Factors affecting English speakers’ perception of L2 Spanish vowels

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FACTORS AFFECTING ENGLISH SPEAKERS’ PERCEPTION OF L2 SPANISH VOWELS

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ABSTRACT

In the existing studies of the perceptual abilities of the English speaking learner of Spanish some important variables have been left unexplored. The first of these regards the difference in size of the vowel inventories of these two languages and the effect of the larger English inventory upon listeners’ perception of the L2 Spanish inventory. Specifically, the English vowel inventory includes some vowel categories whose existence has been shown to interfere with the English speaker’s perception of Spanish vowels (Bradlow 1995, 1996). Additionally, the duration and diphthongized quality of English tense vowels may exert an influence upon the perception of ‘similar’ Spanish vowels. Lastly, studies on the effects of training on vowel perception have shown mixed results, (Francis, et al., 2000; Jamieson & Morosan, 1989; Lisker, 1970; Logan & Pruitt, 1995; Pisoni et al., 1982; Strange & Dittman, 1984; Tees & Werker, 1984; Werker & Tees, 1984). The current study addresses the effects of vowel inventory size, acoustic differences and perceptual training measures upon the vowel perception of native English speakers learning L2 Spanish.
Participants were students of Spanish at the Beginning, Intermediate and Advanced levels, randomly assigned to one of three training groups: Vowel Duration, Vowel Diphthongization and Voiceless Consonant Aspiration (control). Listeners’ perception of Spanish vowels was assessed in tests of Multiple Category Assimilation and Language Identification. Pretest results revealed that the larger L1 inventory does affect L2 vowel perception as participants at all levels exhibited a high frequency of Multiple Category Assimilation (MCA), or the mapping of one L2 vowel category to more than one L1 vowel category. In posttest measures all groups showed decreased instances of MCA, but no significant effect was found for Training group or Level of exposure to L2. Results for the Language Identification task showed that in posttest measures listeners were better able to identify English stimuli than Spanish stimuli, suggesting an increased ability to perceive the acoustic cues present in English vowels but absent in similar Spanish vowels. No significant effect of Training group or Level was found, although a significant effect of Time was found for most vowel stimuli.
This dissertation is dedicated to

G.S. and L.S. for thirty-five years of love, guidance and pride;

R.E.G. for constant support and encouragement, and for “asking”;

and

L.A.G., for being my greatest source of joy and pride.
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Training Group
STATEMENT OF THE PROBLEM

In the relatively young tradition of research on cross-language speech perception, a large number of studies have investigated instances of second language (L2) perception in which the L2 phonemic inventory is larger than that of the native language (L1). Relatively rare are studies which examine the opposite scenario, in which perception of the L2 involves a phonemic inventory smaller than that of the L1. The literature on cross-language perception studies involving English and Spanish are overwhelmingly focused upon the perceptual ability or difficulties faced by native Spanish speakers of L2 English. At the present time there is a need in the perception literature for more empirical studies which directly assess the perceptual ability of English speaking speakers of L2 Spanish.

The comparative nature of the English and Spanish vowel inventories makes them an interesting topic of research. The English vowel inventory is at least twice the size of the Spanish inventory. For native Spanish speaking learners of English, a potential point of difficulty stems from the existence of vowel categories found in English but not in Spanish, for example the lax vowels /ɪ/, /ɻ/, /ɛ/ (where this last vowel is not a regional variant in the Spanish inventory), /Ø/ and the stressed neutral vowel /ə/. Spanish speakers must create additional perceptual categories for these ‘new’ phonemes which are located near the boundaries of the vowels in the five-vowel inventory of Spanish. For English speaking learners of Spanish, acquiring accurate
perception of Spanish vowels seems superficially to be a much easier task. The most notable advantage for English speaker learning Spanish is the existence of the ‘subset’ of English vowels, /i, e, o, u/, which are acoustic near equivalents to Spanish /i, e, o, u/, four of the five vowels in the Spanish inventory. The near equivalency of these vowels common to both English and Spanish may be the reason that perception research to date has excluded a detailed investigation of the English speaking learner of L2 Spanish. In the early stages of L2 acquisition lexical storage and retrieval may be aided by the presence of similar vowels, making it advantageous to the learner to reuse the subset of English vowels which have perceptual equivalents in Spanish (Escudero & Boersma, 2002). However, at some point in his exposure to Spanish, the English speaker will learn that some of his native categories do not exist in Spanish. The question of interest here is how that knowledge is integrated into the L2 perceptual system. Are the extraneous native categories (/I/, /ε/, for example) discarded? The purpose of the present study is to better understand how English speakers learn to reconcile perception for both the native and target languages.

Historically research in L2 perception has examined the end state of phonological acquisition. Indeed, much of the research of past decades compared L2 perception of experienced learners to native speakers of the target language. What current research continues to lack is a sufficient body of empirical research which looks at L2 perception as it develops throughout the learning process. Current and future research needs to address the manner in which perception changes as learners
gain exposure to and use of the L2. Recent studies have explored the notion of perception and production grammars under the framework of Optimality Theory (Boersma & Escudero, 2004; Escudero & Boersma, 2004; Boersma & Hayes, 2001). These studies have modeled the way in which the learner modifies his perception of the L2 through the ranking and reranking of acoustic constraints.

Lastly, previous research on the effectiveness of perceptual training has yielded mixed results. While some studies found little evidence for a positive effect of perceptual training (Lisker, 1970; Strange & Dittman, 1984; Werker & Tees, 1984), more recent research employing perceptual training methods has indicated that training does have an effect on perceptual learning, but that training does not increase the likelihood that a learner will reach a native-like level of perception (Francis, et al., 2000; Jamieson & Morosan, 1989; Logan & Pruitt, 1995; Pisoni et al., 1982; Tees & Werker, 1984).

The current study will address the question of training effects by including a training component for half of the participants. The effects of training on the task performance of the trained group will then be compared to the task performance of the other untrained group.
REVIEW OF RELATED LITERATURE

Perception Research

Introduction

Research on perception in second language acquisition is not a new field of study. However, in more than half a century of research on how listeners perceive the sounds of a second language, the term “perception” is not always precisely defined in perception studies, nor is it always consistently defined across linguistic disciplines. A review of the literature from the linguistic and cognitive fields reveals the overwhelming preference for the term “perception” to identify the manner in which the language learner, of either L1 or L2, responds to the incoming auditory stimuli. It is a matter of some importance to sort through the varied terminology employed across disciplinary fields and lines of research in an attempt to make clear what is meant by “perception”. Additionally, what is meant by “production”? Are perception and production linked? The discussion to follow will address the current understanding of perception in an effort to 1) identify the processes it comprises and 2) discuss the current understanding of the link between perception and production.

Perception versus audition

Beginning at the most basic level, perception is distinct from audition. Johnson (2003) distinguishes the perceptual representation of speech from the auditory representation. Whereas audition describes sound waves that strike the structures of the ear and are shaped by the nonlinear auditory system, perception may comprise more
than the physics of sound. Perception may also be shaped by the visual image of the
talker, be subject to the physical condition of the hearer (Denes & Pinson, 1993), and
importantly, the lifetime linguistic experience of the listener. To further clarify the
difference between audition and perception, Johnson states that although there is little
reason to believe that language experience causes changes to the auditory system and
its physical components, the same is probably not true for speech perception. Speech
perception is shaped by “linguistic tuning” (Johnson, 2003, p. 75). Speakers of
different languages will have different perceptual maps despite having the same
auditory systems (barring disorders of audition). Linguistic experience highly
influences cross-language perception and will be addressed at various points
throughout this analysis.

Early perceptual development

Research on the perceptual abilities of infants can add more to our
understanding of what Johnson referred to as “linguistic tuning”. Iverson et al. (2003)
reviews past and present literature on infant perception, noting a change in our
understanding of the manner in which human language perception begins and most
importantly, how it changes. Newborn infants possess the remarkable ability to
discern differences among all human language sounds (Kuhl & Iverson, 1996). Some
of the early research on infant perception compared this ability to the adult capacity for
categorical perception (Eimas, Siqueland, Jusczyk & Vigorito, 1971; Liberman, Harris,
Hoffman & Griffith, 1957). It was once thought that infants possessed “phonetic
feature detectors” (Eimas & Corbit, 1973) which atrophy if not used over time (Eimas, 1975). However, more recent research has shown that the term “atrophy”, cited previously, does not properly describe the change that takes place in human perceptual development. Research indicates that by approximately six months of age, infant perceptual acuity becomes biased in favor of the sounds of the native language (Kuhl & Iverson, 1996). It appears that at six months infants start to lose sensitivity to nonnative vowels (Polka & Werker, 1994) and by twelve months have lost the capacity to discriminate nonnative consonantal contrasts which can be assimilated to native categories (Best, McRoberts & Sithole 1988; Werker & Tees, 1984). Research by Best, McRoberts & Sithole (1988) shows that adults do retain the ability to distinguish nonnative phonemes, but suggests that the point of difficulty may be the inability to distinguish nonnative phonemes which are allophonic in their native language. Thus it would seem that Johnson’s (2003) use of the term “tuning” is an adequate descriptor for the changes in human perceptual ability occurring very early in life. The question of whether this tuning reflects universals or language-specific sensitivity is a question which will be addressed in later sections of this discussion.

Perception of speech and non-speech; The Motor Theory of speech perception

The Motor Theory of speech perception (Liberman & Mattingly, 1985) claims that humans possess two distinct biologically given neurological modules, one which is specialized for speech and the other which processes general auditory stimuli. The speech signal is separated from general auditory stimuli at the earliest stage of
perception. As described by Bregman and Pinker (1978), “...the sensory effects of a perceptual object are parsed from other concurrent sensory activity and can be analyzed for phonetic attributes.” In other words, the parsing or separation of speech sounds from surrounding non-speech sounds is a first step in translating the speech signal into meaningful units and ultimately a complete message. To elaborate further, the analysis of the speech signal includes up to four distinct stages – the auditory stage, the phonetic stage, the phonological stage and the lexical, syntactic, and semantic stage (Studdert-Kennedy, 1976). Through these four stages the speech signal is converted from the physical, acoustic event to a more abstract unit such as the phoneme, word or sentence, and at times the latter stages inform the former. This process of translation from concrete to abstract is the job of speech perception (Kess, 1992).

