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The Initial State for Californian English Learners  
of Spanish and Portuguese Vowels

A dissertation submitted in partial satisfaction of the  
requirements for the degree Doctor of Philosophy  
in Hispanic Languages and Literatures

by

Polina Vasiliev

2013



## ABSTRACT OF THE DISSERTATION

The Initial State for Californian English Learners  
of Spanish and Portuguese Vowels  
by

Polina Vasiliev

Doctor of Philosophy in Hispanic Languages and Literatures

University of California, Los Angeles, 2013

Professor A. Carlos Quicoli, Chair

Second language (L2) learners often struggle with achieving native-like production and perception of L2 sounds. While there is ample research on the non-native perception of English vowels by native speakers of languages with smaller vowel inventories, scant research exists up-to-date on the opposite scenario. The aim of the present study is to investigate the *initial state* for Californian English (CE) listeners' perception of two different smaller vowel inventories, namely Spanish and Portuguese vowels, before any perceptual learning has taken place. The objective is to determine how CE listeners' native vowel inventory of (at least) ten phonemes affects their non-native perception of the five Spanish and seven Portuguese vowel phonemes.

Monolingual speakers of English from Southern California (N = 18) completed a perceptual assimilation task, in which they labeled naturally produced tokens of Spanish

and Portuguese vowels in terms of ten native English categories, as well as a categorial discrimination task with four Spanish and six Portuguese vowel contrasts. In the perceptual assimilation task, CE listeners mapped almost every Spanish and Portuguese vowel contrast to more than two native categories, resulting in many instances of Multiple Category Assimilation (MCA, Escudero and Boersma, 2002). Furthermore, some phonologically common vowels between Spanish and Portuguese, namely /e/, /o/, and /a/, were mapped differently to English categories, suggesting that cross-linguistic differences in the acoustic distributions of these sounds result in differences in their categorization by non-native listeners.

In the discrimination task, CE listeners were highly accurate at distinguishing all Spanish vowel contrasts but were less accurate on three Portuguese vowel contrasts, /i-e/, /o-u/, and /a-ɔ/. Crucially, MCA was found to be responsible for listeners' lower discrimination accuracy only when it contributed to two vowels being perceptually assimilated to an overlapping set of native categories, i.e., when two different vowels had a high perceptual assimilation overlap score. The results are examined vis-à-vis two main models of second language speech perception, the Perceptual Assimilation Model (PAM, Best, 1995) and the Second Language Linguistic Perception Model (L2LP, Escudero, 2005). Implications for L2 acquisition of Spanish and Portuguese vowels by English-speaking learners are discussed.

The dissertation of Polina Vasiliev is approved.

Claudia Parodi

José Luiz Passos

Patricia Keating

A. Carlos Quicoli, Committee Chair

University of California, Los Angeles

2013

For Olga and Anatoly Vasiliev

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## VITA

### EDUCATION:

**Master of Arts**, Portuguese, University of California, Los Angeles, 2007

**Bachelor of Sciences**, Spanish, *summa cum laude*, Georgetown University, 2001

### PUBLICATIONS:

Vasiliev, P., & Escudero, P. (in press). Speech perception in second-language Spanish. In K. Geeslin (Ed.), *Handbook of Second Language Spanish*. Wiley-Blackwell Publishing.

Escudero, P., & Vasiliev, P. (2011). Cross-language acoustic similarity predicts perceptual assimilation of Canadian English and Canadian French vowels. *Journal of the Acoustical Society of America*, 130: EL277-EL283.

Vasiliev, P. (2007). The Russian and Brazilian communities in Los Angeles: a case study of diglossia. In C. Hulet, Ed., *Encruzilhadas/Crossroads: 30<sup>th</sup> Symposium on Portuguese Traditions*. Los Angeles: University of California.

### PRESENTATIONS:

Vasiliev, P., & Escudero, P. (2013, January). “The initial state for Californian English learners of Spanish and Portuguese vowels.” Panel Presentation, a joint session of the Modern Language Association and Linguistic Society of America.

Vasiliev, P. (2012, February). “Perception of Brazilian Portuguese vowels by English listeners.” Panel presentation, Department of Spanish and Portuguese mini-conference, University of California, Los Angeles.

Vasiliev, P., & Escudero, P. (2011, November) “Cross-language perception of Brazilian Portuguese vowels by Californian English listeners.” Poster presentation, 161<sup>st</sup> Meeting of the Acoustical Society of America, San Diego.

Vasiliev, P. (2011, October). “A percepção das vogais do português brasileiro por falantes nativos de inglês.” Invited talk, Graduate Study Group in Phonetics, University of São Paulo, Brazil.

Escudero, P., & Vasiliev, P. (2011, March). “The interrelation between sound perception and word recognition in English learners of Spanish.” Invited talk, School of International Letters and Cultures. Arizona State University.

Vasiliev, P., & Escudero, P. (2010, November). "Californian English listeners' perception of Spanish vowels." Poster presentation, 160<sup>th</sup> Meeting of the Acoustical Society of America, Cancun.

Vasiliev, P., Escudero, P., & Quicoli, C. (2010, February). "An Auditory Correlate for Vowel Height: testing Syrdal and Gopal's model with Brazilian Portuguese Vowels." Panel presentation, 36<sup>th</sup> Meeting of the Berkeley Linguistics Society.

Vasiliev, P. (2008, August). "Um estudo acústico da nasalização no português brasileiro." Oral presentation, XV International Congress of the Asociación Latinoamericana de Filología y Lingüística (ALFAL), Montevideo, Uruguay.

#### HONORS AND AWARDS:

##### **Research Grants and Fellowships:**

Dissertation Year Fellowship, Recipient, Graduate Division, University of California, Los Angeles, July 2012-July 2013.

Ben and Rue Pine Travel Grant, Recipient, Department of Spanish and Portuguese, University of California, Los Angeles, Summer 2011.

Latin American Institute Summer Research Grant, Recipient, University of California, Los Angeles, 2009.

Graduate Research Mentorship, Recipient, University of California, Los Angeles, 2008.

Graduate Summer Research Mentorship, Recipient, University of California, Los Angeles, 2008.

##### **Teaching Awards:**

Distinguished Teaching Assistant Award, Nominee, University of California, Los Angeles, 2011.

Outstanding Teaching Assistant of the Year Award, Recipient, Department of Spanish and Portuguese, University of California, Los Angeles, 2010.

Outstanding First-Year Teaching Assistant Award, Recipient, Department of Spanish and Portuguese, University of California, Los Angeles, 2006.

# CHAPTER 1

## Introduction

### 1.0 General introduction

Foreign-language learners struggle when it comes to learning to produce the sounds of a target language accurately. These difficulties manifest themselves in the production of vowels, consonants, and suprasegmental features, as can be observed in the phenomenon of “foreign-accented speech”. Recent second-language (L2) acquisition proposals claim that in order to produce L2 sounds accurately the learner must first acquire an accurate perception of these sounds. According to the main current models of nonnative and L2 speech, such as the Perceptual Assimilation Model (Best, 1995), the Speech Learning Model (Flege, 1995), and the Second Language Linguistic Perception Model (L2LP, Escudero, 2005, 2007, 2009), the level of difficulty in acquiring specific nonnative sounds is related to the differences between the phonetic and phonological structure of a listeners’ native language and that of the target language. The present study examines the case of Californian English listeners’ perception of Spanish and Portuguese vowels.

English, Spanish and Portuguese differ greatly in their vowel systems. While American English has ten stressed vowel phonemes, Portuguese has seven, and Spanish, five. The shared vowels between the three languages are common only in their labels, while actually being different in their acoustic characteristics, such as formant structure and duration. These differences typically lead to a series of difficulties that speakers of a particular native language have when trying to perceive and produce the vowels of a foreign language accurately. Extensive speech perception research has been dedicated to

studying how native speakers of languages (L1) with fewer vowels, such as Spanish or Portuguese, perceive and produce vowels in a foreign language (L2) with a larger vowel inventory, such as English. In fact, learning to perceive a phonological difference that does not exist in one's native language is a difficult task. Native speakers of Spanish, for instance, have been shown not to distinguish between the English vowels /i/ and /ɪ/ (Escudero, 2001; 2005), whereas Spanish-dominant Spanish-Catalan bilinguals do not distinguish the Catalan open and closed mid vowel contrasts, even after prolonged exposure to the language (Pallier et al., 1997). Crucially, the inability to hear novel phonological differences has been also shown to lead to difficulties in learning minimal pairs of words in the target language, distinguished by a contrast that is not present in the native language (Cutler, 2005).

The opposite scenario, namely, that of speakers of languages with many vowel categories, such as English, acquiring a language with fewer vowels, such as Spanish or Portuguese, has not received as much attention in the field of second language speech perception, mainly because it was not expected to pose any particular difficulties. However, Escudero and Boersma (2002) demonstrated that Dutch learners of Spanish, whose native language has more vowel categories than the target language, did not perceive the Spanish vowels /e/ and /i/ in an accurate, native-like manner. The authors claimed that the difficulty was due to the fact that Dutch listeners assimilated the two Spanish vowels to three different native vowels. This phenomenon of Multiple Category Assimilation (MCA) was shown to be problematic for learners, at least in an orthographic test of Spanish perceptual proficiency. The main research question of the present study of Spanish and Portuguese vowel perception in English listeners is whether there is MCA

and whether this phenomenon adversely affects listeners' ability to categorize target language vowels in a purely auditory task, without the possibly confounding influence of foreign orthographic labels.

This chapter is dedicated to providing a motivation for the current study as well as an overview of the research questions and experimental design. Section 1.1 discusses issues such as why it is important to study inexperienced listeners' cross-language perception of target language sounds, as well as why vowels are a particularly important element when it investigate when it comes to cross-language perception, and finally why Spanish and Portuguese vowels, as perceived by native speakers of English, present a case scenario that is important to investigate. Section 1.2 presents the main research questions of this study and an overview of the experimental design used to answer those questions.

## **1.1 Motivation for the study**

### 1.1.1 Why cross-language perception?

Cross-language or nonnative perception refers to monolingual listeners' perception of a target language, while L2 perception is that of learners of a second language. For the purposes of evaluating empirical research in the field, Best and Tyler (2007) state that the subjects of nonnative perception studies are “functional monolinguals, i.e., not actively learning or using a second language, [who] are linguistically naïve to the target language of the test stimuli” (16). L2 learners, in turn, “are in the process of *actively learning* an L2 to achieve functional, communicative goals, that is not merely in a classroom for satisfaction of educational requirements” (16).



According to several recent models of nonnative speech processing (PAM, L2LP), learners' initial L2 perceptual system may be equivalent to their native language perception (Best and Tyler, 2007; Escudero, 2005). Studying how learners categorize L2 sounds may not be indicative of the initial difficulties they face, as some perceptual learning has already taken place. Therefore, it is necessary to study inexperienced listeners in order to characterize their initial state of acquisition of a particular L2, thus laying a foundation for further L2 perceptual development studies.

Several recent studies have investigated the *initial state* with which learners come to the task of L2 perceptual development. Within the L2LP framework (Escudero, 2005), Escudero and Chládková (2010) compared Peruvian Spanish listeners' perceptual assimilation patterns for Standard Southern British English (SSBE) and American English (AE) vowels and found that acoustic similarity between each of the English varieties and the native Spanish vowels was a good predictor of the assimilation patterns. Similarly, Escudero and Williams (2011) explored the perceptual assimilation of Dutch vowels by monolingual Peruvian Spanish listeners and made predictions for Peruvian Spanish learners of L2 Dutch using the L2LP model. Within the PAM framework (Best, 1995), Gilichinskaya and Strange (2010) investigated whether listeners' cross-language assimilation patterns of American English (AE) vowels to native Russian categories could be predicted by an acoustical comparison of AE and Russian vowels. Based on the perceptual assimilation patterns the authors sought to make predictions about which AE vowel contrasts would be most difficult to acquire in terms of the PAM model.

One of the main goals of the present study is also to investigate the perceived similarity of nonnative Spanish and Portuguese vowels to native vowel categories in

monolingual Californian English listeners in order to establish a baseline for future studies with L2 learners and to make predictions about the relative ease of acquisition of Spanish and Portuguese vowel contrasts by these learners using both the PAM and the L2LP models.

### 1.1.2 Why vowels?

It has been widely demonstrated that L2 learners differ from native speakers in their perception of both consonantal and vocalic segments. Nevertheless, vowels are especially important because they are produced with higher intensity and longer duration than consonants, so they carry more acoustic information than other segments, according to Best (2003). Vowels also tend to be more variable than consonants, both among languages and among dialects (Best, 2003). This makes vowels an ideal testing ground to evaluate the claim that speech perception is linguistic in nature and is shaped by language-specific mappings of the acoustic signal onto abstract phonetic categories. Therefore, while bearing in mind the broader question of L2 acquisition of Spanish and Portuguese phonology by English learners, this study focuses on vowel perception in particular.

### 1.1.3 Why Spanish and Portuguese vowels?

Numerous cross-language and L2 studies have focused on learners of languages with a smaller vowel inventory (Spanish, Italian, Catalan, French) who acquire languages with a larger inventory, such as Escudero and Chládková (2010) and Fox, Flege, and Munro (1995) for Spanish, Lengeris (2009) for Spanish and Greek, Jia et al. (2006) for

Mandarin, and for Russian, Gilichinskaya and Strange (2010). This is mainly due to the fact that learning to distinguish contrasts that are not present in one's L1 has been shown to be very difficult for learners to achieve. Nevertheless, recent research has shown that learning to perceive a subset of one's native vowel categories may also present a nontrivial learning problem. Escudero and Boersma (2002) demonstrated that L1 Dutch learners of Spanish assimilate the Spanish front vowels /i/ and /e/ to more than one native vowel, a phenomenon the authors called Multiple Category Assimilation (MCA). MCA is defined as contrast in the L2 that is assimilated to more than two categories in the L1 (Escudero and Boersma, 2002). Figure 1.1 gives three examples of multiple-category assimilation. The first one is the specific example that Escudero and Boersma (2002) investigated in their study.

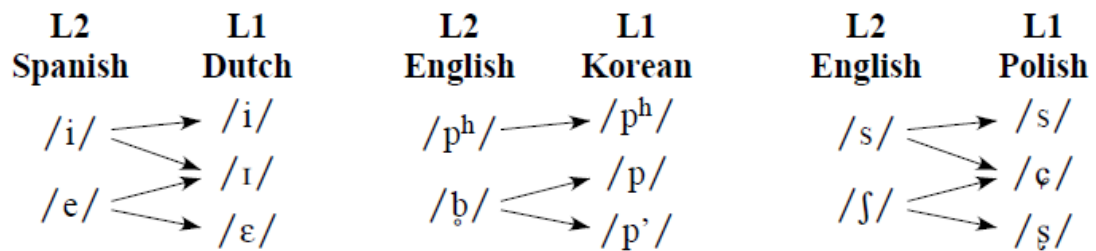


Figure 1.1. Three examples of multiple-category assimilation (from Escudero and Boersma, 2002)

To illustrate, a Dutch learner of English has a “representational” task at hand: he has to learn that /ɪ/ is not a category in Spanish. Even if this task is achieved somewhat easily through lexical learning, there is still a “perceptual” learning task, as the listener cannot help but hear the extra category in the input. Escudero and Boersma (2002)

demonstrated the problematicity of multiple category assimilation by presenting the same tokens of Spanish /e/ and /i/ to a group of Dutch monolingual listeners and to three groups of Dutch learners of Spanish of different levels of proficiency, and by manipulating the “language set” variable to control the language mode in which the listeners would approach the task (Grosjean, 2001). They found that L1 Dutch learners of Spanish assimilate the Spanish front vowels /i/ and /e/ to more than three native vowels, a phenomenon the authors called Multiple Category Assimilation (MCA). In a Spanish task, these Dutch learners of Spanish were dramatically less accurate at identifying Spanish front vowels than native Spanish listeners, which may be attributed to their nonnative perceptual assimilation pattern, i.e., via MCA. Based on the findings, the authors suggest that learning a smaller inventory involves a subset problem in acquisition, i.e., learning on the basis of positive evidence alone that certain categories do not exist in the target language, as well as a perceptual subset problem, that is, the learner cannot help but perceive extra categories in the L2 input. The present study investigates monolingual California English (CE) listeners’ perception of Spanish and Portuguese vowels. Since CE has (at least) 10 vowel phonemes, learning the Spanish five-vowel inventory or the Portuguese seven-vowel system is a case of the subset scenario or MCA, and according to the L2LP, we expect CE listeners to map Spanish and Portuguese vowel contrasts onto several native categories. The aim of our study is to determine whether MCA exists for CE listeners with Spanish and Portuguese vowels and whether this scenario is perceptually problematic for listeners, as the L2LP claims. In the next section the main research questions for this scenario are discussed.

## 1.2 Research proposal

As stated earlier, Escudero and Boersma (2002) demonstrated that Dutch learners of Spanish, whose native vowel inventory contains more categories than their L2 Spanish, exhibit nonnative-like perception of the Spanish front vowel contrast /i-e/. The authors have also shown that this nonnative perceptual boundary is directly related to the phenomenon of multiple category assimilation, where the two members of the Spanish /i-e/ contrast are each assimilated to more than one native Dutch category. Thus a Dutch learner of Spanish faces a perceptual subset issue, i.e., he must learn not to perceive the extraneous native category when listening to Spanish as well as adjust the L2 category boundary to match the optimal Spanish production boundary. Morrison (2003) demonstrated a similar phenomenon for Canadian English learners of Spanish.

The present study explores the phenomenon of multiple category assimilation for California English listeners with Spanish and Portuguese vowels. Following L2LP, it is first necessary to characterize the initial state of perception of Spanish and Portuguese vowels for these listeners in order to generate predictions about their further development as L2 learners of Spanish and Portuguese. Although multiple category assimilation has been shown to exist and also likely to cause problems in categorization of L2 sounds, this problematicity has only been demonstrated in cross-language categorization tasks with nonnative orthographic labels. Nevertheless, orthography may have been a confounding factor, since it has been shown that L1 orthographic correspondences affect not only L2 word recognition (Weber and Cutler, 2004, Escudero, Hayes-Harb, and Mitterer, 2008) but also nonnative segmental perception (Escudero and Wanrooij, 2010). The perceptual assimilation patterns for Spanish and Portuguese vowels onto native English categories

are investigated using the paradigm of a perceptual assimilation task (e.g., Levy and Strange, 2008). Secondly, nonnative perceptual proficiency is tested using a paradigm that does not employ orthographic labels. One such paradigm is the two-alternative forced choice identification task in XAB format, which is a type of categorial discrimination task (e.g., Flege and MacKay, 2004), where the listener is asked to compare tokens of the target language vowels to prototypical target tokens, without the need for orthographic labels. These questions are explored with Californian English listeners using both Spanish and Portuguese vowel tokens. Following the L2LP model (Escudero, 2005), predictions for the present study are based on detailed acoustic comparisons of Californian English, Peruvian Spanish, and Brazilian Portuguese vowels (see Chapter 3). The F1/F2 spaces of the three languages are shown in figure 1.2 below.

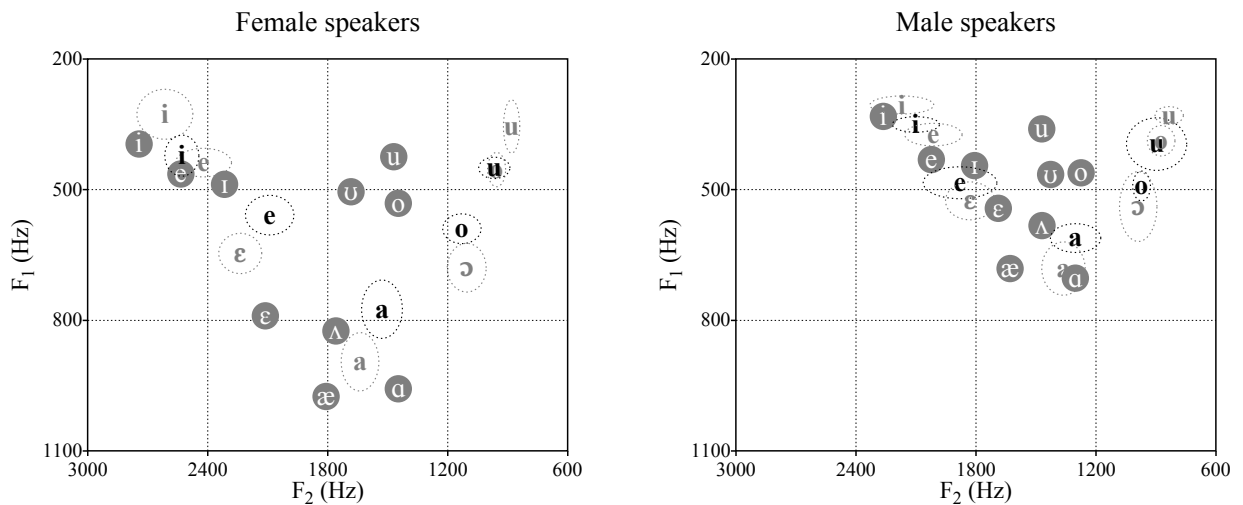


Figure 1.2. Average female and male F1 and F2 values for CE vowels (white symbols, grey circles) from Hagiwara (1997), as well as for the Spanish (black symbols) from Hagiwara (1997).

Chládková et al. (2011) and Portuguese tokens (grey symbols) from Escudero, Boersma, Rauber, and Bion (2009). Ellipses represent one standard deviation from the mean.

Based upon an examination of the F1/F2 vowel spaces of CE in comparison with Spanish and Portuguese, it is possible to speculate about how Spanish and Portuguese vowels *may* be mapped to native CE vowels. We expect CE listeners to map almost every Spanish and Portuguese vowel to more than one native vowel. Furthermore, due to differences in formant structure between the phonologically common vowels in Spanish and Portuguese, we expect to find some cross-linguistic differences in how these vowels are identified in terms of native English categories.

The main research questions of the present study are the following:

Q1. Assess Californian English listeners' perceptual assimilation of Spanish and Portuguese vowels to native English categories. Is there MCA? What are the perceptual assimilation patterns in terms of the PAM and the L2LP scenarios?

Q2. Assess these listeners' accuracy in a categorial discrimination task with the same Spanish and Portuguese vowel stimuli. Do listeners find some Spanish and Portuguese vowel contrasts harder to discriminate than others?

Q3. Do perceptual assimilation patterns predict difficulty in a categorial discrimination task, as proposed by the PAM model (Best, 1995)?

Q4. Is the MCA scenario perceptually problematic for CE listeners?

In order to answer the first research question, a perceptual assimilation task was administered to monolingual Californian English listeners, in which they listened to recordings of Spanish and Portuguese vowels and labeled them in terms of native English vowels, presented in key words. The recordings were part of the corpus collected by Escudero, Boersma, Rauber, and Bion (2009) and Chládková et al. (2011) from monolingual speakers of Portuguese (Sao Paulo) and Spanish (Lima). Classification percentages for each Spanish and Portuguese vowel mapped onto one of ten native English categories were calculated and compared between languages.

To answer the second research question of whether listeners find some Spanish and Portuguese vowel contrasts more to discriminate than others, a categorial discrimination test in XAB format was used. It was designed to test whether CE listeners can accurately discriminate between adjacent vowels in the two target languages based on abstract phonological categories rather than mere acoustic/auditory identity.

