucano, a language spoken in certain regions of Brazil and Colombia, has six oral vowels /i, ɨ, e, a, u, o/ and six nasal vowels /ĩ, ɨ̃, ẽ, ã, ũ, õ/[2] (Waterhouse, 1967). In Tucano, a process of optional shift in pronunciation from one phoneme to another takes place. The articulation of the low oral vowel /a/ and the low nasal vowel /ã/ changes to [ɨ] in certain words when the speaker is using an emphatic speech style; the syllable in which the change happens is disturbed to an exaggerated high pitch (cf. Waterhouse, 1967). The following examples show the changes of the low nasal vowel into central high oral vowel in emphatic speech style, where the nasal variant is considered the correct form in normal speech.

Table 4: Low nasal vowel shifts to central high oral vowels

Word form before shift	Word form after shift	Gloss
waʔãnãʰ	waʔaˈɭɨʰ	‘let’s go’
ʔĩʔãmãʰ	ʔĩʔaᵐˈbɨʰ	‘let me see’
nduhikãʔãʰ	nduhiˈkɨʰ	‘I’m sitting’

The above examples show that, in this language, low oral and nasal vowels undergo a process of optional shift in word final positions during the production of an emphatic speech style. Regarding this language, it can be agreed on that the low nasal vowel may change to central oral vowel because, phonologically and typologically, the class of oral vowels is considered to have a

[2] Waterhouse (1967) used the symbol /˛/ under each nasal vowel to represent nasality. In the present study, the symbol /˜/ is used to present nasal vowels.

higher sonority rank than the class of nasal vowels because the former is less marked than the latter (de Lacy, 2002, 2006). On the other hand, the process of optional shift of the low oral vowel to central oral vowel seems to be odd because, cross-linguistically, it is known that the low oral vowel is more sonorous within the class of oral vowels (Crosswhite, 2000; De Lacy, 2004; Gouskova, 2003; Urbanczyk, 1997). It thus seems strange to replace a high sonorous vowel like the low oral vowel with a less sonorous vowel like the central oral vowel in emphatic speech style. More research is needed regarding this particular phenomenon, which can be explored in future work.

3.2.2.3 The Ikaan Language

Ikaan, a language spoken in south-western Nigeria, has nine oral vowels, /i, ɪ, e, ɛ, a, u, ʊ, o, ɔ/, which contrast in length and nasality. However, only short oral vowels have contrastive nasal vowels (Salffner, 2013). In Ikaan, consonant or vowel sequences are not allowed, therefore, the employment of vowel deletion, vowel assimilation or consonant deletion processes is mandatory. Vowel deletion occurs in verb + object constructions, where the final vowel of the first word is omitted, while the first vowel of the following word remains. An example of this deletion can be seen in the phrase [ɔf-ɛwi] "'s/he hit the goat', where the final vowel of /ɔf**a**/ '3sg.hit' is deleted when an object like /ɛwi/ 'goat' follows it. Vowel assimilation occurs in noun plus modifier constructions. For example, when the noun /ɔt**a**/ "lamp" precedes a possessive like, /ɔrɔ/ '2sg.poss', it becomes [ɔt**ɔ**-ɔrɔ] 'your (sg.) lamp' (cf. Salffner, 2013).

As discussed above, final oral vowels are either removed or assimilated when they meet another vowel across a word boundary. Final nasal vowels, however, do not undergo vowel deletion or assimilation, but remain nasal vowels. Some examples in Table 5 present nasal vowel behaviour in noun + modifier constructions for non-reduplicated and reduplicated forms, where the underlying form of the vowel in the modifier changes according to the nouns attached to it (e.g., àːdʒ, ɛ̀ːdʒ, ɔ̂ːdʒ, etc.) (cf. Salffner, 2013).

Table 5: Nasal vowels at the end of a word

Word in Isolation	Noun + Modifier Construction	Gloss
aʃɛ̃ː	aʃɛ̃ː-aːdʒ	'(my) eggs'
efĩː	efĩː-ɛːdʒ	'(my) he-goat'
ɔtɔ̃	ɔtɔ̃-ekere	'the bottom (of the pot)'
afũː	afũː-aːdʒ	'(my) forehead'
jɔ̃jɔ̃	ajɔ̃-jɔ̃ aːdʒ	'(my) (species of) maggot'
ɪjɔ̃jɔ̃	ɪjɔ̃jɔ̃-ɪːdʒ	'(my) sun'
ɛwĩwĩ	ɛwĩ-wĩ ɛdʒ	'(my) mosquito'
ejĩjĩ	ejĩjĩ-ɛːdʒ	'(my) scorpion'
ɪhjɛ̃hjɛ̃ː	ɪhjɛ̃hjɛ̃ː-iːdʒ	'(my) red ant'

The above table shows the difference in behaviour between the class of oral and nasal vowels. This resistance of nasal vowels to undergo deletion or assimilation is due to a constraint in markedness theory that is called "Preservation of the Marked." This rule requires that the more marked elements are protected from undergoing phonological processes while the less marked segments are forced to undergo them (cf. de Lacy, 2006).

While several final nasal vowels block deletion or assimilation, some final nasal vowels do undergo deletion; however, the new form of the vowel of the modifier keeps the nasality from the deleted nasal vowel. According to Salffner (2013), this occurs when /ĩ/or/ĩ/ are found at the end of the first word. Table 6 illustrates this case.[3]

Table 6: Nasality retention during vowel assimilation

Word in Isolation	Noun + Modifier Construction	Gloss
ɛːgãjĩ	ɛːgãj-ɛ̃ːdʒ	'(my) wasp'
ɛkpĩrĩ	ɛkpĩr-ɛ̃ːdʒ	'(my) ankle bone'

Still, in certain reduplicated forms where the nasal vowel is deleted in noun + modifier constructions, the vowel of the modifier does not keep the nasality. Table 7 illustrates this case.

[3] Examples of this phenomenon taken from Salffner, S. (2013). Final nasal consonants and nasalised vowels in Ikaan. SOAS Working Papers in Linguistics. *16*.

Table 7: Nasality deletion during vowel assimilation

Word in Isolation	Noun + Modifier Construction [/V/dʒ]	Gloss
orũrũ	orũr-ɔːdʒ	'(my) thread'
ɛhwãhwãː	ɛhwãhw-ɛːdʒ	'(my) push fowl'

In Table 6, high front nasal vowels are elided, and their nasality trait is transmitted to the vowel of the modifier. However, the case is different in Table 7, in which the other types of nasal vowels are elided without transmitting their nasality feature to the adjacent vowel. It is worth mentioning that Salffner (2013) pointed out that in these above examples of final nasal vowels there are no following surface nasal consonants, so no alternation similar to French like *bon garçon* [bɔ̃] "good boy" versus *bon ami* [bɔn] "good friend." Moreover, Salffner (2013) suggests that high nasal vowels such as those in Table 6 might be unspecified in the underlying form. That is, they can be deleted without denying the phonological process like the one seen in the nasal vowels in Table 5, in contrast with the examples in Table 5 that are fully specified as nasal vowels in the underlying form.

We can see that, within the class of nasal vowels, there is a difference in behaviour, where the high nasal vowel /ĩ/ spreads the nasality feature to the vowel of the modifier, while the other nasal vowels like /ũ/ and /ã/ are totally removed, along with their nasality feature. It is a bit strange that the high back nasal vowel /ũ/ does not behave like the high nasal vowel /ĩ/, where the former is totally removed. From the above examples, we can conclude that the behaviour of the front high nasal vowel /ĩ/ may indicate that it has a higher sonority level than the other nasal vowels.

3.2.3 Nasal Vowels in Restricted or Limited Positions

In phonology, there exist constraints which prohibit certain segments from occurring freely in all positions of the word (i.e., word initial, medial, or final). This type of constraint targets a specific type of vowel. For example, in the Bariba language, only one type of nasal vowel is found in a limited position.

The Bariba language is spoken in the Cercles of Parakou, Kandi, and Natitingou in Dahomey, and in adjacent sections of Nigeria (Welmers, 1952). This language has seven oral vowels /i, e, ɛ, a, u, o, ɔ/, and five nasal vowels /ĩ, ɛ̃, ã, ũ, ɔ̃/. [4,5] In Bariba, diverse types of oral vowels can be the peak of a syllable. For example, [tim] 'honey', [yɛɛ y] 'those animals', [gɔɔ] 'death', and [ga gu] 'it is dead'. The same thing applies for different qualities of nasal vowels; for example, [trĩĩa] 'becomes black', [tɛ̃] 'immediately', [sɔ̃] 'tell', and [gããru] "stalk" (Welmers, 1952).

However, in this language, the high back nasal vowel [ũ] behaves differently from other nasal vowels. That is, while the other four nasal vowels can be the nucleus of a syllable (as single vowels or sequence of vowels), [ũ] is not attested as the nucleus of a syllable, and instead is only found in sequence of vowels (i.e., it is found with another nasal vowel that differs in quality) as the nucleus of a syllable. The following table presents some examples of this case (cf. Welmers, 1952).

Table 8: High back nasal vowels in a cluster context

High Nasal Vowel /ũ/ in Clusters	Gloss
sũã	'fish'
sɛ̃ũ	'arrow'
bũɛ̃yã	'mosquito'

In this language, only [ũ] cannot be the nucleus by itself. Instead, it is found with another quality of nasal vowels to form the nucleus of a syllable. This particularity about the limited position for [ũ] may show that sonority rank of this nasal vowel is not sufficiently high to enable it to be a nucleus, and that it needs the presence of another nasal vowel to be a nucleus. In addition, Table 8 shows that [ũ] forms a vowel cluster with [ã] or [ɛ̃] which might suggest that the sonority of those vowels is near (e.g., [ɛ̃]) or below (e.g., [ã]) that of the nasal vowel [ũ], which is sufficient to form a vowel cluster that can be the nucleus of the syllable.

We notice that, also in this language, the high back nasal vowel [ũ] does not behave like the high front nasal vowel [ĩ], where the former needs to be with another nasal vowel to be the nucleus of a syllable, but, however, we can notice that it forms a nucleus with mid-low and low nasal

[4] Note that the five nasal vowels are found as phonemic nasal vowels and as nasalized vowels; however, this chapter examines the typology of phonemic nasal vowels.
[5] Welmers, W. E. (1952). Notes on the Structure of Bariba. *Language*, *28*(1), 82-103. https://doi.org/doi:10.2307/409991 uses the superscript /ⁿ/ to stand for nasal vowels.

vowels (e.g., [ã] or [ɛ̃]). This may indicate that mid-low and low nasal vowels have a lower sonority rank than the high nasal vowels which allow them to form a nucleus with the high back nasal vowel.

3.2.4 Placement of Stress on Nasal Vowels

This subsection presents cases of placement of stress on a particular type of nasal vowels in the Cofán language, which is one of the Ecuadorian Indian languages. This language is spoken by about four hundred people who live in different location near the border area between the Ecuador and Colombia (Elson & Peeke, 1962).

This language has five oral vowels /i, ɨ, e, a, o/ and five nasal vowels /ĩ, ɨ̃, ẽ, ã, õ / in which, perceptually, the articulation of the stressed nasal vowel seems to be stronger than that of the other nasal vowels in the same word, while the unstressed nasal vowel is not more articulatorily salient than the other nasal vowels[6] (cf. Elson & Peeke, 1962). For example, the stressed low nasal vowel [ã] in [bõñˈãñẽ] 'to stack', [mõnˈãmĩ] 'bluebird' and the first one in [cˈãmã] 'that' is louder than the other nasal vowels in the same word, whereas in words like [ʔˈõho] 'bathed' and [ʔˈõkĩẽ] 'daughter' the mid high nasal vowel [õ] (in the first syllable) is louder than the other nasal vowels. Another example of a louder nasal vowel is the mid-high nasal vowel [ẽ] in the second syllable of the word [ʔãsˈẽnẽ] 'to start (Elson & Peeke, 1962).