The Motor Theory has undergone repeated revision. The earliest version of the Motor Theory (Liberman, 1957) proposed that infants’ mimicry of the sounds in their environment led to associations between articulation and the acoustic signals that result from articulation. In the last four decades, the Motor Theory has evolved in response to advances in cognitive psychology. A later version of the Motor Theory (Liberman & Mattingly, 1985) reflected the modularity of the mind and the important distinctions between such core concepts as intended phonetic gestures and actual vocal productions. The most recent version (Liberman & Whalen, 2000) interprets in multiple ways the concept of parity, or the necessary convergence of what is intended by the speaker and what is understood by the listener.
That speech sounds are processed uniquely from other sounds can be supported by a number of neurological studies. In previous decades, event-related potentials (ERPs) were frequently the means of measuring the amount and location of activity associated with speech versus non-speech. Results were sometimes mixed, with some studies indicating that linguistic stimuli evoked different components of ERPs than did non-speech stimuli (Ratliff & Greenberg, 1972). Other studies showed hemispheric differences in ERP data (Molfese & Schmidt, 1983), while still others found ERP components to differ in terms of latency, amplitude or polarity (Wall et al, 1991). Later studies employing duplex perception support the findings of the Motor Theory regarding separate regions of processing for speech versus non-speech. Whalen and Liberman (1987) also argue for distinct modes for phonetic and auditory processing and further propose that the phonetic module has priority over the auditory module. In other words, in the presence of competing phonetic and auditory stimuli, speech stimuli are the first to incite brain potentials. Phonological processing as a whole has been shown to occupy different regions of the brain than non-phonological (i.e. semantic) processing (Pillai et al., 2003).

While the Motor Theory is widely cited in cognitive psychology, it is a theory which has been criticized within its own field of speech perception. The Motor Theory of speech perception has been critically reviewed in light of perception research conducted in recent decades. Galantucci et al. (2006) have reexamined the three principle claims of the Motor Theory of speech perception and find that only two of
those claims can be reliably upheld by the available evidence. For its relevance to the present investigation I will devote a few paragraphs to a brief summary of their findings.

The first claim of the Motor Theory of speech perception is that speech processing is special. Galantucci et al. (2006) find that the first claim is difficult to uphold principally due to the fact that it has several readings. It may be interpreted that speech perception is special with respect to audition in that the objects of perception are not acoustic patterns but the distal gestures which generate them. It may also be read to mean that speech is distinct from audition because the motor system is involved. Lastly it may be read that speech perception is special due to the neural circuitry required to process speech, versus nonspeech sounds, a process previously described in this section ("Perception of speech versus nonspeech"). The authors claim that evidence for the last reading is difficult to obtain, ad that only very narrow of interpretations for the first two readings might be confirmed by the available evidence. However, the authors claim that the second and third claims of theory can be corroborated by speech perception research. I will now briefly review that evidence.

The second claim of the Motor Theory of speech perception holds that perceiving speech is perceiving gestures. Galantucci et al. present four types of evidence to support that claim. The first type of evidence is the effect of coarticulation on perception (Liberman et al., 1967). A second kind of evidence comes from the effect of physical gestures on perception. Visual cues, for example, have the potential
to effect perception of speech segments. This phenomenon is often referred to as the McGurk effect (McGurk & MacDonald, 1976), wherein a listener’s perception is affected when he sees a speaker produce one syllable while simultaneously hearing another syllable. A third type of evidence demonstrates that speech perception is aided (i.e. faster) when aided by visual cues. It has been shown that the element of choice may be reduced in the presence of visual information useful for the responses (Fowler et al., 2003; Porter & Castellanos, 1980; Porter & Lubker, 1980). Lastly, the fourth kind of evidence demonstrates that listeners are capable of parsing the speech signal in such a way that the acoustic effects of a gesture is perceived as information for that gesture, despite the effects of coarticulation with another gesture (Mann & Repp, 1980). This can only occur if the Motor Theory’s second claim is true, that perceiving speech is perceiving gestures.

The third claim of the Motor Theory regards the involvement of the motor system in speech perception. Early vowel research demonstrated that listeners’ perception of English /i/, /I/, /e/ and /E/ correlated with their own production of the same vowels (Bell-Berti et al., 1979). Specifically, participants’ perception of tenser vowels (/i/, /e/) correlated with the degree of tenseness of their own productions. There appears to also be an interaction between perception and action, or motor response. Kerzel and Bekkering (2000) found that subjects’ ability to produce syllables produced by a face on a video was negatively affected by the presentation of irrelevant video images in which the faces produced different syllables. Participants’
productions came faster when they saw the same syllable mouthed on the video than when they saw a different syllable produced. The authors’ suggested that the perception of the mouthed gestures activates a motor code that corresponds with the codes activated in the production of the same gestures.

Further evidence for the perception-motor link comes from research which has examined the connection between speech perception and neural activity of the motor system. Separate experiments have shown that when listeners hear utterances produced by certain articulators, they show enhanced muscle activity in the same articulators (Fadiga, et al., 2003; Watkins, et al., 2003). These findings were corroborated by fMRI studies which demonstrate overlap between the cortical areas active during speech production and those active for speech listening (Pulvermüller et al., 2006; Wilson et al., 2004).

Perception of speech and nonspeech; The role of linguistic experience

The processing of both speech and nonspeech may be influenced by linguistic experience. As previously noted, researchers tend to agree that infants are born with the ability to distinguish the sounds of all languages but rapidly lose sensitivity for all but native language phonemes. Kuhl (1991) proposes a “perceptual magnet effect” to account for the sensitivity which develops as infants – and later, adults learning second languages – encounter units of speech. Integral to Kuhl’s perceptual magnet effect is the notion of the phonetic prototype. The notion of a “prototype” is drawn from psychology literature, particularly from Rosch’s (1978) definition of prototypes as
“good instances” of categories. A phonetic prototype is thus, at the basic level, a good instance of a phoneme. The infant learner who has tuned his ear to the input of his language will develop a prototype of each phonetic category in his language. The infant will establish perceptual boundaries for each prototype and when confronted with speech, good instances of a category are pulled toward the prototype, analogous to the functioning of a magnet (Kuhl & Iverson, 1996; Kuhl 1991). Thus the magnet effect implies reduced discrimination sensitivity for the area around a phonetic prototype. For Kuhl, the adult second language learner encounters the same warping of the perceptual space and will compare incoming L2 sounds to L1 prototypes, thereby submitting those sounds to the warping effects of the L1 perceptual space.

It may also be the case that linguistic experience affects the processing of nonspeech sounds. Research in this domain has produced varied findings. Some studies have found an effect of linguistic experience on the processing of speech sounds but no effect for the processing of nonspeech sounds (Miyawaki et al., 1975). In contrast, one study to date has found an effect of language background on nonspeech processing. Specifically, it was shown that native English listeners performed better than Cantonese listeners in tests of frequency discrimination of nonspeech tone complexes. This is an interesting finding given that English is a nontone language.

A recent study by Bent et al. (2006) suggests that perhaps the key to understanding the role of linguistic experience in nonspeech perception is to view
sound processing along a continuum from ‘speech’ to ‘nonspeech’, rather than viewing these concepts as dichotomous (Bent et al, p. 98). These authors investigated speech and nonspeech discrimination in English and Mandarin speakers, using a carefully structured range of perceptual tasks. Tasks were divided between Mandarin tone identification, nonspeech pitch discrimination and nonspeech pitch contour identification. Results indicated that Mandarin listeners were better than English listeners at identifying Mandarin tones, but were less accurate than English listeners in the nonspeech pitch contour test where stimuli were modeled after speech stimuli, and also when the task involved categorization rather than discrimination. Regarding discrimination of nonspeech stimuli were distinct from speech, no listener group differences were found. Therefore this study suggests that linguistic experience can influence nonspeech processing but that, importantly, the extent of that influence varies by task.

Modes of perception

To suggest that speech perception occurs solely at the level of the phoneme would be to misrepresent its complex nature. The literature on speech perception includes studies which further subdivide perceptual skill into distinct modes or tasks. Wode (1994) asserts that the human auditory system is capable of both categorical and continuous perception. *Categorical* perception, as its name implies, recognizes stimuli as belonging to one category or another, without regard to intermediate values. For example, /b/ is categorized as /b/, regardless of the amount of voicing, whether it is
fully, partially or only barely voiced. The obvious benefit of categorical perception is the speed with which incoming stimuli can be sorted, categorized and processed. A second mode of perception is the *continuous* mode, in which the human auditory system discriminates differences in sound on a gradual scale. Werker and Pegg (1992) refer to this type of perception as the *acoustic* factor, or the “ability to discriminate the non-phonetic variability that occurs even within phonetic categories”. To elaborate on the previous example, the listener employing the continuous mode of perception would attend to degree of voicing in /b/ and would theoretically recognize the stimulus as a good or bad example of the category. Lastly, even in cases where an acoustic continuum is perceived discontinuously, speech perception can still be considered categorical. In this instance, the listener discriminates one stimulus as different from another, but also identifies the category to which each belongs. Such differences

Listener capacity for categorical perception both of native language categories (Liberman, Harris, Hoffman & Griffith, 1957; Repp; 1984; Kuhl, 1987) and L2 categories (Flege 1988, 1992) has been the subject of experimental research which will be reviewed in sections to follow.

While both categorical and continuous modes are necessary for speech perception, it is the continuous mode which facilitates the speaker’s ability to check his production against community norms. Wode (1994) proposes that the interaction of these two modes of perception play a role in language change and variation. The influence of speech perception on phonological systems is evident in cases where the
listener’s erred perception of the speech signal results in the modification of his own utterance to match the misapprehended speech (Hume & Johnson, 2001; Ohala, 1981; Beddor et al., 2001). The role of categorical perception is significant in L2 phonological acquisition and is a topic that will be addressed at different moments and in a bit more detail in the ensuing sections of this study.

To briefly summarize, perceptual ability involves more than basic audition, as audition can and often does also include non-speech sounds. Perception involves categorical and continuous discrimination of speech sounds and it seems that the ultimate goal of perception is the identification and correct categorization of sounds selected from an incoming stream of speech. From an early age humans are able to identify elements of speech stimuli that fit their established prototypes and filter out sounds that do not. Kuhl’s model (1991) claims that the adult learner of a second language applies the same network of prototypes and shrunken perceptual space to L2 speech stimuli. In summary, perception is probably best viewed as a complicated process in which physical stimuli are registered by the auditory system, sorted by the brain into meaningful (speech) and non-meaningful (non-speech or noise) stimuli and finally interpreted in terms of the linguistic map of the hearer.