For the third research question, in order to determine whether perceptual assimilation patterns predict difficulty in a categorial discrimination task, as proposed by the PAM, perceptual assimilation overlap scores were calculated based on the perceptual assimilation task results for each Spanish and Portuguese vowel contrast following the metric introduced in Levy (2009a). Levy (2009a) introduced the perceptual assimilation *overlap score* metric in order to test the link between perceptual assimilation and discrimination, as posited by the PAM (Best, 1995). Perceptual assimilation was operationalized by computing an assimilation overlap score, which was calculated for each vowel pair by adding the minority percentages of times that the two members of a pair were mapped to the same native categories. Levy (2009a) found that both group and



individual perceptual overlap scores were correlated with more errors in an AXB discrimination task with Parisian French vowels for inexperienced American English listeners, as well as for L2 learners. In order to answer the question whether perceptual assimilation patterns are predictive of discrimination accuracy for CE listeners with Spanish and Portuguese vowels, the extent to which the members of a Spanish or Portuguese binary vowel contrasts were mapped to the same native English categories was quantified in terms of perceptual overlap scores and compared to the discrimination accuracy obtained for each vowel contrasts.

Finally, to answer the question of whether MCA is perceptually problematic for CE listeners, we shall examine whether those Spanish and Portuguese vowel contrasts that were mapped to CE categories via MCA were difficult for CE listeners to discriminate.

The rest of this dissertation is organized as follows. Chapter 2 discusses the main theories of L2 phonological acquisition and reviews the current findings on nonnative and L2 perception of Spanish and Portuguese consonants, vowels, and suprasegmental features, such as stress and intonation. A special emphasis is made on studies investigating English perception of Spanish and Portuguese vowels, as it is most pertinent to the present study. Chapter 3 presents the experimental design of the empirical study, namely the participants, the stimuli, and the tasks. Expected results are also formulated and an outline is provided for how the data will be analyzed. In Chapter 4 the results of the perceptual assimilation task are presented and discussed. Based on these results, predictions are made about the relative ease of discrimination of various Spanish and Portuguese vowel contrasts using the PAM framework. Chapter 5 is dedicated to

presenting and analyzing the results of the categorial discrimination task with Spanish and Portuguese stimuli. Finally, Chapter 6 brings together the empirical results of the present study and the main theories that have been proposed to explain the phenomena of nonnative categorization and discrimination of sounds.

## CHAPTER 2

### Nonnative perception: theories and findings

#### 2.0 Introduction

In the field of L2 acquisition of phonology, speech production has received more attention than perception, and relatively little is known about nonnative and L2 perception of Spanish and Portuguese sounds. Research on the acquisition of L2 Spanish phonology, however, has a relatively long history, dating back to important studies such as Lado (1956) and Stockwell and Bowen (1965), which explained English speaking learners' difficulties with Spanish pronunciation by comparing the phonological systems of English and Spanish. Until recently, however, no particular attention was given to how Spanish sounds were perceived by L2 learners. Speech perception research in L2 Spanish is only starting to answer questions such as which specific sounds and sound patterns of Spanish are difficult for L2 learners to perceive, how L1 background relates to these perceptual difficulties, whether L2 learners of Spanish attain native-like L2 perception, and which factors influence successful acquisition of L2 Spanish perception.

This chapter provides a review of experimental and theoretical works relevant to speech perception in second language (L2) Spanish and Portuguese. I first discuss some facts on L2 speech perception in general, including the models that have been proposed to account for these facts. Next, I review empirical studies on the perception of vowels, consonants, and suprasegmental features, such as lexical stress and intonation, in the L2 Spanish and L2 Portuguese of learners from different L1 backgrounds. For each topic,

relevant studies on Spanish are discussed first, followed by Portuguese, whenever such studies are available.

## **2.1 Some facts about L2 speech perception**

Early research on L2 phonological acquisition was already informed by the insight that L2 learners' "foreign accent" arises from the influence of the L1 perceptual system. Polivanov (1931/1964) gave examples of how L2 phonemes are perceived through the L1 system, while Trubetzkoy (1939/1969) claimed that the L1 system served as a "phonological filter" for the perception and categorization of L2 sounds. Nevertheless, many subsequent approaches to L2 phonological acquisition focused mainly on production (e.g., Lado, 1957; Eckman, 1977; Major, 1987). More recently, however, a growing body of cross-linguistic perception research has shown that learners reuse their L1 perceptual strategies when learning L2 sound categories (see Strange, 1995 for a review). Furthermore, it has often been claimed that in L2 acquisition accurate perception precedes accurate production and is in fact a prerequisite for it. Llisterra (1995) and Leather (1999), for instance, provide a review of a large number of studies that support the view that L2 perception precedes accurate production and is a prerequisite for it. Borden, Gerber & Milsark (1983) found that Korean learners of English were more native-like in phonemic identification than in production of the English /r/-/l/ contrast. Barry (1989) and Grasseger (1991) found that learners who had "well-established perceptual categories" were also more accurate in producing those categories. Flege (1993) and Rochet (1995) also provided further support for the

precedence of L2 perception over production and the idea that it is in fact a prerequisite to native-like production.

Not all research in L2 perception and production is in agreement on this matter. Sheldon and Strange (1982) studied Japanese learners of English in their perception and production of the English /r/-/l/ contrast, and found that perception may lag behind accurate production. Several bilingual studies have demonstrated that production can be more accurate than perception (e.g, Elman et al., 1977; Mack, 1989). Nevertheless, as Escudero (2005) points out, the experimental setup of these studies may have influenced the results. A variable that none of the bilingual studies controlled for is “language set”, i. e. making sure that the bilingual subject is not activating both languages simultaneously. If the listeners were in “bilingual mode,” i.e. activating both of their languages while performing the perception task, their perception may have been less native-like (monolingual) than their production. Thus, the majority of the evidence seems to suggest that perception needs to be mastered first before accurate production can be achieved.

Insight into the factors leading to the difficulty that adult learners experience when attempting to acquire accurate L2 perception can be found in the field of L1 sound perception. Infants become attuned to the language-specific properties of their L1 within the first year of life and learn to ignore acoustic properties that do not play a role in their language (e.g., Kuhl et al., 1992; Jusczyk et al., 1993; Werker and Tees, 1984). Thus, adult learners’ problems with perceiving L2 sound differences stem from the fact that such differences are not made in their L1. L2 learners’ difficulty has been documented for almost every aspect of perception, including vowels (e.g., Pallier, Bosch, and

Sebastián-Gallés, 1997), consonants (e.g., Iverson et al., 2008), and suprasegmental features (e.g., Dupoux et al., 2008).

Importantly, not all L2 sounds cause equal difficulty: numerous studies have shown that the ability to distinguish L2 sound contrasts that do not differentiate meaning in the L1 may vary from near-chance (guessing) to near-ceiling (native-like), thus showing that listeners attend to the fine-grained acoustic differences between L1 and L2 segments (see Strange, 1995 for a review of these studies).

Below I discuss some of the models that have been proposed to account for L2 sound perception, including the relative degree of difficulty that specific sounds may have. A number of theoretical models have been proposed to account for L2 learners' difficulty in acquiring L2 sounds. Here I will focus on models that include perception as a key factor to predicting “success” in L2 phonological acquisition.

## **2.2 Theoretical models of L2 perception**

### **2.2.1 The Native Language Magnet Model**

The Native Language Magnet model (NLM) (Kuhl, 1991) is mainly concerned with first language acquisition, so it will not be discussed in much detail here. NLM proposes that early in life, infants develop acoustic prototypes for native phonemic categories. Native prototypes have magnet-like effects, in which the nearby perceptual space is “shrunk,” making it more difficult to discriminate phonetic variation around prototypes than around non-prototypes, or poor exemplars of the same category. Infants are initially capable of discriminating almost all sound contrasts, including those not exploited in their native

language. Adults, on the other hand, are not as sensitive to sound differences outside their native language. NLM claims that exposure to the native language results in a distortion of the perceptual space. Native phonetic categories are organized as phonetic prototypes, or best instances of a category. A prototype attracts other sounds within the same category, thus reducing the perceptual distance between it and other members, a phenomenon Kuhl (1991) describes as the perceptual magnet effect. This has been confirmed for adults and infants as young as six months of age in an experiment involving synthetic vowels that varied around a prototypic /i:/ and a non-prototypic instance of the same vowel. Discrimination of variants around the prototype was significantly poorer than that of variants around the non-prototypic exemplar of the same vowel.

As far as L2 speech perception is concerned, NLM posits that the perceptual magnets and boundaries of the native language are transferred to L2 speech. L2 speech sounds that are phonetically similar to established L1 categories are affected by the magnet effect, so their perception may be significantly influenced by the distorted perceptual space.

### 2.2.2 The Speech Learning Model

James Flege's Speech Learning Model (SLM), as described in Flege (1995) and Flege and MacKay (2004), has focused primarily on the L2 speech production of experienced learners, although the model also has a strong perceptual component. The SLM proposes that adults retain the ability to accurately perceive the properties of L2 sounds and to form new phonetic categories throughout their lifetime, but the success of L2 learning

depends on the perceived cross-language similarity between L2 and L1 sounds, as well as the age at which learning starts and the amount of L1 use. The SLM proposes that L2 sound perception is dominated by Equivalence Classification, which is a process whereby learners identify physically different tokens of L2 sounds as instances of a particular L1 phonetic category at a position-sensitive allophonic level, rather than at the level of phonemes.

The SLM predicts that “similar” L2 sounds, those that are perceived as phonetically close to a native category, will be more difficult to acquire because learners are less likely to create separate L2 categories for these acoustically similar sounds. On the other hand, “new” L2 sounds, namely those that are not acoustically close to any native category, are more likely to result in the creation of a new L2 category in the learner, given enough exposure to the L2, and facilitated by early age of onset of learning (AOL) and little L1 use. Interestingly, Flege claims that equivalence classification not only results in inaccurate representations for L2 sounds, but also that learners’ L1 phonetic categories will be affected, even in early stages of L2 learning. This is because, according to Flege (see Flege, 2002), L1 and L2 categories are represented cognitively in a common phonological space and will influence each other.

### 2.2.3 The Perceptual Assimilation Model

While the SLM makes its predictions based on a comparison of individual sounds in L1 and L2 to explain nonnative perception, the Perceptual Assimilation Model (PAM) (Best, 1995; Guion et al., 2000), and its extension to L2 acquisition, PAM-L2 (Best and Tyler,



2007), compares L2 sound contrasts to L1 categories. It was proposed originally to account for the fact that not all “new” foreign sounds are hard for inexperienced listeners to discriminate. The PAM is rooted in Motor Theory (Liberman and Mattingly, 1985) and it advocates a direct-realist account of speech perception (Best, 1995). Thus, the model considers actual articulatory gestures to be the primitives of speech perception and claims that phonemes correspond to stable gestural “constellations”. Nonnative gestures, on the other hand, are assumed to be perceived in terms of their similarities to and differences from the closest native gestural constellations. With regard to cross-language perception, the PAM proposes that accuracy in the discrimination of nonnative sound contrasts depends on the way the members of each contrast are assimilated (or perceptually equated) to L1 sound categories. For example, when two nonnative sounds are assimilated to two different L1 categories (two-category assimilation), discrimination is predicted to be very good, whereas when they are mapped onto a single L1 category as equally good exemplars of it (single-category assimilation), discrimination is predicted to be poor. In cases where both members of the L2 contrast are mapped to the same L1 sound, but one member is a “better” exemplar of the native category than the other, discrimination is expected to vary depending on the degree of the category-goodness difference. Furthermore, L2 sounds can be uncategorizable, that is, still heard as speech sounds but not mapped onto any single L1 category, or heard as non-speech.

The PAM-L2 (Best and Tyler, 2007) adopts Flege’s proposal that L1 and L2 categories exist in a common phonological space. Reinterpreting SLM tenets in PAM terms, PAM-L2 makes predictions about whether L2 learners will form a separate category for an L2 sound based both on its perceived distance from an L1 phonetic

category and on a comparison of the L1 and L2 phonological contrasts. Thus, for instance, in the case of category-goodness assimilation, the member of an L2 contrast that is perceived as a good exemplar of a native category is likely to be merged with the L1 sound, whereas the poorer exemplar may be learned as a separate L2 category.

#### 2.2.4 The Second-Language Linguistic Perception Model

More recently, the Second Language Linguistic Perception model (L2LP) has been proposed in an attempt to capture the entire developmental process of L2 speech perception (Escudero, 2005; 2007; 2009). The L2LP claims that upon first encountering the L2, learners create a duplicate of their L1 perception system and handle L2 sounds through this newly formed system, thus leaving the L1 perceptual system intact, contrary to the claims made by the SLM. Thus, it is possible for a learner to exhibit native-like perception in both languages because L1 and L2 are handled by two separate systems, making native-like performance possible (although not guaranteed) in both languages.

The L2LP, just like the PAM, makes predictions about the relative ease of nonnative sound perception based on a comparison of L2 contrasts to L1 categories. Nevertheless, it diverges from the PAM in that it does not accept that a sound can be truly uncategorizable. As Escudero and Boersma (2002) argue, if a sound was truly not assimilable to any native category, then all native categories would make equally good attractors for this new sound, and this has never been the case in previous studies. Furthermore, studies like Rochet (1995) have shown that there is no uncommitted vowel

space in the learners' L1 system, and all L2 sounds are necessarily perceived as some native category.

With respect to L2 development, unlike the two previous models, the L2LP proposes different scenarios that entail different *learning tasks*. If learners map an L2 contrast to a single native category, via Single Category assimilation in Best's terms or as a New Scenario in the terms of L2LP, they will need to create a new L2 category or split an existing L1 category to acquire the new contrast. If, on the other hand, learners map a new contrast to two different native categories, known as Two Category assimilation in the PAM or Similar Scenario in the L2LP, they will have to merely reuse existing L1 categories and shift their native category boundary to the optimal location for the L2. A Category Boundary Shift is predicted to be easier to achieve than a Category Split or Category Creation.

The L2LP also advances a third possibility, already introduced in Chapter 1 of this dissertation, namely the Subset or Multiple Category Assimilation Scenario (Escudero and Boersma, 2002; Escudero, 2005; Boersma and Escudero, 2008), which occurs when the learner's L2 contains a subset of the sound categories present in the L1. Escudero and Boersma (2002) investigated this scenario in Dutch learners of Spanish, a case that will be discussed in more detail in the next section.

## 2.3 Empirical findings in L2 perception of Spanish and Portuguese

### 2.3.1 Perception of vowels

The most commonly studied scenario in L2 vowel perception is that of learners of languages with smaller vowel inventories acquiring languages with larger vowel inventories, mainly because learning novel vowel contrasts has been demonstrated to be very difficult for L2 learners (e.g., Pallier, Bosch, and Sebastián-Gallés, 1997; Flege, Bohn, and Jang, 1997). The perception and production of L2 Spanish vowels has not received much attention due to its relatively small, and perhaps easy to acquire, five-vowel system.

One case of learners of Spanish whose L1 has a smaller vowel inventory is that of L1 Quichua (Ecuadorian Quechua) learners of Spanish, whose native vowel system consists of three vowels, /ɪ, a, ʊ/. Guion (2003) investigated the vowel productions of five Spanish monolingual speakers and 20 Quichua-Spanish speakers who were divided into four groups: simultaneous, early, mid, and late bilinguals. An acoustic analysis of the bilingual speakers' Spanish vowel productions demonstrated that the age at which they learned the L2 was a significant factor for the acquisition of Spanish vowels: only simultaneous bilinguals produced the five Spanish vowels with monolingual-like values. Early and some mid bilinguals acquired Spanish vowels, whereas late bilinguals did not. Furthermore, only some simultaneous and early bilinguals produced their Quichua /ɪ/ with values different from their Spanish /i/ or /e/. Apparently, none of the bilinguals were able to acquire the two Spanish vowels and at the same time maintain a third separate Quichua vowel for back vowels.

Following Flege's SLM terminology, Guion (2003) reinterprets the results in

perceptual terms and hypothesizes that these bilinguals perceptually equate their Quichua /ɪ/ to Spanish /i/ and their Quichua /ʊ/ to either Spanish /u/ or /o/. However, as the author points out, this hypothesis is in need of empirical testing. Thus, it is necessary to investigate the same bilinguals' perception of Spanish and Quichua vowels testing Quichua and Spanish in separate sessions, which was not the case in Guion's (2003) production study and which is suggested in Escudero (2005) to ensure that the listeners are in the "monolingual mode" for each language.

While Quichua-speaking learners of Spanish face the task of developing a vowel system with more categories, speakers of languages such as English, which has more vowels than Spanish, face the opposite scenario, namely that of acquiring a subset of their L1 vowels. Much less is known about the *subset scenario* (as proposed by Escudero and Boersma 2002 and Escudero 2005) in L2 vowel perception, probably because it has often been assumed that it should not present any significant perceptual difficulties (cf. Simonet, 2012). If phonological equivalence told the whole story, English speakers would be able to reuse the five English vowels that are phonemically equivalent to the five Spanish vowels or at the most make some minor adjustments in category boundaries for their L2 vowel system (as suggested in Escudero 2005).

One of the few studies that has considered this scenario presented American English (AE) listeners with synthetic vowel tokens along the Spanish /i/-/e/ and /o/-/u/ continua in an identification task with orthographic labels corresponding to AE /i/ and /e/ or /o/ and /u/ (Bradlow, 1996). The results demonstrated that whether listeners categorized the stimuli as one or the other category was strongly affected by the presence of extra AE phonological categories. The uncertainty regions, where AE listeners

identified the Spanish-like stimuli with less than 80% consistency, corresponded to the regions in the acoustic space occupied by their native /ɪ/ and /ʊ/ categories. Additionally, Fox, Flege, and Munro (1995) found that monolingual English listeners use different dimensions to perceive Spanish-like vowel stimuli than native Spanish listeners, thus suggesting that these differences might interfere with their native-like L2 perceptual acquisition.

Although Bradlow (1996) and Fox et al. (1995) suggest that having more categories and perceptual dimensions in the L1 may affect listeners' identification of Spanish vowels, Escudero and Boersma (2002) were the first to directly demonstrate the problematic nature of the subset scenario. They presented naturally produced tokens of Spanish /i/ and /e/ to L1 Dutch monolinguals and to Dutch learners of L2 Spanish.

The first task sought to demonstrate that Dutch listeners used all three short Dutch vowel categories (/i/, /ɪ/ and /ɛ/) when classifying the Spanish vowels /i/ and /e/. Listeners were presented with CVC tokens containing the two Spanish vowels and embedded in a Dutch carrier phrase and supplemented with Dutch sounding fillers. The tokens were produced by a balanced Spanish-Dutch bilingual. The subjects were told that they were listening to Dutch nonwords and directed to choose from the native Dutch vowel categories presented to them. Results from the first task indicated that Dutch listeners at all levels of Spanish proficiency used all three Dutch categories in their perception of the two Spanish vowels and no significant effect of experience was found, which means that in *monolingual mode*, Dutch learners of Spanish behave the same as monolingual Dutch listeners.

In the second task the same CVC stimuli were embedded in Spanish carrier phrases and supplemented with Spanish-sounding fillers. For this task, listeners were correctly told that they would hear Spanish words but were instructed to listen with “Dutch ears” and to classify the vowels as Dutch vowels. Results showed that listeners did in fact use /ɪ/ less in the “mixed” perception mode. Furthermore, the reduction in /ɪ/ use correlated with the level of experience with the Spanish language.

The third task was a test of perceptual proficiency in Spanish, where the listeners heard the same Spanish stimuli and this time they were asked to identify them in terms of Spanish vowel categories. Based on the number of errors the authors calculated the perceptual boundary between the Spanish /i/ and /e/ for each group of listeners and compared it to the optimal boundary, as indicated by the production boundary. The results are shown in Figure 2.1.

<i>stim:</i>	<b>Dut.</b> <i>resp:</i>	<b>Beg.</b> <i>resp:</i>	<b>Int.</b> <i>resp:</i>	<b>Adv.</b> <i>resp:</i>	<b>Bil.</b> <i>resp:</i>	<b>Spa.</b> <i>resp:</i>
/i/ →	<u>i</u>	<u>i</u>	<u>i</u>	<u>i</u>	<u>i</u>	<u>i</u>
/e/ ↗ ↘	<u>e</u>	<u>e</u>	<u>e</u>	<u>e</u>	<u>e</u>	<u>e</u>

Figure 2.1. Average identification of the 50 Spanish vowel tokens. Dut: monolingual Dutch, Beg: beginning learners of Spanish, Int: intermediate learners of Spanish, Adv: advanced learners of Spanish, Bil: Dutch-Spanish bilinguals, Spa: native Spanish controls (from Escudero and Boersma, 2002).

Surprisingly, inexperienced Dutch listeners mislabeled the Spanish /e/ as /i/ up to 67% of the time. These errors were explained by the listeners' identification of the same tokens as three different Dutch vowels, namely /i/, /ɪ/, and /ɛ/, when performing a Dutch vowel identification task, also known as a perceptual assimilation task, which implies listening to Spanish stimuli and classifying them as vowels in the listeners' L1 (Dutch in this case). The authors demonstrated that Multiple Category Assimilation (MCA), that is, the mapping of two vowels onto more than two native categories, was responsible for Dutch listeners' errors in the Spanish vowel identification task (classifying the same stimuli as Spanish vowels). Advanced but not beginner and intermediate L2 learners of Spanish were native-like in their /e/-/i/ category boundary, as observed in their more accurate performance in the Spanish vowel identification task. This increased accuracy was correlated with a reduction in the use of the extra category /ɪ/ when listeners (aware that they were listening to Spanish) classified Spanish vowels using Dutch vowel labels. The authors conclude that in the case of the subset scenario, Dutch learners of Spanish are capable of eliminating the extraneous category from their perceptual grammars and shifting the category boundary for the Spanish /e/-/i/ contrast to a native-like position.

Interestingly, other studies investigating the subset scenario with L1 English learners of Spanish found evidence for MCA, yet no significant problems in Spanish vowel identification. Following Escudero and Boersma's experimental design, Morrison (2003) found instances of MCA in Canadian English learners of Spanish, but there was no dramatic problem in their vowel identification. In an English forced-choice labeling task, Canadian English listeners identified tokens of Spanish /sV/ syllables with the five Spanish vowels in terms of English categories. Morrison found that the Spanish vowel /u/



was assimilated to English /u/ and /o/, while Spanish /a/ was assimilated to the English /æ/, /ʌ/, /ɑ/, and /ɛ/, which lead the author to conclude that Canadian English listeners assimilated two Spanish vowels, namely /u/ and /a/ via MCA. In a Spanish vowel identification task the same listeners misidentified Spanish /i/ as /e/ 10% of the time, /o/ as /u/ 9% of the time and /o/ as /a/ 13% of the time, leading the author to conclude that the listeners' boundaries for these contrasts differed from native Spanish boundaries.

Similarly, Gordon (2008, 2011) found MCA in American English (AE) learners of L2 Spanish for the front vowels /e/ and /i/, but even fewer problems in the Spanish identification task, with over 90% accuracy for the five Spanish vowels. García Bayonas (2007) also found that AE learners of Spanish were over 94% accurate in their identification of the five Spanish vowels with natural stimuli and were native-like in their perception of synthetic Spanish vowels in a Method of Adjustment (MOA) task (Johnson, Flemming, and Wright, 1993). These findings are in contrast to the nonnative-like performance of the Dutch and the Canadian English listeners in a similar perceptual proficiency task.