In this language, the nucleus of the syllable may entail one vowel (V) or two different vowel qualities (V1V2) that form a cluster. Vowel clusters, in this language, are entirely oral or entirely nasal and any vowel cluster may occur with or without stress. When the nucleus is a vowel cluster, the stress is placed by default on the second vowel of the nucleus except if the first vowel is /a/, /e/, or /ã/, where these three vowels can attract the stress. The following examples present this case, where /ã/ prevents the placement of the stress on the second vowel within the vowel cluster (Elson & Peeke, 1962).

[6] The phonological-word stress represented by /ˈ/ in this language.

Table 9: Stress displacement on nasal vowels clusters

Stress on the second vowel	Gloss	Stress on the first vowel /ã/	Gloss
c̃õˈĩ	‘sparrow’	ʔˈãĩ	‘dog’
gĩˈõʔgĩõ	‘bird’	ʔˈãõnã	‘skimmer’
t̃ɨ̃ˈĩfa	‘chambira palm’	gˈãĩñĩ	‘scattered dust’
ñõã́ʔmẽ	‘really’	nˈãĩnĩ	‘to the river’
mõˈẽhã	‘hand it’	potˈãĩʔgo	‘shot-gun’

In this language, each nasal vowel, when it occurs solely as the nucleus of the syllable, can bear the stress and be louder than the other nasal vowels in the same word, but the low nasal vowel can change the default place of the stress and attracts it in a particular situation—that is, when it forms a vowel cluster with another quality of nasal vowels. We have seen in the other languages that the low nasal vowel does not show any behaviour indicating that it has a higher sonority level than the other qualities, however, in this language in particular, the case is different, where it attracts the stress when it appears as the first vowel in the vowel cluster. Nevertheless, we can not yet confirm that it has a higher sonority rank based on only one language.

3.3 Research Questions

The above section reviewed some phonological processes that target a particular subset of nasal vowels. In some cases, the group of high nasal vowels is targeted by phonological processes, while in others, the low nasal vowel is the target. Nevertheless, we have noticed that the targeted qualities of nasal vowels do not correspond to the same qualities of oral vowels, and thus their sonority rank are different from oral vowels. Based on the above observations, we have set up some research question about the probable intensity measurements of nasal vowels, which will be presented and discussed in the next chapters.

III. Will the intensity readings of nasal vowels reflect the phonological behaviour of nasal vowels? That is to say, will the group of high nasal vowels be the highest in intensity within nasal vowels, as it is the more targeted nasal vowels typologically?

IV. Will intensity levels for some subsets of nasal vowels be close to the intensity levels for oral vowels, for example, the case of high nasal and oral vowels which are the target of the same phonological process in standard Yoruba (Akinbiyi, 2007)?

3.4 Summary

The preceding section dealt with different phonological processes that influence one type of nasal vowel but not the other. For example, in the Mòbà dialect of Yoruba, the number of high nasal vowels is greater than the number of low nasal vowels because of nasal harmony (Ajiboye, 2017). In addition, standard Yoruba's high nasal vowels undergo a vowel reduction process in weak syllables, which seems to be a sonority reduction in a weak syllable (Akinbiyi, 2007). As for other languages like Tucano, the low nasal vowel undergoes an optional shift during the emphatic speech style (Waterhouse, 1967). In contrast, in the Ikaan language, nasal vowels are preserved from undergoing elision or assimilation, but, in some forms, high nasal vowels are elided and their nasality feature is preserved while other nasal vowels in reduplicated forms are elided without the retention of their nasality feature (Salffner, 2013).

For other languages, such as the Bariba language, the high back nasal vowel is not allowed to be the nucleus of the syllable, except for when it is with another nasal vowel, while the other nasal vowels can independently form the nucleus of the syllable (Welmers, 1952). This restriction on the high back nasal vowel may suggest that, in this language, this type of nasal vowels has a low rank in sonority and so it cannot be a peak of a syllable all by itself.

Regarding the influence of sonority hierarchy on stress position, the Cofán language illustrates a particular case concerning the low nasal vowel. In this language, it seems to be that the low nasal vowel attracts the stress from the other nasal vowel, but only when it occurs in a vowel cluster (Elson & Peeke, 1962).

4 Chapter 4 – Methodology

4.1 Introduction

The empirical goal of this thesis is to quantify, with reference to Québécois French, the sonority of nasal vowels in contrast with oral vowels through measuring the segmental intensity, known as the most relevant physical correlate of sonority. In this experiment, we hypothesized that the factor of vowel height, which plays a role in determining the amount of vowel nasality, will also affect the intensity values that reflect their sonority rank. To collect phonetic data which can reflect the phonological processes targeting nasal vowels according to their sonority rank, we developed and conducted a nasometric experiment in Montreal, Quebec, Canada in March 2022. Seven French participants from Quebec provided the data for this study. The data presented and analyzed here include two reading tasks: First, a French passage made of words with a mixture of oral and nasal phonemes to measure nasalance scores for the subjects. Second, two lists of constructed phrases that had meta-linguistic words of nasal syllables (NṼN) and oral syllables (CVC). We used a clinical nasometer to measure maximum intensity, and percentage of nasalance for targeted phonemes in the reading task.

The structure of the stimuli is discussed in section 4.2. Section 4.3 describes the participants and their characteristics. Experimental procedures, including instrumentation and the actions performed in the reading tasks, are given in section 4.4. Data annotation and measurements are described in section 4.5. Section 4.6 presents the parameters for the statistical analysis presented in the next chapter. Finally, section 4.7 is a summary of the chapter.

4.2 Stimuli

The stimuli in the present experiment include two reading tasks. The first task was a brief passage in the French language which is usually used by researchers who specialized in nasality. The second reading task consisted of constructed phrases with specific phonetic environments that surround the targeted qualities of nasal and oral vowels. The following subsections discuss the two reading tasks in detail.

4.2.1 The Rainbow Passage

The following reading task was performed to measure participants' nasalance scores, which result from the ratio of the oral plus nasal acoustic energy. The ratio is multiplied by one hundred and expressed as a percentage of nasalance score. The nasalance score can be described as:

$$N = N \div (N + O) \times 100$$

The first (N) in the above formula refers to nasalance; the second and the third (N) refer to the nasal energy; and (O) refers to the oral energy. After each participant's nasalance score was calculated, the resulting value was compared to normative data. If the levels of a participant's nasalance was higher than the normative levels, this suggested that they had hypernasality, and if their levels of nasalance were lower than the normative data, then it suggested that they had hyponasality. Nasalance scores are usually acquired by asking the participant to read a normalized passage or set of sentences. Some well-known standardized passages that are used to obtain most English language normative nasalance are: the Zoo passage, which has no nasal phonemes (Fletcher, 1972); the Rainbow Passage, which has both oral and nasal phonemes (Fairbanks, 1960); and Nasal Sentences, which consist mainly of nasal consonants (Fletcher, 1978). For the needs of the present study, a French version of the Rainbow Passage was used. This French version is a brief paragraph of a known story in French, the story known as "Monsieur Seguin" (cf. Garnier, 2012). The complete passage is found in Appendix A.

4.2.2 French Reading Lists

The reading list was created to be the surrounding phonetic environment for nasal and oral vowels. Ten carrier phrases were formed with specific phonetic criteria in mind, with each phrase containing one meta-linguistic stimulus, along the lines of (Carignan, 2021; Delvaux, 2006). Each meta-linguistic stimulus consists of one closed syllable containing one type of nasal or oral vowel (e.g., [did], [ded], [dad], [nĩn], [nẽn], [nãn]). The consonants of the meta-linguistic syllable, which is oral obstruent for oral vowels (i.e., /d/) was chosen to avoid any nasality effect on intensity readings of oral vowels, while nasal obstruent (i.e., /n/), was chosen to be the surrounding environment of nasal vowels to further encourage nasality during the production of nasal vowels. This makes a total of ten nasal vowels and ten oral vowels of all major qualities in the world's languages (see Table 10).

Table 10: Stimuli of nasal and oral vowels

Stimuli of nasal vowels	Stimuli of oral vowels
[nĩn]	[did]
[nɨ̃n]	[dɨd]
[nẽn]	[ded]
[nɛ̃n]	[dɛd]
[nãn]	[dad]
[nõn]	[dod]
[nœ̃n]	[dœd]
[nũn]	[dud]
[nʊ̃n]	[dʊd]
[nɔ̃n]	[dɔd]

Target words were read in a carrier sentence like *Jacques et Chad demandent* "___" *trop.* Meta-linguistic stimuli were written within the empty space "___", in which they are framed as quoted words which are normally pronounced with additional stress. Even though the word is not in a normal stressed position in a French sentence (i.e., final syllable of the phrase), the fact that it is framed as some sort of direct quotation should mean that it is not pronounced as unstressed syllable (cf. Demers, 1998, for discussion about the prosody of reported speech in Quebec French). Other similar types of sentences, such as *Jacques et Chad répondent [nãn/dad] tranquillement* were employed to avoid repetitions of the same sentence. The proper name *Jacques* was selected because it has the low vowel /a/ which was used to relativize the intensity values of the target vowels. Specific verbs that end with an obstruent were chosen to precede the target vowel to avoid having an adjacent vowel that may affect on the intensity reading of the target vowel. The same was considered for the adverb following the target word, where it was chosen to start with an obstruent to avoid the acoustic effect of an adjacent vowel. Table 11 presents a sample of French sentences. The complete list is found in Appendix B.

Table 11: An example of French reading task

Voyelles orales	**Voyelles nasales**
1. Jacques et Chad demandent [did] trop	2. Jacques et Chad demandent [nĩn] trop
3. Jacques et Chad répondent [dɨd] tout de suite	4. Jacques et Chad répondent [nɨ̃n] tout de suite
5. Jacques et Chad plaident [ded] toujours	6. Jacques et Chad plaident [nẽn]toujours

The low oral vowel serves as a reference point for intensity calculations to control for random variations in loudness across participants and tokens. In addition, this reference point appears sentence-initially with primary lexical stress (cf. Paradis & Deshaies, 1990, for rules on stress assignment in Quebec French), to form a stable, maximum-intensity point against which all target phones are compared. Therefore, the maximum intensity of the /a/ in *Jacques* in each utterance was subtracted from the maximum intensity of the peak of the test segment measured in the same utterance to yield a relative intensity (i.e., measured as sound level differences in decibels between a target segment and a constant reference segment in the environment (Parker, 2008)), where this relative intensity value is suitable for statistical analysis (cf. Parker, 2008) (See figure 1).

Filename	Sentence	TextGrid Label	Duration	Maximum intensity
Fr01	Jacques et Chad demandent [nĩn] trop	a	0.059609842	76.46797509
Fr01	Jacques et Chad demandent [nĩn] trop	[nĩn]	0.21564737	69.84068529
		Relative intensity		-6.627289803
Fr01	Jacques et Chad demandent [nĩn] trop	a	0.045583997	76.62854678
Fr01	Jacques et Chad demandent [nĩn] trop	[nĩn]	0.117466453	71.69678089
		Relative intensity		-4.931765883

Figure 1: Relative intensity calculation for two repetitions of the same target vowel

Figure 1 shows the maximum intensity of the target nasal vowel /ĩ/ for two repetitions, where the resulting value of relative intensity differs from one repetition to another for the same participant because intensity readings of target and reference vowels differ in each repetition. Thus, after calculating the relative intensity for each repetition, we have calculated the average of the five repetitions for each participant to normalize the slight difference in values of relative intensity. Figure 1 shows that values of relative intensity are negative, which indicates that the intensity of the reference vowel is higher than the intensity of the target vowel. On the other hand, when the value of relative intensity is positive, it indicates that the intensity of the target vowel is higher than the intensity of the reference vowel (e.g., the low oral vowel /a/ as a target vowel).