**Perception and awareness**

What is the relationship between perception and “awareness”? The construct of awareness is well-documented in SLA literature (Schmidt, 1990; Schmidt 1993; Nissen & Bullemer, 1987). First, perception is not synonymous with awareness. Awareness
is more closely equated to consciousness than to perception. Additionally, perception may be a first level of awareness but the reverse is not necessarily true. Schmidt (1990) states:

In both common usage and theoretical treatments of the topic, consciousness is commonly equated with awareness. Many writes on the subject have recognized that there are degrees or levels of awareness. Various levels may be distinguished, but …three are crucial: Level 1: Perception; Level 2: Noticing (focal awareness); Level 3: Understanding.

Is awareness or noticing necessary for perception to take place? The literature on perception generally excludes both terms, but there is some mention of the role of attention. Francis et al. (2000) note that recent work on native phonological development supports the hypothesis that phonetic categories are learned by shifting attention to differentially weighted acoustic cues. If awareness is a higher level of processing than perception, awareness may or may not be present for perception to occur. It is accepted that the infant learning the sounds of his native language is probably not aware of the acoustic cues he attends to, but learns nevertheless. It is more likely that the L2 learner shows awareness of the differences between L1 and L2 phonemic categories, but at what level? Most commonly, levels of awareness are examined on tasks of lexical or grammatical learning. SLA studies focusing on phonological learning or acquisition favor a comparison of implicit versus explicit learning tasks, where the learner’s awareness of a phonetic feature might be raised in the explicit task but not necessarily in the implicit task.
Perception and production

What is the relationship between perception and production? Is perception necessary for production? These are two questions which must be addressed in any study of speech perception. First it may be necessary to define what is meant by “production”. In some sense it seems that this is a “catch-all” term in perception literature that may refer to anything ranging from the single articulatory gesture of a phoneme to a complete sentence uttered by a speaker. For the purposes of the present investigation, I take the term “production” to refer to 1) the execution of the articulatory gestures of a linguistic unit and 2) the resultant acoustic event that becomes the auditory input for the listener.

In terms of L1 acquisition it is commonly accepted that perception and production are linked in the development of speech. The Motor Theory of speech perception, referenced earlier in this discussion (Liberman & Mattingly, 1985), suggests that listener perception is the recognition of the articulatory gestures which produce the speech signal. In its current form the Motor Theory assumes that the simplest articulatory gestures perceived by infants are linguistic in nature and processed by a special language module in the brain specialized for linguistic information. Best (1994) also argues for a link between perception and the knowledge of how speech is produced, but argues that language-specific speech perception requires time for the child to detect the systematic nature of language. Indeed, a link between perception and production is advantageous to a child who must not only learn
to discriminate and identify sounds but who must also learn and perfect the motor control necessary to imitate the sounds they hear (Pisoni & Lively, 1995).

For the acquisition of second and subsequent languages, the link between perception and production is not as clear. The lack of certainty on this point in part stems from mixed results obtained from studies which have sought to determine perception must precede production in the acquisition of a second language. There is empirical evidence to suggest that in fact for some speakers production can precede perception. One early study by Briere (1966) examined the ability of English speakers to perceive and produce non-English sounds. Briere’s participants were in some cases able to produce foreign sounds before they could adequately perceive them. A similar study by Goto (1971) studied the /r/-/l/ contrast, a notoriously difficult contrast for native Japanese speakers. The ability of Goto’s subjects to produce the contrast exceeded their ability to perceive it. However, the orthographically cued stimuli could have been a confounding variable in Goto’s study, as many Japanese speakers are aware of the difference in articulation between these two English liquids and could have been cued by the written stimuli. Sheldon and Strange (1982) replicated Goto (1971) and found supporting evidence that production can sometimes precede perception.

Does perception precede production in the remainder of cases? Flege (1987) reports evidence that experienced learners of a foreign language appear to approximate the phonetic standard of L2 to a greater extent than less experienced L2 learners, but
that the effects of equivalence classification, in which L2 sounds are identified with L1 sounds, might impede the learner’s ability to produce authentically certain L2 sounds. According to equivalence classification, difficult L2 sounds, such as those not found in the L1 inventory, might be easier to perceive because the learner will create a new phonetic category for them. The claim is then that different sounds may also be easier to produce than sounds that are close in quality to L1 sounds.

The mere fact that humans are in fact capable of learning second (and additional) languages provides strong evidence that speech perception is strongly linked to speech production. If category boundaries learned for L1 did not remain flexible to some degree, it would be difficult to explain the success of the scores of people who successfully acquire the phonology of a foreign language. Additionally, research in training both perception and production of L2 sounds provides strong evidence that adults are not only capable of correct L2 perception but can also modify their L2 production accordingly (Jamieson & Morsosan, 1986, 1989; Pisoni et al., 1982; Rochet, 1995; Tees & Werker, 1984).

The interplay of speech perception and production

Research on language sound systems has typically been spurred by what is observed to occur in the physical realm of the human speech articulators. Historically the aim of research on perception and production has been to explain the influence of one upon the other. Only in the recent past have researchers begun to explore the possible interplay between phonology and speech perception. This is one aspect of a
proposal advanced by Hume & Johnson (2001) which argues in favor of the interplay between speech perception and phonology, briefly outlined in the paragraphs which follow.

The authors take up the issue of the ways in which speech perception has an influence upon phonological systems. They propose three ways in which this might occur: failure to perceptually compensate for articulatory effects; avoidance of weakly perceptible contrasts; and avoidance of noticeable alternations. The first circumstance could occur when a listener misapprehends the speech of another, perhaps due to articulatory effects such as coarticulation, and in turn produces speech intended to match the misapprehended target (see also Beddor et al, 2001; Ohala, 1981). The second way in which speech perception may affect phonology, the avoidance of weakly perceptible contrasts, can be seen in cases where contrasts which are pronounceable but of little salience might be avoided in speech. The authors offer epenthesis in Maltese, dissimilation in Greek and metathesis in Faroese as examples. Lastly, the avoidance of noticeable alternations may affect phonological systems. In this case, alternations are only accepted if they are auditorily similar to their points of departure or do not constitute risk of misapprehension for the speaker (see also Kohler, 1990).

Taking a broader interpretation of the aforementioned ways in which speech perception influences phonology, Hume and Johnson identify four external forces which act as filters between speech perception and phonological systems: perception,
production, generalization and conformity. The key to understanding the function of these filters is to first understand the ways that “realities in the domain of speech perception interface with the cognitive symbolic representation of language sound structure” (p. 11). Furthermore, the external factors interact with not just one but two symbolic domains; the symbolic cognitive representation (characterized as \( p \) by the authors) and formal phonological theory. The authors suggest a model (Figure 1) which demonstrates the bidirectional nature of a system in which perceptual and productive abilities (two of the four external forces) can both influence phonology and be influenced by it. The third external force, generalization, is comprised of the speaker’s ability to simplify cognitive representations relative to what is perceived. Conformity, the last of the external forces, describes the social and communicative factors involved in shaping language sound systems. Social norms can and do exert great influence over which changes are acceptable and which are not. Social factors influencing speech production will receive further mention in the section titled “Additional factors in second language perception”.

**INSERT FIGURE 1 ABOUT HERE**

**Perception across disciplines**

The question of perception has been addressed by authors from varied disciplinary and theoretical backgrounds. The next section of this paper will provide a descriptive summary of the common lines of research in Cognitive Science, Psycholinguistics and Linguistic Theory. Following the summary I will outline the
areas of intersection among these disciplines as well as any points of disagreement. Lastly I will briefly comment on the aspects of these fields which may be of the most use in my future line of research.

**Cognitive science**

Research in cognitive science addresses a multitude of issues concerning the development and functioning of the human brain. Because speech – as distinct from communication – is a uniquely human trait, it is a wise endeavor to look to the cognitive sciences for further understanding of the cognitive processes which allow us to perceive and produce speech. From research in cognition language we now have a better understanding of order of processing, levels of processing, and the potential limits of human processing of language.

Research in cognition has revealed that processing of speech stimuli can occur in a specified order in some contexts. Dehaene-Lambertz (1997) used a measure of mismatch negativity (MMN) response to test listeners’ reaction to and processing of deviant (nonnative) consonants. Two phonetic boundaries (one native, one nonnative) were examined and results showed that deviant items that crossed the native boundary were accompanied by large MMNs, whereas native items did not produce large MMNs. According to the authors, this suggests that phonetic organization is computed very early in speech processing and additionally, categorization appears to be highly dependent on the subject’s native language.
Research on native phonotactics reveals details about the order and levels of phonemic processing. Hierarchical models of speech perception make a couple of interesting claims. First, that segmental information (phonemes or bundles of features) is derived first from speech input (Marslen-Wilson & Warren, 1994). Secondly and more specifically, this segmental information is used to construct a hierarchical phonological representation that contains higher-order units such as morae, syllables, and feet (Pallier, 1994). Given this information, and the foregoing assertions that the L1 phonotactics assert great influence on the perception of L2 speech, it could be proposed that incorrect phonological forms are automatically corrected by a parsing device (Dehaene-Lambertz, Dupoux & Gout, 2000).

What is meant by “higher-order” and by extension, “lower-order” processing? The explanation may be as simple as what is easy and what is difficult. These terms appear in cognition research to describe, in essence, the level of complexity of a particular stimulus. In a study on perceptual learning, Ahissar (1999) describes higher and lower-level cortical processing associated with perceptual learning. Ahissar’s experiment focused on visual perception, but the general comments on high and low-level learning are applicable to auditory/phonemic perception as well. Learning ‘easy’ stimuli produces more general learning which is easily transferred to novel conditions. Learning ‘difficult’ stimuli produces more specific learning but is much less likely to transfer to novel conditions. In terms of auditory perception, what do these statements mean? A perceptual study by Iverson et al. (2003) addressed high and low-level
processing. Citing research by Kuhl (1991) previously mentioned here, Iverson et al. (1991) suggest that the shrinking of the perceptual space around phonetic prototypes occurs at an early phonetic (i.e. low) level, prior to the recognition or categorization of speech in terms of higher-level linguistic units. Iverson et al. trained native Japanese speakers on both small /l/-/r/ stimulus sets and also on larger, high variability sets. Consistent with statements by Ahissar (1999), the most successful (generalizable) procedures for teaching /l/ and /r/ were the larger, high variability stimulus sets. From these studies, therefore, we now understand that both order and level of processing are significant factors in the study of perception.