Importantly, all previous MCA studies used orthographic labels to assess L2 learners' perceptual proficiency with Spanish vowels, which may constitute a confounding factor, especially since Escudero and Wanrooij (2010) have shown that native orthography strongly influences L2 vowel perception. For this reason, the present study uses a non-orthographic categorization task, namely a categorial discrimination task in XAB format to test whether listeners are accurate at categorizing Spanish and Portuguese vowels. Furthermore, monolingual listeners who are unfamiliar with Spanish

and Portuguese cannot be expected to use nonnative orthographic labels as required by a traditional multiple-forced choice identification task.

Turning to the perception of Portuguese vowels, very few studies are available to date. An important perception study involving Portuguese speakers is that of Rochet (1999), which investigated the perception of French /i-u/ continuum by Portuguese and English listeners. Rochet (1995) showed that despite the fact that both Portuguese and English have only two high vowels, namely /i/ and /u/, Portuguese listeners categorize French front rounded vowel /y/ as their own front unrounded /i/ whereas English listeners categorize it as their own back rounded /u/. This fact can be interpreted to mean that the cue-weighting of English and Portuguese listeners is different. While Portuguese listeners pay more attention to F2, the acoustic correlate of the front/back dimension, English listeners favor F3, which corresponds to rounding.

Goodin-Mayeda (2009) studied the effect of language experience on the perception of the coarticulatory effects of nasalization in adult speakers of Spanish and Brazilian Portuguese. She presented listeners with synthetic /u/-/o/ continua in oral, nasal (contrastive) and nasalized (contextual) conditions and found that experience with contrastive nasality, which only Brazilian Portuguese speakers possess, was a factor in how listeners categorized the /u/-/o/ continuum, suggesting that coarticulatory influences of nasalization are perceived in a language-dependent, rather than a universal manner.

Two recent studies deal with native and nonnative perception of Brazilian Portuguese (BP) vowels. For native BP vowel perception, Chládková and Escudero (2012) report on the perception of synthetic BP-like stimuli by monolingual native speakers of BP and compares these listeners perceptual vowel spaces to their production

vowel spaces, as reported in Escudero, Boersma, Rauber, and Bion (2009). In regards to nonnative perception of BP vowels, Elvin and Escudero (2013) is highly relevant to the project of this dissertation, since the study investigated the perceptual assimilation and categorial discrimination of BP vowels in Australian English monolinguals and Spanish-English bilinguals who learned English as a second language. Using the same corpus and very similar experimental procedures as the present study, Elvin and Escudero found that in the XAB categorical discrimination task group accuracy scores were similar on all six BP contrasts but not all contrasts were equally difficult for the listeners. The ranking of difficulty in both monolinguals and bilinguals, from least to most difficult, was /a-ɛ/ << /a-ɔ/ ~ /e-ɛ/ ~ /o-ɔ/ << /e-i/ ~ /o-u/, where “<<” means “easier than” and “~” signifies “no difference”. Interestingly, in the perceptual assimilation task, the two groups differed in their selection of response categories for individual BP vowels, suggesting a task-dependent influence of language background. Elvin and Escudero (2013) suggest that Spanish-English bilinguals performed differently from Australian English monolinguals only in one of the two tasks because of the different number of response categories across tasks and the availability of orthography in only the perceptual assimilation task. These results are discussed vis-à-vis the findings of the current study in Chapter 5 of this dissertation.

To summarize, L2 acquisition of Spanish vowels has been studied in Quichua speakers, whose language has a smaller vowel inventory, but only in production. It would be interesting to see if Quichua speakers’ difficulty in producing new Spanish vowel contrasts is mirrored in their perception of these contrasts. L2 Spanish vowel perception has also been investigated in L1 Dutch and L1 American and Canadian English learners.

It is not yet clear whether learning a vowel inventory that is a subset of the native one presents auditory difficulties to these learners. Nonnative perception of Brazilian Portuguese vowels has been investigated in Australian English monolinguals and Spanish and English bilinguals (Elvin and Escudero, 2013).

### *2.3.2 Perception of consonants*

Studies investigating the production of Spanish consonants by nonnative speakers are more numerous than those investigating the perception of the same segments. For instance, the production of the alternations between Spanish voiced stops /b, d, g/ and approximants /β, ð, ɣ/, as in words like [b]aca, “cow” and ca[β]allo, “horse”, has been studied in English learners of Spanish (e.g., Zampini, 1994; González-Bueno, 1995; Díaz-Campos, 2004; Face and Menke, 2009), yet, as far as I know, no study to date has investigated the perception of Spanish stops and their approximant counterparts in the same learner population.

One area of L2 Spanish consonants that has been investigated thoroughly both in production and perception is that of voiced and voiceless stops in early Spanish–English bilinguals and late English-speaking L2 learners of Spanish (e.g., Zampini, 1998; Zampini and Green, 2001). Here I discuss the relevant findings on L2 perception of the voiced-voiceless distinction. Spanish /p/ has a short-lag positive Voice Onset Time (VOT) (the time between the onset of voicing and the release of the articulators) whereas Spanish/b/ has a negative VOT. In addition, Spanish /b/ (when produced as a stop) has a significantly shorter closure than Spanish /p/. In contrast, English /p/ has a long-lag

positive VOT, while English /b/ has a short-lag positive VOT and does not differ from /p/ in terms of stop closure interval word-initially (Zampini and Green, 2001). Zampini and colleagues (Zampini, 1998; Zampini and Green, 2001) examined the auditory discrimination of the Spanish /p-/b/ in L1 English late learners of Spanish at three different points in the semester. They compared the learners' performance to that of early Spanish-English bilinguals and English monolinguals. L2 learners' perceptual boundary for the VOT of /p/ and /b/ differed from that of English monolinguals in the second and third sessions of this longitudinal study, indicating that perceptual learning had occurred. Furthermore, late learners' perception of /p-/b/ did not differ from that of early Spanish-English bilinguals in the second and third session, which can be interpreted as further evidence of a reorganization of late learners' perceptual abilities.

Green, Zampini, and Clarke (1998) compared English monolinguals and early Spanish-English bilinguals' perception of both VOT and stop closure interval in word-initial /p/ and /b/. They found that, when tested in a monolingual mode, early Spanish-English bilinguals had monolingual-like VOT boundaries in both of their languages. The bilingual listeners also perceived stop closure intervals differently depending on whether they were in English or Spanish mode, suggesting that they had differentiated systems to process each of their languages. It remains to be seen whether late learners of English also acquire Spanish-like perception of stop closure intervals, which is likely since their production is native-like when they are in Spanish mode (Zampini and Green, 2001).

Regarding other Spanish consonants, ample attention has been devoted to the production of the Spanish tap /ɾ/ and trill /r/, as found in such minimal pairs as *caro* 'expensive' and *carro* 'car,' by English-speaking adult learners of Spanish (e.g., Major,

1986; Reeder, 1998; Waltmunson, 2005; Face, 2006). The perception of these segments was investigated by Rose (2010), which studied the perception of intervocalic rhotics by English monolinguals and late L2 Spanish learners with three different levels of L2 experience. In a perceptual assimilation task, English listeners identified tokens of intervocalic Spanish /r/, /r/, /t/, and /d/ presented in real words in terms of six native categories (/ɹ/, /t/, /d/, /s/, /l/ and /ð/), and also rated each token as a good or poor example of the native consonant. The Spanish trill was identified as a fairly good English /ɹ/ over 90% of the time, while the tap was identified as a poor example of the English /ɹ/ (58%) and as a poor /d/ (30%), making the trill-tap contrast a Categorized-Uncategorized type of assimilation in PAM terms (thus discrimination is predicted to be good). The intervocalic /t/ was identified as a fair English /t/ (65%), a poor /d/ (22%), and a poor /ð/ (12%), whereas the Spanish /d/ was mapped to /l/ (54%), /d/ (32%) and /ɹ/ (11%) and was judged to be a poor variant of all three. Thus, the Spanish /r/-/t/ and /r/-/d/ contrasts appeared to be “both uncategorizable,” with discrimination predicted to vary depending on the degree of proximity of the sounds to each other and to the same L1 phonemes.

Rose (2010) tested the predictions of the PAM with an AXB discrimination task, where listeners need to decide whether the middle sound is the same as the first or the third sound. As expected, the /r/-/r/ contrast was discriminated by all learners with accuracy higher than 90%. This finding was interpreted as evidence for the claim that English learners’ difficulties with this contrast are due to articulatory constraints and not an inability to perceive the contrast. The intervocalic /r/-/d/ contrast yielded significantly lower accuracy than both /r/-/r/ and /r/-/t/. The explanation for the relative difficulty of /r/-/d/ may be that both members of the contrast were mapped to the same native

categories, /ɹ/ and /d/, creating some perceptual overlap, which was not the case for /r/-/t/, whose members were mostly mapped to different L1 categories. Some of the limitations of Rose's (2010) study include the use of real words without control for lexical frequency and the use of different tokens in the perceptual assimilation and discrimination tasks.

Spanish dialectal variation and its effect on L2 perception is another topic that has only recently received attention. Schmidt (2011) investigated the acquisition of socio-phonetic variation, namely s-aspiration, in 47 native speakers of Spanish from aspirating and non-aspirating dialects and 215 English-speaking learners of Spanish with varying experience with the target language. The L2 learners began to identify syllable-final word-internal aspirated variants of /s/ in pseudo-words at the high-intermediate level of proficiency and became native-like by the advanced level. Study abroad experience in s-weakening regions was found to have a facilitating effect on the acquisition of perception of the aspirated /s/.

In sum, the most well-investigated area of consonantal perception is that of the distinction between voiced and voiceless consonants, while research on the perception of other Spanish segments is still scarce. Nonnative perception of Portuguese consonants is an unexplored area of study.

### 2.3.3 Suprasegmental phenomena

Suprasegmental phonology is concerned with the organization of vowels and consonants into syllables, as well as features such as stress, tone, intonation, and speech rhythm. In the realm of nonnative perception, the two areas that have received more attention are the

perception of lexical stress and intonation in L2 Spanish. In this section I review perception studies on L2 Spanish lexical stress, L2 Spanish intonation, and L2 phonotactics.

One of the most productive areas of research has been the acquisition of Spanish lexical stress by speakers of French, whose language does not possess contrastive stress. Using different experimental procedures, Dupoux and colleagues (Dupoux, Pallier, Sebastián-Gallés, and Mehler, 1997; Dupoux, Peperkamp, and Sebastián-Gallés, 2001; Dupoux, Sebastián-Gallés, Navarrete, and Peperkamp, 2008) demonstrated that monolingual French speakers were less accurate than native Spanish speakers in discriminating nonce words that were differentiated by the placement of stress only (e.g., [bópelo] vs. [bopélo]). This difficulty was found in cognitively demanding tasks (i.e., those involving higher memory loads due to the phonetic variability of the stimuli), but not in simpler procedures such as AX discrimination tasks, where listeners have to decide if two tokens are the same or different (Dupoux et al., 2001).

An initial explanation for this apparent “stress deafness” was that French speakers lacked a metalinguistic representation for contrastive stress. Dupoux et al. (2008) tested French-speaking listeners at different levels of L2 Spanish proficiency and found that all groups of late learners, regardless of their L2 proficiency, had difficulty in a sequence recall task with stimuli that differed only in stress position. Additionally, in a speeded lexical decision task with word-pseudo-word pairs that differed in stress placement (e.g., [rópa] “clothes” versus [ropá] (nonce word)), advanced learners did not differ from beginners. Dupoux and colleagues concluded that the “stress deafness” was better explained by French listeners’ inability to create separate phonological representations



for different stress patterns.

The authors discuss the methodological and theoretical implications of their study, pointing out the importance of using different experimental procedures in investigating similar phenomena, and claiming that phonetically-based models that rely on prototype formation and only aim at explaining segmental phenomena, such as the PAM (Best 1995) or SLM (Flege 1995), are insufficient to explain the suprasegmental processing limitations, whereas models such as Lado (1957) and Brown (1998), which focus on phonological features, offer a better explanation of this persistent impairment. Further research should show whether a model that is embedded within phonological theory but also takes into account acoustic phonetic detail and considers perceptual and lexical phenomena, such as the L2LP (Escudero, 2005), can explain this type of L2 suprasegmental phenomena.

Studies that demonstrate French listeners' sensitivity to acoustic cues to stress suggest that "stress deafness" is not complete (e.g., Schwab and Llisterri, 2011). Schwab and Llisterri (2011), for instance, conducted an in-depth investigation of nonnative perception of the acoustic cues that signal stress in Spanish by testing French listeners with varying experience with the target language. They asked the listeners to identify the stressed syllable in proparoxytone, paroxytone, and oxytone words and pseudo-words manipulated to investigate the individual and combined influence of fundamental frequency ( $f_0$ ), amplitude, and duration on correct identification of Spanish stress. The authors found that advanced learners of Spanish were faster and more accurate at identifying stress position than monolingual French listeners, thus confirming that exposure to Spanish increases sensitivity to Spanish stress.

As is the case with most other languages, L2 perception of Spanish intonation has received little attention with a few notable exceptions. Nibert (1999; 2000; 2005; 2009) studied the perception of the Spanish phrase accent (T-), which is a tonal category that marks the right edge of intermediate phrases in Spanish intonation. Spanish exploits two distinct levels of phrasing to create meaning contrasts. For instance, the utterance “[lilas y lirios amarillos ]L-]L%” consists of one intermediate phrase delimited by a phrase accent L-, contained within the intonational phrase marked by a boundary tone L% at its right edge, using the standard notation of the Tones and Break Indices (ToBI) framework (Beckman et al. 2002). This form means ‘yellow lilies and irises,’ where both flower types are yellow. When two intermediate phrases are present within an intonational phrase, as in [[lilas ]H- [y lirios amarillos ]L-]L%, the same form maps to a different meaning, ‘lilies and yellow irises.’

In Nibert’s studies, native Spanish listeners as well as L1 English beginning, intermediate, and advanced learners of Spanish identified the meaning of Spanish phrases that varied in the disambiguating high (H-) phrase accent in intonation contours. Nibert (2005) found that intermediate and advanced L2 learners were able to perceive and interpret the H- phrase accent even in phrases that contained complex syntax that is absent in English, and advanced learners’ performance was native-like. L1 transfer was also found in beginning learners, who were only able to interpret correctly the H- phrase accent in syntactic structures similar to those of English (Nibert, 2009). Thus, different stages of L2 development as well as possible ultimate attainment were demonstrated. The results are interpreted as support for the Full Transfer/Full Access to Universal Grammar hypothesis (Schwartz and Sprouse, 1996), which, in general terms, states that at the initial

state of L2 acquisition, learners use their L1 grammar, and that learners have full access to UG when attempting to learn L2 properties.

Spanish intonation is especially challenging from the perspective of L2 learners due to the great dialectal variation that exists between different varieties of Spanish, thus presenting a “moving target” to the learner (Prieto and Roseano, 2010; Trimble, in press). While Nibert’s (2005) participants listened to Peninsular Spanish intonation only, Trimble (in press) incorporated dialectal variation into his study of broad-focus declaratives versus absolute interrogatives by beginning and advanced L1 English learners of L2 Spanish. He found that absolute interrogatives as produced in Andean Venezuelan Spanish, which are marked by a “circumflex” final rise-fall pattern, were harder to identify than those produced by a speaker of Toledo Spanish and a Spanish instructor from the Midwestern United States. Importantly, there was a positive effect of a semester study abroad in Merida, Venezuela, on the learners’ ability to identify the Andean Venezuelan interrogatives (72% accuracy for the study abroad learners versus 52% average for all other learners).

Another under-explored topic in L2 Spanish suprasegmental perception is that of phonotactics. Rather than learning new sounds, the acquisition of phonotactics is concerned with learning the combinations in which different sounds are allowed to occur. Kilpatrick (2009) investigated whether L2 learners are capable of learning, on the basis of positive evidence alone, that some sequences that are grammatical in their L1 are ungrammatical in their L2. For instance, Spanish allows fewer coda consonants than English. In fact, the legal coda consonants in Spanish are a subset of those allowed in English. In Kilpatrick’s perception experiment, L1 English learners of Spanish listened

to bisyllabic nonce words ending in different consonants and had to decide how Spanish-like the stimuli were on a Likert scale from 1 to 9. The stimuli contained some of the codas that are legal both in English and Spanish ([ð, n, s]), thus constituting a subset of the English ones), as well as others that are legal in English but not in Spanish ([k, p, m]). The results indicated that L1 English learners of Spanish give significantly higher ratings to legal Spanish codas than to the ones that are legal only in English. This means that they have acquired a subset of the forms that are grammatical in their L1 as well as the knowledge of the ungrammaticality of the set that does not appear in Spanish.

In sum, empirical studies on the perception of suprasegmental features in L2 Spanish such as lexical stress, intonation, and phonotactics exist but are scarce. Evidence seems to suggest that difficulties with L2 suprasegmental contrasts can persist despite extensive exposure to the target language (e.g., Dupoux et al., 2008), but there is also evidence that learners can make progress towards more native-like perception of intonation (Nibert, 2005; Trimble, in press) and phonotactics (Kilpatrick, 2009). Yet again, when it comes to the perception of suprasegmental features in Portuguese has not been investigated yet.

## **2.4 Summary of the chapter**

The goal of this chapter was to review some influential theoretical models of nonnative and L2 speech perception and provide an overview of speech perception studies in second language (L2) Spanish and Portuguese. Empirical studies on Spanish are far more numerous than those on Portuguese, so this chapter was mainly dedicated to discussing

the perception of vowels, consonants, and suprasegmental features in L2 Spanish. The area of nonnative vowel perception in Spanish and Portuguese is the most directly relevant one to the present study and will be a topic of further discussion in the remainder of this dissertation.

## CHAPTER 3

### Experimental Design

#### 3.0 Introduction

As described in Chapter 1, this dissertation investigates Spanish and Portuguese vowel perception in monolingual speakers of English from Southern California using two different experimental procedures, namely a perceptual assimilation task and a categorical discrimination task. The first task aims at establishing how listeners categorize Spanish and Portuguese vowels in terms of native vowel categories, while the second seeks to determine how accurate the same listeners are at distinguishing adjacent vowels in Spanish and in Portuguese. The link between perceptual assimilation and discrimination accuracy is then examined vis-à-vis the PAM (Best, 1995) and the L2LP (Escudero, 2005) models in Chapters 5 and 6 of this dissertation.

This chapter starts by providing an overview of different experimental procedures used in cross-language perception studies in order to explain the choice of the methodology of the present study. The rest of the chapter is dedicated to describing the experimental design of the study, namely the participants, the natural and synthetic stimuli used in the experiments, and the experimental procedures. Finally, expected results will be discussed and an outline will be provided for the analysis of the data.

### 3.1 Methods for investigating cross-language speech perception

The focus of this section is on methodological issues involved in the design of experiments in cross-language vowel perception. Several factors need to be taken into account when designing a cross-language perceptual assimilation and/or discrimination study, such as the participants, the nature of the task, the stimuli, and the response categories (e.g., Beddor and Gottfried, 1995).

When choosing the subjects, it is important to control not only for native language background and exposure to foreign languages, but also for L1 dialect. Several studies have demonstrated that native language *accent* affects the perception of target language sounds. For instance, Evans and Iverson (2004) showed that speakers of Northern British English listened to Southern British vowels in a “northern way”, even when those vowels were embedded in a Southern-British accented carrier phrase. Escudero (2001) demonstrated that Southern British and Scottish English listeners labeled the same synthetic stimuli on the /i/-/ɪ/ continuum differently, depending on their L1 accent.

Furthermore, several recent studies demonstrate that L2 dialect may also affect nonnative perception. For instance, Escudero and Chládková (2010) found differences in L1 Spanish speakers’ perceptual assimilation of the vowels shared by Standard British English and American English, which according to the L2LP is due to cross-dialectal differences in the acoustic realizations of these vowels. Similarly, Escudero and Williams (2012) found that the acoustic differences between Iberian and Peruvian Spanish vowels lead to a difference in the perception of these vowels in L1 Dutch learners of L2 Spanish.

In order to control for the native dialect, the participants of this study were monolingual speakers of English from Southern California. Furthermore, target language

dialect was also controlled: the listeners were presented with Spanish vowel tokens as produced in Lima, Peru and with Portuguese vowels as produced in Sao Paulo, Brazil.

Many cross-language experiments, even very recent ones like Gilichinskaya and Strange (2010), have used stimuli produced by only one speaker. Nevertheless, a single speaker's vowel productions may not be indicative of the typical vowel productions of the language under investigation and thus may not generalize to the language. Other studies used steady-state synthetic vowels (e.g., Escudero and Chládková, 2010), which lack some of the information present in natural vowels. Thus using natural vowel tokens produced by a large number of speakers is essential to better represent the natural input that the listener confronts in real life. Nevertheless, synthetic stimuli are sometimes preferable when there is a need to manipulate particular acoustic properties of the stimuli, such as duration or formant structure, systematically.

Another issue that needs to be taken into consideration is the consonantal context in which the vowel stimuli are produced and presented. Many studies have shown that consonantal context systematically affects the perceptual assimilation patterns of vowels (e.g., Gottfried, 1984; Strange et al., 2001; Levy, 2009b; Levy and Strange, 2008; Escudero and Vasiliev, 2011). Levy (2009b) and Levy and Strange (2008) showed that American English learners of French as well as American English monolingual listeners assimilated French front rounded vowels differently in bilabial versus in alveolar context, indicating that native language allophonic variation affects cross-language categorization. Escudero and Vasiliev (2011) found that L1 Spanish listeners identified the vowels /ɛ/ and /æ/ differently depending on whether they were produced with Canadian English or Canadian French values and that the consonantal context in which the vowels were



presented affected the perceptual assimilation patterns. Thus, sometimes it may be preferable to use isolated vowels to avoid effects of consonantal context on vowel perception.

The nature of the task is another crucial issue in designing a perception study. The common way of investigating cross-language perceptual assimilation patterns is with forced-choice categorization tasks (e.g., Best and Strange, 1992). A multiple-forced choice task asks the listener to label the stimuli in terms of several native categories, represented orthographically. The number of categories usually corresponds to the full set of phonemes of the L1, although in some studies a two-forced choice paradigm is used, where the stimuli are also blocked by contrast (presented in pairs) and the response options correspond to two native orthographic labels. Studies conducted to investigate the predictions of Best's Perceptual Assimilation Model also tend to include "none" as an option. This presupposes that some of the vowel space is "uncommitted" and some sounds may not be categorizable in terms of any native category.

Goodness of fit is also investigated within the PAM framework by asking the listener to rate the stimuli as good or poor exemplars of a native category on a Likert scale. Since the PAM predicts that a category goodness assimilation type will be easier to discriminate than a Single Category assimilation scenario, it is important to gather information about goodness of fit, within this model. Alternatively, goodness rating may be problematic because they tap into metalinguistic knowledge by asking the listener to consciously rate a token, and this may not be indicative of how the listener actually perceives vowels in real life online speech processing (Escudero, 2005).

According to the PAM, labeling tasks may be used to predict discrimination difficulties, whereas discrimination tasks are used to demonstrate actual nonnative-like performance in foreign listeners. One type of discrimination task is the AX task, or the same-different task. It asks the listener to determine whether the second sound is the same or different from the first. The AX tasks were typically used in early categorical perception studies (e.g., Williams, 1977). An issue with this type of task is that it asks the listener to judge the *physical* identity of two tokens, without necessarily tapping into phonological categorization. Furthermore, a same-different task might cause a bias towards a “same” response when discrimination is difficult (Beddor and Gottfried, 1995).