4.3 Participants

Seven participants (six females and one male) were recruited to conduct the present experiment. They all were students at the *Université de Montréal* from different departments; however, they all have a knowledge of phonetics because there are some oral and nasal vowels that do not exist in French (e.g., /ĩ, ɨ̃, ɨ, ʊ̃/). Three out of seven participants had already finished one or two phonetics courses while the other four were enrolled in one or two phonetics courses during the time of the experiment. The age of the participants ranged from 20 to 48 years old. Table 12 shows a general sociolinguistic information about the participants.

Table 12: The sociolinguistic background of the participants[7]

Participant	Age	Place of birth	Gender	Mother language	Other known languages	Parents' language	Level in linguistics
Fr01	22	Montréal	Female	French (QC)	English Spanish sign language	French (QC)	2 courses in phonetics & phonology
Fr02	30	Montréal	Female	French (QC)	English Ancient Greek	French (QC) English	1 course in phonetics & phonology
Fr0	38	Sainte-Agathe-des-Monts	Female	French (QC)	English Spanish Italian Arabic	French (QC)	1 course in phonetics & phonology
Fr04	22	Brossard	Female	French (QC)	English Spanish	French (QC)	1 course in phonetics & phonology
Fr05	29	Montréal	Female	French (QC)	English Italian	French (QC)	M.A in linguistics
Fr06	20	Montréal	Female	French (QC)	English	French (QC)	1 course in phonetics & phonology
Fr0	48	Montréal	Male	French (QC)	English Spanish	French (QC)	Minor in linguistics

As it is shown in Table 12, all the participants speak Québécois French, and all of them were born either in or close to Montreal. In addition, they all speak at least one foreign language, and they already have a sufficient knowledge of the different sounds found in the International Phonetic Alphabet (IPA) chart.

It important to mention that the vocalic system of Québécois French incorporates twelve oral vowels /i, e, ɛ, a, ɑ, o, u, ɔ, œ, y, ø, ə/, and four nasal vowels /ɛ̃, ɑ̃, ɔ̃, œ̃/ (cf. Delvaux, 2006; Martin et al., 2001). These 16 vowels phonemes correspond to 41 phonetic variants (e.g., [i, ɪ], [ã, ɑ̃], [ɛ, ɛ:]) (Martin et al., 2001). Oral vowels are usually distributed in various positions in the syllable;

[7] Each participant's name was replaced by a code.

for example, they are found in closed-final syllable (e.g., *pattes* ‘paws’), open-final syllable (e.g., *deux* ‘two’), non-final closed syllable (e.g., *mystique* ‘mystical’), and non-final open syllable (e.g., *côté* ‘side’). Also, nasal vowels are found in final closed syllable (e.g., *cinq* ‘five’), final open syllable (e.g., *pain* ‘bread’), non-final closed syllable (e.g., *un stade* ‘a stadium’), and non-final open syllable (e.g., *lundi* ‘Monday’) (Léon, 1983; Martin et al., 2001). In the present study, the stimuli have some vowels that do not exist in the vocalic system of Québécois French, adding to that, in Québécois French, nasal vowels are not typically found in a context where they are followed by a nasal consonant. Thus, we have recruited participants with knowledge in phonetics to be able to pronounce any vowel within a meta-linguistic task that are not found in their language system.

4.4 Experimental Procedures

Data were collected in Montréal, Canada at the *Université de Montréal* in March and April 2022 in a room reserved for this purpose at the *Département de linguistique et de traduction.*

4.4.1 Equipment

Both reading tasks were recorded with a clinic nasometer (NAS-1 SEP Clinic) connected to a Lenovo laptop (model LAPTOP-6NNR8J3O). The nasometer consists of a split channel set of microphones separated by a removable plate, and it was held up to the participant’s face by a padded handle at the point between the nose and the mouth. Three varied sizes of plates were available (small, medium, and large), according to the participant’s anatomy. Several tests were run before conducting the real experiment to verify that the apparatus was running accurately.

Recordings were done in stereo using Praat and were sampled at 44.1 kHz. A photographic illustration of the device is provided in Figure 2.

Figure 2: The Clinical Nasometer

4.4.2 Procedure

The first reading task was presented on a paper sheet, while the second reading task was randomly arranged and distributed across five pages for the repetition process (see Appendix B). We conducted these sessions, and we were present throughout the entire session for each participant. Participants completed all tasks within a single session. All sessions were held in the quiet environment of a reserved research room at the *Département de linguistique et de traduction* at the *Université de Montréal.*

Due to the COVID-19 pandemic, strict preventive measures had to be followed for sanitary reasons. Therefore, the participants were received individually, and the following procedures were followed. First, before the participants came to the *Université de Montréal* for the experiment, they were asked to complete a form of health declaration the day before their appointment and to send it back via email (see Appendix C). Participants had to practice hand hygiene upon arrival and departure and wore their own masks upon arrival at the research site and during the interview, except for during the recording, at which point they were asked to remove their masks. Due to the need to remove the masks during recording, the researcher had to keep a minimum distance of 2 metres. When the researcher had to approach the participants, the participants were asked to put their masks back on.

At the time of experimentation, participants were informed about the general nature of the study (which referred only to reading a brief passage and then to reading lists of phrases in French), then consent was obtained, and participants were asked if they were suffering from a cold or allergies. Participants next filled out a brief questionnaire which addressed standard sociolinguistic information (see Appendix C). Before reading each task, participants were encouraged to read each task aloud to familiarize themselves with the diverse types of nasal and oral vowels.

The training consisted of a demonstration of the equipment and of practicing the articulation of vowels. Correct holding of the nasometer was demonstrated for the participants and entailed carrying the device from the handle to the face with one of the plates inserted and with the elbow placed on the table. Participants were told that contact between the plate and the face is essential. They were then shown that the angle at which they held the nasometer was indicated by an X mark on the table. Participants were told they could move around a bit; however, they were instructed not to move their elbow far from the X mark point. When the plate of suitable size was correctly identified for each participant, it was cleaned and inserted into the nasometer prior to use.

Before the actual recording of the reading task, participants were asked to review the stimuli again to avoid orthographic difficulties or any uncertainty about the stimuli pronunciation due to the existence of distinct types of nasal and oral vowels that are not found in French. The IPA chart 2021 of pronunciation was used to show the exact pronunciation of the vowels, especially, the ones that do not exist in French (see Appendix D).

Before recording, participants were instructed to read the combinations at a normal speed, as they would in everyday conversation. This was done to avoid any exaggeration during the pronunciation of the stimuli which might affect on the intensity readings. They were then asked to use this same rate with the rest of the phrases. If participants paused or exaggerated in articulation, they were told to pronounce the stimuli again more naturally. The task was displayed on a sheet of paper where all phrases were numbered to make it easier for the participant and the researcher to reach a specific phrase for the purpose of repronouncing or for any other clarifications. This procedure was repeated five times, with the sound file being saved at the end of the task. Participants were informed that the list consisted of the same sentences, but in a different order, and they were told that they could take breaks during recordings whenever necessary. At the end of the session, participants were thanked and compensated for their participation.

4.5 Annotations and Measurements

This section presents the annotations and measurements of the two reading tasks. Subsection 4.5.1 discusses the annotation and measurements of nasalance for the Rainbow Passage as well as the target vowels. Then subsection 4.5.2 discusses the annotations and measurements of the intensity values for the second reading task.

4.5.1 Nasalance Measurements

The whole Rainbow Passage was recorded without any pauses and then it was selected as one interval on the first tier. A Praat script which calculates nasalance was run to extract total nasalance score for the whole passage for each participant. Figure 3 presents an example of the annotated spectrogram for the Rainbow Passage.

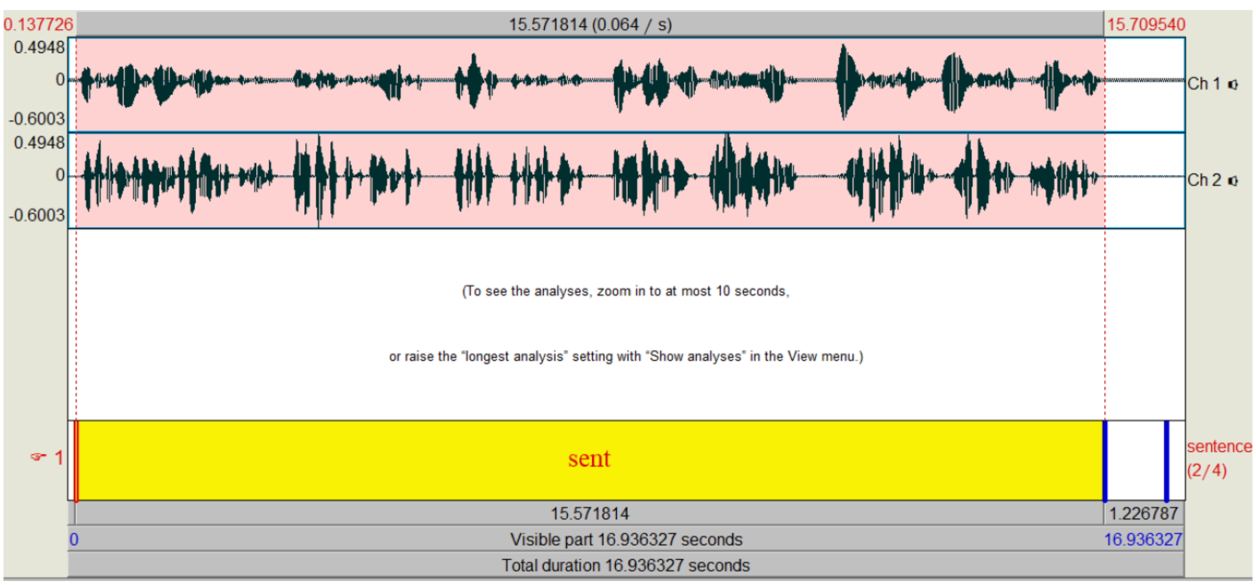

Figure 3: The spectrogram of the Rainbow Passage for one participant

The same nasalance formula was used to calculate the nasalance score for target vowels and reference phonemes in the second task. This measurements for the target vowels helped in figuring out if high nasalance values in the Rainbow Passage had an effect on the intensity values of the target segments or not. This issue is discussed more thoroughly in Chapter 5.

4.5.2 Intensity Measurements

The total number of tokens for this experiment is 1400 including nasal vowels, oral vowels, and the reference vowel. The selected reference is the low oral vowel /a/ in *Jacques*. All these segments were measured for maximum intensity using the methods described in the following section. Only the segments of concern (i.e., the nasal vowels, the oral vowels, and the reference vowel /a/) were annotated on the first tier and the whole sentence was annotated on the second tier in Praat. Nasal and oral vowels were annotated within their meta-linguistic stimuli, but only the portion of each target segment that included the intensity peak was selected, to make sure not to include the intensity protrusion of an adjacent segment (Parker, 2008). Figure 4 presents Praat spectrograms of the three labeled phonemes in each phrase.