Lastly, studies in cognitive science have revealed potential limits of human perception. A study of Spanish-Catalan university students in Barcelona reveals a potential limit on the brain’s ability to integrate new perceptual categories, even in cases where learning begins at an early age (Pallier et al., 1997). The key difficulty for these bilinguals was learning phonetic categories which overlap (see also Best et al., 1988). The Spanish-Catalan study will be explored again later in this discussion.

Psycholinguistics

Psycholinguistics is the branch of linguistics which studies the mental processes involved in the acquisition and use of language (Ellis, 1997). Arguably the most extensively studied area of psycholinguistics is L1 transfer. There are several types of transfer which can manifest themselves singly or in combination in the speech of the L2 learner. Zero transfer describes the case where a structure or sounds found in
the L2 is not a feature of the L1. Negative transfer occurs when an L1 feature is found in the L2 but not in the same environment or distribution. Examples could be allophonic distribution, phonotactic constraints, or any number of grammatical structures. Lastly, positive transfer describes the case where the L1 and L2 share a feature in terms of both its structure or features and its distribution. However, cases of positive transfer rarely if ever are a source of errors.

One early model of acquisition to address transfer effects was the Contrastive Analysis Hypothesis (Lado, 1957). The Contrastive Analysis Hypothesis (CAH) claimed that L1-L2 differences were most often the source of difficulty in L2 speech. It was thought that the elements of L2 familiar to the learner from L1 would be easy to learn while the elements different from the L1 would be difficult. Lado predicted allophonic differences between L1 and L2 to be the chief source of difficulty. In time the CAH fell out of favor, in part because it was not difficult to find cases where learners did not have difficulty with new and different phonemes in the L2.

Research in the tradition of the CAH continued for several decades and gave rise to Flege’s studies of equivalence classification (1987). According to equivalence classification studies, L2 sounds deemed by the learner to be equivalent to L1 sounds are harder to acquire because the learner is likely to assign both sounds to one (L1) category rather than create a new L2 category specific to the L2 sound. Different sounds, according to Flege, would be easier to learn because the learner would be forced to create new categories for them. These predictions are at the heart of Flege’s
The weakness of both CAH and SLM were that, until that time, the criteria for what constituted “similarities” and “differences” had not yet been precisely defined (Eckman, 2004). The Perceptual Assimilation Model (PAM) slightly echoes the tenets of Flege’s SLM, but focused on the behavior of nonnative listeners (Best, 1995). The Perceptual Assimilation model proposes that the difficulty of nonnative contrast discrimination can be predicted based on the perceived similarity of L2 categories to L1 categories. In other words, PAM accounts for learner perception of nonnative sounds in terms of the phonological system of L1. Specifically, PAM proposes that the articulatory characteristics of nonnative sounds will determine the extent to which they will be assimilated into L1 phonetic categories. In turn, the degree of assimilation of the nonnative sound will determine the learner’s ability to detect any contrast.

Another well-investigated line of research has been Interlanguage Theory (Selinker, 1972). The principle idea behind an interlanguage (IL) is that L2 learners construct their own version of the L2 by drawing in part from L1 and in part by constructing their own grammar. Interlanguage theory has occupied much of the research of the last several decades and has been the framework for studies on a variety of languages and structures. Eckman (1981a, 1981b) studied speakers of Cantonese, Japanese, Mandarin and Spanish and found them to perform differently in their production of voiced obstruents in codas, a L1-L2 difference common to all. Perhaps the most revealing finding of Eckman’s study was that for the Spanish and Cantonese
speakers, the motivation for their IL devoicing rules were not found in either the L1 or
the L2, indicating they had constructed their own interlanguage grammar. More
evidence in support of the Interlanguage Theory comes from Hungarian-speaking
learners of English (Altenberg & Vago, 1983) and Farsi-speaking learners of English
(Eckman, 1984) who motivated new IL rules for devoicing word-final obstruents.

Psycholinguistic research also includes the role of consciousness in L2
acquisition. Some of the points to be covered here have been touched upon in previous
sections but are nevertheless useful within a review of the development of
psycholinguistics. Discussions on the role of consciousness can be dated back to early
work by Krashen who proposed the need to distinguish “acquired” L2 knowledge from
“learned” L2 knowledge. The claim that these were knowledge systems independent
of one another eventually gave rise to controversy and led Schmidt to address the then
overgeneralized use in SLA of the word ‘consciousness’. Eventually Schmidt (1990,
1993) argued that consciousness takes many forms, such as ‘intentionality’ and
‘attention’, and that noticing is an essential component of learning. Schmidt’s
proposals on the role of consciousness in learning have had far-reaching effects in
SLA, spawning over a decade of research on the interplay of attention, awareness,
noticing and many other factors.

The role of consciousness in L2 speech perception and acquisition is much less
clear. From what has already been reviewed thus far, it seems that acquiring the
sounds of the L1 takes place with little conscious attention. Rather, the attention that is
given to differing acoustic cues takes place at the unconscious level. However, it may still be true that the adolescent or adult learner of a second language does draw upon conscious processes in some way. If so, to what extent is consciousness (of any form) necessary for perception and hence, L2 speech learning? The majority of research addressing L2 phonological acquisition does not question the issue of consciousness in the same manner as studies of production (i.e. grammatical or conversational structures).

**Linguistic theory**

The most logical point of departure for a discussion of linguistic theory is Universal Grammar (UG). Credited to Chomsky (1965), Universal Grammar proposes a set of grammar principles, shared by all languages, which explain the manner in which humans learn first and subsequent languages and further, how they are able to do so often in spite of a lack of positive evidence for certain structures. For L2 learning, access to UG could theoretically be complete, partial or dual (Ellis, 1997). Learners with complete access to UG are exemplified by the so-called “talented” learners, one of which will be soon be described in this paper. Learners with no access will rely on general learning strategies and never achieve full competence. Learners with partial access will be able to switch to L2 parameter settings but only with the help of direct instruction. And lastly, learners with dual access will employ both UG and general learning strategies but UG will be blocked by the general strategies, producing “impossible” errors.
Optimality Theoretic perception grammars

In recent years linguistic theory has offered an explanation of where perception and production fit into a theory of Universal Grammar. A great deal of this work has been done under the framework of Optimality Theory. To better understand how linguistic theory addresses perception and production, the following discussion will review the relevant literature in an attempt to address two questions. First, are perception and production separate systems? Also, how and when do they interact?

An argument in favor of a separate perception grammar is presented by Boersma (1999). The author offers evidence for a functional phonology which includes four processing systems (Figure 2): the production grammar which maps underlying forms to phonetic forms, the perception grammar which maps phonetic forms to phonological surface structures, the recognition grammar which maps phonological surface structures to underlying lexical forms, and lastly, a comparison module by which a speaker compares his output to adult forms.

A notable aspect of Boersma’s model is that while it includes only one articulatory representation, it includes six perceptual representations which mark the distinct stages of the speech chain between speaker and listener (Boersma, p. 2):

a. The perceptual specification contains lexical forms expressed in terms of discrete perceptual features such as periodicity, spectrum and loudness.

b. The acoustic output is the auditory result of the articulatory output.
c. The perceptual output is the acoustic output perceived by the speaker.

d. The acoustic input is the auditory signal received by the listener.

e. The perceptual input is the acoustic input received by the listener.

f. The underlying form is the form the listener finds in the lexicon and is the same as the speaker’s perceptual specification.

The task of the perception grammar is one of perceptual categorization. It takes the acoustic signal and all of its components and constructs phonological surface structures. In doing so it accomplishes a couple of different tasks. The first is a classification of continuous auditory input (height, place, sonority, etc.) into discrete categories. This is done via the interaction of perceptually motivated constraints. Examples of constraints are those that militate against anything from mapping acoustic input to perceptual classes defined by formant values (*CATEG) or those constraints which militate against large discrepancies between the acoustic form and perceptual form (*WARP).

The second task that the perception grammar is capable of handling is the perception of feature combinations. Feature combinations pose a challenge to perception due to the balance that must be struck between ease of perception of a ‘new’ category and the desire to minimize the number of categories that the learner must store in his inventory. Boersma offers the example of the combination of the perceptual feature values /+nasal/ and /labial place/. For many languages it is easy to perceive this combination as the bilabial nasal /m/. However, this requires the addition of the extra perceptual category. Therefore the perceptual grammar must find an
appropriate ranking of constraints that militate against the addition of new categories and those that militate against the synchronization of gestures.

A crucial aspect of the nature of the perception grammar is that it is not about audibility (Boersma p. 5). This echoes the point made in the first pages of the preceding literature review. In Boersma’s example, the perception grammar maps [530 Hz] to [470 Hz]. The fact that the perception grammar can map an acoustic input to the nearest category does not mean that the listener is incapable of perceiving both acoustic forms. Rather, what it demonstrates is the efficiency of the perception grammar to maintain enough categories so that any given acoustic input is mapped to a nearby category, thus preventing a miscategorization.

The role of perception grammar in production

The perception grammar plays a critical role in production. Specifically, the perception grammar handles the variations in gestures that can yield the same perceptual result. Evidence from this and other sources (Johnson et al., 1994) indicates that speech production is perceptually oriented. Both inter- and intraspeaker variations in production can yield the same result: the same perceptual output for the speaker and perceptual input for the listener. Boersma gives the example of the Dutch trill. Either of two articulatory implementations, [r], and alveolar trill and [R], a uvular trill, can converge on the same result. The same observation can be made for vowel perception. An empirical study by Johnson et al. (1994) revealed within-speaker consistency and between-speaker variability in the production of American English vowels. Crucially,
however, differences in articulation yielded the same perceptual result. Therefore the perceptual grammar must handle the variation that can occur between the perceptual specification and the perceptual result, as exemplified in the previous paragraph. Once again Boersma’s model achieves this via gestural (i.e. articulatory) and perceptual constraints.