A different type of task, the categorial discrimination task or XAB, avoids this problem. In an XAB task, X is a physically different token from both A and B but belongs to either the category of A or B. This ensures that the listener cannot make a simple physical identity judgment. Variations of the XAB task, such as AXB and ABX, have also been used in many studies. While some claim that AXB reduces the processing load by making A and B equidistant from X, it has not been demonstrated that the results are any different in an AXB as opposed to the other formats of the same task. Furthermore, the XAB format has been used successfully with children as young as 4 years of age, while other formats of the same task seem to be more difficult to use with children due to their elevated cognitive load.

Furthermore, it has been shown that the Inter-Stimulus Interval (ISI, the time allowed to elapse between the presentation of each sound in a pair or triad) influences sound perception. Werker and Logan (1985) demonstrated that, with a long enough ISI, sound perception may go from purely auditory discrimination of physically different

sounds to a phonological categorization of those sounds. English listeners in their study were able to hear the difference between dental and retroflex Hindi stops, a contrast that is not present in English, when the time between the speech stimuli (ISI) was reduced. Strange (1995) and Escudero (2005) attribute these results to the type of perception that is involved, auditory or phonological. When the stimuli are played with a short interval in between, they may be differentiated on the basis of auditory properties, but when there is a longer interval between the stimuli listeners cannot rely on auditory differences and must activate their phonological representations to discriminate between the sounds.

To summarize, the different methodological issues involved in investigating how monolingual listeners perceive vowels in a different language involve choosing natural versus synthetic stimuli, type and number of response categories, and choosing between several labeling and discrimination tasks available. The rest of the chapter describes the participants, the stimuli, and the tasks utilized in this study.

## **3.2 Methodology of the present study**

### **3.2.1 Participants**

The subjects in this study were 6 male and 12 female monolingual undergraduates between 18 and 30 years of age, born and having lived in Southern California most of their lives. They were selected on the basis of a background questionnaire. A monolingual participant was defined as someone who did not speak or understand any other language with a proficiency of more than 3, self-rated on a scale from 0 to 7.

Since it has been shown that native language dialect affects cross-language and nonnative vowel perception (Escudero and Williams, 2012; Chládková and Podlipský,

2011), monolingual speakers of only the Southern California variety of American English were recruited for the study. The choice of Southern Californians as opposed to Californians in general was based on the following considerations. First of all, there are differences between the Southern and Northern varieties, so they cannot be treated as one. Secondly, since testing took place in Los Angeles, fewer Northern Californians would have been available to participate.

### 3.2.2 Stimuli

For the perceptual assimilation tasks, naturally produced tokens of Spanish and Portuguese vowels were used. For the XAB categorization tasks a subset of the natural Spanish and Portuguese stimuli as well as synthesized prototypes were presented to the listeners.

The stimuli consisted of Peruvian Spanish vowels from the corpus described in Chládková et al. (2011), as well as Brazilian Portuguese vowels from the production data collected for the Escudero, Boersma, Rauber, and Bion (2009) study. These stimuli, as well as the synthetic vowels used in the discrimination task, are described in the sections that follow.

#### *3.2.2.1 Natural stimuli*

The natural stimuli consisted of Peruvian Spanish vowels from the production data described in Chládková et al. (2011) and Brazilian Portuguese vowels from the production data collected for the Escudero, Boersma, Rauber, and Bion (2009) study. Both studies followed similar methodology, with comparable subjects, stimuli and tasks.

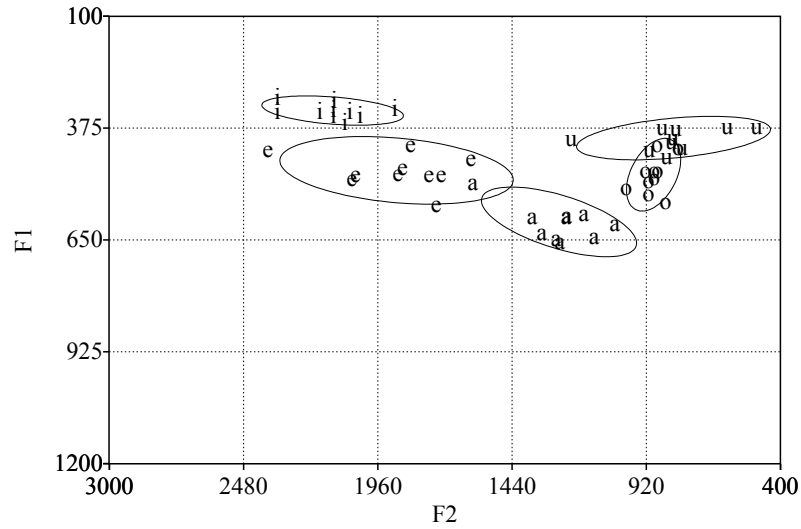
For each language 10 males and 10 females were recorded producing /CVCV/ tokens in a carrier phrase. For Peruvian Spanish, only 9 female recordings were available. The five Spanish vowels and the seven oral vowels of Portuguese were embedded between the voiceless consonants /p, t, k, f, s/. The carrier phrase, in the case of the /fVf/ context for instance, was “En fVfe y fVfo tenemos /V/” or in its Portuguese equivalent, “Em fVfe e fVfo temos /V/” (“In fVfe and fVfo we have /V/”). The present study used vowels extracted from the voiceless fricative context, since the voiceless stops differ in VOT (voice onset time) and formant transitions among Spanish, Portuguese, and English. For each speaker, the first vowel in the first /fVfe/ in the carrier sentence was extracted. Using isolated vowels extracted from their context reduces processing load while preserving the information contained in the formant transitions. Furthermore, as Escudero (2005) points out, the use of isolated vowels makes listeners rely on their abstract representations of these vowels and thus helps avoid the contextual effects on vowel perception (e.g., Gottfried, 1984; Gottfried and Beddor, 1988; Strange et al., 2001; Escudero and Vasiliev, 2011).

There were 95 vowel tokens for Spanish (19 speakers X 5 vowels) and 140 tokens for Portuguese (20 speakers X 7 vowels) to be used in the labeling tasks. For the XAB tasks only the first 5 female and 5 male tokens were used, resulting in 10 tokens per vowel for each language, for a total of 50 Spanish and 70 Portuguese vowel tokens.

The Spanish vowels used in this study are plotted in figures 3.1 (A - males, B - females) below. Let us now examine Figure 3.1 with respect to the distribution of the vowel tokens. It appears that both male and female speakers’ tokens of the five Spanish vowels have very distinct distributions in the F1 and F2 vowel space, with no overlap

among the tokens as produced by female speakers and only slight overlap in F1 values of the /o/ and /u/ tokens as produced by male speakers.

### A. Males



### B. Females

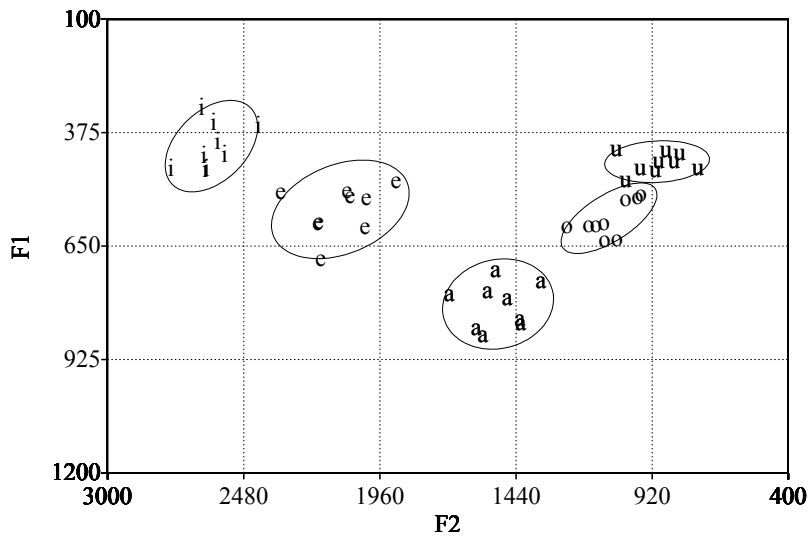


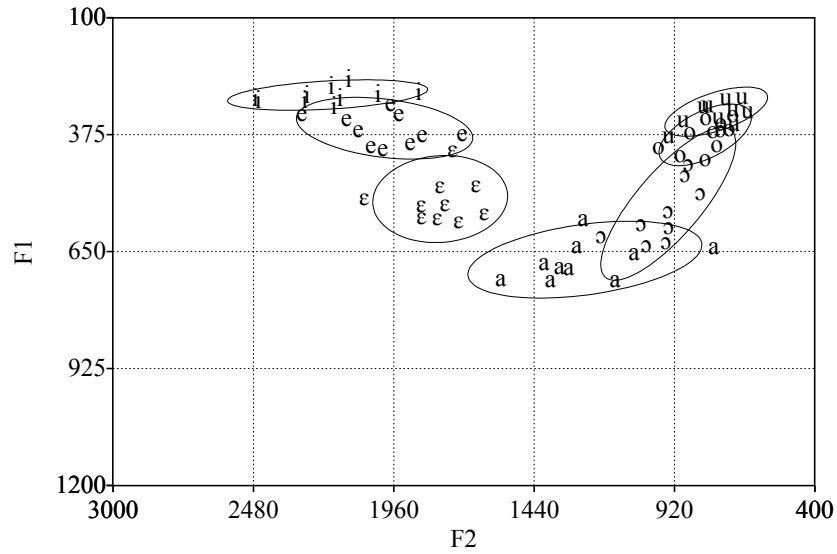
Figure 3.1. The mean F1 and F2 in Hertz of the five Spanish vowels produced in the /fVf/ context by ten male speakers (A) and nine female speakers (B) from Lima, Peru. Ellipses represent two standard deviations from the mean. The tokens were part of the corpus described in Chládková et al. (2011).

We now turn to the distribution of the Portuguese tokens, shown in Figure 3.2. It can be seen that some tokens of Portuguese /i/ and /e/ overlap in F1 and F2 values in both male and female productions. As for the Portuguese back vowels /o/ and /u/, there is considerable overlap in the F1 and F2 values of the two vowels as produced by both male and female speakers. Turning to the Portuguese mid-vowel pairs<sup>1</sup>, the front vowels /e/ and /ɛ/ and the back vowels /o/ and /ɔ/ are produced with different F1 and F2 values by both males and females, with only slight overlap for the female productions of the front vowel pair. The vowels /a/ and /ɛ/ have very distinct distributions in both male and female productions, whereas /ɔ/ as produced by male speakers partially overlaps with /a/ both in F1 and F2 values. The tokens of /ɔ/ produced by females are clearly separated on the F2 dimension, although there is some overlap in F1.

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<sup>1</sup> Portuguese open vowels /ɛ/ and /ɔ/ have been analyzed by Quicoli (1990, 1995), Hall (1943), Reed & Leite (1947), and Head (1964) as low vowels, assuming three vowel heights defined in terms of tongue-body features. Alternatively, Redenbarger (1981) and Lopez (1979) treat Portuguese closed and open vowels as low-mid and high-mid. The present study is concerned with the acoustic properties of Portuguese vowels and its analysis is not directly related to the phonological analysis of vowel height in Portuguese.

A. Males



B. Females

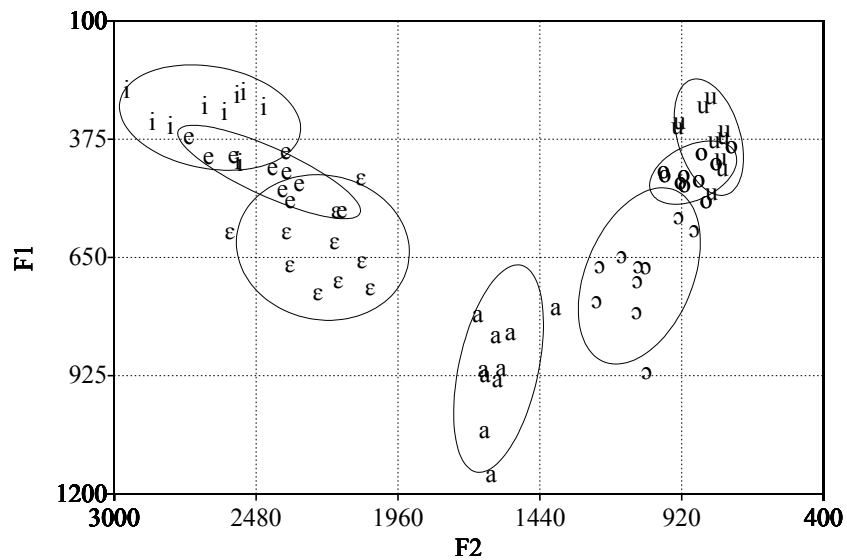


Figure 3.2. The mean F1 and F2 in Hertz of the seven Portuguese vowels produced in the /fVf/ context by ten male speakers (A) and ten female speakers (B) from Sao Paulo,



Brazil. Ellipses represent two standard deviations from the mean. The tokens were part of the corpus described in Escudero, Boersma, Rauber, and Bion (2009).

The average F1 and F2 values in Hertz, as well as the duration values in milliseconds for the vowel tokens used in this study are provided in Table 3.1 for Spanish and Table 3.2 for Portuguese. As seen in Table 3.2, Portuguese /o/ and /u/ have very close F1 values both in male and female productions. The average F1 values of the /a/ and /ɔ/ tokens as produced by male speakers are much more similar than for female speakers.

Table 3.1. Average F1, F2 (in Hertz) and duration (in milliseconds) for the five Spanish vowels produced by 10 Peruvian males and 10 females in the /fVf/ context. Standard deviations are given in italics below.

Vowel	Males			Females		
	F1(Hz)	F2(Hz)	Dur. (msec)	F1(Hz)	F2(Hz)	Dur. (msec)
a	609	1264	81	782	1509	94
	<i>35</i>	<i>136</i>	<i>19</i>	<i>71</i>	<i>110</i>	<i>16</i>
e	474	1885	74	553	2113	83
	<i>39</i>	<i>198</i>	<i>13</i>	<i>48</i>	<i>130</i>	<i>18</i>
i	332	2123	72	408	2585	90
	<i>19</i>	<i>127</i>	<i>18</i>	<i>50</i>	<i>92</i>	<i>14</i>
o	482	909	80	586	1079	84
	<i>36</i>	<i>48</i>	<i>20</i>	<i>36</i>	<i>103</i>	<i>19</i>
u	380	828	68	438	905	74
	<i>64</i>	<i>162</i>	<i>18</i>	<i>26</i>	<i>84</i>	<i>18</i>

Table 3.2. Average F1, F2 (in Hertz) and duration (in milliseconds) for the seven Portuguese vowels produced by 10 Brazilian males and 10 females in the /fVf/ context.

Standard deviations are given in italics below.

Vowel	Males			Females		
	F1(Hz)	F2(Hz)	Dur. (msec)	F1(Hz)	F2(Hz)	Dur. (msec)
a	669	1251	126	908	1591	140
	<i>45</i>	<i>217</i>	<i>23</i>	<i>121</i>	<i>82</i>	<i>29</i>
e	360	1994	111	451	2432	119
	<i>36</i>	<i>163</i>	<i>18</i>	<i>54</i>	<i>167</i>	<i>28</i>
ɛ	526	1788	123	627	2235	143
	<i>51</i>	<i>125</i>	<i>25</i>	<i>85</i>	<i>159</i>	<i>30</i>
i	282	2205	101	324	2648	107
	<i>18</i>	<i>185</i>	<i>15</i>	<i>61</i>	<i>166</i>	<i>33</i>
o	375	806	105	452	877	116
	<i>36</i>	<i>86</i>	<i>16</i>	<i>37</i>	<i>80</i>	<i>30</i>
ɔ	538	942	122	693	1075	137
	<i>90</i>	<i>125</i>	<i>27</i>	<i>103</i>	<i>112</i>	<i>36</i>
u	321	765	98	370	820	95
	<i>29</i>	<i>95</i>	<i>16</i>	<i>68</i>	<i>63</i>	<i>26</i>

### 3.2.2.2 Synthetic stimuli

For the XAB tasks, one “prototypical” steady-state token of each of the five Spanish and seven Portuguese vowels based on male models was synthesized in Praat (Boersma and Weenink, 1992-2013), using a cascade model of synthesis and following a similar procedure to the one described in Escudero and Wanrooij (2010). The values for  $f_0$ , F1, F2 and duration were based on the averages taken from Chládková et al. (2011) Chládková et al. (2011) for Spanish and Escudero, Boersma, Rauber, and Bion (2009) for Portuguese. For  $f_0$ , the midpoint of the vowel corresponded to the average  $f_0$  reported in

Chládková et al. (2011) and Escudero, Boersma, Rauber, and Bion (2009); the initial value was 10 Hz higher and the endpoint value was 10 Hz lower to ensure a natural falling pitch contour. The duration was equal to the vowel-specific averages reported in the studies above. The choice of preserving the vowel-intrinsic and language-specific differences in pitch and duration, minor but significant, was to allow for synthetic prototypes that were more natural-sounding and more similar to the stimuli used in the assimilation task. All the synthetic stimuli were scaled in intensity to match the average intensity of the natural stimuli. The fundamental frequency (f0), F1, F2, and duration values for the prototypical synthetic tokens in each language are given in Table 3.3 and 3.4 below.

Table 3.3. The values for f0, F1, F2 in Hertz and duration in milliseconds of the synthetic male vowel prototypes of Peruvian Spanish.

	f0	F1	F2	Duration
a	128	650	1400	83
e	131	470	1929	75
i	137	323	2186	67
o	133	500	900	67
u	139	371	824	68

Table 3.4. The values for f0, F1, F2 in Hertz and duration in milliseconds of the synthetic male vowel prototypes of Brazilian Portuguese.

	f0	F1	F2	Duration
a	122	683	1329	127
e	131	385	2028	122
ɛ	124	565	1831	123

i	137	285	2198	95
o	132	390	804	110
ɔ	122	574	927	123
u	140	310	761	100

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### 3.2.3 Procedure

Listeners were tested individually in a soundproof booth at the UCLA Phonetics Lab or a quiet room at the UCLA Department of Psychology Baby Lab in two sessions, which took place at least one week apart. Each session lasted less than one hour. During the first session, listeners first completed a series of XAB categorial discrimination tasks with Spanish stimuli. After a short break they then completed a perceptual assimilation task with the same stimuli. The order of doing the discrimination task before the assimilation task was fixed across subjects in order to avoid any familiarization with the natural stimuli, which might have influenced discrimination performance. For the second session, the format was the same, but the stimuli were Portuguese vowels. The order of the sessions was not counterbalanced across subjects because the Portuguese data was collected at a considerably later time. The perceptual assimilation task will be described prior to the discrimination task, although the order of administration of the tasks was the opposite. This is because throughout this dissertation, perceptual assimilation results are used to make predictions about discrimination and are thus presented first.

#### 3.2.3.1 *Perceptual assimilation task*

For the perceptual assimilation tasks, the stimuli were the natural vowel tokens described in Section 3.2.2.1. They were presented in random order in Praat via headphones. The options on the screen were “beat, bit, bait, bet, bat, but, bought, boat, but(cher) and boot” corresponding to the ten American English vowel phonemes /i, ɪ, e, ε, æ, ʌ, ɑ, o, ʊ, u/. These categories and labels in /bVt/ context were chosen following the design used in Mayr and Escudero (2010) for American English learners of L2 German vowels. Listeners were told that they would hear vowel sounds extracted from English words read in sentences at a fast rate and were asked to click on the word that contained a vowel that was most similar to the vowel they had heard. They were asked to choose a response even when unsure. The consonantal context for the keywords was chosen to be different from the context in which the stimuli were produced for several reasons. First, the /fVf/ context does not generate real words for all of the ten vowels. Secondly, since the vowels were presented in isolation, and the listeners were instructed to identify the word that contained the same kind of vowel as one of the keywords, using a different consonantal context encouraged a more abstract level of processing.

Each listener completed a short practice session in order to become familiar with the task and the type of stimuli. The between-trial interval was one second. There was a possibility to take a short pause every 20 trials. For the second session, which happened at least one week later, the participants repeated the same task with Portuguese stimuli. There were 95 trials for Spanish and 140 trials for Portuguese. Participants took on average 10 to 15 minutes to complete each experiment.

### *3.2.3.2 Categorial discrimination task*

Listeners also completed a series of two-forced choice identification tasks (XAB) where the stimuli were auditory only. For Spanish the contrasts tested were /i/-/e/, /e-a/, /a/-/o/, and /o/-/u/. For Portuguese, the contrasts were /i/-/e/, /e/-/ɛ/, /ɛ/-/a/, /a/- /ɔ/, /ɔ/-/o/, and /o/-/u/. “A” and “B” were the prototypical synthetic tokens of Spanish and Portuguese vowels described in section 3.2.2.2 above. For “X” a subset of the natural stimuli, described in section 3.2.2.1 was used, i.e. tokens produced by the first five male and female speakers of each language.

Listeners were asked to identify the first vowel X as more similar to either the second vowel A or the third vowel B by clicking on either “2” or “3” displayed on the screen. The order of presentation of the prototypes was counterbalanced: half of the trials were presented in the order of XAB and the other half, as XBA. The inter-stimulus interval was set to 1.2 seconds in order to trigger language-specific phonological identification (Werker and Logan, 1985). With 10 tokens per vowel (five male and five female), two presentation orders, and two vowels per contrast there were 40 experimental trials per contrast. For each contrast, four extra trials were added with the synthetic prototypes as “X”, thus making X physically identical to either A or B, in order to make sure that the subjects were paying attention. This resulted in 44 trials per contrast. More than one mistake on the trials that included only the prototypes was considered a criterion of exclusion from the study. Listeners were given an optional break after every block of 44 trials. A short practice test with an easy contrast, /i-u/, preceded the experimental task. The order of presentation of the vowel contrasts was randomized within each language.

Importantly, as Escudero and Wanrooij (2010) point out, the XAB task should be considered a two-alternative forced choice (2AFC) identification task rather than a

discrimination task because listeners were forced to identify each token auditorily as one of two phonological categories. This was because the 1.2 second inter-stimulus interval (ISI) between the three sounds in each trial was long enough to trigger phonological categorization (Werker and Logan, 1985; Van Hesse and Schouten, 1999). Furthermore, the target stimuli (X) and the response categories (A and B) had different values and were natural versus synthetic tokens, as in Escudero and Wanrooij (2010) and Escudero, Benders, and Lipski (2009).

### **3.3 Predictions and analysis**

The purpose of this section is to make predictions about the results of the experiments described above and to outline how the data will be analyzed before presenting the results in the next chapters.

Qualitative predictions for the results of the perceptual assimilation tasks can be made by comparing the F1/F2 space of CE vowels to the vowel spaces of Spanish and Portuguese. The male and female average F1 and F2 values for CE (Hagiwara, 1997), for BP (Escudero, Boersma, Rauber, and Bion, 2009), and for PS (Chládková et al., 2011) are plotted in Figure 3.3 (reproducing Figure 1.2 in Chapter 1). The values for Spanish and Portuguese are also the averages (with standard deviation ellipses) of the tokens used in the perceptual assimilation task, since they were taken from Tables 3.1 and 3.2 above.