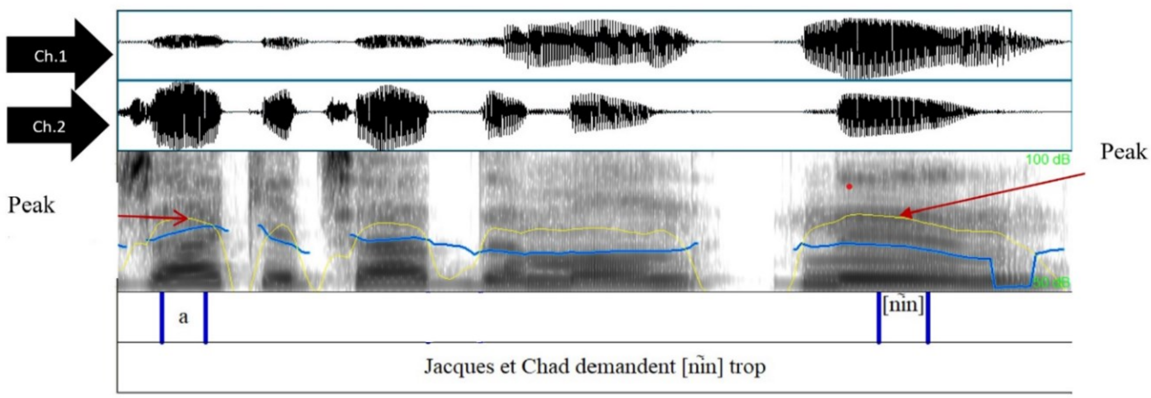

Figure 4: Phoneme choice and labeling on a Praat spectrogram

As it is shown in Figure 4, the choice on the spectrogram was only for the peak of the concerned phonemes to avoid the influence of the adjacent segments. The spectrogram also illustrates the intensity contour (above in yellow) and the pitch contour (below in blue) for the whole sentence. In Figure 4, the first wave channel (Ch.1) stands for the nasal sound recorded by the microphone set near the nose, while the second wave (Ch.2) is the oral sound recorded by the microphone placed near the mouth. Then the resultant intensity data for each target vowel were normalized by subtracting the maximum intensity value of the reference vowel /a/ from the maximum intensity value of the target vowel.

4.6 Statistical Analysis

The relative intensity values extracted from the data of seven participants were analyzed with repetitive measures two-way ANOVA (RMANOVA) with type (nasal and oral) and height (high, mid-high, mid-low, or low) as intra-participant factors. The resulting statistical scores such as average, standard deviation, and confidence intervals were calculated for each vowel type and height for the seven participants. The software (SPSS v26) was used for the statistical analysis with a significance level of (p=.005) for interaction between type and height.

4.7 Summary

The present experiment was conducted to quantify intensity of nasal vowels in contrast with their oral counterparts. This was done through recording seven French (Québécois) participants during their reading of two French tasks: the Rainbow Passage and the reading list of French sentences. The two tasks were recorded and analyzed using Praat. For the first task, the nasalance values were calculated by selecting the whole passage on the first tier in Praat, and the same nasalance formula was used in the script of the second task to calculate the nasalance scores for each target vowel. The extracted intensity of each target vowel was subtracted from the intensity value of the reference low vowel. Then the resulting relative intensity was used in the statistical analysis to identify the sonority rank of each vowel.

5 Chapter 5 – Results

5.1 Introduction

This chapter presents the overall results of this nasometric experiment for each target vowel along with the statistical analysis. The rest of the chapter is organized as follows: Section 5.2 presents the nasalance results for the Rainbow Passage task. The intensity results of the main reading task are in section 5.3. Section 5.4 presents the statistical analysis done for the intensity results. A summary of the chapter is found in section 5.5.

5.2 The Rainbow Passage Task

This section presents the nasalance results for each participant. It is important to mention that there is a variance in nasalance values between the seven participants. This difference in values may be due to the difference in age and gender between participants. Although Leeper et al. (1992) and Rochet et al. (1998) conducted a study in Canada to measure the normative nasalance for English and French Canadians, their French participants were from provinces other than Quebec, so it appears that there are no constructed normative nasalance values for French Quebecers that might serve as a reference for our nasalance results. Table 12 presents the nasalance scores that were calculated for the oral and nasal phonemes of the whole Rainbow Passage. In addition, we have included the calculations of nasalance within the measurements of the second reading task. That is, within the script written for the second task to calculate maximum intensity for target and reference segments, we have measured the nasalance of the oral and nasal vowels in the list of phrases to make sure there were no significant differences of nasalance values between participants, even though their nasalance values when reading the Rainbow Passage varied. Table 13 shows the age and gender of each participant and his/her nasalance score for the Rainbow Passage reading task.

Table 13: Nasalance scores for each participant

Participant	Age	Gender	Nasalance (%)
Fr01	22	Female	40.4
Fr02	30	Female	32.4
Fr03	38	Female	32.9
Fr04	22	Female	52.7
Fr05	29	Female	59.8
Fr06	20	Female	24.9
Fr07	48	Male	19.5

As mentioned before (see Subsection 4.4.2), while filling out the sociolinguistic survey, participants were asked if they had any allergies, influenza, or a congested nose during the prior two weeks. All participants answered negatively to the relevant question.

Table 13 shows that participant (Fr05) has a high nasalance score, while the only male participant (Fr07) has a low score. On the other hand, participants (Fr02 and Fr03) had scores that were near the nasalance scores suggested in the study of Rochet et al. (1998) for French Canadians. Rochet et al. (1998) showed that normative nasalance scores for 20- to 44-year-old French-Canadian women is (30.1%), while nasalance scores for 45- to 85-year-old French-Canadian men is (26%).

To clarify that high nasalance values of some participants did not have an effect on the intensity values for the type of vowel (nasal or oral) and its height (high, mid-high, mid-low, low), we have calculated mean nasalance, along with the mean of relative intensity of the target vowels for the second reading task for each participant (see Appendix E). For example, Figures 5 and 6 present mean relative intensity and mean nasalance values of target vowels from the second reading task, which show a comparison between mean nasalance and mean of relative intensity scores for Fr05, who had the highest nasalance score for the Rainbow Passage, for both nasal and oral vowels.

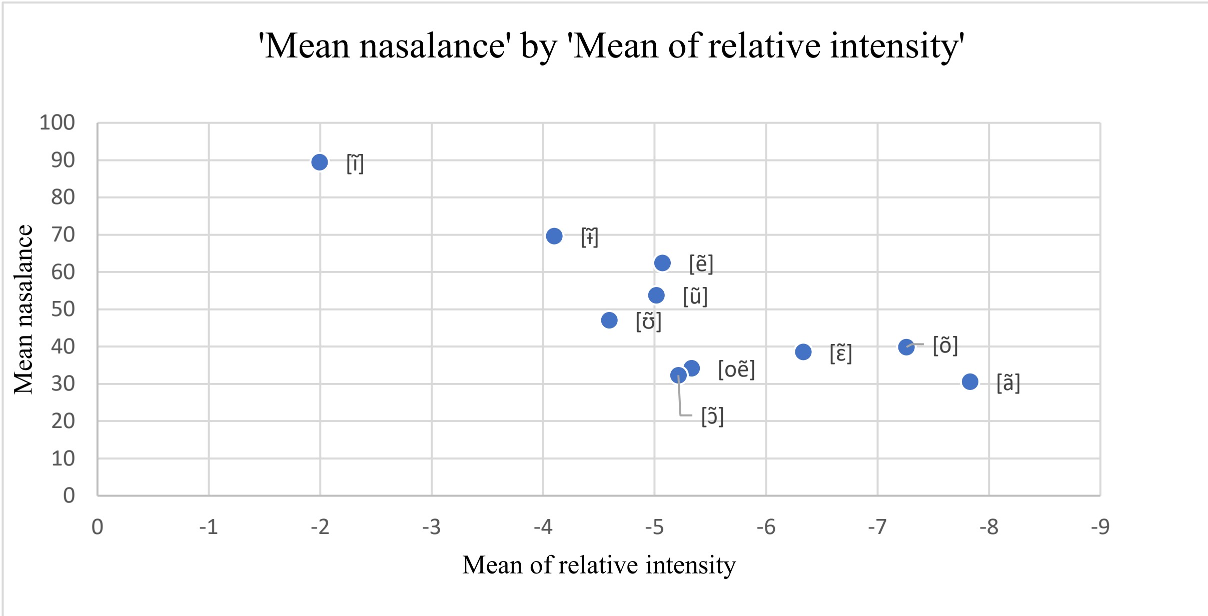

Figure 5: Mean of relative intensity by mean nasalance of nasal vowels for Fr05

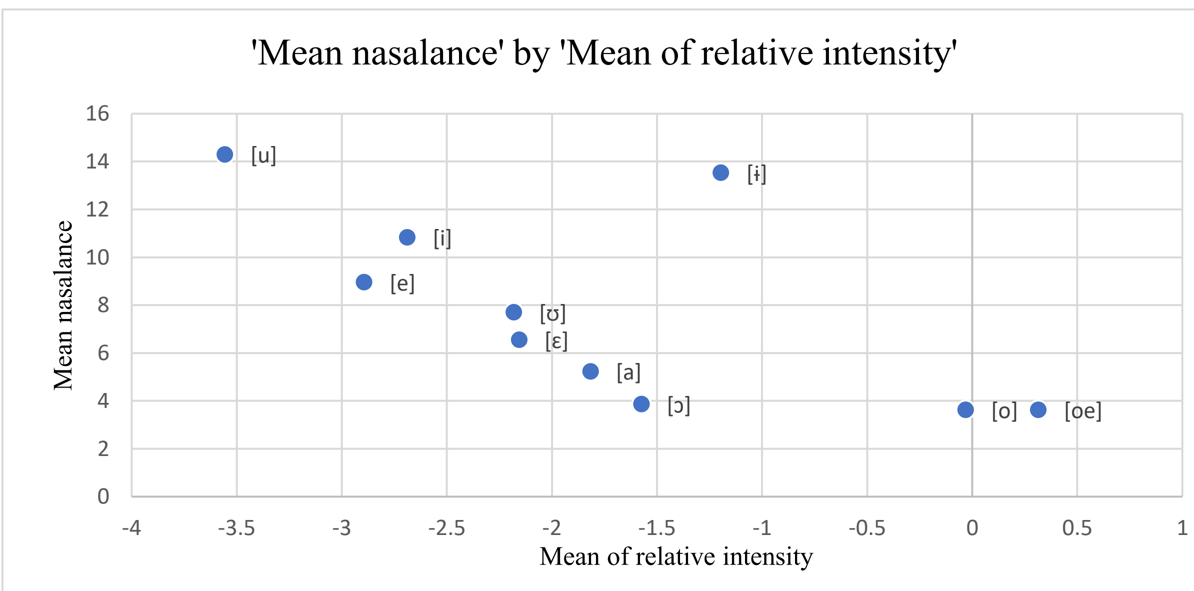

Figure 6: Mean of relative intensity by mean nasalance of oral vowels for Fr05

Figures 5 and 6 show that high nasalance values from the rainbow passage for Fr05 did not influence mean of relative intensity values for nasal and oral vowels. That is, high nasal and high oral vowels still have the highest mean nasalance scores in both classes, but their mean of relative intensity values differ according to their type, where high nasal vowels exhibit a high mean of relative intensity level within the class of nasal vowels, while high oral vowels exhibit a low mean of relative intensity level within the class of oral vowels.

It has been noted, in Figures 5 and 6 and in the other figures, which are presented in Appendix E, that the group of high nasal and high oral vowels /i, ɨ, u, ʊ, ĩ, ɨ̃, ũ, ʊ̃/ has higher mean nasalance scores than those of the other vowels. This phenomenon has been observed in other research of normative nasalance. Lewis and Watterson (2003) explained that this variance in nasalance depends on the type of vowel produced. Kummer (2005, 2008) showed that high vowels display greater levels of nasalance than low vowels.

Thus, the above graphs showed that the nasalance results for the Rainbow Passage did not affect mean of relative intensity values of target vowels, where each graph for every single participant displayed high mean nasalance values for high and mid-high vowels (i.e., nasal and oral) and lower mean nasalance values for low and mid-low vowels.

5.3 The Reading Task for Oral and Nasal Vowels

This subsection presents the obtained mean of relative intensity values for each of the target segments organized by type (i.e., nasal and oral). Each table in the following subsections is accompanied by a brief discussion of some general aspects of the data it displays, without looking precisely to relate the data presented with sonority. Subsections 5.3.1 and 5.3.2 display the overallmean of relative intensity values for oral and nasal vowels, respectively. Section 5.4 presents the results of the statistical analysis for the group of oral and nasal vowels. Finally, a summary of the entire chapter is in section 5.5.