The advantage of a separate perception grammar in Boersma’s functional phonology is its ability to restore the role of *sameness* in the grammar (p. 10). Whereas an earlier generative model had done away with sameness, the functional model restores it. This is important because the learner will change her grammar only if she detects that her perceptual output is not the same as her perception of the adult form. It is at this point that the comparison module, mentioned earlier, comes into play. When the learner compares her production to the adult form and notices her error, she is driven to raise the constraints violated by her incorrect production and lower constraints violated in the correct form. After enough linguistic input and opportunity to make these changes to her grammar, the learner will achieve a ranking which matches adult forms. This error-driven process is the essence of the gradual learning algorithm (GLA) (Boersma 1998; Escudero and Boersma, 2003; Boersma et al., 2003). An important aspect of this process is that when the learner notices that her production is incorrect and thus in violation of a particular constraint, this does not constitute a change to her production *grammar*. The changes in constraint ranking take
place only after the learner’s comparison module acts to make her aware of the discrepancy between her production and the adult norm.

**L1 and L2 perception grammars**

In the acquisition of L2 phonological perception the learner will negotiate two perception grammars, one for each language. The L2 perception grammar begins as a clone of the L1 perception grammar (Boersma and Escudero, 2004; Escudero and Boersma, 2002). During the acquisition of L2 the L1 perception grammar will not change, but the L2 perception grammar will gradually depart from a copy of the L1 to a perception grammar more appropriate to the L2.

As seen in L1 perceptual learning, L2 perceptual learning is lexicon-driven (Boersma and Escudero, 2004). For cases in which L2 categories are similar to L1 categories, the initial copying of the L1 perception grammar to the L2 will be advantageous to the learner, creating an initial ease of comprehension. However, at some point the learner will have to make adjustments to her L2 perception grammar so that it approximates native perception. Boersma and Escudero (2004) model such a scenario with Dutch learners of Spanish. The task for this population is to discard some of the vowel categories of their larger native inventory and arrive at an L2 perception grammar that approximates native Spanish perception as closely as possible. In the initial stages of acquisition, the learner’s recognition system may lead to mapping to an incorrect lexical item. In such a case, the learner’s L2 lexicon (i.e.
the learner’s knowledge of L2 lexical representations) will send an error message to the perception system, making similar misperceptions less likely in the future.

Boersma and Escudero (2004) show how Dutch learners of Spanish approach a more native-like Spanish perception. In mapping auditory representations to phonological surface structure, the OT perception grammar uses negatively formulated constraints to militate against perceiving an auditory feature value (an F1 value, for example) as a particular phonological category. This happens just as it does in L1 perceptual acquisition. For Dutch speakers, relevant auditory feature values are duration and F1 and F2 values. Therefore for initial L2 acquisition, the speaker’s perception grammar will include the negatively formulated constraints appropriately constructed around his 12 Dutch vowels (still assuming that L2 perception is initially copied from L1).

Acquisition of L1 perception thus complete, the adult learner is then exposed to L2 (in this case, Spanish). As previously stated, the job for the Dutch learner of Spanish will be to rid her L2 perception of some of the native categories which do not appear in the L2. For example, the learner perceives an incoming auditory feature value as belonging to /I/ (Dutch lax front vowel), which is not a member of the Spanish vowel inventory. Because her perception grammar is lexicon-driven, her interlanguage lexicon (recognition system) will tell her that she is mistaken and should have perceived a different vowel, perhaps /i/ or /e/. As a result the relevant constraints ([F1 = x] is not /I/) will be promoted in the ranking scale and should make it less likely that
the next time she perceives the same F1 it will not be perceived as /I/. It will take years of L2 input for the learner to have sufficient opportunity to experience this error/correction scenario and to then develop an L2 perception that is closer to native Spanish perception. Boersma Dutch (2004) gives a more detailed reading of the simulated Dutch learner and his acquisition of Spanish perception.

Summary of interdisciplinary view of perception

Among the disciplinary fields reviewed above, it seems that cognition research and psycholinguistics are the two disciplines which best compliment each other in terms of their goals and findings. Cognitive science offers the most in terms of our current understanding of the mental processes responsible for human linguistic perception. At present we know that speech stimuli is processed uniquely from other auditory stimuli, as evidenced by fMRIs showing specialized location for phonetic processing (Siok, Jin, Fletcher & Tan, 2003) and ERPs which reveal that phonetic processing is processed before nonspeech stimuli. Cognitive science also provides consistent evidence that L1 perceptual networks play a large role in shaping our perception of both native and nonnative speech stimuli.

The role of L1 in the acquisition of L2 is likewise the chief concern of theories of transfer. For L2 phonology, transfer effects are frequently seen in the allophonic distribution of L1 phonemes in the L2. Also frequently observed in the speech of L2 learners are transfer effects due to L1 phonotactic constraints carried over to the L2. However, phonotactic constraints can be the product of markedness relationships and it
is difficult to determine whether those relationships correspond directly to the ease or difficulty of perception.

Linguistic theory of the last decade has been largely driven by advances in Optimality Theory. Optimality Theory is no longer only a mechanism for explaining the mapping from underlying phonological representations to surface phonetic forms. Rather, OT has been shown to be a tool flexible enough to explain perception, or the mapping from auditory representation (input) to phonological surface structure (output). Linguistic theory has long sought to determine the precise relationship between perception and production, and the development of models of perception grammar may bring researchers even closer to the goal. If indeed perception grammars are distinct from production grammars as some Optimality theorists have suggested, it may well provide a new way of looking at the old perception/production question. The current investigation will not be conducted under and OT framework, but will nevertheless be served by what OT research can offer regarding the nature of perception grammars. Specifically, perception is dynamic and even the adult learner can retain enough plasticity to acquire L2 perception and furthermore, to improve it with increased exposure.

**Additional factors in second language perception**

In addition to the larger concepts already discussed, such as the nature of perception and the contributions of multiple fields of study, there are a number of individual and social factors which may play a role in second language perception. In
fact, each of the factors to be mentioned in the ensuing discussion has a well-established research history. I would like to review some of these factors and along the way will make reference to the factors which I think will play a role in my line of research.

**Age**

Arguably the most frequently-cited theory to address the role of age in language acquisition is the Critical Period Hypothesis (CPH) (Lenneberg, 1967; Penfield & Roberts, 1959; Scovel, 1988). The CPH is probably most often cited in reference to L2 phonological acquisition, as it proposes that an L2 must be learned early, perhaps as early as six years of age, for the learner to acquire native pronunciation. This cutoff is much earlier than for other components of language acquisition, such as syntactical or lexical structures. The CPH has been viewed differently in recent decades, with some suggesting that the age-related difficulties of L2 perception are not merely due to age progression but to a change in cognitive functioning that is not yet well defined (Wode, 1994).

The CPH has never really been disproven, only reanalyzed in light of new findings regarding the flexibility or inflexibility of mental processes associated with language acquisition. Hemispheric specialization was originally proposed as the cause for learning difficulties after a certain age, with a younger cutoff for phonological learning. However, cases of child learners who do not successfully acquire native L2 pronunciation (Flege, Munro & MacKay, 1995) as well as cases of adult learners who
do (Schneiderman & Desmarais, 1988) suggest that normal neurological changes associated with maturity cannot be the sole explanation for perceptual or acquisitional difficulties.

Another view on the effects of age on L2 learning can be found in Flege’s Speech Learning Model (SLM; Flege, 1995). The SLM proposes that the ability to learn speech remains intact throughout the lifespan, but the establishment of L1 phonetic categories early in life will complicate the acquisition of L2 sounds. Later studies by Flege found age of learning and amount of learner use of the L2 (Flege, Schirru, & MacKay, 2003) as well as amount of input received (MacKay, Flege, Piske, & Shirru, 2001) to be more significant factors than chronological age in the overall success of L2 learners.

Wode (1994) also contributes a new view to the old debate about age. Based upon a review of studies on speech perception, Wode cautions that there is more than one way in which age may affect language acquisition and that at present, no single theory can account for all the facts. Wode points to current evidence which strongly suggests changes in perceptual acuity of the older learner are most likely attributable to lack of attention or increased difficulty in accessing original perceptual ability due to established patterns of storing and/or retrieving phonological information (Werker & Tees, 1984; Best, McRoberts & Sithole, 1988).

The age factor will play only a small role in my own line of research. My investigation will not be focused on proving or disproving the effects of age on
learning, as it is already well-established that adult learners are commonly challenged by phonological aspects of L2 learning. My research will focus on adult learners and will seek to add to our current knowledge of how the established L1 perceptual system affects perception of L2 stimuli and potentially, what correlation exists between L2 perception and L2 production.

**Learner aptitude**

Learner aptitude is an internal individual variable that is very often cited in cases of successful learners. The language aptitude construct can be collapsed into three components: auditory ability, linguistic ability, and memory ability (Carroll, 1965, 1991; Skehan, 1986, 1993). These three components correlate to the stages of new language learning: input processing, analysis, and storage. Skehan (1986) has shown that some successful learners are linguistically sensitive, while others possess exceptional memories for storage. It is of course possible that some successful language learners possess a combination of these skills (see also Cook, 1996; Sanz, 2000).

A construct closely related to aptitude is that of talent. While learner aptitude is most often measure with proficiency scores and can identify the better-than-average learner, talented learners cannot be singled out by the same measures (Ioup et al., 1994). The characteristics of the talented learner can be found in published accounts of Julie, a native English-speaking woman who began her acquisition of Egyptian Arabic following her marriage to an Egyptian and her subsequent move to Cairo. Julie learned
in a natural setting but possessed additional qualities that undoubtedly advanced her degree of success in achieving fluency in Arabic. Julie kept journals of daily observations she made about the language. In addition, she received some explicit feedback from family members when gaps in her knowledge impeded communication. Indeed, Julie reported an appreciation for the corrections she received from her listeners. It thus seems that Julie possessed a great level of awareness of the intricacies of language learning and perhaps even high levels of what Schmidt (1990) would call noticing. Julie’s story of language learning is evidence of what great gains can be achieved by the human language learning device.

Motivation

Julie also exemplifies the construct of motivation, another frequently cited individual variable of language learning (Ellis, 1997; Cook, 1996). Motivation can be of at least three types: instrumental, integrative or intrinsic. Instrumentally motivated learners make efforts to learn a language due to requirements of school or career or perhaps for the possibility of advancement in said environments. Integrative motivation describes the case of the learner who is interested in the culture of the people who speak the language in question. Lastly, the intrinsically motivated learner is much like the learner with integrative motivation, but this learner finds the activity of the learning exercise to be motivating in and of itself. Motivation can be a difficult construct to measure due to its dynamic nature (Moyer, 1999). A learner can experience differing levels of motivation as a result of many factors, among them the
varying degrees of difficulty of the language learning experience itself. From one week, month or year to the next a learner may identify himself as being at a different level of motivation and such variability makes correlating motivation with success a more complicated endeavor.