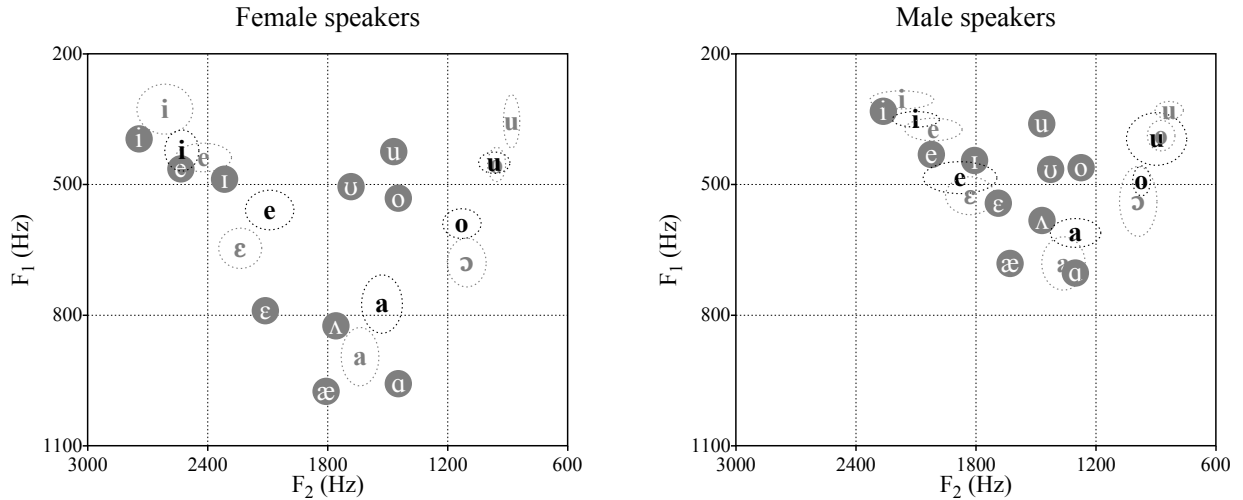


Figure 3.3. Average female and male F1 and F2 values for CE vowels (white symbols, grey circles) from Hagiwara (1997), as well as for the Spanish (black symbols) from Chládková et al. (2011) and Portuguese tokens (grey symbols) from Escudero, Boersma, Rauber, and Bion (2009). Ellipses represent one standard deviation from the mean.

According to the L2LP model, we expect CE listeners to map almost every Spanish and Portuguese vowel to more than one native vowel. Furthermore, due to differences in formant structure between the phonologically common vowels in Spanish and Portuguese, the L2LP model predicts some cross-linguistic differences in how these vowels are identified in terms of native English categories. Based upon an examination of the F1/F2 vowel spaces of CE in comparison with Spanish and Portuguese, we can predict how Spanish and Portuguese vowels *may* be mapped to native CE vowels.

As seen in Figure 3.3 above, Spanish /a/ is higher (has a lower F1) than Portuguese /a/, and is thus more likely to be assimilated to CE /ʌ/, whereas Portuguese /a/ might be mapped to CE /æ/ more often. Another observable difference is that between



Spanish, Portuguese, and CE high vowels /i/ and /u/. Portuguese /i/ seems to be higher than Spanish /i/ and is likely to be mapped almost exclusively to CE /i/. Spanish /i/ on the other hand may be mapped to CE /i/ and /e/ as well. Another striking observation is that Spanish /i/ and Portuguese /e/ seem to overlap almost entirely. The same is true for Spanish /u/ and Portuguese /o/. Thus we can expect Spanish high vowels to have similar assimilation patterns as Portuguese high-mid vowels. Portuguese low mid vowels are closer to Spanish mid vowel and may have similar mappings to English. The possible assimilation patterns are the given in Table 3.5 below.

Table 3.5 Possible assimilation patterns for Spanish and Portuguese vowels to English labels.

Spanish vowel->	English label(s)	Portuguese vowel->	English label(s)
/a/	/ʌ/, /ɑ/	/a/	/ʌ/, /ɑ/, /æ/
/e/	/ɪ/, /e/, /ɛ/	/e/	/i/, /ɪ/, /e/
/i/	/i/, /ɪ/, /e/	/i/	/i/
/o/	/o/	/o/	/u/, /o/
/u/	/u/, /o/	/u/	/u/
---	---	/ɛ/	/ɛ/, /ɪ/
---	---	/ɔ/	/ɑ/, /o/

It must be noted that neither Spanish nor Portuguese use duration as a cue to vowel identity, whereas American English does (e.g., Hillenbrand et al., 2000). Although

CE listeners might pay attention to the durational cues when classifying Spanish and Portuguese vowels, this is not a topic of the present investigation.

The perceptual assimilation patterns will be analyzed by comparing the mean percentages of each Spanish and Portuguese phonologically common vowel mapped to each of the ten CE categories. Spanish does not possess the phonemes /ɛ/ and /ɔ/, but the vowel space plot suggests that these BP vowels might be similarly categorized as the corresponding Spanish mid vowels /e/ and /o/. Thus, a separate analysis will be conducted to compare the assimilation patterns for Spanish mid vowels and BP open vowels /ɛ/ and /ɔ/.

Next, perceptual overlap scores (Levy, 2009a) will be calculated based on the results of the labeling tasks. As mentioned in Chapter 1, the cross-language assimilation overlap method quantifies perceived similarity of nonnative contrasts to native speech sounds by means of an “overlap” score, which is defined in Levy (2009a) as “the smaller percentage of responses when two members of a pair of nonnative speech sounds are assimilated to the same native category”. The method then ranks the vowel contrasts in terms of perceptual assimilation overlap, and predictions about the difficulty in discrimination for the vowel contrasts are made based on this ranking, without reference to goodness ratings. One of the main goals of the present study is to determine whether this analysis would find a relationship between perceptual assimilation overlap and discrimination accuracy in monolingual CE listeners perception of Spanish and Portuguese vowels.

### **3.4 Summary of the chapter**

In this chapter, methodological issues regarding cross-language vowel perception experiments were discussed and the methodology of the study of this dissertation was presented and justified. Predictions were made about the results of the experiments and it was also explained how the perceptual assimilation and the XAB data are to be analyzed and integrated.

Chapter 4 will present the results of the perceptual assimilation tasks for CE listeners with Spanish and Portuguese vowels. Based on these results, the PAM and the L2LP models will be used to make predictions for how accurate CE listeners will discriminate Spanish and Portuguese vowel contrasts in a categorial XAB discrimination task.

## **CHAPTER 4**

### **Perceptual assimilation of Spanish and Portuguese vowels**

#### **4.0 Introduction**

This chapter reports the results of the perceptual assimilation task with Spanish and Portuguese natural vowel stimuli. To summarize the experimental design described in Chapter 3 of this dissertation, 18 monolingual Californian English (CE) listeners completed a multiple-forced choice identification task in which they listened to naturally produced vowels in Spanish and Portuguese and were asked to label the tokens as one of ten English phonemes presented in keywords.

CE possesses (at least) ten phonemes in its phonological vowel space, whereas Spanish has five, and Portuguese, seven. Furthermore, the distributions of the vowels among three languages are different in the F1/F2 vowel space, as discussed in Chapter 3 and shown in Figure 3.3. The L2LP model posits that the differences found in the production of the sounds of a language should also be found in both native and nonnative perception of these sounds. Specifically, the model predicts that most Spanish and Portuguese vowels will occupy the same perceptual vowel space as several different CE vowels and will consequently be mapped to more than one native category. One of the key research questions of the present study is whether CE listeners, when given ten English phonemes as categories, map Spanish vowel contrasts via Multiple-Category Assimilation (MCA, Escudero and Boersma, 2002; Escudero, 2005), which Escudero and Boersma (2002) define as “perceiving a binary contrast in a second language as more than two categories in the first language”.

The PAM does not mention MCA, but the PAM-L2 (Best and Tyler, 2007) hints at its possibility when discussing the Categorized-Uncategorized and the Both-Uncategorized scenarios in perceptual assimilation. An Uncategorized sound, according to this model, is one that is not assimilated consistently to any one L1 category, but is rather heard as a poor example of several different L1 categories. It is precisely the scenario described above that is expected to be relevant for CE listeners with Spanish and Portuguese vowels. We expect to see several vowel contrasts of the Uncategorized-Categorized or Both-Uncategorized types, in PAM terms.

Unfortunately, a limitation of the PAM is that it defines the terms “Categorized” and “Uncategorized” in qualitative terms, without an objective measure of perceptual

similarity between native and nonnative speech sounds. For this reason, the results of the perceptual assimilation task of the present study are analyzed in more than one way. First, each Spanish and Portuguese vowel contrast is defined in terms of particular perceptual assimilation patterns proposed by the PAM and predictions for accuracy in discrimination are made using the PAM framework. Next, in order to operationalize perceptual assimilation and make testable predictions for discrimination, the metric introduced by Levy (2009a) is applied to the perceptual assimilation results (see Chapter 3 for an introduction to this procedure). The PAM perceptual assimilation patterns have been operationalized in diverse ways, such as using listeners' orthographic transcriptions of the sound (Best, McRoberts, and Goodell, 2001), or using inter- and intra-subject consistencies of categorization (Strange et al., 2009). Harnsberger (2001) defined a speech sound as uncategorized if it was not assimilated to a single native category at least 90% of the time. Others have used goodness ratings (e.g., Best, 1995) or combinations of categorization results with goodness of fit ratings (e.g., Guion et al., 2000). Since these various approaches may result in different assimilation patterns, leading to different predictions of discrimination accuracy, and since the present study did not make use of goodness ratings, a different quantitative technique was employed, namely the cross-language assimilation overlap method introduced by Levy (2009a).

The cross-language assimilation overlap method quantifies perceived similarity of nonnative contrasts to native speech sounds by means of an “overlap” score, which is defined in Levy (2009a) as “the smaller percentage of responses when two members of a pair of nonnative speech sounds are assimilated to the same native category”. The method then ranks the vowel contrasts in terms of perceptual assimilation overlap, and

predictions about the difficulty in discrimination for the vowel contrasts are made based on this ranking, without reference to goodness ratings. One of the main goals of the present study was to determine whether this analysis would find a relationship between perceptual assimilation overlap and discrimination accuracy in monolingual CE listeners perception of Spanish and Portuguese vowels.

Another main goal of the present study was to examine CE perception of Spanish and Portuguese vowels in terms of the L2LP model (Escudero, 2005), which does not consider that a nonnative sound can be truly uncategorizable. In Escudero and Boersma's (2002) terms, a nonnative binary contrast mapped to more than two native categories is a case of the Multiple Category Assimilation (MCA) scenario. In the present study the above concept of MCA is adopted with the objective of ascertaining whether CE listeners map Spanish and Portuguese vowels to native English categories via MCA, and whether nonnative vowel contrasts perceptually assimilated to L1 sounds via the MCA scenario are difficult for listeners to discriminate (see Chapter 5). When the members of the binary contrast are mapped onto more than two categories in the L1, these native categories may be the same or different for each member of the contrast. In other words, a binary L2 contrast may be mapped onto several overlapping categories or each member of the contrast can be assimilated to several different L1 phones. It can be hypothesized that MCA may be perceptually problematic insofar as it contributes to perceptual overlap for a particular nonnative contrast. If two adjacent Spanish or Portuguese vowels are mapped to an overlapping set of CE phonemes, difficulty in the discrimination of such a contrast can be expected. Thus the perceptual assimilation overlap score metric

introduced in Levy (2009a) to test the predictions of the PAM model can also be applied within the framework of the L2LP model.

The rest of the chapter is organized as follows. Section 4.1 reports the results of the perceptual assimilation task for Spanish and examines them vis-à-vis the PAM and the L2LP models. Section 4.2 presents the result and the same analysis for Portuguese. In section 4.3 perceptual assimilation patterns for the Spanish and Portuguese vowels are compared. In section 4.4, based on the results of the perceptual assimilation task, the metric of perceptual overlap scores (Levy, 2009a) is used to make predictions for CE listeners' discrimination accuracy with Spanish and Portuguese vowel contrasts. Section 4.5 provides a summary of the chapter.

#### 4.1 CE perceptual assimilation of Spanish vowels

Let us now examine the results of the perceptual assimilation task with Spanish vowels by CE listeners. Table 4.1 gives the mean classification percentages for each Spanish vowel as one of ten English categories.

Table 4.1 Mean percentage responses (and standard deviations below in italics) to each Spanish vowel as one of ten English labels. Table 4.1 displays the average percentages that each of the five Spanish vowels was identified as each of the ten native vowel categories.

		English Label									
		i	ɪ	e	ɛ	æ	ɑ	ʌ	o	ʊ	u
<u>Spanish</u>	<u>vowel</u>	i	70	25	1	2	-	-	-	-	-

	<i>17</i>	<i>16</i>	<i>3</i>	<i>3</i>	-	<i>1</i>	-	-	<i>1</i>	<i>1</i>
e	-	18	16	66	-	-	-	-	-	-
	<i>1</i>	<i>19</i>	<i>20</i>	<i>28</i>	<i>1</i>	-	-	-	-	-
a	-	-	1	4	27	39	22	4	2	-
	<i>1</i>	<i>1</i>	<i>3</i>	<i>4</i>	<i>24</i>	<i>5</i>	<i>25</i>	<i>4</i>	<i>26</i>	-
o	-	-	-	-	-	7	3	82	2	5
	-	-	-	-	-	3	9	15	5	5
u	-	-	-	-	-	-	1	12	6	80
	-	-	-	<i>1</i>	-	<i>9</i>	<i>1</i>	<i>11</i>	<i>2</i>	<i>14</i>

As can be observed from Table 4.1, CE listeners used all of the English labels in the task, but to different extents, depending on which Spanish vowel they heard. Spanish /i/ was mapped predominantly to CE /i/ ('beat'), but also to /ɪ/ ('bit'). Spanish /e/ was mapped mostly to /ɛ/ ('bet'), but also to /ɪ/ ('bit') and /e/ 'bait', to a lesser extent. Spanish /a/ was more or less evenly spread between three CE categories, namely /ɑ/ ('bought'), /æ/ ('bat'), and /ʌ/ ('but'). Spanish /o/ was labeled mostly as CE /o/ ('boat'), but also infrequently as /u/ ('boot'). Spanish /u/ was mapped to the English /u/ ('boot') the majority of the time, but also to /o/ and /ʊ/ ('butcher') to a lesser extent. The perceptual mappings of Spanish vowels to CE listeners' native categories are summarized in Figure 4.1.



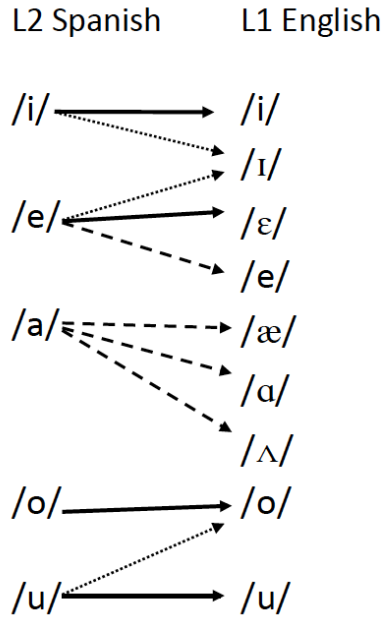


Figure 4.1 Perceptual assimilation of Spanish vowels to English categories: solid arrows above 60%, dashed arrows 30-50%, dotted arrows 10-25%.

We now examine the results vis-à-vis two different models of nonnative speech perception, namely the PAM and the L2LP. Consider first the Perceptual Assimilation Model (PAM, Best 1995). In PAM terms, the Spanish /i-e/ and /o-u/ contrasts are both instances of the Two-Category Assimilation scenario, since both members of each contrast were mapped to two different native vowels. According to the PAM, these should not present any difficulties in discrimination for CE listeners. On the other hand, the low vowel /a/ is an Uncategorized vowel, since it is not perceptually assimilated to any single CE vowel. This makes /a-o/ an Uncategorized-Categorized contrast, and the PAM predicts that CE listeners will discriminate this contrast very accurately, since none of the categories to which /a/ was assimilated constitute attractors for /o/. Similarly /a-e/

is another instance of the Uncategorized-Categorized Scenario, and its discrimination is predicted by the PAM to be very good. These predictions will be tested when the results of the categorial discrimination task with Spanish stimuli are presented in Chapter 5.

Let us now turn to another model that bases its analysis on how L2 contrasts are mapped to native categories, namely the Second-Language Linguistic Perception model (L2LP, Escudero 2005). Recall from Chapter 2 of this dissertation that this model claims that upon first encounter with the L2 the learner creates a copy of her L1 perceptual system and engages with the L2 input via this newly created system. The L2LP model posits three scenarios that the learner can encounter, each with its own learning task that must be completed for accurate L2 perception to be achieved. In the case of a Similar Scenario, a binary L2 contrast is mapped onto two different L1 vowels, and its acquisition is predicted to be easy, requiring only a Category Boundary Shift in order to match the native boundary. When a contrast is mapped onto a single native vowel, known as the New Scenario in L2LP, learners will face the difficult task of either creating a new category or splitting the existing category to acquire an accurate perception of the novel contrast. The third scenario posited by L2LP is the Subset Scenario, also known as Multiple Category Assimilation (MCA), which is when a binary contrast in the L2 is mapped onto more than two native categories. This scenario requires the learner to eliminate the extra categories from his L2 perceptual system and to adjust category boundaries to match the native boundary found in the production distributions of the target language sounds.

Let us examine the results above in terms of the three scenarios of L2LP. Regarding the New Scenario, which is the most difficult one according to this model, no

instances of this type of assimilation were found in the CE listeners' data. Namely, none of the Spanish contrasts was mapped onto a single CE vowel, which is not unexpected, given that the CE vowel inventory is larger than that of Spanish and possesses more vowel contrasts.

We shall now examine the perceptual assimilation patterns of each Spanish contrast in terms of the other two scenarios posited by the L2LP. An instance of the Similar Scenario is the Spanish /o-u/ contrast for CE listeners. As seen in Table 4.1, Spanish /o/ was mapped to English /o/ 82% of the time, whereas Spanish /u/ was mapped to English /u/ 80% of the time. Since some Spanish /o/ tokens were also mapped to English /u/, this can be taken as evidence that a Category Boundary Shift may be necessary for the CE learner of L2 Spanish to acquire an accurate perception of this contrast. Turning to the /i-e/ contrast, this is a case of MCA (Escudero and Boersma, 2000; Escudero, 2005), since this is a binary contrast mapped to more than two native vowels. While most tokens of Spanish /e/ and /i/ were mapped to separate English vowels, /i/ and /ɛ/ respectively, some tokens of the two Spanish vowels were labeled as English /ɪ/. This is similar to what Escudero and Boersma (2002) found for L1 Dutch L2 learners of Spanish for the same /e-i/ contrast. According to the L2LP model, the learning task in this case is expected to be somewhat more difficult, since the CE learner will have to eliminate the extra /ɪ/ category on a representational and a perceptual level, as well make a category boundary shift to match the native Spanish boundary between /e/ and /i/.

Similarly, the contrasts between low and mid vowels, /a-o/ and /a-e/, are also instances of the MCA scenario for CE listeners, insofar as both are binary contrasts mapped to more than two L1 categories. Differently from Spanish /e/ and /i/, the vowels

/a/ and /o/ are not mapped to the same L1 categories, and neither are /a/ and /e/. In this case L2LP proposes that the learning task is to eliminate the extra native categories from the L2 Spanish inventory, a representational task that should be solved easily through lexical learning. On a perceptual level, a category boundary shift may also be easy to achieve, since the two L2 vowels do not cover the same perceptual space.

Thus, unlike the PAM, the L2LP does not make predictions only about the accuracy of discrimination of nonnative contrasts, but also about the ease of acquisition and the specific learning task that a CE learner of L2 Spanish faces when acquiring an accurate L2 perceptual system.

Table 4.2 below summarizes the outlined analysis above for the four Spanish vowel contrasts in terms of the PAM and the L2LP.

Table 4.2 Summary of the PAM and L2LP learning scenarios for each of the four Spanish vowel contrasts.

Contrast	PAM scenario	L2LP scenario	L2LP learning task
/i-e/	Two-Category (easiest)	MCA	Eliminate extra categories, adjust category boundaries

/e-a/	Categorized-Uncategorized (easy)	MCA	Eliminate extra categories, adjust category boundaries
/a-o/	Categorized-Uncategorized (easy)	MCA	Eliminate extra categories, adjust category boundaries
/o-u/	Two-Category (easiest)	Similar Scenario	Adjust category boundary

We now turn to the results of the perceptual assimilation task with Portuguese stimuli.

#### 4.2 CE perceptual assimilation of Portuguese vowels

CE listeners performed the same perceptual assimilation task with Portuguese vowels. The results of this task are given in Table 4.3, which presents CE listeners' mean percentage responses to each of the seven Portuguese vowels as one of ten English labels.

Table 4.3 Mean percentage responses (and standard deviations below in italics) to each Portuguese vowel as one of ten English labels.

		English Label									
		i	ɪ	e	ɛ	æ	ɑ	ʌ	o	ɔ	u
Portuguese Vowel	i	75	23	2	1	-	-	-	-	-	-
	e	24	22	5	3	-	-	-	-	-	-
e	e	22	35	12	30	-	-	-	-	-	1

	18	17	12	21	-	-	-	-	1	3
ε	-	-	6	88	5	-	-	-	-	-
	1	1	13	16	9	1	-	1	-	-
a	-	-	1	-	38	48	12	-	1	-
	-	1	4	1	32	33	21	1	2	1
ɔ	-	-	-	-	5	71	8	17	-	-
	-	-	-	-	8	13	9	11	-	-
o	-	-	-	-	-	4	4	62	6	25
	-	1	-	1	-	5	6	19	8	14
u	-	-	-	-	-	-	2	7	8	83
	-	-	-	-	-	1	4	8	10	15

As seen in Table 4.3 Portuguese /i/ was mapped predominantly to the English /i/ ('beat'), but also to a lesser extent to /ɪ/ ('bit'). Portuguese /e/ was mapped to four different English categories, /ɪ/, /ɛ/, /i/ and /e/. Portuguese open vowel /ɛ/ was classified mostly as English /ɛ/. Portuguese /a/ was mapped to three different English vowels, /ɑ/, /æ/, and to a lesser extent /ʌ/. Portuguese low-mid vowel /ɔ/ was mostly mapped to English /ɑ/, and sometimes to /o/. The high-mid vowel /o/ was labeled mostly English /o/, but also as English /u/. Portuguese /u/ was mapped to English /u/ ('boot') the majority of the time, but also to /o/ and /ɔ/ less than ten percent of the time. Figure 4.2 summarizes the CE listeners' perceptual assimilation patterns of Portuguese vowels.

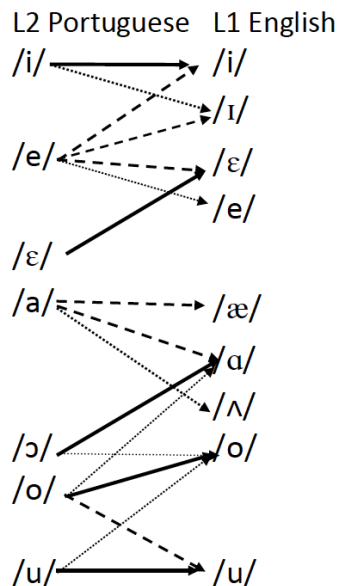


Figure 4.2. Perceptual assimilation of Portuguese vowels to English categories: solid arrows above 60%, dashed arrows 30-50%, dotted arrows 10-25%.