5.3.1 Intensity of Oral Vowels for All Participants

This section organizes oral vowels according to their mean of relative intensity for all participants (see Appendix E for mean of relative intensity values per each participant). The calculatedmean of relative intensity, in Table 14, is the average of thirty-five tokens for each vowel. Then the resulting mean of relative intensity values organize the vowels from the highest to the lowest in intensity.

Table 14: Means of relative intensity of oral vowels for all participants

Oral vowels	Height	Mean of relative intensity
[ʊ]	High	-0.7
[œ]	Mid-low	-0.9
[a]	Low	-1.3
[o]	Mid-high	-1.4
[ɛ]	Mid-low	-1.5
[ɔ]	Mid-low	-1.9
[e]	Mid-high	-2.2
[u]	High	-2.2
[ɨ]	High	-2.5
[i]	High	-3.3

In Table 14, the high oral vowel [ʊ] surprisingly occupies the top of the scale as the highest in mean of relative intensity, followed by the mid-low vowels [œ]. To make sure that there was no error in the measurements, we have checked out the first two formants and duration for these two vowels to ensure that they did not affect intensity readings. Our investigation showed that the values of F1 and F2 frequencies and duration for [ʊ] and [œ] were within their normal range and corresponded to their articulation. The same held true for the target low oral vowel [a].

Therefore, we assume that the high mean of relative intensity reading for these two vowels was due to the added pressure or the effort in articulating these two vowels, since the high vowel [ʊ] does exist as an allophonic in Québécois French, though, under high vowel laxing. Thus, participants faced uneasiness while pronouncing it and this might have added more pressure on its articulation. As for the rest of the vowels, though, some of them, for example, [ɨ] do not exist in any variety of French language, and they displayed the general order for intensity readings seen in previous studies (e.g., Parker, 2008). Furthermore, in Parker (2002), the results of intensity for English female participants placed [ʊ] as higher in intensity than [a], so participants might have been affected by this high vowel pronunciation as in the English language, which affected intensity values. However, these results will be considered within the vowel group in the statistical analysis, which helps in normalizing the high values of such vowels (see Section 5.4).

The following figure presents a graph of mean of relative intensity and mean nasalance values of oral vowels calculated for all participants to show that nasalance levels did not affect on mean of relative intensity values for target vowels. The graph presents the average of thirty-five tokens for each vowel were calculated to extract mean of intensity and mean nasalance values.

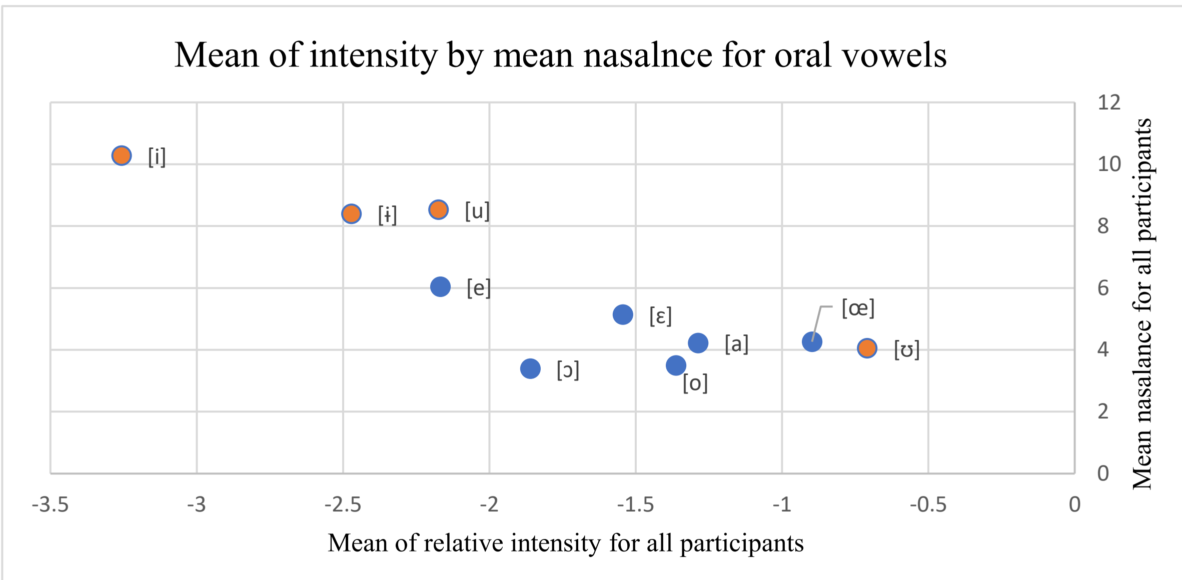

Figure 7: Mean of relative intensity by mean nasalance for all participants

Figure 7 strongly suggests that nasalance readings did not affect mean of relative intensity levels for each type of vowel. That is, mean nasalance readings of all vowels for all participants showed that high oral vowels (colored in orange) displayed the highest degree of mean nasalance, but their mean of relative intensity values were not the highest among oral vowels.

5.3.2 Intensity of Nasal Vowels for All Participants

This section categorizes nasal vowels corresponding to their mean of relative intensity for all participants (see Appendix E for mean of relative intensity values per each participant). The calculated mean of relative intensity, in Table 15, is the average of thirty-five tokens for each vowel type. The resulting mean of relative intensity values organize the vowels from the highest to the lowest in intensity.

Table 15: Means of relative intensity of nasal vowels for all participants

Nasal vowels	Height	Mean of relative intensity
[ĩ]	High	-1.9
[ũ]	High	-2.3
[ʊ̃]	High	-2.8
[ɨ̃]	High	-3.1
[õ]	Mid-high	-3.2
[ẽ]	Mid-high	-3.3
[ɔ̃]	Mid-low	-3.4
[œ̃]	Mid-low	-3.7
[ã]	Low	-4.0
[ɛ̃]	Mid-low	-4.3

We noticed that there was a high correlation between mean of relative intensity scores of nasal vowels and their height. The group of high nasal vowels had the highest levels of mean of relative intensity starting from [ĩ] to [ɨ̃]. Then came the group of mid-high vowels [õ] and [ẽ]. After that came the group of mid-low vowels, which was separated by the low vowel [a]. It was noteworthy that nasalisation had affected the organization of vowels, in that mean of relative intensity scores of the class of oral vowels placed three out of four high vowels at the bottom of the table, whereas the class of mid-high and mid-low vowels were scattered in separate places. In addition, the low vowel [a] was placed as the third in mean of relative intensity in the class of oral vowels, while its contrastive nasal vowel was placed before the end. This difference in scaling nasal and oral vowels is due to the added nasality feature and its effect on the intensity readings. The next section discusses the statistical analysis of both classes of vowels and shows the significant interaction between vowel height and vowel nasality (i.e., oral or nasal).

Figure 8 presents a graph of mean of relative intensity and mean nasalance values of nasal vowels for all participants to show that nasalance levels did not affect on mean of relative intensity values of target vowels.

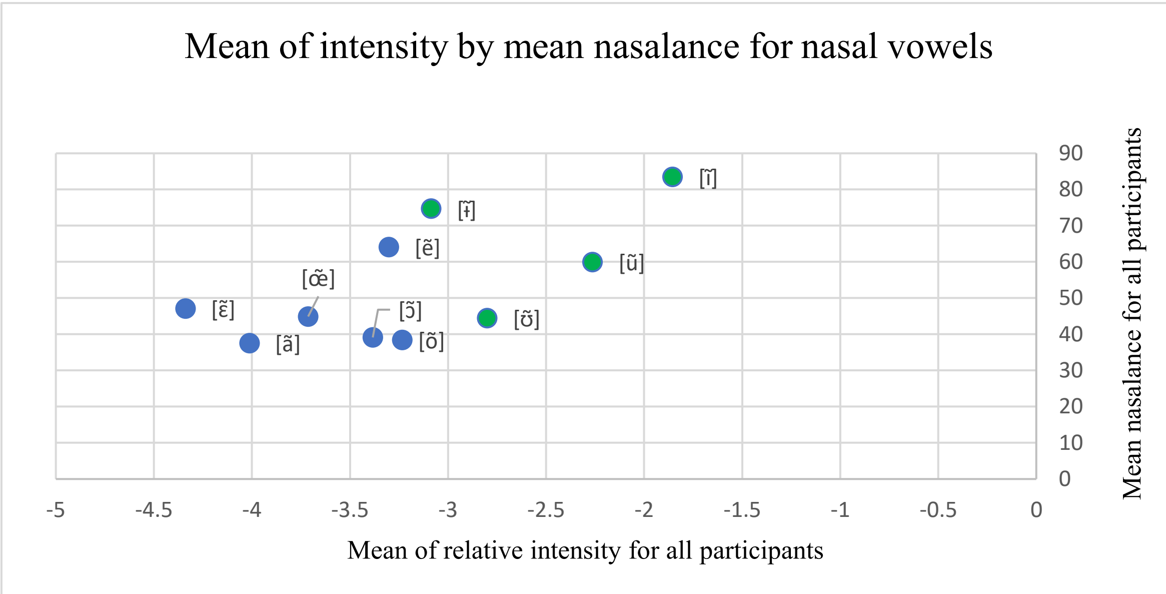

Figure 8: Mean of relative intensity by mean nasalance for all participants

The above graph shows that high nasal vowels (colored in green) exhibit the highest mean nasalance and the highest mean of relative intensity values among all nasal vowels. This observation suggests that nasalance levels did not affect mean of relative intensity readings, where high oral and nasal vowels had the highest mean nasalance scores among their distinct types, but with the former having low mean of relative intensity values among oral vowels and the latter having the highest mean of relative intensity values among the nasal vowels.

5.4 Statistical Analysis

This section presents the repeated measures of two-way ANOVA analysis of variance with within-subject factors: type of vowels, with its two levels (i.e., oral and nasal) and height of vowels, with its four levels (i.e., high, mid-high, mid-low, and low), and one dependent variable: mean of relative intensity. The two-way ANOVA was performed to analyze the effect of height of vowels and type of vowels on means of relative intensity which were calculated for each group of vowels. A two-way ANOVA revealed that there was a statistically significant interaction between type and height on means of relative intensity ($F(3, 18) = 6.12$, p=.005).

Table 16 shows the descriptive statistical analysis, which includes a total of eight groups of vowels that are classified according to height of vowels (high, mid-high, mid-low, and low), and type of vowels (oral and nasal). For oral and nasal vowels, the group of high vowels includes four vowels (e.g., [i, u, ʊ, ɨ]), the group of mid-high vowels incorporates two vowels (e.g., [e, o]), mid-low vowels have three vowels (e.g., [ɔ, œ, ɛ]), and the group of low vowels has only one vowel (e.g., [a]). Table 16 presents mean oof intensity for each group of vowels for both types, nasal and oral, along with their standard deviation and confidence interval.

Table 16: Descriptive statistical analysis for vowels according to height and type

Mean group of vowels (height, type)	Valid N	Mean relative intensity	Standard deviation	95% Confidence interval
Mean low oral	7	-1.29	1.83	[-2.977; 0.404]
Mean mid-low oral	7	-1.43	1.92	[-3.214; 0.346]
mid-high oral	7	-1.76	2.25	[-3.847; 0.318]
Mean high oral	7	-2.15	1.84	[-3.852; -0.453]
Mean high nasal	7	-2.5	3.04	[-5.314; 0.313]
Mean mid-high nasal	7	-3.27	3.17	[-6.195; -0.340]
Mean low nasal	7	-3.81	2.66	[-6.588; -1.436]
Mean mid-low nasal	7	-4.01	2.78	[-6.273; -1.351]

Within the eight groups presented in the above table, the group of the low oral vowel has the highest mean of relative intensity, while the group of mid-low nasal vowels has the lowest intensity level.

To report simple main effect of this significant interaction, more analyses and comparisons were done to show which independent variable has main effect on mean of relative intensity. Table 17 below presents a paired comparison of the effect of type of vowels (oral and nasal) on the height of vowels.