Social factors

The interaction between the L2 learner and the language community has been investigated as variable affecting the success of the language learner. The degree of the L2 learner’s investment in the speech of his community has been examined in bilingual speech communities such as Catalonia (Sanz, 2000; Pallier, Bosch, & Sebastián-Gallés, 1997). Other studies have examined the integration of the immigrant in the L2 society and the social challenges arising from nonnative speech (McKay & Wong, 1996; Pierce 1995). Still others have examined the connection between speech production and the speaker’s goal of ethnic association (Bell, 1997; Ohara, 2001). Piller (2002) conducted interviews with L2 learners who defined themselves as successful language learners, indeed as people capable of passing as native in certain contexts. The common thread in all of these studies is motivation. In the case of the Chinese immigrants in McKay & Wong’s study, learner motivation was integrative. For the subjects of Bell, Ohara and Piller, motivation was perhaps intrinsic and integrative. The crucial point here is that the factors at work in the language community often go hand in hand with the motivation of the learner, potentially increasing or decreasing levels of motivation and potentially, degrees of success.
Time of exposure to L2

There is a body of research by Flege and colleagues addressing the effect of time of exposure on L2 perception and production. Research by Flege et al. (2003) with native Italian-speaking learners of English focused on production of the /e/ vowel of English. Subjects were classified by age of arrival (AOL) and amount of continued L1 (Italian) use. The subjects’ productions were rated by native English-speaking adults and ratings indicated that early bilinguals (i.e. earlier AOL) tended to produce the English vowels more accurately than late bilinguals did and low-L1-use bilinguals tended to produce English vowels more accurately than high-L1-use bilinguals. An earlier study by MacKay et al. (2001) also examined bilinguals in Canada who differed according to AOA and amount of continued L1 use. The findings of this study differed from those of Flege et al (2003). MacKay et al. (2001) examined the production of English /b/ and the perception of short-lag /b d g/ tokens. The observed differences between early and late bilinguals were attributed to differences in amount and quality of English input rather than to any likelihood that early learners have an advantage over late learners for establishing new phonetic categories. Indeed, the effect of time of exposure to the L2 is anything but clear. In a study of Spanish-Catalan bilinguals, all subjects had at least 12 years of exposure to Catalan (Pallier et al., 1997). In spite of both high use and over a decade of exposure, results of this study indicated that the bilinguals had not mastered the perceptual contrast between Catalan /e/ and /ε/ phonemes. The authors claim that these results constitute strong evidence that the sound system learned by the
bilinguals is very biased by the first language learned, and that these speakers do not have two systems between which they might have switched.

Cross-language perceptual training

Cross-language perception research of roughly the last thirty years has given increasing attention to the issue of perceptual training, reflecting the growing opinion that developmental changes due to experiential influences might not be permanent (Werker, 1994). Throughout this period, L2 perceptual training studies have reported mixed results regarding the effectiveness of training measures on accurate second language perception. A fair amount of early work in L2 centered on VOT perception, and indicated that training had minimal influence on nonnative perception of VOT contrasts (Lisker, 1970; Strange, 1972). Later studies, however, found that training methods did in fact have a positive influence on accurate L2 perception, and that adults can acquire varying levels of success on even difficult non-natives phonemes as a result of training (Pisoni et al., 1982; Pisoni et al., 1994; Tees & Werker, 1984).

Successful training studies share the perspective that phonological training involves shifting attention to relevant acoustic cues but more specifically, shifting attention away from familiar cues and to unfamiliar cues (Francis et al., 2000). For the L2 learner, the ability to shift attentional cues in this manner results in a reduction of incorrect hypotheses about the linguistic category of a speech sound, resulting in a more efficient use of cognitive resources (Pisoni et al., 1994). An important aspect of this discussion regards the linguistic relevance of training procedures. In particular,
training may be of little use if the learner has not established the category on which he is being trained. Evidence of this can be garnered from two studies. Strange and Dittman (1984) reported little success at training Japanese speakers on the English /r/-/l/ distinction using discrimination training. Logan et al. (1991), however, found that in some conditions Japanese adults were able to learn the English /r/-/l/ distinction when trained on a two-choice labeling procedure. Thus it appears that when learners are trained in a manner which facilitates the creation of a new category, training can be more effective.

Another important issue for cross-language training regards both the size of the training sets and the duration of training. Naturally both of these issues are subject to a multitude of complicated constraints which invariably pop up in any type of human perceptual training. However, these are factors which merit attention when one is planning an experiment in cross-language training. Regarding the size of training sets, both small and large training sets have their advantages and disadvantages. While training methods involving smaller stimulus sets are generally easier to learn due to reduced demand on memory and attention, they may not generalize to new stimuli (Strange & Dittman, 1984). Duration of training – short- and long-term - is also a matter of practical importance. Short-term training is most often confined to one session (Logan & Pruitt, 1995), and has been shown to be successful in some studies (Lisker, 1970; Pisoni et al., 1982). However, the results of these same studies were not
clear regarding the ability of learners to generalize learning to novel stimuli, suggesting that short-term training may have limited success.

Jamieson and Morosan (1989) outline three important criteria for successful training of non-native phonetic contrasts. These criteria involve both training tasks and selection of stimuli. These authors stipulate that successful training must ensure that 1) training takes place not in isolation but in the appropriate phonetic context, 2) identification tasks with (categorical) feedback are used in lieu of discrimination tasks (see also Strange, 1995; Logan & Pruitt, 1995) and 3) stimuli must be sequenced so that learner attention is initially focused on extreme cases of a category, followed by less extreme cases, a technique called perceptual fading. The fading technique is best applied to stimuli that can be varied either temporally or synthetically to modify critical acoustic parameters (Logan & Pruitt, 1995). The criteria given above will be revisited in the description of the experimental tasks given later in this study.

In summary, there is sufficient research on cross-language training to support the addition of a training component to the current investigation. The description of experimental tasks which follows will treat with more depth the measures to be used to train a group of participants on the acoustic parameters relevant to the English-Spanish vowel distinction.

Implications for current research

In any thorough study of human behavior, individual learner characteristics should be considered. This is especially true for studies of language learning, as
linguistic, social or age factors affect subject performance on the variables under study. The present study on L2 perception will need to be conducted with regard to a few of the factors mentioned previously, for reasons which I will now briefly review.

As previously stated, this investigation will not provide evidence to uphold nor disprove the well-attested observation that the difficulties of L2 perception and production increase with age. I do not intend to compare young learners with older learners. This research will focus on the adult learner who is, according to most research, most likely to be influenced by the pre-established perceptual system of the L1. I will focus on native English-speaking learners of Spanish because in my view of perception literature I find a paucity of studies addressing this population.

Regarding time or amount of exposure, this will indeed be a variable worthy of investigation in my experimental study. I intend to study students of Spanish with varying degrees of exposure to the language. In my previous research with this population I have found that amount and type of exposure to the L2 can vary not only in terms of hours of instruction but also in the amount of exposure outside of the classroom. Additionally, geographic location may provide other opportunities for exposure to the language in question, making it necessary to determine current and previous exposure to the language outside of the formal learning environment.

Motivation is not a central concern of my current research interests but could be addressed by means of profile questionnaires. At present I believe cognitive-perceptual sensitivity to be influenced more by previous language experience than by
affective factors such as motivation. However, it is conceivable that the motivated language learner would seek out additional exposure, thereby increasing the frequency of input of the object of research and perhaps also his sensitivity to any critical perceptual cue weightings.

Of the factors discussed here, I find the influence of L1 perception to be the most pertinent and relative to my own research interests. During years of personal observation I have noted that even L2 speakers of Spanish do not acquire the vowel contrasts between the “similar” /i,e,u,o/ vowels of English and Spanish. This is often the case even when the speaker has acquired Spanish phonemes unique to English or has acquired the allophonic processes of Spanish. Given the recent findings of Bradlow (1995, 1996) regarding the operation of language universals as well as language-specific sensitivities in the perceptual ability of English and Spanish speakers, it seems logical to test these findings with a new set of learners.

Lastly, this study will also comprise a training component to test the effectiveness of training learners on acoustic differences between English and Spanish vowels. Will trained participants perform better on measures of vowel discrimination than untrained participants? The measures used to test this question will be outlined in the Methodology section of this study.

Vocalic spaces of English and Spanish

Perhaps the most notable difference between these two languages is that the English vowel inventory is approximately twice the size of the Spanish vowel
inventory, as seen by the comparison of Figures 3 and 4, below. The quadrilateral and triangle outlines of the English and Spanish vowel inventories, respectively, are not intended to give an indication of the positions of vowels relative to the overall acoustic space, but instead to indicate a general configuration of the vowels of each system relative to their other members. Five vowel inventories are the most common among world languages, found in approximately one quarter of documented languages. Large vowel inventories such as that of English are much less common, occurring in only three to five percent of languages. The vowel systems of both languages are considered to be “balanced”, partial evidence of which can be deduced by the presence of vowels commonly known as the “point vowels”, or vowels with the most extreme values for height and backness. For Spanish these are /i, a, u/ and for English, /i, Ψ, u/. The point vowels are found in the vowel inventories of most of the 317 languages studied by Maddieson (1984) and their presence in a language implies a balanced use of the vowel space (Disner, 1984). The notion of a balanced system grows out of Dispersion Theory, which has evolved from an early theory of maximal contrast (Liljencrants and Lindblom, 1972; Lindblom, 1975) to theory of adequate contrast (Lindblom, 1990). Dispersion Theory states that sounds of languages are selected in such a way as to reduce the chance for confusion between vowel categories. I will discuss vowel category dispersion and its relation to perception in greater depth in sections which follow. While a number of the world’s languages are “unbalanced” due to gaps or even crowding in certain regions of the vowel space, the vowel systems of
both English and Spanish can be considered balanced systems. The Spanish vowel system is a “triangular” system, the most common pattern for the five vowel systems (Disner, 1984). English, by comparison, utilizes more of the peripheral areas of the vowel space for the front and back vowels in its inventory. Also in contrast to Spanish, English utilizes the mid-central region of the vowel space for the vowel category /ə/ (as well as for its counterpart in reduced syllables, /ɒ/). Both English and Spanish have front, unrounded vowels balanced by back, rounded vowels. Neither the English nor the Spanish vowel space is characterized by the gaps or crowded regions seen in “unbalanced” vowel systems. Disner (1984) Lastly, neither English nor Spanish uses rounding, length or nasalization as contrastive features (Bradlow, 1995).