Let us now examine the results in light of the PAM and L2LP models. According to the PAM, Portuguese /i-e/, /ε-e/, and /ε-a/ can be interpreted as instances of the Categorized-Uncategorized scenario, with discrimination expected to be very good (Best 1995). Portuguese /a-ɔ/ may be considered a Category-Goodness difference type of assimilation, because both /a/ and /ɔ/ were assimilated to English /α/, but only /ɔ/ was consistently heard as the low back English vowel, whereas /a/ was also mapped to English low front vowel /æ/. As mentioned in Section 4.1, the PAM usually measures category goodness differences by asking listeners to give a goodness rating for each stimulus as an example of the native category to which it is similar. Alternatively, category goodness may only be inferred from the classification percentages. It is reasonable to think that Portuguese /ɔ/ is a better exemplar of English /α/ than Portuguese

/a/, because /ɔ/ was classified as English /ɑ/ 71% of the time, and /a/ was classified as English /ɑ/ only 41% of the time. In the case of a Category Goodness type of assimilation, discrimination is expected to be moderate to good, depending on the magnitude of difference in category goodness between the two nonnative sounds. Finally, /o-ɔ/ and /o-u/ are both cases of the Two-Category Assimilation scenario, since both members of each contrast were mapped to separate categories, with discrimination predicted to be excellent. The predictions that the PAM generates based on CE listeners' perceptual assimilation data will be tested in Chapter 5, when the results of the Categorical discrimination task are presented and analyzed.

We now examine the Portuguese results in terms of the L2LP model. Five out of six Portuguese contrasts, all except for /o-u/, can be considered instances of MCA. Their assimilation patterns differ only in terms of the number of categories to which each nonnative contrast was mapped, as well as whether those native categories were overlapping or distinct for each member of the contrast. Portuguese /i-e/, /e-ɛ/, and /a-ɔ/ were mapped to multiple categories, some of them overlapping. The difficulty in acquiring an accurate perceptual system for these contrasts is predicted to vary depending on the degree of overlap between the native categories to which the members of each contrast were mapped. On the other hand, the /a-ɛ/ contrast was mapped to two different non-overlapping sets of L1 phonemes. Thus, its discrimination is predicted to be easy. Portuguese /o-u/ was mapped predominantly to English /o/ and /u/ respectively, constituting a Similar Scenario, for which the learner is required only to shift the boundary between the two vowels to match the native boundary. Yet, since Portuguese /o/ was also mapped to English /u/ 25% of the time, the Category Boundary Shift may be



large enough to present the learner with a challenge. This should be evident in less than optimal discrimination of this particular contrast, according to the L2LP, but according to the PAM it should be an easy contrast to discriminate. Table 4.4 below summarizes the analysis above for the six Portuguese vowel contrasts.

Table 4.4 Summary of the PAM and L2LP learning scenarios for each of the six Portuguese vowel contrasts.

Contrast	PAM scenario	L2LP scenario	L2LP learning task
/i-e/	Categorized-Uncategorized (easy)	MCA	Eliminate extra categories, adjust category boundaries
/e-ɛ/	Uncategorized-Categorized (easy)	MCA	Same as above
/e-a/	Uncategorized-Categorized (easy)	MCA	Same as above
/a-ɔ/	Category-Goodness difference (moderate to easy)	MCA	Same as above
/o-ɔ/	Two-Category (easiest)	MCA	Same as above
/o-u/	Two-Category (easiest)	Similar Scenario	Adjust category boundary

### 4.3 Cross-language comparison

We now turn to a comparison of the perceptual assimilation patterns for the shared Spanish and Portuguese vowels. The perceptual assimilation patterns for Spanish and Portuguese are combined in Figure 4.3 below. It appears that the classification

percentages and categories used to label /i/ and /u/ were very similar for both Spanish and Portuguese. As for the rest of the vowels, some differences between languages can be observed. Consider the other phonologically common vowels of Spanish and Portuguese, /e/, /o/, and /a/. Spanish and Portuguese /e/ was mapped to several English categories, but, as observed from Figure 4.3, the categories chosen appear to be different depending on whether the stimulus was a Spanish or a Portuguese vowel. While Spanish /e/ was mostly mapped to English /ε/ and to a lesser extent to /e/, Portuguese /e/ was mapped to English /e/ to a much lesser extent, and was heard more often as three different English vowels, /i/, /ɪ/, and /ε/, to more or less the same extents. Spanish and Portuguese /o/ also seem to differ in their assimilation patterns. While Spanish /o/ was mapped predominantly onto CE /o/, Portuguese /o/ was also mapped to CE /u/ 25% of the time. As for the low vowel, Spanish /a/ appears to be assimilated more often to English /ʌ/ in comparison to the Portuguese /a/.

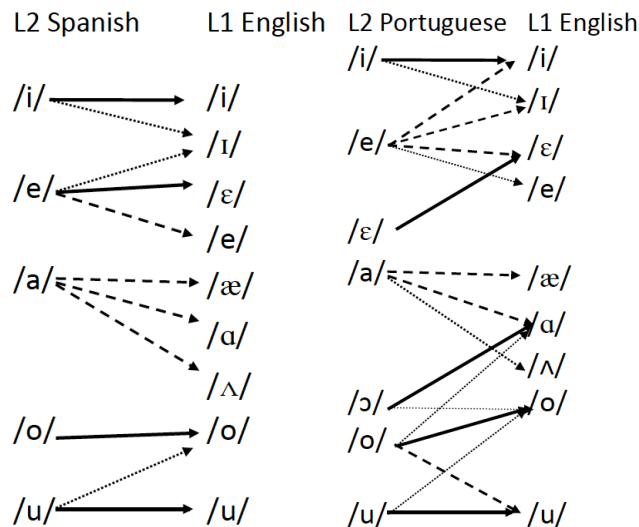


Figure 4.3 Perceptual assimilation of Spanish (left) and Portuguese vowels (right) to English categories: solid arrows above 60%, dashed arrows 30-50%, dotted arrows 10-25%.

In order to make it easier for the reader to follow, the classification percentages given in Tables 4.1 and 4.2 (omitting the standard deviations) are reproduced in Tables 4.5 and 4.6 with Portuguese values always placed below the Spanish values for ease of comparison. Table 4.5 presents the mean percentage of time that CE listeners classified each of the five phonologically common Spanish and Portuguese vowels as each of the ten native vowel categories. Table 4.6 compares the classification of the Spanish mid vowels to that of the Portuguese mid-low vowels.

Table 4.5. Mean classification percentages for each of the five phonologically common Spanish and Portuguese vowels identified as an English category. Significant differences are in bold.

			English Label									
			i	ɪ	e	ɛ	æ	ɑ	ʌ	o	ʊ	u
Vowel (Spanish/Portuguese)	/i/	Sp	70	25	1	2	-	-	-	-	-	-
		Port	75	23	2	1	-	-	-	-	-	-
	/e/	Sp	-	18	16	<b>66</b>	-	-	-	-	-	-
		Port	<b>22</b>	35	12	<b>30</b>	-	-	-	-	-	1
	/a/	Sp	-	-	1	<b>4</b>	27	39	<b>22</b>	<b>4</b>	2	-
		Port	-	-	1	-	38	48	<b>12</b>	-	1	-
	/o/	Sp	-	-	-	-	-	7	3	<b>82</b>	2	<b>5</b>
		Port	-	-	-	-	-	4	4	<b>62</b>	6	<b>25</b>
	/u/	Sp	-	-	-	-	-	-	1	12	6	80
		Port	-	-	-	-	-	-	2	7	8	83

Table 4.6. Classification percentages for Spanish (Sp) /e/ compared to Portuguese (Port) /ɛ/ and for Spanish /o/ compared to Portuguese /ɔ/. Significant differences are in bold.

	English Label									
	i	ɪ	e	ɛ	æ	ɑ	ʌ	o	ʊ	u
Sp /e/	-	<b>18</b>	<b>16</b>	<b>66</b>	-	-	-	-	-	-
Port /ɛ/	-	-	<b>6</b>	<b>88</b>	5	-	-	-	-	-
Sp /o/	-	-	-	-	-	<b>7</b>	3	<b>82</b>	2	<b>5</b>
Port /ɔ/	-	-	-	-	4	<b>71</b>	8	<b>17</b>	-	-

To test the significance of the observed differences across languages, the categorization patterns of the five phonologically common vowels of Spanish and Portuguese, namely, /i, e, a, o, u/ were compared. A repeated-measures analysis of variance where the dependent measure was the classification percentage and the within-subject factors were Language (2 levels = Spanish and Portuguese), Vowel (5 levels = 5 vowels common to Spanish and Portuguese), and Response (10 levels = 10 English response categories) revealed a significant triple interaction Language \* Vowel \* Response,  $F(36, 612) = 10.990, p < .0001$ . This suggests that one or more (but not all) of the common vowels were classified differently depending on the language in which they were produced. A series of paired samples t-tests was conducted to determine which vowel and response combinations yielded different results between the two languages. Since there was a total of five vowels compared, and each vowel received on average 3 different responses, the alpha level was corrected accordingly,  $\alpha = .003 (.05/(5*3))$ . The tests revealed that the vowels /e, a, o/ had different assimilation patterns depending on the language in which they were produced (all  $ps \leq .002$ ). Specifically, /e/ was classified more often as English /i/ and less often as English /ɛ/ in Portuguese than in

Spanish. Spanish /a/, compared to Portuguese /a/, was mapped more frequently to English /ʌ/, /ɛ/, and /o/. Spanish /o/ was classified more often as English /o/ and less often as /u/, compared to Portuguese /o/.

Next we repeated the same analysis of variance, this time treating Portuguese /ɛ/ and /ɔ/ as equivalent to Spanish /e/ and /o/, since acoustically Spanish mid vowels are also close to the Portuguese open mid vowels. The comparison between the classification of the Spanish mid vowels and the Portuguese open vowels is presented in Table 4.6 above. The triple interaction Language \* Vowel \* Response was again significant,  $F(36, 612) = 34.042, p < .0001$ . Post-hoc paired-sample t-tests revealed Portuguese /ɛ/ and /ɔ/ also differed from Spanish /e/ and /o/ in how they were assimilated to English vowels (all  $ps < .001$ ). Portuguese /ɛ/, compared to Spanish /e/, was identified less often as English /ɪ/ and /e/ and more often as English /ɛ/. Portuguese /ɔ/, compared with Spanish /o/, was mapped more often to /ɑ/ and less often to /o/ and /u/. Thus Portuguese open vowels were not found to be perceptually similar to Spanish mid vowels, as far as perceptual assimilation to native English vowels is concerned.

Thus it can be concluded that fine-grained acoustic differences in the realizations of the mid and low vowels in Spanish and Portuguese affect how inexperienced CE listeners categorize those vowels, which constitutes evidence for the L2LP model's claim that differences in the acoustic realizations of nonnative sounds predict differences in nonnative perception of those sounds. The findings also lend strong support to the L2LP's proposal that detailed acoustic comparisons are necessary to make predictions for how nonnative sounds will be mapped onto native categories. Also, according to both the

L2LP and the PAM, differences in categorization patterns are expected to be linked to differences in discrimination accuracy of some Spanish and Portuguese contrasts.

The next section presents a quantitative analysis of the perceptual assimilation patterns for CE listeners with Spanish and Portuguese vowels in order to allow for more specific predictions about their accuracy in a categorial XAB discrimination task with the same vowel stimuli.

#### **4.4 Predictions for discrimination**

Recall from Chapter 3 that CE listeners were presented with a subset of the natural stimuli in the XAB discrimination task. While they labeled tokens produced by 19 speakers of Spanish and 20 speakers of Portuguese, for the discrimination task only the productions of the first five females and the first five males of each language were used, resulting in 50 tokens for Spanish and 70 tokens for Portuguese. Thus, in order to make quantitative predictions about how listeners will discriminate the stimuli, it is necessary to reanalyze the results of the perceptual assimilation task for only the first 10 speakers of Spanish and Portuguese. The results are presented in Table 4.7 for Spanish and Table 4.8 for Portuguese.

Table 4.7. Mean classification percentages for CE listeners' perceptual assimilation of Spanish vowel tokens produced by the first 5 male and first 5 females speakers.

		English Label									
		i	ɪ	e	ɛ	æ	ɑ	ʌ	o	ʊ	u
Spanish Vowel	i	71	27	-	2	-	-	-	-	-	-
	e	-	20	15	65	-	-	-	-	-	-
	a	-	-	1	-	22	45	25	7	-	-
	o	-	-	-	-	-	7	2	84	2	5
	u	-	-	-	-	-	-	2	15	5	78

Table 4.8. Mean classification percentages for CE listeners' perceptual assimilation of Portuguese vowel tokens produced by the first 5 male and first 5 females speakers.

		English Label									
		i	ɪ	e	ɛ	æ	ɑ	ʌ	o	ʊ	u
Portuguese Vowel	i	82	15	3	-	-	-	-	-	-	-
	e	35	32	9	23	-	-	-	-	-	1
	ɛ	-	-	8	88	4	-	-	-	-	-
	a	-	1	1	1	45	41	11	-	-	-
	ɔ	-	-	-	-	7	73	10	10	-	-
	o	-	-	-	-	-	4	5	56	6	29
	u	-	-	-	-	-	-	-	1	8	91

Following the procedure introduced in Levy (2009a), in order to test the predictions of the PAM about the link between perceptual assimilation and discrimination accuracy, perceptual overlap scores for Spanish and Portuguese vowel contrasts were calculated directly from Tables 4.7 and 4.8. For each vowel contrast, an overlap score was calculated by adding the minority percentages that overlapped over each response category. For instance, as seen in Table 4.7, Spanish /i/ and /e/ were both classified as

English /ɪ/ and /ɛ/ to some extent. Spanish /i/ was mapped to /ɪ/ 20% of the time, and Spanish /e/ was mapped to the same category 27% of the time. Spanish /i/ was also mapped to /ɛ/ 2% of the time, versus 65% for the Spanish /e/. An overlap score is obtained by adding the smaller percentages in each case, 20 + 2, results in a score of 22 for the Spanish /e-i/ contrast. In the case of the Portuguese /e/ and /i/, both were classified as English /i/, /ɪ/, /e/, and /ɛ/. Adding the smaller of the percentages of time that /i/ and /e/ were mapped to each of these categories, that is, 35 + 15 + 3 + 1, we obtain an overlap score of 54. Overlap scores for each vowel contrast were calculated using the procedure outlined above. The overlap scores are presented in Table 4.9, ranked from lowest to highest for each language.

Table 4.9. Perceptual overlap scores for four Spanish and six Portuguese vowel contrasts, presented in the order from lowest to highest overlap.

	/a-e/	/a-o/	/e-i/	/o-u/		
Spanish	1	19	22	25		
	/a-ɛ/	/o-ɔ/	/e-ɛ/	/o-u/	/e-i/	/a-ɔ/
Portuguese	7	19	33	37	54	59

If perceptual overlap is predictive of discrimination accuracy, as suggested by the PAM, then higher overlap scores should be correlated with lower accuracy in a discrimination task. Overall, Portuguese vowel contrasts received higher perceptual overlap scores than the Spanish ones. It can be predicted, then, that CE listeners will be less accurate on some Portuguese contrasts than on some of the Spanish contrasts. The predicted (approximate) order of difficulty, from easiest to most difficult, for Spanish is /a-e/ << /a-o/ << /e-i/ << /o-u/ and for Portuguese, /a-ɛ/ << /o-ɔ/ << /e-ɛ/ << /o-u/ << /e-i/ << /a-ɔ/, where ‘<<’ means ‘easier



than'. That is, the lower the overlap score for a particular vowel pair, the less accurate CE listeners should be in the discrimination of the pair. In Chapter 5, the results of the discrimination task will be presented and a series of correlations (following Levy, 2009a) will be conducted in order to determine whether perceptual overlap is negatively correlated with discrimination accuracy.

#### **4.5 Summary of the chapter**

The main goal of this chapter was to examine the results of the perceptual assimilation task with Spanish and Portuguese stimuli for CE listeners in terms of the PAM and L2LP models and to make a cross-linguistic comparison of how the vowels of the two languages are mapped onto English categories by monolingual CE listeners. The L2LP model explicitly states that naive listeners' perceptual assimilation patterns are indicative of the initial state with which they come to the task of learning Spanish or Portuguese as a second language. While the PAM makes specific claims about how native language perceptual assimilation patterns predict difficulty in discrimination of nonnative contrasts, the L2LP proposes that different perceptual mappings of nonnative contrasts result in different learning scenarios, which in turn entail different tasks for further L2 development.

As for the cross-linguistic comparison, Spanish and Portuguese assimilation patterns were compared statistically to determine whether language affected how vowels with the same IPA labels were classified by the listeners. Indeed, the vowels /e/, /a/, and /o/ exhibited differential assimilation patterns depending on whether they were produced with Spanish or Portuguese values. Similarly, Portuguese open vowels /ɛ/ and /ɔ/ differed

from Spanish mid vowel /e/ and /o/ in how they were mapped onto English categories. This suggests that cross-linguistic acoustic differences play a significant role in how “similar” vowels are perceived by nonnative listeners, which supports the L2LP model’s claim that differences in the production distributions of sound categories result in differences in nonnative perception of those sounds.

Furthermore, in order to make specific quantitative predictions about relative ease of discrimination of Spanish and Portuguese vowel contrasts, perceptual overlap scores (Levy, 2009a) were calculated based on the results of the assimilation tasks. Both the PAM and the L2LP models predict that the higher the degree of single-category assimilation and therefore the higher the overlap score, the less accurate CE learners should be at discriminating a particular Spanish or Portuguese contrast. In the next chapter, these predictions are tested on the results for CE listeners’ categorial XAB discrimination of Spanish and Portuguese vowel contrasts.

## CHAPTER 5

### Categorical discrimination of Spanish and Portuguese vowel contrasts

#### **5.0 Introduction**

In Chapter 4, the results of the perceptual assimilation task for CE listeners with Spanish and Portuguese vowels were reported and analyzed. A method for quantifying assimilation patterns was introduced, namely the perceptual assimilation overlap method that Levy (2009a) used to test the predictions of PAM (Best 1995) and PAM-L2 (Best and Tyler 2007) regarding the link between the perceived similarity of nonnative and L2 contrasts and successful discrimination of those contrasts. Perceptual overlap scores were calculated in order to quantify the degree to which each Spanish and Portuguese vowel contrast was mapped to overlapping native vowel categories. Based on these perceptual overlap scores, predictions were made as to the relative accuracy in categorical discrimination of these contrasts for the same listeners.

In this chapter, the results of the XAB categorical discrimination tasks are reported. Sections 5.1 and 5.2 report the results of the XAB task with Spanish and Portuguese vowel contrasts respectively. Section 5.3 presents a cross-language analysis of categorical discrimination accuracy between Spanish and Portuguese. Section 5.4 is dedicated to answering the question of whether perceptual assimilation overlap is predictive of accuracy in discrimination.

## 5.1 Results of the Spanish XAB task

Table 5.1 shows the mean accuracy in categorial discrimination of the four Spanish contrasts by CE listeners. Since X was always equal to either A or B, but not both, because A and B were always instances of different categories, there was always a right or wrong answer. Each response was coded as either right or wrong, and accuracy was calculated as the number of correct responses out of 40 experimental trials, converted to a percentage. As can be seen from Table 5.1, mean accuracy was high for all subjects combined, ranging from 94.4% to 98.2%.

Table 5.1. CE listeners' mean percentage correct (and standard deviations below) on the four Spanish contrasts.

	/a-o/	/a-e/	/e-i/	/o-u/
Accuracy	94.4	98.2	96.1	95.3
St. Dev.	3.0	2.1	8.1	3.7

To test whether listeners found any of the contrasts harder to discriminate than others, a repeated-measures ANOVA was run on the percentage correct as the dependent measure and Contrast (4 levels = 4 Spanish vowel contrasts) as a within-subjects factor. If Mauchly's test of sphericity was violated in this and subsequent ANOVAs, Huynh-Feldt corrections were applied. The ANOVA did not reveal a significant main effect of Contrast,  $F[1.83\varepsilon, 31.1\varepsilon, \varepsilon = .61] = 2.03, p = 0.152$ . This suggests that there were no significant differences in accuracy between the four Spanish contrasts.

Listeners' accuracy on categorizing each of the two vowels within a contrast was also examined (Table 5.2). That is, for all trials in which X was an instance of "A", accuracy was calculated. The same was done for when X was equal to "B". It appears that listeners were also very accurate at identifying each vowel in each of the four Spanish contrasts (90 – 98.3%).

Table 5.2. CE listeners' mean percentage correct (and standard deviations below) on each of the two vowels in the four Spanish contrasts.

	/a-o/		/a-e/		/e-i/		/o-u/	
	a	o	e	a	e	i	o	u
Accuracy	90.0	98.9	98.3	98.1	96.1	96.1	93.9	96.7
St. Dev.	5.7	2.1	3.0	2.5	10.6	6.5	5.6	5.1

Thus, given the high accuracy, likely at ceiling, with which these monolingual CE listeners categorially discriminated the four Spanish vowel contrasts, it can be concluded that Spanish vowel contrasts did not present any perceptual difficulties for these listeners.

## 5.2 Results of the Portuguese XAB task

For the six Portuguese contrasts, the average accuracy is given in Table 5.3. In contrast to the results of the Spanish XAB task, CE listeners were not at ceiling in discriminating

some Portuguese vowel contrasts, with accuracy ranging from 68.5% on /e-i/ to 99.1% on /a-ε/.

Table 5.3. CE listeners' mean percentage correct (and standard deviations below) on the six Portuguese contrasts.

	/a-ɔ/	/a-ε/	/e-i/	/o-u/	/e-ε/	/o-ɔ/
Accuracy	82.5	99.1	68.5	74.5	94.9	93.8
St. Dev.	9.5	2.0	11.3	12.8	4.8	4.2

To test the significance of the observed differences in accuracy between contrasts, a repeated-measures ANOVA was conducted on the percentage correct as the dependent measure and Contrast (six levels = six Portuguese contrasts) as a within-subjects factor. It revealed a significant main effect of Contrast,  $F[5_{\epsilon}, 80_{\epsilon}, \epsilon = .658] = 41.422, p < .00001$ , suggesting that in Portuguese, unlike Spanish, CE listeners found some contrasts more difficult than others. Bonferroni-corrected post-hoc tests revealed /a-ε/ was easier to discriminate than any of the other five contrasts (all  $ps < .031$ ). Listeners were also more accurate on /e-ε/ and /o-ɔ/ than on the remaining three contrasts. Finally /a-ɔ/ was easier than /e-i/ ( $p = .019$ ) but not significantly easier than /o-u/ ( $p = .752$ ). The /e-i/ and /o-u/ contrasts were nearly equally difficult ( $p = 1.0$ ). Thus the order of difficulty, from easiest to most difficult was:

$$/a-\epsilon/ \ll /e-\epsilon/ \sim /o-\sigma/ \ll /a-\sigma/ \ll /e-i/; /a-\sigma/ \sim /o-u/; /o-u/ \sim /e-i/$$

where “<<” means “more accurate than” and “~” means “no significant differences in accuracy”.

Upon examination of the results for each of the two vowels in each Portuguese contrasts (Table 5.4 below), it appears that lower accuracy on the high versus high-mid vowel contrasts was driven by the fact that listeners were at or near chance on distinguishing /e/ from /i/ and /o/ from /u/ in the XAB task, with only 45.3% correct for /e/ and 57.6% correct for /o/.

Table 5.4. CE listeners' mean percentage correct (and standard deviations below) on each of the two vowels in the six Portuguese contrasts.