Table 17: Paired comparison for the type of vowels

Height	(I) Type	(J) Type	Mean difference (I-J)	Standard error	Significance (*p*)	95% Confidence interval for the difference
High	Oral	Nasal	.348	.673	.623	[-1.298; 1.995]
Mid-high	Oral	Nasal	1.503	.774	.100	[-0.390; 3.396]
Mid-low	Oral	Nasal	2.378	.536	.004*	[1.066; 3.690]
Low	Oral	Nasal	2.725	.682	.007*	[1.058; 4.393]

The above table shows that there is a significant difference in type (i.e., oral and nasal) between oral and nasal vowels for the group of mid-low vowels (p=.004) and the group of low vowels (p=.007). We can see that the independent variable of type of vowels has an effect on the height of vowel which mainly affects on the relative intensity results of low and mid-low vowels depending on their nasality.

The second paired comparison for the effect of height of vowels on the two levels of type of vowels (oral and nasal) showed that there was a (marginal) significant difference in height (p=.015) without Bonferroni correction between mid-low nasal vowels and high nasal vowels, where the former was placed as the lowest in the intensity while the latter was placed as fifth in intensity (see Table 15). However, this significant difference changed to be non-significant (p=.091) with Bonferroni correction. We can see that different levels of height have a marginal effect on the type of vowel, in that, within nasal vowels, there is only a marginal effect of height between high and mid-low nasal vowels. This marginal effect may be due to the small number of participants which could not elucidate clearly the effect of height on type of vowels.

5.5 Summary

This chapter presented the results of two reading tasks. The results of the first task showed that there was a difference in nasalance levels between participants. However, a comparison between mean nasalance and mean of relative intensity values of nasal and oral vowels showed that mean nasalance do not affect mean of relative intensity values for all diverse types of oral and nasal vowels.

The results of the second task concerned intensity values for nasal and oral vowels compared to the reference vowel [a]. General results of mean of relative intensity values varied for both classes of target vowels. The class of oral vowels displayed noticeable high mean of relative intensity values for two mid vowels while the low oral vowel was placed at the third place. These high values for the high vowel and the mid-low vowel were later normalized when their relative intensity values were calculated within their height group in the statistical analysis.

As for the class of nasal vowels, it has been shown that high nasal vowels were the highest in relative intensity while mid-low and low nasal vowels are the least in relative intensity. The same order was seen in the statistical analysis, where high nasal vowels are placed in fifth place after their oral counterparts while mid-low nasal vowels were placed at the end of the scale.

6 Chapter 6 – Discussion

This chapter presents a phonological definition of the observed phenomena in Chapter 3, then correlates it with the intensity results in Chapter 5. First, section 6.1 presents the phonological processes targeting nasal vowels and the relevant sonority relation for each of these processes. Then, section 6.2 correlates the defined phenomena with the experimental findings of relative intensity and answers research questions (see Chapter 3).

6.1 Sonority Relations for Nasal Vowels

We saw in Chapter 3 that there is a difference between the studied languages about which nasal vowel is the target of phonological processes. In Chapter 3, in three out of six languages, phonological processes like nasal harmony, vowel reduction and position constraint target one type or all types of high nasal vowels. For example, in the Mòbà dialect of Yoruba, high nasal vowels are distributed in different positions in the word because there are two variants of high nasal vowels: the underlying or phonemic high nasal vowels and the derived high nasal vowels(Ajiboye, 2017). According to Rice (2007), in terms of markedness relations, high vowels are frequent in inventories and, generally, the presence of mid vowels in an inventory implies the presence of high vowels. That is, in the Mòbà dialect of Yoruba there exist two variants of high nasal vowels (underlying and derived) but just one variant of the low nasal vowel (underlying). As for mid vowels, there is neither an underlying nor a derived nasal variant for them. In addition, according to valid markedness diagnostics, provided by de Lacy (2006), a segment is considered less marked if it is the output of a structurally-conditioned phonological process. In Mòbà dialect of Yoruba, high oral vowels undergo a structurally-conditioned phonological process of nasal harmony to output high nasal vowels, which indicates that high nasal vowels are less marked than the low nasal vowel in this language. As a result, high nasal vowels may be more sonorous than the low nasal vowel.

Moreover, high nasal vowels undergo a process of vowel reduction to a syllabic nasal in standard Yoruba when they occur at the end of the word, which is considered a weak position in this language. Akinbiyi (2007), who described this phenomenon, suggested that the process of vowel reduction occurring in standard Yoruba is in fact a process of sonority reduction in weak positions. Since the constraint on the structure of the prosodic word requires that the head (the primary stressed nucleus) entails the least marked vowel (i.e., in sonority notion, the highest in sonority), then non-heads entail more marked vowels that display a low sonority level. Thus, when a vowel with a high sonority rank is found in a non-head position, a process of vowel reduction is employed. In standard Yoruba, high nasal vowels undergo a process of vowel reduction in non-head position, which may suggest that they are least marked and have a high sonority rank in this language (cf. Crosswhite, 2000; de Lacy, 2006)

In Bariba, the back high nasal vowel [ũ] cannot be the nucleus of the syllable by itself, so it must be found with another nasal vowel to be able to perform as the nucleus. In examples from this language, we noticed that it is found with either [ã] or [ɛ̃] (Welmers, 1952). Although the high back nasal vowel [ũ] does not behave like the high front nasal vowel [ĩ], where the former needs to be with another nasal vowel to be the nucleus of a syllable, but, however, we can notice that it forms a nucleus with mid-low and low nasal vowels. This may indicate that mid-low and low nasal vowels have a lower sonority rank than the high nasal vowels which allow them to form a nucleus with the high back nasal vowel.

On the other hand, phonological processes in two languages out of six studied languages, such as optional shift and assignment of stress, target the low nasal vowel. For example, In Tucano, the low oral and nasal vowels [a, ã] at the end of the word undergo an optional shift in empathic speech style which change them qualitatively to the high central oral vowel [ɨ]. In this language the low oral and nasal variant is the correct form in normal speech (Waterhouse, 1967). It seems logical that the low nasal vowel change to a central oral vowel if the class of oral vowels is considered to have a higher sonority rank from the class of nasal vowels. According to valid markedness diagnostics, provided by de Lacy (2006), the nasal vowel undergoes a structurally-conditioned shift to output a central high oral vowel, which indicates that the former is more marked than the latter.

In Cofán, the low nasal vowel [ã] and oral vowels [a, e] attract the stress when they are found in a vowel cluster. The default place of the stress is on the second vowel of the cluster, but if one of the later three vowels occurs as the first vowel in the cluster, the stress is placed on it (Elson & Peeke, 1962). According to sonority-driven stress process, the low nasal vowel, only in this language, may exhibits a high sonority rank, which attracts the stress from its default position in a vowel cluster nucleus to place it on the first vowel (here, either the low oral or nasal vowel) (De Lacy, 2004).

In the Ikaan language, the class of oral vowels undergo deletion or assimilation when a modifier is added to a noun. The vowel at the end of the first word (the noun) is either deleted or assimilated because of the vowel of the subsequent word. However, this language shows that all nasal vowels are exempted from undergoing deletion or assimilation when they are at the end of the first word of a noun + modifier construction (Salffner, 2013). According to de Lacy (2006) this phenomenon is called the preservation of the marked, where the more marked segments are preserved from undergoing some phonological processes like deletion while the less marked are forced to undergo the phonological process. On the other hand, within the class of nasal vowels, there is a difference in behaviour, where the high nasal vowel /ĩ/ spreads the nasality feature to the vowel of the modifier, while the other nasal vowels like /ũ/ and /ã/ are totally removed, along with their nasality feature. Thus, the front high nasal vowel /ĩ/ may show that it has a higher sonority level than the other nasal vowels.

6.2 Intensity Values and Sonority Relations

From the phonological side, mainly high nasal vowels are the target for phonological processes in the studied languages. However, there is a difference in phonological behaviour between the high front nasal vowel and the high back nasal vowel. That is, the high front nasal vowel showed a high sonority rank, while, in two languages, the high back nasal vowel did not show a high sonority rank like high front nasal vowel. For instance, in two languages, Mòbà dialect of Yoruba (Ajiboye, 2017) and standard Yoruba (Akinbiyi, 2007), high nasal vowels appear to be more sonorous, while in two other languages, Ikaan (Salffner, 2013) and Bariba (Welmers, 1952), the high back nasal vowel displays a lower sonority rank than the high front nasal vowel. Similarly, there is a discrepancy in the phonological behaviour of the low nasal vowel, where the latter optionally shifts to a central oral vowel in the Cofán language (Waterhouse, 1967), while it attracts the stress in vowel cluster in the Tucano language (Elson & Peeke, 1962).

However, from a phonetic stance, relative intensity values show that the group of high nasal vowels are the highest in relative intensity while the group of low nasal vowels are the second lowest in relative intensity. See the relative intensity scale in (8) that is proposed according to results from the statistical analysis of nasal vowels within the group.

(8) high nasal vowels > mid-high nasal vowels > low nasal vowels > mid-low nasal vowels

Thus, five of the above-mentioned languages adapt well to the scale in (8), where the group of high nasal vowels are the highest in relative intensity. In addition, the Ikaan language aligns with the general relative intensity scale of both classes of oral and nasal vowels. This language demonstrates that the sonority of nasal vowels is less than the sonority of oral vowels, which adapts to the proposed scale in (8). Table (16), in Chapter 5, shows that all groups of oral vowels are higher in intensity than the group of high nasal vowels, where the latter is the highest in intensity within the class of nasal vowels.

Nevertheless, the behaviour of nasal vowels in one language varies; for example, the Cofán language is opposing the intensity scale, in which the low nasal vowel does not behave as shown in the experimental findings. This language needs to be more investigated in future work to verify the behaviour of the low oral vowel in emphatic style.

As it is mentioned in the book of de Lacy (2006), the markedness of different types of vowels varies according to the structure of the language, where sometimes one type of vowels is less marked in a particular position while it is more marked in another. Thus, nasal vowels may also follow this pattern in alternating in markedness according to the structure of the concerned language. Therefore, the best way is to classify them according to relative sonority which is best displayed by intensity values. Thus, the proposed scale in (8) can be considered as a preliminary representation of the sonority hierarchy of nasal vowels.

Concerning the observed reversibility of the hierarchy according to the prosodic context for oral vowels, we hypothesize that nasal vowels may also behave like oral vowels. In this case, in future investigations, we may see some phonological phenomena that display the sonority hierarchy of nasal vowels according to the prosodic context. For example, we may find that high nasal vowels (phonetically, high in sonority) are chosen to be the prosodic head of a syllable while mid-low nasal vowels (phonetically, least in sonority) are chosen to be the prosodic non-head. In addition, high nasal vowels may be deleted or reduced to another quality in weak or unstressed positions and bear the primary stress of the prosodic word whereas mid-low nasal vowels are deleted in a stressed position, and the stress is not placed on them in the presence of a more sonorous nasal vowel.

Although there are some variations between different subsets of nasal vowels, the current intensity results, along with our typological observations suggest an answer to the research questions posed in Chapter 3. Regarding the first two questions about the typological observations of nasal vowels, the group of high nasal vowels was the target of most phonological processes, as opposed to the oral vowels, where the low oral vowel is the target of phonological processes. As a result, high nasal vowels show high sonority rank within the class of nasal vowel which is the opposite within the class of oral vowels, where the low oral vowel is the highest in sonority. As for the third and fourth questions related to the empirical work in this study, high nasal vowels were the highest in intensity while the low nasal vowel was second to last (see the scale in (8)). In addition, the intensity readings of high nasal and high oral vowels were near to each other, which affirms the third and fourth research questions.