Acoustic comparison of English and Spanish vowels

Having established that the crucial difference between the English and Spanish vowel systems lies in the number of vowels, the next step is to look at the phonetic components of the vowels of the respective inventories. In this section I will discuss the auditory qualities, or acoustic events which signal the phonetic categories associated with each vowel. In the following section comparing English and Spanish
vowels I will take a closer look at the subset of the English vowels often thought to be very similar to four of the Spanish vowels. I will review research which indicates that “similar” vowels are perhaps not so similar in an articulatory or perceptual sense.

The most common approach to an acoustic description of any vowel is by reference to its formants. In the strictest sense, formants are the resonant frequencies present in the speech signal and the resulting peaks produced by these resonances in the sound spectrum. The term ‘formant’ also refers to the frequencies at which these spectral peaks occur. In a sound spectrogram formants appear as dark horizontal bands and represent maximum intensity of resonance at given frequencies. For a more detailed treatment of the foregoing explanation, see Fry (1999). Vowels are universally described in terms of the first two to three formants (F1, F2, F3). Current tools of spectrographic analysis can retrieve values for even the fourth and fifth formants of a given vowel even when the intensity of F4 and F5 are weak, but the essential cues for vowel recognition are carried in the first three formants, and vowels are most commonly labeled in terms of F1 and F2.

Descriptions of the acoustic vowel categories of English are abundant in the phonetic literature (Johnson, 2003; Denes & Pinson, 1993; Johnson, Ladefoged & Lindau, 1994; Syrdal & Gopal, 1986; Miller, 1989). By contrast, studies that directly compare the acoustic realizations of English and Spanish vowels are infrequent in the phonetic literature. For its relevance to the present study I now turn to one study which
in fact focuses on a direct comparison of the acoustic realization of English and Spanish vowels.

Bradlow (1995) compares the acoustic realization of the vowels in these languages for the purpose of uncovering any universal and/or language-specific constraints resulting chiefly from inventory size. Bradlow used vowel tokens extracted from the spoken words of English and Spanish native speakers, averaged over five productions. While Bradlow reports the means and standard deviations of all vowels of each language, the focus of the study centers on the four vowels common to both languages, /i/, /e/, /o/ and /u/. Plotting the locations of English and Spanish /i/, /e/, /o/ and /u/ against each other, Bradlow finds a general upward shift in the F2 dimension of all four of the English vowels relative to the Spanish vowels. After ruling out any effect for different vocal tract sizes of speakers and measuring vowel production across similar syllable types, Bradlow finds a statistically significant main effect for language, indicating that English vowels are generally higher in F2 than the Spanish, and a lack of statistical significance for differences in the F1 dimension. Bradlow interprets these results as evidence for a language-specific base-of-articulation effect. A second experiment compared the range of the acoustic space covered by the four common vowels. The findings indicated that in closed syllables, the area covered by the English vowels is 12.7% greater than the area covered by the Spanish vowels. In open syllables, the English area is only 1.8% greater. These findings taken together indicate that the area covered by English /i/, /e/, /o/ and /u/ is expanded relative to the area
covered by the same Spanish vowels. Lastly, the tightness of within-category clustering was not found to vary significantly as a function of inventory size. In particular, point vowels did not differ from non-point values in terms of their within-category variation. Simply put, the simple fact that English has more vowels does not mean that English vowel categories are crowded relative to Spanish vowel categories.

There are several observations to make regarding Bradlow’s findings. First, that these results contrast with earlier claims of Dispersion Theory which claim that boundaries of the acoustic space are defined universally and that distance between categories is a matter of overall dispersion. Similarly, these findings stand in contrast to the claims of the Quantal Theory of Speech (1972, 1979), which predicts that certain vowels, the point vowels in particular, are acoustically stable and therefore their locations in the acoustic space should be constant across all languages. Instead, the Bradlow data on English and Spanish vowels indicates that “similar” vowels are in fact acoustically unique, owing both their locations and overall range of presence in the vowel space to language-specific base-of-articulation properties. Subsequent research by the same author (Bradlow, 1996) explores further the challenges of cross-language perception, and is reviewed in detail in the next section.

Perceptual comparison of English and Spanish vowel contrasts

Bradlow (1996) is a study of cross-language vowel perception (English-Spanish / Spanish-English) which is relevant to the current research in a number of ways. I will therefore devote the following section of this chapter to a detailed summary of that
study in order to highlight the findings which inform the present study and also to discuss ways in which the present study will deviate from Bradlow (1996) in an effort to contribute more to our understanding of English-Spanish cross-language vowel perception.

The principle manner in which Bradlow (1996) contributes to the present research is in the languages and vowels which it investigates. The goal of Bradlow (1996) was to investigate language-specific and universal acoustic-perceptual characteristics of the /i/-/e/ and /u/-/o/ contrasts in English and Spanish. In particular, the researcher sought to determine the effect on perception of vowels present in one language but absent in the other, specifically /I/ and // of English. As one goal of the present research is to determine whether English speakers demonstrate multiple category assimilation for Spanish, the findings of Bradlow (1996) make an important contribution to the discussion.

The Bradlow (1996) study included two experiments. The first phase of the first experiment was an acoustic analysis of English and Spanish /i/, /e/, /o/ and /u/ as spoken by native speakers of English and Spanish. Speakers read words created by the target vowels placed between an initial bilabial consonant and a final alveolar consonant. The words were then read in carrier sentences, each repeated five times in random order, producing a total of 20 tokens of each vowel category for each language. Recordings were digitized and for /e/ and /o/ vowels, the offglide portion of the vowel was removed to insure that formant measurements then taken were of the
vowel and not the offglide. First and second formant (F1 and F2) measurements were plotted on the mel scale (for perceptual equivalency) and plotted graphically in an M1 x M2 plane. In this way Bradlow demonstrated considerable overlap between English /e/ and the neighboring /I/ categories, as there is between English /o/ and // /. From the recordings taken of each vowel category for each language, perceptual data stimuli were then created.

Following Kuhl’s (1991) method, two groups of perceptual stimuli were created, one group around each of the two mean vowels drawn from the contrasts under investigation. Stimuli were arranged in concentric circles with radii of 30, 60, 90 and 120 mels from the mean, with eight evenly spaced stimuli on each ring. This yielded a total of 66 stimuli per set. Mel values of the acoustic stimuli were then converted back to Hertz and used to create synthetic stimuli. Higher formants (F3, F4 and F5) and other relevant acoustic characteristics were kept at constant values and the duration of all stimuli was 250 ms. The synthetic vowels created by these means were then used in perception experiments with native English and Spanish speakers.

Experiment 1

Experiment 1 tested subjects’ perception of their native categories. Subjects responded to each of the 66 synthetic in one stimulus set 5 times, for a total of 330 trials per condition. Subjects gave both an identification label and a goodness rating (1-5) to each stimulus. In the following paragraphs I will summarize the findings for each condition of experiment 1.
In the English /i/ - /e/ Contrast condition of Experiment 1, English-speaking subjects’ identification and rating responses were plotted and compared to the area covered by the acoustic stimuli, or the tokens produced by native English speakers. It was found that the /i/ - /e/ boundary region in the perceptual space covers a broader range than the corresponding boundary region in the acoustic space. In other words, even tokens of /i/ or /e/ that were placed farther from the mean values were correctly identified by subjects. Subjects were consistent in their /i/ - /e/ identification, but ratings of those tokens were less consistent. Specifically, the ratings for tokens of /i/ and /e/ that overlapped with the /I/ region of the acoustic space were shown to be significantly lower, indicating an uncertainty regarding category goodness due to the presence of /I/ in the region close to /i/ and /e/.

In the Spanish /i/ - /e/ Contrast condition of Experiment 1, Spanish-speaking subjects’ identification and rating responses were plotted and compared to the area covered by the acoustic stimuli produced by native Spanish speakers. Results indicated that the location of the perceptual boundary between Spanish /i/ and /e/ and the location of the acoustic categories were closely linked. Subjects preferred front vowels with high F2 values (as evidenced by higher ratings), but were equally consistent when identifying vowels at the outer and inner edges of categories.

In the English /o/ - /u/ Contrast condition of Experiment 1, English-speaking subjects’ identification and rating responses were plotted and compared to the area covered by the acoustic stimuli produced by native English speakers. A very close link
was found between the arrangement of the phonemic /u/, /o/ and /u/ acoustic and perceptual categories. Also observed was a clear effect of the /u/ category, as reflected by the lower ratings of /o/ and /u/ tokens at the edge of their acoustic boundaries which lay within the acoustic space corresponding to the /u/ category. The highest ratings were given to stimuli with lower F2 values, even when those stimuli lay outside the acoustic /o/ regions.

In the Spanish /o/-/u/ Contrast condition of Experiment 1, Spanish-speaking subjects’ identification and rating responses were plotted and compared to the area covered by the acoustic stimuli produced by native Spanish speakers. Listener responses showed evidence of only two categories in that region of the vowel space, /o/ and /u/. Importantly, those categories had the same F1 and F2 characteristics of the acoustic categories produced by native Spanish speakers. Additionally, and as seen in the English /o/-/u/ rating task, a concentration of higher ratings was observed at the outer edge of the entire vowel space implied by the stimuli, rather than at the outer edge of the stimulus range. Higher ratings were observed for stimuli with low F2 values, both at the lower F2 edge of the general Spanish vowel space as well as at the lower F2 edge of the stimulus range. This was accompanied by low ratings for stimuli at the upper F2 edge of the stimulus range but inside the general Spanish vowel space. These data indicate that listeners judged stimuli with reference to the acoustic properties of the entire vowel space.
Bradlow makes a couple of important observations in light of the results of the Experiment 1 tasks. First, regarding the /i/ - /e/ distinction, it appears that for both languages the primary distinction occurs along the F1 dimension. However, a relatively high F2 can override the F1 boundary effect and therefore make an important perceptual contribution to the /i/ - /e/ distinction in both languages.

Additionally, for both languages the region of uncertainty for the /i/ - /e/ distinction is not in the center of the stimuli range. Rather, for the English stimuli the perceptual boundary is shifted toward /e/ and for the Spanish stimuli the boundary is shifted toward /i/. This means that in both languages the perceptual boundary is located in such a place that the division of phonetic categories is unequal. Yet Bradlow’s results showed these boundary locations to be centered around an F1 of 390 Hz for both languages. This cross-language consistency suggests a natural, auditory-perceptual boundary for that region of the perceptual space.