	/a-ɔ/		/a-ɛ/		/e-i/		/o-u/		/e-ɛ/		/o-ɔ/	
	a	ɔ	a	ɛ	e	i	o	u	e	ɛ	o	ɔ
Accuracy	91.5	73.5	98.8	99.4	<b>45.3</b>	91.8	<b>57.6</b>	90.6	92.6	97.1	93.8	93.8
St. Dev.	13.8	18.1	3.6	1.6	10.8	23.2	23.8	10.7	8.2	3.0	5.0	7.4

The XAB categorial discrimination results for both Spanish and Portuguese vowel contrasts will be evaluated vis-à-vis the predictions made in Chapter 4 using the perceptual assimilation overlap metric in Section 5.4. The next section is dedicated to a comparison of categorial discrimination accuracy between Spanish and Portuguese vowel contrasts.

### 5.3 Cross-language comparison

To compare how accurate listeners were on Spanish versus Portuguese contrasts, Portuguese /a-ɔ/ and /a-ɛ/ were treated as equivalent to Spanish /a-o/ and /a-e/

respectively. The high-mid versus low-mid vowel contrasts in Portuguese, which Spanish does not possess, were left out of the analysis. Spanish /a-o/ was treated as equal to Portuguese /a-ɔ/, and Spanish /a-e/, to Portuguese /a-ɛ/. The results for the four “common” contrasts are reproduced in Table 5.5, with significant cross-language differences represented in bold font.

Table 5.5. Mean percentages correct on the four “common” contrasts in Spanish and Portuguese. Significant differences between languages are in bold.

	/a-o/ /a-ɔ/	/a-e/ /a-ɛ/	/e-i/	/o-u/
Spanish	<b>94.4</b>	98.2	<b>96.1</b>	<b>95.3</b>
Portuguese	<b>82.5</b>	99.1	<b>68.5</b>	<b>74.5</b>

A repeated measures ANOVA with the percentage correct as the dependent measure and Language (two levels = Spanish and Portuguese) and Contrast (four levels = 4 common contrasts) as within-subject factors revealed main effects of Language,  $F(1, 17) = 202.465, p < .00001$ , and Contrast,  $F[3\varepsilon, 51\varepsilon, \varepsilon = .86] = 28.989, p < .00001$ , as well as an interaction Language \* Contrast,  $F(3\varepsilon, 51\varepsilon, \varepsilon = .86) = 26.067, p < .00001$ . Post-hoc tests at a significance level of .0125 (alpha = .05/4) revealed that three out of four contrasts were more difficult for CE listeners to discriminate in Portuguese than in Spanish. Portuguese /e-i/, /o-u/, and /a-ɔ/ were harder than Spanish /e-i/, /o-u/, and /a-ɔ/ respectively (all  $p$ s < .00001). There was no significant difference in accuracy between the Portuguese /a-ɛ/ and the Spanish /a-e/ contrasts,  $p = .11$ .



Figure 5.1 illustrates the results of the categorial discrimination tasks with Spanish and Portuguese stimuli. For each Spanish and Portuguese vowel pair tested in the XAB tasks, the mean percentage correct and standard error bars are shown. Significant differences between Spanish and Portuguese are marked with a star symbol.

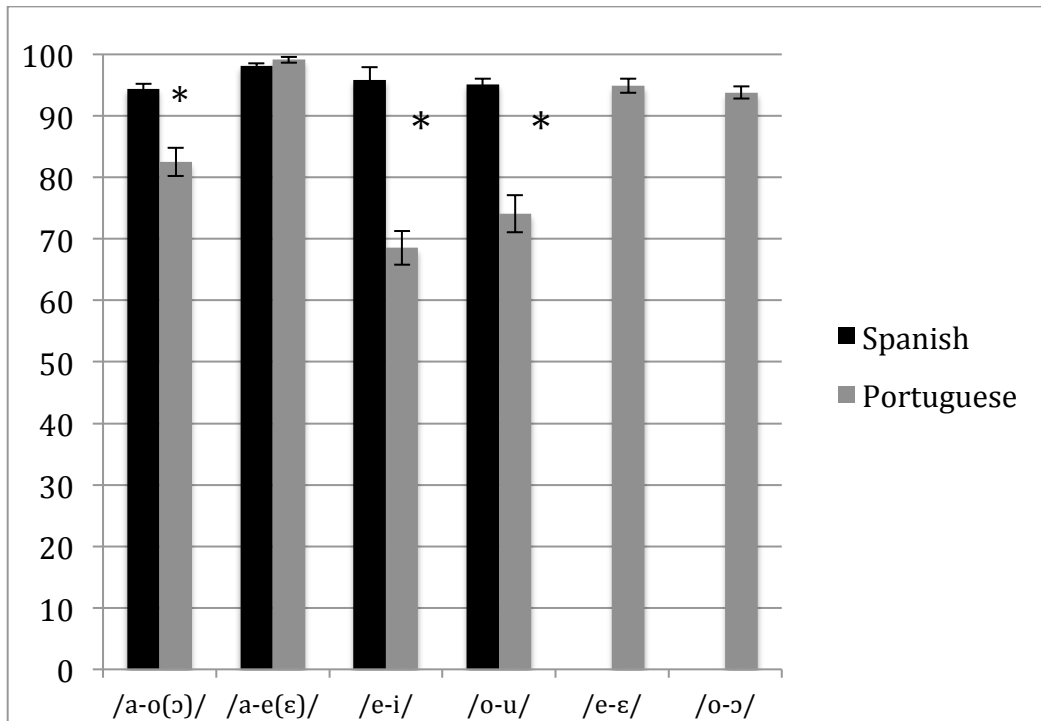


Figure 5.1. Mean accuracy in the XAB tasks with Spanish and Portuguese stimuli. Error bars represent the standard error of the mean. Significant cross-language differences are marked with a star.

In the next section the results of the XAB discrimination tasks are evaluated vis-à-vis the PAM's claim that higher perceptual assimilation overlap should result in lower discrimination accuracy of nonnative vowel contrasts.

#### **5.4 Does perceptual assimilation predict discrimination accuracy?**

The link between perceptual assimilation and discrimination, as posited by the PAM (Best 1995), was examined using a metric introduced in Levy (2009a). Perceptual assimilation was operationalized by computing an assimilation overlap score, which was calculated for each Spanish and Portuguese vowel pair by adding the minority percentages of times that the two members of a pair were mapped to the same native categories. Levy (2009a) found that both group and individual perceptual overlap scores were correlated with more errors in an AXB discrimination task with Parisian French vowels for inexperienced American English listeners as well as for L2 learners. In order to answer the question whether perceptual assimilation patterns are predictive of discrimination accuracy for CE listeners with Spanish and Portuguese vowels, the extent to which the members of a Spanish or Portuguese binary vowel contrasts were mapped to the same native English categories was quantified in terms of perceptual overlap scores (Levy, 2009a) and compared to the discrimination accuracy obtained for each vowel contrasts.

Overlap scores and discrimination accuracy for each Spanish and Portuguese contrast are reproduced in Table 5.6, ranked by lowest to highest overlap score, which in turn was the predicted order of difficulty, from easiest to most difficult. As reported in Section 5.1 above, there were no significant differences in accuracy between the four Spanish contrasts, and listeners were over 94% accurate on all of the contrasts, indicating that they were most likely at ceiling. On the other hand, for Portuguese, the predicted order of difficulty was only generally consistent with the results reported in Section 5.2. Specifically, the three contrasts with the highest overlap scores, /a-ɔ/, /e-i/, and /o-u/,

were more difficult to discriminate than the three contrasts with the lowest overlap scores, /a-ε/, /o-ɔ/, and /e-ε/. Nevertheless, it was unexpected that /e-i/ was more difficult than /a-ɔ/ because the overlap scores were similar for the two contrasts. Furthermore, although /e-ε/ and /o-u/ received similar overlap scores, /o-u/ was significantly more difficult to discriminate than /e-ε/, contrary to the predictions.

Table 5.6. Perceptual overlap scores and percentages correct for each Spanish and Portuguese vowel contrast. The order of the vowel pairs is from lowest to highest overlap score for each language.

Spanish Contrasts	/a-ε/	/a-o/	/e-i/	/o-u/		
Overlap Score	1	19	22	25		
XAB Accuracy	98.2	94.4	96.1	95.3		
Portuguese Contrasts	/a-ε/	/o-ɔ/	/e-ε/	/o-u/	/e-i/	/a-ɔ/
Overlap Score	7	19	33	37	54	59
XAB Accuracy	99.1	93.8	94.9	74.5	68.5	82.5

Following Levy (2009a), Spearman rank-order correlations were used to test the hypothesis that the more often listeners labeled two different vowels as the same category, the lower their categorial discrimination accuracy would be for that vowel contrast. Nonparametric correlations were used because the perceptual assimilation results could not be considered interval measures. A negative correlation between overlap scores and discrimination accuracy was predicted, i.e., the higher the assimilation overlap

score, the lower the percent accuracy was expected to be found in discrimination. Thus, when overlap scores for each pair were ranked from lowest to highest, discrimination accuracy results were predicted to be ordered from highest to lowest.

Figure 5.2 graphs the correlation between cross-language assimilation overlap and discrimination performance on four Spanish and six Portuguese vowel pairs by CE listeners. Along the x-axis are the cross-language assimilation overlap scores, while the y-axis represents the percent correct in discrimination, with each point on the graph representing the group's mean response to a particular vowel pair.

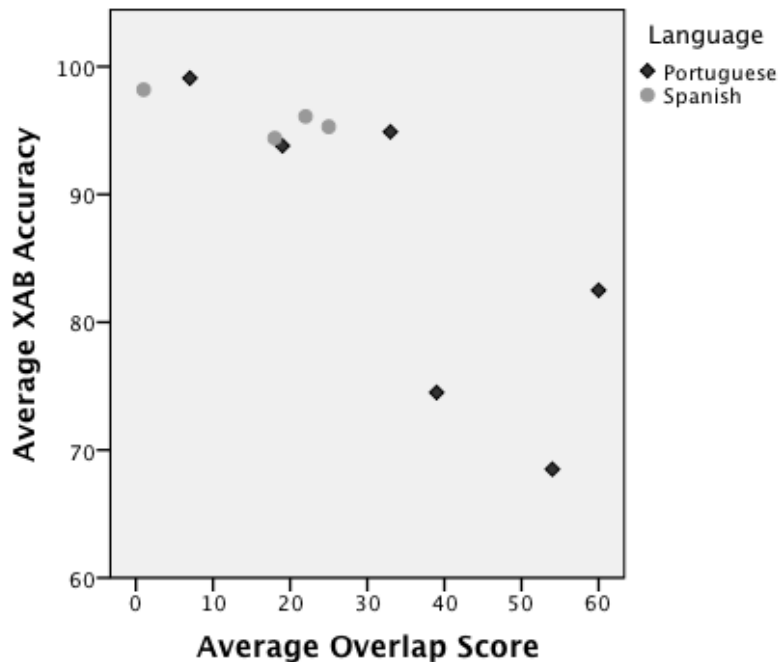


Figure 5.2. Scatterplot of relationship between cross-language assimilation overlap patterns and percent correct in categorical discrimination by CE listeners with vowel pairs /a-e/, /a-o/, /e-i/, and /o-u/ for Spanish and /a-ε/, /a-ɔ/, /e-i/, /o-u/, /e-ε/, and /o-ɔ/ for Portuguese as sampling variables.

First, separate correlations were performed for Spanish and Portuguese. For the four Spanish vowel contrasts, /a-e/, /a-o/, /e-i/, and /o-u/ the correlation between group overlap scores and categorial discrimination accuracy was not significant,  $r_s(4) = -.4$ ,  $p$  (one-tailed) = .3, which is not surprising given that there were only four sampling variables and that listeners were highly accurate on all four contrasts. However, for the six Portuguese vowel contrasts, /a-ɛ/, /a-ɔ/, /e-i/, /o-u/, /e-ɛ/, and /o-ɔ/, there was a significant strong negative relationship between overlap scores and discrimination accuracy,  $r_s(6) = -.771$ ,  $p$  (one-tailed) = .036. Although the correlation for Spanish was not significant, a correlation performed on the four Spanish and six Portuguese vowel contrasts as sampling variables revealed a an even stronger negative relationship,  $r_s(10) = -.851$ ,  $p$  (one-tailed) = .001, between perceptual assimilation overlap and categorial discrimination accuracy for nonnative vowel contrasts. Nevertheless, even though the correlations were significant, due to the small number of sampling variables it cannot yet be concluded that perceptual overlap is negatively correlated with discrimination accuracy.

To investigate whether in fact assimilation overlap was a strong predictor of discrimination accuracy, individual listeners' overlap scores were correlated with individual discrimination accuracy on Spanish and Portuguese vowel contrasts. Figure 5.3 graphs the relationship between individual listeners' overlap scores and their discrimination accuracy for each vowel pair in Spanish and Portuguese. The sampling variables were average percent correct and overlap scores for each listener on each vowel pair, resulting in 72 (18 listeners X 4 contrasts) data points for Spanish and 108 (18

listeners X 6 contrasts) for Portuguese. Once again, there was a significant negative correlation between CE listeners' individual overlap scores and categorial discrimination accuracy, for Spanish,  $r_s(72) = -.364$ ,  $p(1\text{-tailed}) = .001$ , and for Portuguese,  $r_s(108) = -.697$ ,  $p(1\text{-tailed}) < .0001$ . Finally, a correlation on individuals' percentage correct and overlap scores for both Spanish and Portuguese pooled together revealed a strong negative relationship between overlap scores and discrimination accuracy,  $r_s(180) = -.668$ ,  $p(1\text{-tailed}) = .001$ . The results suggest that the more trials in which individual CE listeners assimilated two members of a Spanish or Portuguese vowel pair to a single native category, the lower their discrimination accuracy was for that vowel pair, thus providing quantitative support for the PAM (Best 1995).

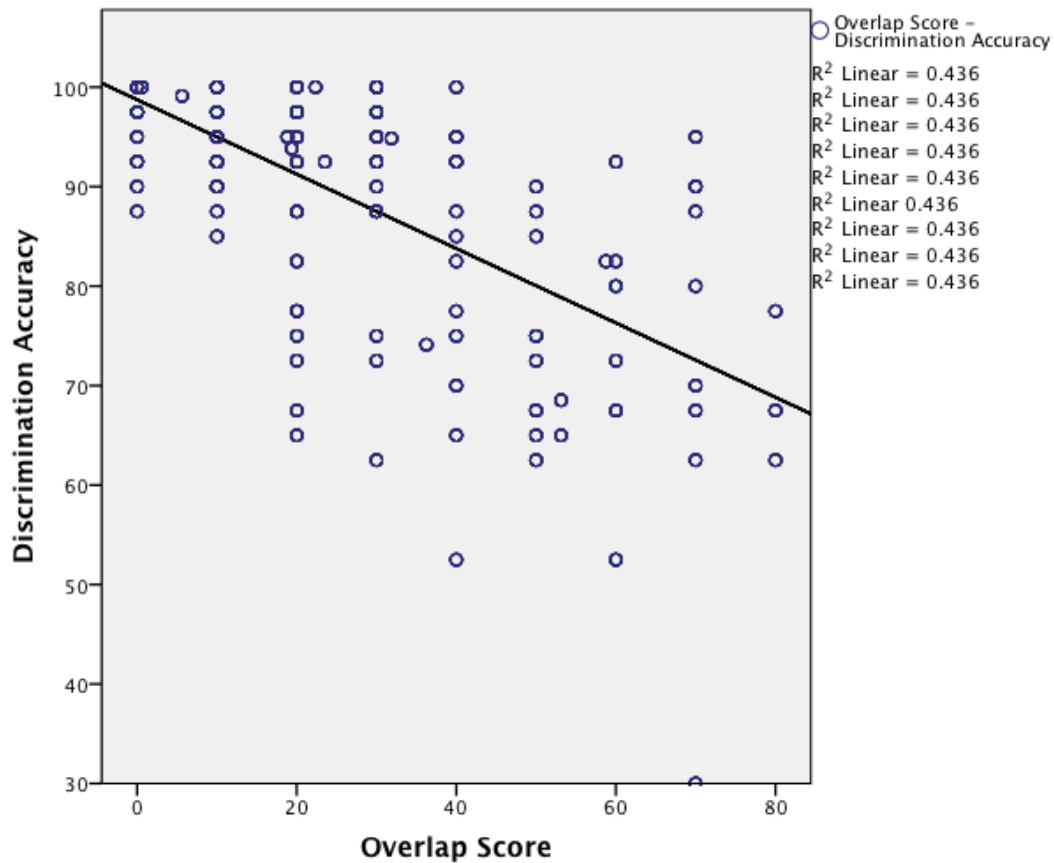


Figure 5.3. Scatterplot of the relationship between overlap scores and discrimination accuracy for 18 CE listeners on six Portuguese and 4 Spanish vowel pairs. Each point represents a listener's average response to a particular vowel contrast. The line is a linear best-of-fit line.

Thus Levy's (2009a) metric, applied to perceptual assimilation of Spanish and Portuguese vowels by CE listeners, appears to be a good predictor of the same listeners' discrimination accuracy with Spanish and Portuguese vowel contrasts. This finding lends direct empirical support to the PAM's claim about the link between perceptual assimilation and nonnative sound discrimination.

## **5.5 General discussion**

To summarize the findings reported in this chapter, CE listeners were over 94% accurate in discriminating Spanish vowel contrasts, with no significant differences in difficulty between contrasts, even though categorization showed overlaps in the use of native labels for some of the Spanish contrasts. This suggests that when two vowels in a pair are acoustically distinct, discrimination is easy, regardless of the native categories to which the two members of the contrast may be assimilated.

The results for Spanish are compatible with the PAM, according to which Spanish contrasts are assimilated by CE listeners either via Two-Category (TC) Assimilation or as a Categorized-Uncategorized (CU) type of scenario. The PAM predicts that nonnative contrasts that constitute a TC or a CU type of assimilation scenario should be

discriminated very well by nonnative listeners. This was in fact the case for CE listeners with Spanish vowels.

The above findings for Spanish vowels also have important implications for the concept of Multiple Category Assimilation or the Subset Scenario, as proposed by the L2LP model. Three out of four Spanish contrasts were mapped to CE categories via MCA, yet no difficulty in discrimination was found for any of the contrasts, suggesting that MCA is not perceptually problematic when it does not contribute to perceptual assimilation overlap for a nonnative contrast.

For Portuguese, some contrasts were more difficult than others to discriminate. Specifically, the high versus high-mid vowel pairs, /i-e/ and /o-u/, as well as the low versus low-mid back vowel contrast, /a-ɔ/, were significantly more difficult than the mid vowel contrasts /e-ɛ/ and /o-ɔ/. The low versus low-mid front vowel contrast, /a-ɛ/, was easier than all the others. Interestingly, CE listeners confused Portuguese /e/ with /i/ and /o/ with /u/, but not vice versa, nearly 50% of the time, suggesting that CE learners may have difficulties achieving accurate perception of the two high-mid vowels.

Let us first consider the Portuguese results in terms of the PAM. Turning first to /a-ɔ/, this contrast can be considered an instance of the Category-Goodness Difference scenario. The PAM predicts discrimination to be moderate to easy in this case, depending on the degree of category goodness difference between the members of the nonnative contrast. Indeed, Portuguese /a-ɔ/ was not an easy contrast for CE listeners, probably because both vowels were assimilated to English /a/, but Portuguese /ɔ/ was likely to sound as a better example of CE /a/ than Portuguese /a/. Thus some discrimination difficulty with this contrast is expected under the PAM, which is consistent with the



findings of the present study. However, the PAM framework does not appear to be successful at explaining why /i-e/ and /o-u/ were also difficult for CE listeners to discriminate. In PAM terms, /i-e/ is considered a Categorized-Uncategorized contrast, and its discrimination is predicted to be very good, contrary to what we found in CE listeners. Similarly, /o-u/ should be even easier to discriminate than /i-e/, because according to the PAM it is an instance of the Two-Category Assimilation scenario. Nevertheless, CE listeners found the contrast difficult in the XAB task.

Examining the above findings within the L2LP framework, Portuguese /o-u/ can be considered an instance of the Similar Scenario, since /o/ was mapped mostly to CE /o/ and /u/, to CE /u/. The L2LP predicts that the Similar Scenario presents a learning task of its own, namely that of adjusting the boundary between the two Portuguese vowels. Inexperienced CE listeners were less accurate at discriminating Portuguese /o-u/ than most other contrasts, suggesting that the native boundary between these two vowels is not the same as the one between CE /o/ and /u/. Thus, the L2LP, unlike the PAM, predicts that the Similar Scenario (Two-Category Assimilation in PAM terms) may also be problematic if the perceptual boundary mismatch is large enough. This appears to be the case of the Portuguese /o-u/ for CE listeners. The explanation seems to lie in the acoustic distribution of Portuguese /o/ and /u/, which overlap considerably in F1 and F2 values, as was demonstrated in Chapter 3, Figures 3.1 and 3.2. Thus overlap in how two members of the contrast are produced may result in lower discrimination accuracy for this contrast, which is consistent with L2LP acoustic account of nonnative perception. Turning to the rest of the Portuguese vowel contrasts, all of them were mapped onto more than two English categories, constituting MCA in L2LP terms. Nevertheless, only /i-e/ and /a-ɔ/,

but not /e-ɛ/ and /o-ɔ/, were difficult for CE listeners to discriminate. This can be explained by the perceptual assimilation overlap metric (Levy, 2009a), since /i-e/ and /a-ɔ/, unlike the other two contrasts, had high assimilation overlap scores. This suggests, once again, that MCA is only perceptually problematic insofar as it contributes to perceptual assimilation overlap. Thus the L2LP concept of MCA, when taken together with the perceptual overlap metric, does appear to explain CE listeners' lower performance on the /i-e/ contrast, whereas the PAM concept of Two-Category assimilation does not explain the findings.

Furthermore, we can once again turn to the acoustic distribution of the Portuguese /i-e/ and /a-ɔ/ tokens in order to explain lower discrimination accuracy. As seen in Figures 3.1 and 3.2, both these contrasts were produced with some overlap in F1 and F2 values by Brazilian Portuguese speakers. This is especially true for female productions of /a/ and /ɔ/. This constitutes evidence for the L2LP's claim that acoustic differences in vowel production explain differences in perception.

As for differences between Spanish and Portuguese, CE listeners were less accurate on /e-i/ and /o-u/ in Portuguese than in Spanish, and Portuguese /a-ɔ/ was more difficult than Spanish /a-o/, which can also be explained by the overlap in F1 and F2 values for the members of the three Portuguese contrasts and by the absence of acoustic overlap for their Spanish counterparts.

Another goal of this chapter was to evaluate whether Levy's (2009a) metric of assimilation overlap was a good predictor of discrimination accuracy in CE listeners with Spanish and Portuguese vowels. Two previous studies, Levy (2009a) and Strange et al. (2011) had found that both group and individual perceptual overlap scores were

correlated with more errors in an AXB discrimination task for both naive listeners and L2 learners of different language backgrounds and with different target language vowels. Similarly, the present findings suggest that both group and individual assimilation overlap scores are strongly correlated with discrimination accuracy for CE listeners with Spanish and Portuguese vowel pairs. Significant negative correlations were found between group overlap scores and average discrimination accuracy for Portuguese, as well as for Spanish and Portuguese vowel pairs combined. For both languages, significant negative correlations were revealed between individual listeners' assimilation overlap scores and discrimination accuracy, thus providing empirical evidence for the PAM's and L2LP's proposals that the more listeners map a nonnative vowel contrast to overlapping native vowels, the more difficulty they have in discriminating this contrast.