Nevertheless, this limited number of studied languages is not enough evidence to confirm or reject the intensity results of the present experiment, and it is not obvious which kind of historical changes have been applied to these languages that lead them to display variant phonological behaviour of diverse types of nasal vowels. Thus, we believe that a more exhaustive typological overview of nasal vowels in the world's languages may display more phenomena that can adapt well to the intensity scale of the current study.

7 Chapter 7 – Conclusion

This last chapter reviews the chapters of this thesis, discusses future work, and finally sets out the empirical and theoretical contributions made by this thesis.

7.1 Summary

This study discussed different angles of the phonology and phonetics of nasal vowels. Chapter 2 discussed two parts: the notion of sonority, phonologically and experimentally, and the acoustics of nasal vowels. The phonological part on sonority presented the proposed sonority hierarchies of different phonemes, and how researchers were able to figure out the sonority rank of the segment according to their behaviour in the language system and discussed the relation between markedness and sonority and revealed that vowels were better distinguished from each others according to their relative sonority because vowel markedness varies according to the prosodic context. As for the experimental side, many researchers investigated various physical correlates to see which one was the best correlate of sonority. Mainly, intensity was found to be the best physical correlate of sonority which was the approach adopted in this study. The second part of Chapter 2 presented a brief description of the acoustic and articulatory aspects of nasal vowels and discussed how the acoustic correlates of vowel height had an influence on the nasal coupling which manifested in changing the values of the formant frequencies.

Chapter 3 presented a typological overview of the nasal vowels in the world's languages. This chapter revealed that the behaviour of diverse types of nasal vowels differs from one language to another. For instance, in the Mòbà dialect of Yoruba and the standard Yoruba language, high nasal vowels are the target of phonological processes. The opposite is true for the Tucano and Cofán languages, in which the low nasal vowel is the target of phonological process. The typological observation of five studied languages suggests that high nasal vowels are more sonorous than the low nasal vowel. However, in two studied languages, the high back nasal vowel has a different phonological behaviour from the front high nasal vowel. In addition, one language suggests that the low nasal vowel is more sonorous than high nasal vowels. This discrepancy might be due to historical changes in the vocalic system of these languages. Thus, this limited number of languages cannot definitely confirm which type of nasal vowels is more favoured.

Chapter 4 presented the methodology for the current study, where two tasks were performed. The first task was performed to calculate the nasalance score for each participant. The second task was performed to calculate the maximum intensity of the peak points of the nasal and oral vowels, along with two reference phonemes.

Chapter 5 revealed the results of the experiment, where the general results showed that the high nasal vowel [ĩ] was the highest in intensity, whereas the mid low nasal vowel [ɛ̃] was the lowest in intensity. For the class of oral vowels, the case was different, where the intensity of the high oral vowel [ʊ] was unexpectedly higher than the low oral vowel. However, when all vowels were statistically analysed within groups according to their type (nasal or oral) and height (high, mid-high, mid-low, low), the high intensity value of [ʊ] was normalized, and a more reliable scale was proposed. In the statistical analysis, the group of low oral vowel was the highest in intensity while the group of high oral vowels was the least in intensity. The opposite was true for the nasal vowels, where the group of high nasal vowels was the highest in intensity, and the group of low nasal vowel was the second least in intensity.

Finally, Chapter 6 defined the observed behaviour of the nasal vowels in the world's languages according to sonority rules. The next section discussed the relation between the experimental findings of the current experiment and the observed phenomena that target diverse types of nasal vowels. The conclusion was that the current typological work might not be sufficient to reflect the intensity findings and that a more exhaustive typological observation in future work might adapt well to the resultant intensity scale in (7).

7.2 Future Work

Two sorts of data were gathered in this study which were analyzed for one language variety (French of Quebec) in this thesis. Along with more exhaustive typological work, we hypothesize that examining the intensity of nasal vowels in more French varieties (e.g., Parisian French, Belgian French, and varieties of French spoken in Africa, such as Moroccan French) and for a larger number of participants may lay out interesting results that can be matched with a more thorough typological study. In addition, we might consider measuring SPLH, introduced by Fant et al. (2000), in our future research, because, according to Fant et al. (2000), it can detect changes in the area of F2 and F3 formants, and could appropriately fit the notion of sonority.

Furthermore, the current study of nasalance scores for the Rainbow Passage for French Quebecers was performed on a limited number of participants (i.e., only seven participants), so this small sample size may not exactly reveal whether their nasalance scores were normative or not. Therefore, in future work, building a normative nasalance data set for a considerable number of French Quebecers to use as a reference during measurements for intensity of nasal vowels might lay out a more comprehensive result.

7.3 Empirical and Theoretical Contributions

This thesis aimed to fill the research gap in the literature concerning the sonority of nasal vowels through investigating the behaviour of nasal vowels cross-linguistically and measuring their intensity (a physical correlate of sonority). The typological observation of the behaviour of diverse types of nasal vowels showed that there was a discrepancy between the studied languages concerning which nasal vowel height is more favourable. As for the empirical work, the intensity values showed that high nasal vowels were the highest in intensity while mid-low nasal vowels were the lowest in intensity. Thus, a general scale of nasal vowels was proposed depending on the statistical analysis done on vowel groups according to their height.

We believe that this study took the first step in classifying nasal vowels according to relative sonority and that a more exhaustive typological and empirical work on this issue will complete what has been started in the current study.

Appendix A: The Rainbow Passage for French participants

Monsieur Seguin n’avait jamais eu de bonheur avec ses chèvres. Il les perdait toutes de la même façon : un beau matin, elles cassaient leur corde, s’en allaient dans la montagne, et là-haut le loup les mangeait. Ni les caresses de leur maître, ni la peur du loup, rien ne les retenait.

(Garnier, 2012)

Appendix B: Complete list of French sentences used to extract intensity

As mentioned in subsection 4.2.2, the following list shows all the utterances used to elicit phonetic data of nasal and oral vowels, with the five repetitions.

Table 18: List of phrases for oral and nasal vowels – 1st repetition

Voyelles orales	Voyelles nasales
1. Jacques et Chad demandent [did] trop	2. Jacques et Chad demandent [nĩn] trop
3. Jacques et Chad répondent [dɨd] tout de suite	4. Jacques et Chad répondent [nɨ̃n] tout de suite
5. Jacques et Chad plaident [ded] toujours	6. Jacques et Chad plaident [nẽn]toujours
7. Jacques et Chad entendent [dɛd] typiquement	8. Jacques et Chad entendent [nɛ̃n] typiquement
9. Jacques et Chad répondent [dad] tranquillement	10. Jacques et Chad répondent [nãn] tranquillement
11. Jacques et Chad répondent [dod] tout de suite	12. Jacques et Chad répondent [nõn] tout de suite
13. Jacques et Chad entendent [dœd] typiquement	14. Jacques et Chad entendent [nœ̃n] typiquement
15. Jacques et Chad plaident [dud] toujours	16. Jacques et Chad plaident [nũn] toujours
17. Jacques et Chad demandent [dʊd] trop	18. Jacques et Chad demandent [nʊ̃n] trop
19. Jacques et Chad répondent [dɔd] tranquillement	20. Jacques et Chad répondent [nɔ̃n] tranquillement

Table 19: List of phrases for nasal and oral vowels – 2nd repetition

Voyelles nasales	Voyelles orales
1. Jacques et Chad répondent [nɔ̃n] tranquillement	2. Jacques et Chad répondent [dod] tout de suite
3. Jacques et Chad plaident [nũn] toujours	4. Jacques et Chad répondent [dɨd] tout de suite
5. Jacques et Chad entendent [nɛ̃n] typiquement	6. Jacques et Chad plaident [dud] toujours
7. Jacques et Chad répondent [nõn] tout de suite	8. Jacques et Chad plaident [ded] toujours
9. Jacques et Chad répondent [nɨ̃n] tout de suite	10. Jacques et Chad entendent [dɛd] typiquement
11. Jacques et Chad plaident [nẽn]toujours	12. Jacques et Chad demandent [did] trop
13. Jacques et Chad demandent [nʊ̃n] trop	14. Jacques et Chad répondent [dɔd] tranquillement
15. Jacques et Chad entendent [nœ̃n] typiquement	16. Jacques et Chad entendent [dœd] typiquement
17. Jacques et Chad demandent [nĩn]trop	18. Jacques et Chad demandent [dʊd] trop
19. Jacques et Chad répondent [nãn] tranquillement	20. Jacques et Chad répondent [dad] tranquillement

Table 20: List of phrases for oral and nasal vowels– 3rd repetition

Voyelles orales	**Voyelles nasales**
1. Jacques et Chad entendent [dɛd] typiquement	2. Jacques et Chad répondent [nõn] tout de suite
3. Jacques et Chad demandent [did] trop	4. Jacques et Chad plaident [nẽn] toujours
5. Jacques et Chad demandent [dʊd] trop	6. Jacques et Chad demandent [nĩn] trop
7. Jacques et Chad plaident [ded] toujours	8. Jacques et Chad répondent [nɨ̃n] tout de suite
9. Jacques et Chad répondent [dɔd] tranquillement	10. Jacques et Chad répondent [nãn] tranquillement
11. Jacques et Chad entendent [dœd] typiquement	12. Jacques et Chad demandent [nʊ̃n] trop
13. Jacques et Chad répondent [dod] tout de suite	14. Jacques et Chad entendent [nœ̃n] typiquement
15. Jacques et Chad répondent [dɨd] tout de suite	16. Jacques et Chad plaident [nũn] toujours
17. Jacques et Chad plaident [dud] toujours	18. Jacques et Chad entendent [nɛ̃n] typiquement
19. Jacques et Chad répondent [dad] tranquillement	20. Jacques et Chad répondent [nɔ̃n] tranquillement

Table 21: List of phrases for nasal and oral vowels – 4th repetition

Voyelles nasales	**Voyelles orales**
1. Jacques et Chad répondent [nɨ̃n] tout de suite	2. Jacques et Chad répondent [dad] tranquillement
3. Jacques et Chad répondent [nãn] tranquillement	4. Jacques et Chad plaident [dud] toujours
5. Jacques et Chad entendent [nœ̃n] typiquement	6. Jacques et Chad demandent [did] trop
7. Jacques et Chad plaident [nẽn]toujours	8. Jacques et Chad demandent [dʊd] trop
9. Jacques et Chad demandent [nʊ̃n] trop	10. Jacques et Chad entendent [dœd] typiquement
11. Jacques et Chad répondent [nõn] tout de suite	12. Jacques et Chad répondent [dɔd] tranquillemen
13. Jacques et Chad entendent [nɛ̃n] typiquement	14. Jacques et Chad répondent [dɨd] tout de suite
15. Jacques et Chad plaident [nũn] toujours	16. Jacques et Chad répondent [dod] tout de suite
17. Jacques et Chad répondent [nɔ̃n] tranquillement	18. Jacques et Chad entendent [dɛd] typiquement
19. Jacques et Chad demandent [nĩn] trop	20. Jacques et Chad plaident [ded] toujours

Table 22: List of phrases for oral and nasal vowels – 5th repetition

Voyelles orales	Voyelles nasales
1. Jacques et Chad entendent [dœd] typiquement	2. Jacques et Chad entendent [nœ̃n] typiquement
3. Jacques et Chad répondent [dɨd] tout de suite	4. Jacques et Chad demandent [nõn] trop
5. Jacques et Chad répondent [dɔd] tranquillement	6. Jacques et Chad entendent [nɛ̃n] typiquement
7. Jacques et Chad entendent [dɛd] typiquement	8. Jacques et Chad répondent [nɨ̃n] tout de suite
9. Jacques et Chad répondent [dad] tranquillement	10. Jacques et Chad plaident [nẽn]toujours
11. Jacques et Chad demandent [did] trop	12. Jacques et Chad répondent [nõn] tout de suite
13. Jacques et Chad plaident [ded] toujours	14. Jacques et Chad plaident [nũn] toujours
15. Jacques et Chad répondent [dod] tout de suite	16. Jacques et Chad demandent [nĩn] trop
17. Jacques et Chad demandent [dʊd] trop	18. Jacques et Chad répondent [nɔ̃n] tranquillement
19. Jacques et Chad plaident [dud] toujours	20. Jacques et Chad répondent [nãn] tranquillement

Appendix C: IPA Chart for oral vowels

In subsection 4.4.2, it is mentioned that participants were trained on pronunciation for the experiment using an IPA chart. However, this chart does not include nasal vowels, only oral vowels. Therefore, participants were encouraged to pronounce the oral vowel then add the nasality feature to the relevant vowel and produce it within its nasal environment.

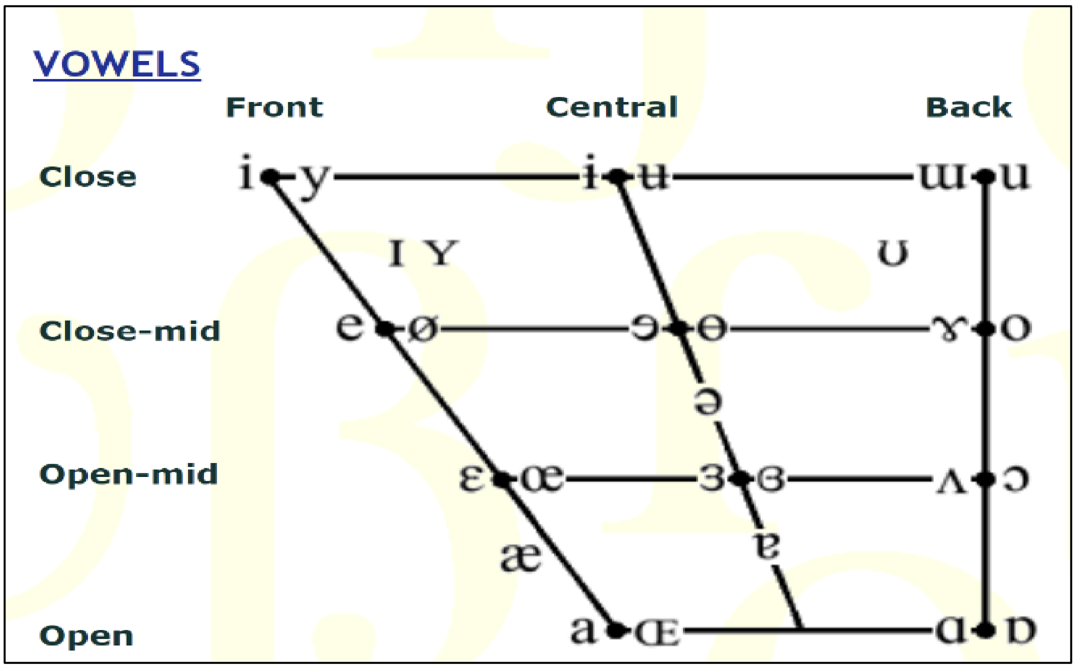

Figure 9: IPA chart for all types of nasal vowels

Appendix D: Forms used in the experiment

As discussed in subsection 4.4.2, the following figures present the relevant forms used in the experiment.

Code:______
(pour équipe de recherche)

Questionnaire sociolinguistique

Informations générales

Nom :

Sexe :

Âge :

Plus haut niveau de scolarisation atteint en linguistique (même si un diplôme n'a pas [encore] été obtenu) :

Informations géographiques

Lieu de naissance :

Où avez-vous vécu la plus grande partie de votre vie ? Précisez le pays, la région et la ville :

Antécédents linguistiques

Langue(s) maternelle(s)[1]:

Autre(s) langue(s) connue(s), par âge approximatif de début d'acquisition et niveaux par mode d'expression (**niveaux à utiliser** : (1) Quasi-natif, (2) Avancé, (3) Intermédiaire, (4) Débutant)

(voir la page suivante pour tableau)

[1] Langue parlée depuis l'enfance & acquise au moins majoritairement sans enseignement explicite.

Code:______
(pour équipe de recherche)

Langue	Âge	Parler	Écouter	Lire	Écrire

Langue(s) maternelle(s) de vos parents : (merci d'indiquer toute langue employée à la maison et/ou avec vos parents)

Autre

Souffrez-vous d'allergies saisonnières ou avez-vous été malade dans les deux semaines dernières? Si oui, le nez congestionné fait-il, ou a-t-il fait partie de vos symptômes ?

Figure 10: The filled out sociolinguistic survey before the experiment

Réinitialisation du formulaire

Santé COVID-19 — Déclaration de santé pour les participants à des études

Code d'identification du projet :

Cher(ère) participant(e) de la recherche,

Avant de vous déplacer ou de rencontrer un membre de l'équipe de recherche, nous vous demandons de bien vouloir remplir cette déclaration de santé **la veille de la rencontre prévue**. Ce formulaire vise à vous informer des symptômes les plus courants de la COVID-19 et à réduire le risque de transmission de la maladie. Soyez assuré que l'équipe de recherche remplit les mêmes conditions avant de vous rencontrer.

En présence d'une réponse positive à l'une ou l'autre des sections suivantes, veuillez ne pas rencontrer l'équipe de recherche et en informer la personne-ressource indiquée dans la lettre d'information au participant qui pourra alors convenir avec vous de nouvelles modalités pour votre participation.

Un seul des symptômes ou des conditions suivantes justifie une non-participation à la recherche à la date prévue	**OUI**	**NON**
Avez-vous une fièvre mesurée avec une température prise par la bouche égale ou supérieure à 38 °C (100,4 °F) ou d'avoir des frissons comme lors d'une grippe?	☐	☐
Avez-vous de la toux récente ou aggravation d'une toux chronique ?	☐	☐
Avez-vous de la difficulté à respirer ou êtes-vous essoufflé même au repos?	☐	☐
Avez-vous une perte soudaine de l'odorat ou du goût ?	☐	☐
Mal de gorge sans autre cause évidente	☐	☐
Nez qui coule ou congestion nasale de cause inconnue (allergie exclue)	☐	☐
Avez-vous voyagé à l'extérieur du Canada au cours des 14 derniers jours ?	☐	☐
Est-ce que vous avez été en contact avec des personnes infectées à la COVID-19 au cours des 14 derniers jours ?	☐	☐
Avez-vous obtenu un résultat positif à un test de dépistage pour la COVID-19 dans les 14 derniers jours ?	☐	☐

Ce document sera conservé durant les 14 jours suivant votre participation et il sera détruit par la suite.

Révision 31 mai 2021

Santé COVID-19 — Déclaration de santé pour les participants à des études

Code d'identification du projet :

Une réponse « Oui » à au moins deux des symptômes suivants justifie une non-participation à la recherche à la date prévue	**OUI**	**NON**
Fatigue intense inhabituelle sans raison évidente	☐	☐
Douleurs musculaires ou courbatures inhabituelles (non liées à un effort physique)	☐	☐
Perte d'appétit importante	☐	☐
Mal de tête inhabituel	☐	☐
Nausées (maux de cœur), vomissements	☐	☐
Diarrhée	☐	☐
Maux de ventre	☐	☐

En cas de symptômes, nous vous invitons à communiquer avec la ligne 1 877 644-4545 mise en place par le Gouvernement du Québec afin d'obtenir plus d'information sur la démarche à entreprendre.

Si malgré les mesures de protection mise en place, il advenait que vous avez été mis en contact avec une personne atteinte de la COVID-19, est-ce que vous nous autorisez à transmettre votre nom et numéro de téléphone à la santé publique afin qu'elle vous contacte ?

○ Oui ○ Non

Veuillez compléter, signer et remettre ce formulaire à un membre de l'équipe de recherche qui en fera une copie avant de vous le redonner en format papier ou numérique, à votre convenance.

Nom, prénom — Numéro de téléphone

Signature du participant à la recherche — Date (JJ-MM-AAAA)

Ce document sera conservé durant les 14 jours suivant votre participation et il sera détruit par la suite.

Révision 31 mai 2021

Figure 11: Participant health declaration form

Appendix E: Complete list of figures for nasalance and intensity correlation

As pointed out in section 5.2, the following tables show the mean of relative intensity and mean nasalance for oral and nasal vowels of each participant.

Table 23: Mean of relative intensity and mean nasalance of oral vowels

Vowel	FR01		FR02		FR03		FR04		FR05		FR06		FR07	
	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance
[i]	-3.9	9.8	0.2	4.3	-4.7	7.8	-1.2	22.5	-2.7	10.8	-3.7	6.4	-6.7	10.3
[ɨ]	-3.3	3.7	0.2	5.8	-7.4	7.2	-2.4	19.7	-1.2	13.5	0.2	5.0	-3.3	3.8
[e]	-1.5	5.2	-0.4	5.8	-6.6	5.6	1.4	7.9	-2.9	9.0	-2.0	4.3	-3.3	4.6
[ɛ]	-1.4	3.6	0.4	4.6	-3.3	5.7	1.2	9.6	-2.2	6.6	-2.2	2.8	-3.4	3.1
[a]	-2.0	4.5	2.3	4.3	-3.4	3.5	-0.2	4.7	-1.8	5.2	-2.1	4.5	-1.8	2.8
[o]	-0.2	4.1	-0.7	2.6	-4.4	3.3	1.1	4.3	0.0	3.6	-0.7	3.0	-4.6	3.5
[oe]	-1.3	4.5	1.3	3.3	-5.6	4.4	3.0	7.2	0.3	3.6	-1.5	4.0	-2.6	2.9
[u]	1.0	4.8	-0.2	3.8	-1.1	5.7	1.6	15.6	-3.6	14.3	-5.6	6.7	-7.3	8.8
[ʊ]	-0.9	3.0	-0.4	4.1	-1.5	3.8	2.9	4.2	-2.2	7.7	-0.5	2.6	-2.4	2.9
[ɔ]	-1.9	3.2	-1.1	3.5	-5.0	3.6	-0.2	4.0	-1.6	3.9	-0.9	2.6	-2.3	3.0

Table 24: Mean of relative intensity and mean nasalance of nasal vowels

Vowel	FR01		FR02		FR03		FR04		FR05		FR06		FR07	
	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance	Intensity	Nasalance
[ĩ]	-5.0	81.1	3.5	70.3	-5.2	74.5	2.8	96.4	-2.0	89.4	-3.4	81.1	-3.8	91.6
[ɨ̃]	-5.9	78.7	-1.6	79.1	-6.0	76.1	4.2	93.2	-4.1	69.7	-3.5	67.1	-4.8	58.8
[ẽ]	-3.9	68.3	1.3	52.3	-6.5	53.8	1.9	92.3	-5.1	62.4	-5.2	62.9	-5.7	56.9
[ɛ̃]	-5.4	57.8	-0.7	51.1	-7.5	46.4	-0.3	83.5	-6.3	38.5	-5.2	27.1	-5.0	25.3
[ã]	-4.6	26.3	0.2	55.5	-4.8	40.2	-0.8	66.3	-7.8	30.6	-4.3	17.9	-5.9	26.0
[õ]	-3.1	30.2	1.2	30.7	-6.2	47.2	-0.1	59.6	-7.3	39.9	-2.4	18.4	-4.8	43.1
[oẽ]	-5.5	45.0	1.3	36.2	-7.4	45.7	-0.5	76.3	-5.3	34.2	-3.8	46.3	-4.8	30.6
[ũ]	-2.0	33.3	1.8	51.0	-6.2	55.2	3.5	84.5	-5.0	53.8	-4.0	56.1	-3.8	85.3
[ʊ̃]	-2.3	25.7	1.2	56.0	-5.3	45.4	-0.9	57.7	-4.6	47.1	-4.2	34.4	-3.4	44.7
[ɔ̃]	-2.4	27.7	1.0	39.0	-6.4	43.3	-2.1	63.2	-5.2	32.3	-3.4	20.6	-5.1	47.9

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