Let us now discuss the findings of the present study vis-à-vis previous studies on MCA. The results for Spanish are consistent with Gordon's (2008, 2011) and Morrison's (2003) findings for English speaking L2 learners of Spanish. Gordon (2008, 2011) found that American English learners of L2 Spanish were highly accurate at identifying the five Spanish vowels in an orthographic vowel identification task. Morrison (2003) also used an orthographic vowel identification task to examine perceptual proficiency in Canadian English learners of L2 Spanish vowels. Morrison's participants were also highly accurate at identifying the five Spanish vowels, with percent errors ranging from four to 13 percent. The current study used a categorial discrimination task without orthographic labels in order to avoid possible effects of orthography, and also because the participants were linguistically naive listeners unfamiliar with Spanish orthographic labels. The findings suggest that Californian English learners should not have difficulties learning to

categorize L2 Spanish vowels accurately because high categorial discrimination accuracy seems to suggest that the Spanish category boundaries should be easily matched in the L2 perception of these listeners. It would be beneficial to conduct the same experiments, as well as an additional orthographic vowel identification task, with CE learners of L2 Spanish in order to confirm this hypothesis.

On the other hand, the current results are in stark contrast to the results obtained by Escudero and Boersma (2002) with L1 Dutch learners of L2 Spanish, who had many identification errors for the /e-i/ contrast. Since Escudero and Boersma (2002) used an orthographic Spanish vowel identification task to test Dutch perception of Spanish vowels, L1 phoneme-grapheme correspondences may have been responsible for the results. Since the Spanish orthographic labels were “i” and “e”, and in Dutch the letter “i” corresponds to the high lax vowel /ɪ/, when hearing Spanish “e” inexperienced Dutch listeners may have heard it as an instance of their /ɪ/ and thus chose “i” as a label. In order to rule out possible effects of Dutch orthography on these learners perception of Spanish vowels, it would be necessary to conduct a categorial discrimination test without orthographic labels with the same population.

Turning to Portuguese, the discrimination results for Portuguese vowels obtained in this study are very similar to those of Elvin and Escudero’ (2013) pilot study on Australian English (AusE) perception of Brazilian Portuguese vowels. Elvin and Escudero found that monolingual AusE listeners found Portuguese /a-ɛ/ easier to discriminate than /a-ɔ/, /e-ɛ/, and /o-ɔ/, which in turn were easier than /e-i/ and /o-u/. The present findings for CE listeners differ only in that /a-ɔ/ was found more difficult than /e-ɛ/ and /o-ɔ/. This is expected, since the /a-ɔ/ contrast is not present in Californian (or

American) English and CE listeners, unlike AusE listeners, have thus learned to ignore this difference. Perceptual assimilation patterns for AusE and CE listeners would need to be compared in a future study to test the PAM's claim about the link between assimilation and discrimination. An acoustic comparison of L1 production of vowels in AusE and CE would be needed as well as to test the L2LP's claim that acoustic differences in the production of AusE and CE vowels should be responsible for the differential performance of AusE and CE listeners when discriminating Portuguese vowel contrasts.

## **5.6 Summary of the chapter**

To summarize, in this chapter we have presented the results for CE listeners' XAB discrimination of Spanish and Portuguese vowels. Levy's (2009a) perceptual overlap metric was found to be highly predictive of discrimination accuracy for CE listeners, lending quantitative support to the PAM's claim that assimilation predicts discrimination. The acoustic distribution of the Spanish and Portuguese tokens in the F1/F2 space was also crucial in explaining the results. Unsurprisingly, overlap in the acoustic distribution of some Portuguese vowels seemed to lead to perceptual confusion of those vowels by CE listeners.

The results of the categorial discrimination task with Spanish and Portuguese vowels were also examined in terms of the PAM and the L2LP models. Both models claim that discrimination accuracy for nonnative sound contrasts can be predicted based upon the perceived similarity between the members of a nonnative contrast and L1 sound categories. The two models propose different perceptual assimilation or mapping

scenarios, which entail different degrees of perceptual difficulty for nonnative listeners. It was found that the L2LP model was better at explaining CE listeners' lower accuracy on the Portuguese /o-u/ and /e-i/ contrasts than PAM. It was also found that L2LP's predictions for the MCA scenario as being more challenging than the Similar Scenario were only partially borne out. In fact, MCA was found to be perceptually problematic only when it created perceptual overlap in the mapping of a Portuguese contrast onto L1 CE vowels. In the absence of such overlap, which was the case for all of the Spanish contrasts and some Portuguese contrasts, even though there was MCA, discrimination was not affected. This suggests that perceptual overlap is a concept that needs to be incorporated into the L2LP model to refine its predictions about nonnative perception of contrasts.

Chapter 6 of this dissertation provides a summary of the findings and a conclusion. Based on the results of our study with monolingual CE listeners, specific predictions for CE learners of L2 Spanish and Portuguese vowels will be discussed.

## CHAPTER 6

### Implications for theories of L2 speech perception

#### 6.0 Summary of the empirical findings

The core of this dissertation is an empirical study that characterizes the initial state of second-language (L2) acquisition of Spanish and Portuguese vowels by Californian English (CE) speakers. While there is ample research on the acquisition of English vowels by speakers of languages with smaller vowel inventories, such as Spanish and Portuguese, scant research exists up to date on the opposite scenario. The present study is innovative not only because it examines the initial state of L2 phonological acquisition of a smaller vowel inventory, but also because it considers two different target languages with smaller vowel inventories for English-speaking learners.

As described in Chapter 3, 18 monolingual speakers of English, born and raised in Southern California, participated in the study. Monolingual listeners were chosen in order to examine the initial state of their phonological system, before any L2 perceptual learning has taken place. The participants completed a perceptual assimilation task, in which they listened to naturally produced Spanish and Portuguese vowels and identified each vowel as one of ten English keywords, *beat*, *bit*, *bait*, *bet*, *bat*, *but*, *bought*, *boat*, *but(cher)*, and *boot*, which corresponded to the CE phonemes /i, ɪ, e, ε, æ, ʌ, ɑ, o, ʊ, u/ respectively. The recordings were part of the corpus collected by Escudero, Boersma, Rauber, and Bion (2009) and Chládková et al. (2011) from monolingual speakers of Portuguese (Sao Paulo, Brazil) and Spanish (Lima, Peru). CE listeners also completed a

categorial discrimination task with the same vowel stimuli, designed to test whether the listeners can accurately discriminate between adjacent vowels in each of the target languages without the availability of orthographic labels.

Four research questions were formulated in Chapter 1 of this dissertation. We are now in a position to answer each question based on the findings of this study.

Q1. Assess inexperienced Californian English listeners' perceptual assimilation of Spanish and Portuguese vowels to native English categories. Is there Multiple Category Assimilation (MCA)? What are the perceptual assimilation patterns in terms of the Perceptual Assimilation Model (PAM) and the Second Language Linguistic Perception model (L2LP) scenarios?

Indeed, CE listeners perceptually assimilated three out of four Spanish contrasts and five out of six Portuguese contrasts via MCA. In PAM terms, several different assimilation scenarios were found for CE listeners with Spanish and Portuguese vowels. The scenarios were characterized in detail in Chapter 4. Furthermore, there were significant differences in how the vowels /e/, /a/, and /o/ were mapped to CE categories, depending on whether they were produced with Spanish or Portuguese values. Portuguese /ɛ/ and /ɔ/ also differed from Spanish /e/ and /o/ in how they were assimilated to CE vowels (all  $ps < .001$ ).

Q2. Assess these listeners' accuracy in a categorial discrimination task with the same Spanish and Portuguese vowel stimuli. Do listeners find some Spanish and Portuguese vowel contrasts harder to discriminate than others?



CE listeners were highly accurate when discriminating the four Spanish vowel contrasts, but were less accurate on Portuguese /o-u/, /i-e/, and /a-ɔ/ than on the Spanish counterparts of these contrasts. The above three Portuguese contrasts were also more difficult than the remaining three contrasts.

Q3. Do perceptual assimilation patterns predict difficulty in a categorial discrimination task, as proposed by the PAM model (Best, 1995)?

Perceptual assimilation, when quantified in terms of an assimilation overlap score (Levy, 2009a), was strongly predictive of discrimination accuracy for CE listeners with Spanish and Portuguese vowels. A Spearman rank-order correlation on each listener's assimilation overlap score and discrimination accuracy for each of the four Spanish and six Portuguese contrasts revealed a strong negative relationship between overlap and accuracy. This means that the higher a listener's overlap score was for a particular Spanish or Portuguese contrast, the lower his discrimination accuracy was for that particular contrast, as predicted by the PAM.

Q4: Is the MCA scenario perceptually problematic for CE listeners?

It was found that MCA is only problematic when it contributes to perceptual overlap for a particular contrast. Spanish /i-e/, /e-a/, and /a-o/, and Portuguese /ɛ-a/, /e-ɛ/, and /o-ɔ/ were each mapped to more than two non-overlapping CE categories, thus exhibiting MCA, but no perceptual overlap. Consequently, CE listeners had no difficulties in discriminating the above contrasts. On the other hand, Portuguese /a-ɔ/ and /i-e/ were also mapped via MCA, but the CE categories to which the two members of each contrast were mapped tended to be the same, thus resulting in perceptual overlap.

The above Portuguese contrasts were more difficult to discriminate, confirming that MCA may be perceptually problematic for listeners when it contributes to assimilation overlap.

It has now been established that Multiple-Category Assimilation (MCA) can in fact be perceptually problematic for learners and therefore it is a scenario that needs to be accounted for by models of nonnative and L2 speech perception. In Section 6.1 we examine the PAM-L2 (Best and Tyler, 2007) and how this model can account for MCA as a perceptual assimilation scenario. Section 6.2 considers how the L2LP model, which already incorporates MCA as a learning scenario, can be modified to account for our findings with CE listeners.

### **6.1 MCA as a learning scenario in PAM-L2**

The PAM-L2 (Best and Tyler, 2007) is an extension of the PAM to account for L2 speech learning. The PAM-L2 agrees with the Speech Learning Model, SLM (Flege, 1995) that L1 and L2 categories exist in a common phonological space. Since the SLM was designed specifically to deal with L2 speech production and was mostly concerned with ultimate attainment, the PAM-L2 uses SLM concepts but reinterprets them in PAM terms. Essentially, the PAM-L2 makes predictions about whether L2 learners will form a separate category for an L2 sound based both on its perceived distance from an L1 phonetic category and on a comparison of the L1 and L2 phonological contrasts. Thus, for instance, in the case of a Two-Category Assimilation scenario, each member of a L2 contrast is assimilated to a different L1 phone, so the learner will likely merge the “similar” L2 phone with a native L1 category, and will not create a separate category for

the L2 sound. In the case of a Single-Category assimilation scenario, the learner will need to create a separate L2 category for each of the members of the novel L2 contrast in order to be able to distinguish minimal pairs of words differentiated by that contrast. Under such lexical pressure, learning to distinguish contrasts not present in the L1 may be possible according to the PAM-L2.

Turning to the MCA scenario, although the term MCA was first coined by Escudero and Boersma (2002), Best and Tyler (2007) hint at this possibility when discussing the Categorized-Uncategorized (CU) and the Both-Uncategorized (UU) scenarios. In the CU scenario, only one of the members of a L2 contrast is assimilated to a native category, whereas the other may be heard as somewhat similar to several native categories. In the case of a UU type of L2 contrast, neither of the two contrasting sounds is assimilated to any single native phonological category, but rather each sound is somewhat similar to more than one native phone. Specifically, in the case of an Uncategorized L2 sound, whether a new phonological category will be created in the inter-language depends not only on how this sound is perceptually assimilated to a set of native categories, but also on how other contrasting L2 sounds are assimilated to native phonological categories. For instance, in the case of the Both-Uncategorized scenario, if two contrasting L2 sounds are assimilated to an overlapping set of L1 phonological categories, i.e., if they are close to each other in the L1/L2 phonological space, they may be difficult for nonnative listeners to discriminate, according to Best and Tyler (2007). If the lexical-functional pressure to discriminate the sounds is great enough, the learner may create a new L2 phonological category, distinct from any of the L1 categories that are somewhat similar to it. Best and Tyler (2007) mention lexical frequency and

neighborhood density as some of the factors that may exercise pressure on the learner to develop new L2 categories and thus be able to create separate lexical representations for minimally contrasting L2 words. Otherwise, there might emerge a single new L2 category that encompasses both members of the Uncategorized L2 contrast.

Applying the above concepts to our findings, Spanish /e-a/ and /a-o/ were both found to be instances of the Categorized-Uncategorized scenario, because Spanish /a/ was mapped to several different CE vowels and thus considered Uncategorized. Furthermore, the members of the above contrasts are not close in the L1/L2 phonological space in PAM-L2 terms, since CE listeners did not exhibit any overlap in the assimilation of the two contrasts. Using the PAM-L2, it can be hypothesized that a CE learner will not create a separate L2 category for the Spanish /a/, because it is quite distinct from other Spanish vowels, but will rather merge his Spanish /a/ with one of the closest L1 vowels in production. Recall that this hypothesis assumes a common L1/L2 phonological space, a concept that the L2LP rejects entirely.

As for /i-e/ and /o-u/ in Spanish, these are both cases of the Two-Category assimilation scenario, and according to PAM-L2, CE learners of L2 Spanish will likely merge each of the four vowels to a native CE vowel to which it was mapped. them with the CE vowels to which they assimilated them. Within this framework, the above predictions can be tested on CE learners of L2 Spanish through a categorial discrimination task with Spanish-English vowel pairs.

We now turn to the PAM-L2 predictions for CE learners of L2 Portuguese vowels. First consider Portuguese /i-e/, /e-ɛ/, and /ɛ-a/, all instances of the Categorized-

Uncategorized scenario. CE learners of L2 Portuguese are likely to merge Portuguese /i/ with their L1 /i/, and their Portuguese /ɛ/ with their native English /ɛ/. As for Portuguese Portuguese /ɛ-a/, /a/ was heard as similar to several L1 vowels but /a/ and /ɛ/ were not mapped to overlapping categories and are thus unlikely to be confused with each other. Thus there would be no pressure to create a separate L2 category for /a/, if we considered only the /ɛ-a/ contrast. However, /a/ also contrasts with /ɔ/ in Portuguese, and this contrast was found to be an instance of category-goodness assimilation. Portuguese /ɔ/ was mapped predominantly to English /ɑ/, whereas Portuguese /a/ was also mapped to English /ɑ/, but less often, thus suggesting that it could be a poorer exemplar of that vowel. In this case PAM-L2 suggests that CE learners of L2 Portuguese will likely merge Portuguese /ɔ/ with their English /ɑ/ and may learn Portuguese /a/ as a separate category, given enough lexical pressure to differentiate it from /ɔ/. Finally, Portuguese /o-u/ and /o-ɔ/ were found to be assimilated as a Two-Category type of scenario, and thus CE learners will likely merge each of the vowels with the native vowel to which it was mapped, according to PAM-L2. However, the prediction that PAM-L2 makes for Portuguese /o-u/ is not consistent with our finding that this was a difficult contrast for CE listeners to discriminate. Once again, all of the above predictions would need to be tested on CE learners of L2 Portuguese.

The L2LP does not agree with the PAM-L2 or the SLM on the issue of a common L1/L2 phonological space. The L2LP claims that the L1 and L2 systems are separate, and any phenomena in bilingual speech perception and production that seem to indicate that the bilingual's L1 was affected by L2 acquisition can be explained by the fact that both the L1 and the L2 systems can be activated at the same time. If the language mode

variable is rigorously manipulated, bilinguals or L2 learners can perform as monolingual speakers or listeners of their L1. Furthermore, given enough input, a L2 learner should be capable of achieving optimal perception in the L2, which includes both learning the exact number of categories in the L2 inventory, as well as perceptual boundaries and cue-weighting, according to the L2LP (Escudero, 2005, 2007, 2009). We now turn to the L2LP model and the predictions that it generates for CE learners of Spanish and Portuguese vowels.

## **6.2 MCA as a learning scenario in L2LP**

As mentioned earlier, Escudero and Boersma (2002) defined MCA as a binary contrast in the L2 that is mapped onto more than two native categories. The authors found that L1 Dutch learners of L2 Spanish mapped the Spanish /i-e/ contrast onto three Dutch vowels, /i/, /ɪ/, and /ɛ/, and their perception of this L2 contrast was inaccurate, but did improve at higher proficiency levels. The case of the Dutch learners of Spanish is probably an instance of MCA with perceptual overlap, since both Spanish /i/ and /e/ were mapped onto the extra Dutch category /ɪ/. Setting aside the possibility that orthography could have influenced the performance of the Dutch listeners in the Spanish vowel identification task, which was used as a measure of perceptual proficiency, it could still be the case that perceptual overlap did contribute to Dutch listeners' low accuracy in identifying these Spanish vowels. Escudero and Boersma (2002) demonstrated that Dutch learners of Spanish with higher L2 used the extra Dutch category /ɪ/ less when asked to label Spanish tokens of /i/ and /e/ and that the reduction in the use of /ɪ/ was correlated with higher

accuracy in the identification of the Spanish vowels. The authors conclude that Dutch learners of Spanish are able to overcome the MCA issue by eliminating the extra L1 category on both a perceptual and a representational level and by adjusting their boundary between Spanish /e/ and /i/ to match the one found in native Spanish production.

Similarly, the task of a CE learner of L2 Spanish and Portuguese vowels would be to eliminate extra CE categories from her perception grammar and to adjust category boundaries to match those of native Spanish and Portuguese speakers. However, we have now established that CE listeners do not have problems distinguishing vowels that are mapped via MCA, unless there is overlap in the mappings of those vowels to L1 categories. We saw in Chapter 5 that CE listeners were highly accurate on all of the Spanish contrasts and on three out of six Portuguese contrasts, even though the majority of those contrasts were assimilated via MCA. Thus perceptual overlap and not MCA was predictive of difficulties in discrimination. When MCA contributed to the perceptual overlap of a target language contrast, listeners exhibited perceptual problems with that contrast. Several questions arise in light of the present findings. What are the tasks that a CE learner of L2 Spanish and Portuguese faces in the case of perceptual assimilation overlap? Is it the same task when no overlap exists? Will CE learners of L2 Spanish easily establish accurate perceptual boundaries for the five Spanish vowels?

According to the L2LP, at the onset of L2 learning, the learner creates a copy of her perceptual system and handles the L2 through that newly formed system, which is initially identical to her L1 perception. In the case of the subset scenario, a learner will need to eliminate the extra phonetic categories from her L2 grammar, which can easily be

achieved through lexical learning. Now it can be hypothesized that when the extra categories do not contribute to any confusion of nonnative sounds, the category boundary adjustment will be minimal. This is evidenced by the fact that inexperienced CE listeners were highly accurate in a categorial discrimination task with Spanish vowels. It is likely that for CE learners of L2 Spanish, achieving accurate perceptual boundaries for Spanish categories will not be problematic.

In contrast, when MCA contributes to high perceptual overlap, as is the case of Portuguese /i-e/ and /a-ɔ/ for CE listeners, the category boundary adjustment will be more difficult because, as Escudero and Boersma (2002) point out, the learner cannot help but perceive the extra categories in the input. This has been demonstrated for Portuguese /i-e/ and /a-ɔ/, two contrasts mapped via MCA that resulted to be more difficult for CE listeners to categorially discriminate. The L2LP predicts that in the case of MCA with perceptual overlap, the CE learner of L2 Portuguese will need to eliminate her extra native categories on a representational and a perceptual level in order to achieve accurate perception of the more difficult vowel contrasts. The L2LP's predictions for L2 acquisition of vowel contrasts mapped via MCA are in need of testing with actual L2 learners of Spanish and Portuguese.

Having examined the predictions that the PAM-L2 and the L2LP models generate for CE learners of L2 Spanish and Portuguese vowels, we can now conclude by offering directions for future research in the area.



### 6.3 Directions for future research

Second-language speech perception is a vibrant but relatively young field within second-language phonology, which makes it a tremendously exciting area in which to conduct novel research. The present study investigated how English speakers categorize and distinguish vowel contrasts in Latin American Spanish (as spoken in Lima, Peru) and Brazilian Portuguese (as spoken in Sao Paulo, Brazil), languages with smaller vowel inventories than English. The findings suggest that extra L1 vowel categories may interfere with accurate perception of nonnative vowels.

One limitation of the present study is that it does not include native listener data, which would be beneficial to have in order to interpret better the results of the categorial discrimination tasks, especially for Portuguese, where lower accuracy was found on some contrasts as opposed to others. Also, predictions about perceptual assimilation and discrimination of Spanish and Portuguese vowels by Californian English (CE) listeners were based on an acoustic comparison of the distribution of the Spanish and Portuguese tokens to the average values for the ten CE vowel phonemes reported in Hagiwara (1997). Although this may be a good approximation of our CE listeners' phonological vowel space, more accurate predictions could be made if CE speakers' production data of native English vowels were available. Escudero and Vasiliev (2011) investigated the claim made by the L2LP that native language production distributions should be mirrored in native and nonnative perception. Using a Discriminant Analysis (Klecka, 1980) procedure, the authors found that the acoustic properties (F1 and F2) of native Peruvian Spanish vowels predicted how Peruvian listeners classified Canadian English and Canadian French /æ/ and /ɛ/. Gilichinskaya and Strange (2011) also used a Discriminant

Analysis procedure and found that acoustics predicted the perceptual assimilation of American English vowels by Russian listeners. The same type of analysis of CE listeners' native vowel production and nonnative vowel perception could reveal more about the acoustic cues that these listeners used when classifying and discriminating Spanish and Portuguese vowels.

Having established the initial state for CE learners of L2 Spanish and Portuguese, which will serve as a baseline for comparison, it is essential to conduct a perceptual study with actual L2 learners of the languages at different levels of proficiency. The results of such a study could shed light on whether the PAM-L2 or the L2LP offer a better account of further perceptual development. The current study should be replicated with L2 learners of Spanish and Portuguese, and furthermore, it would be beneficial to have the learners perform a L2 vowel identification task with orthographic labels, which is precisely what Escudero and Boersma (2002) did with L1 Dutch learners of L2 Spanish. If MCA is in fact perceptually problematic when it contributes to perceptual overlap for a target language contrast, then L2 learners of Portuguese should exhibit lower accuracy in the identification of some Portuguese vowels. Moreover, to examine the effect of L1 phoneme-grapheme correspondences on L2 perception of Spanish and Portuguese vowels, a XAB categorial discrimination task with both auditory and orthographic options (e.g., Escudero and Wanrooij, 2010) should also be conducted.

Another possible venue of research is to compare CE learners of Brazilian and European Portuguese vowels, since Escudero, Boersma, Rauber, and Bion (2009) found cross-dialectal differences between how some vowels were produced in Brazilian versus European Portuguese. The cross-dialectal differences found in production were also seen

in the native perception of vowels by Brazilian and European monolingual listeners (Chládková and Escudero, 2012). Thus we can expect to find differences in nonnative and L2 perception of vowels in the two varieties of Portuguese.

Finally, it is important to go beyond the L2 to the study of third-language acquisition. Many of the students who learn Portuguese at UCLA are speakers of Spanish as a foreign-language, and it is essential to gain an understanding of how Spanish as a second language influences the developmental path of third language acquisition. Further inquiry into CE learners' L2 perception as well as their production of Spanish and Portuguese segments will surely contribute to an understanding of how we learn foreign languages and of how to help learners enhance their communication skills in today's multilingual world.

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