For the /o/ - /u/ tasks of Experiment 1, Bradlow reports results similar to those for the /i/ - /e/ distinction. Principally, for both languages the boundary region is primarily in the F1 dimension and centered around an F1 value of between 366 and 414 Hz. Thus there appears to be consistency between languages regarding the /o/ - /u/ boundary location, regardless of the effect found of the /u/ category in English. This again points to the possibility of a natural, auditory-perceptual boundary for that region of the perceptual space.

**Experiment 2**
Experiment 2 utilized the same materials and procedures as those used for Experiment 1. However, in Experiment 2 English listeners responded to the Spanish stimuli and Spanish listeners responded to the English stimuli. The following paragraphs will describe the results found for the different experimental conditions.

For English listeners and Spanish synthetic /i/ - /e/ stimuli, results indicated that listeners judged the stimuli with reference to their native vowel space. The Spanish /i/ - /e/ stimulus group and the English /i/ - /e/ native categories differed principally in the F2 dimension, where the English categories are significantly higher in F2. Evidence of this is that Spanish stimuli generated around /e/ were located outside of the area corresponding to acoustic English /e/ and in fact, many were located in the region that corresponds to English /I/. In their labeling of these Spanish stimuli, the English listeners showed a high degree of inconsistency. The stimuli that fall into the region of uncertainty for these listeners are those that fall between English /i/ and English /e/ as well as those that fall outside of the range of English /e/. Bradlow interprets these results as evidence that listeners treat these stimuli as vowels in their native vowels space, with no adjustment of their perceptual space to match the categories indicated by the stimuli.

In terms of the ratings given by English listeners to Spanish stimuli, listeners gave the highest ratings to stimuli at the outer edge of those given /i/ labels. These were stimuli with relatively low F1 values and relatively high F2 values. For stimuli receiving a majority of /e/ labels, the highest ratings were again those located at the
outer edge of the stimulus range. Here it is important to note that because the whole of the Spanish stimulus group is lower in F2 than the listeners’ native categories, the preferred stimuli at the outer edges of the Spanish group correspond best with English native categories.

In a second condition of Experiment 2, native Spanish speakers listened to synthesized English /i/ - /e/ stimuli. As stated before, the English stimuli are higher in F2 and extend beyond the region of the native /i/ and /e/ acoustic categories. When Spanish listeners were presented with the English stimuli, their responses indicated a shift in the region of uncertainty toward the /i/ end of the stimulus range. Bradlow suggests that this is an instance of listeners shifting their perceptual /i/ and /e/ categories to match the locations indicated by the stimuli. However, the region of uncertainty for Spanish listeners hearing English /i/ - /e/ stimuli is not the same as the region for English listeners hearing Spanish /i/ - /e/ stimuli. Whereas for Spanish listeners the uncertainty region was consistent with the between-category region, for English listeners the uncertainty region shifted toward /e/. Bradlow cites these results as further evidence in favor of language-specific effect for listeners of different backgrounds responding to similar stimuli. Lastly, and as previously observed, Spanish listeners gave highest ratings to English stimuli at the outer edge of the vowel space implied by the stimuli.

In Experiment 2 both language groups also identified and rated the back vowels /u/ - /o/ in the other language. For English subjects listening to Spanish /u/ - /o/
stimuli, it was found that the uncertainty region matched the general shape of the uncertainty region of English subjects responding to native /u/ - /o/ stimuli. However, the crucial difference for the cross-language experiment is that the Spanish /u/ - /o/ stimuli were generated around means that were outside the bounds of the native English vowel space (lower in F2 than the lower F2 boundary of the native English space). Therefore if the region of uncertainty was much the same between the native and cross-language experiments, this would suggest that English listeners shift their perceptual spaces to match the experimental stimuli. Data suggest that the perceptual boundary found for the native /u/ - /o/ boundary also persists in the cross language condition. For English subjects listening to Spanish stimuli, half of the stimuli correspond with the /u/ - /o/ perceptual boundary region, and half correspond to stimuli within the /u/ - /o/ region. Lastly, English listeners gave the highest ratings to stimuli with the lowest F2 values, even though these values did not match values for native categories. Bradlow suggests that this underscores the salience of low F2 values for back vowels regardless of category means. In general, it appears that once again listeners judge stimuli with reference to native categories and shift their perceptual space accordingly.

Lastly, Spanish subjects responded to English /u/ - /o/ stimuli. The region of listeners’ perceptual uncertainty corresponded to the region between the Spanish produced /u/ and /o/ categories. No evidence was found for any other boundary, such as that observed when English listeners responded to Spanish /u/ - /o/ stimuli and
demonstrated uncertainty in the region corresponding to English /i/. Bradlow interprets these data as further evidence of a close production-perception link, even when stimuli are not centered on acoustic category means. Spanish subjects gave higher ratings to stimuli with low F2 values, pointing again to the salience of low F2 values for back vowels.

In summary, data from Bradlow’s summary reveal a close link between perception and production in both English and Spanish. In other words, the perceptual boundaries for the vowels pairs coincide closely with the region in the vowel space between acoustic categories of the same vowels. This was observed for both within language and cross-language perceptual experiments. These findings strongly point toward the effect of language background on vowel perception. Of greatest relevance to the present study in cross-language perception is the English subjects’ tendency to judge the Spanish stimuli with reference to their native vowel categories. The result of that tendency was the strong effect of the /I/ and /I/ categories, vowels present in English but not in Spanish. When listening to Spanish vowels, English speakers’ area of uncertainty corresponded to the acoustic space corresponding to these English vowels.

Bradlow’s data support the ‘Hyperspace’ effect found by Johnson et al. (1993). Where Johnson found that his subjects matched extreme versions of synthetic vowels to target English vowels, Bradlow similarly found that listeners generally gave higher goodness rating to front vowels with relatively high F2 values and to back vowels with
relatively low F2 values. Bradlow cites this data as evidence that listeners rate vowels relative to the stimuli they encounter rather than in terms of absolute formant values.

Of further relevance to the present cross-language study in perception is the fact that Bradlow’s data refute findings by Kuhl (1991) and the notion of the ‘perceptual magnet’. Kuhl’s ‘magnet’ describes perception in terms of the matching of incoming stimuli against prototypes, wherein stimuli that share enough features with the prototype will be identified as a member of that category. Bradlow’s data suggests instead that vowel categories are not defined in terms of absolutes, but rather in a relative sense and are adjustable according to their acoustic characteristics.

The present investigation will differ in a few important ways from Bradlow’s work. The first difference regards the participants under study. This investigation focuses only upon English speaking learners of L2 Spanish and therefore there will not be a population of Spanish speakers evaluated on their perception of English vowels. The population of interest for the current investigation will be native English speakers only. A second difference in participant characteristics will be their classification by level of experience with the target L2 (Spanish). Bradlow’s participants varied both in terms of age and the amount of experience each had with the non-native language (for the cross-language perceptual tests). The current study will more tightly control for participant characteristics such as age and amount of exposure to the L2.

A second and very important difference between the current investigation and Bradlow’s research will be the acoustic characteristics of the stimuli. Bradlow’s
stimuli were varied only in terms of F1 and F2 values, with stimuli arranged in concentric circles radiating from central, mean formant values. However, the stimuli did not vary in any other fashion, such as temporal or spectral qualities. In order to address the hypotheses that duration and spectral quality (degree of diphthongization) affect English speakers’ perception of Spanish vowels, the stimuli used in the current study will necessarily vary in duration and degree of offglide.

**Perceiving a smaller vowel inventory**

**Difficulties presented by the English subset**

Commonly reported in the perception literature are cases where the L2 is larger than the L1. In such cases the learner is faced with problems associated with assimilating, or equating two L2 categories to just one L1 category, what Best (1995) refers to as *single category assimilation* (Best, 1995; Flege, 1995; Flege, Schirru & MacKay, 2003). Less common are studies which have examined the challenges faced by the language learner starting from the point of an L1 inventory that is larger than the L2 inventory, as is the case for English learners of Spanish as an L2. An experiment by Escudero and Boersma (2002) examined Dutch speakers’ perception of L2 Spanish, a scenario in which the L1 had a larger vowel inventory than the L2. The authors describe a pattern of multiple category assimilation (MCA) by Dutch learners of Spanish, showing that MCA causes categorization problems in L2 perceptual development and also describe the strategy most commonly used by learners to solve that problem. For its relevance to the present investigation I will dedicate the next
section to a detailed summary of the experimental tasks and findings of the Escudero and Boersma (2002) study as well as to point out the aspects most relevant to the development of my own investigation.

Escudero and Boersma define MCA as the perception of a binary contrast in a second language as more than two categories in the first language. As applied to the Dutch speakers in that study, MCA might be manifested in their perception of the Spanish front vowels /i/ and /e/. Because Dutch has three front vowels /i/, /I/ and /ɛ/, Dutch speakers may sometimes perceive Spanish /i/ as Dutch /i/ but sometimes as /I/ and still other times as /ɛ/. These authors pose two possible problems that might result from MCA. The first is what the authors refer to as the *subset problem*, wherein the learner must learn through positive input only that a particular feature does not exist in the target language. Further, in the case where a learner does in fact “learn” that a third vowel category does not exist, the second possible problem concerns the learner’s ability to *stop* perceiving the spurious category. This position assumes that initial L2 perception is a copy of L1 perception, a position already taken up in previous sections of this study.

In order to test for first, the existence of MCA and second, whether MCA of Spanish front vowels is more problematic for Dutch speakers than two category assimilation (TCA) for Spanish back vowels, a series of listening experiments was administered to 38 Dutch learners of Spanish. The participants were divided into beginner, intermediate and advanced groups according to their level of experience with
Spanish. Experimental stimuli consisted of the five Spanish vowels, embedded between two consonants chosen to sound ambiguously Dutch/Spanish. Listeners heard 25 tokens of each of the CVC tokens containing the Spanish stimuli. The 125 CVC tokens were taken from a Spanish text and read aloud by a native female speaker from Madrid. The stimuli also included 55 filler stimuli with Spanish-sounding consonants, such as the single and multiple vibrants /r/ and /4/.

The first task sought to demonstrate that listeners used all three short Dutch vowel categories (/i/, /I/ and /ε/) when classifying Spanish vowels. The CVC stimuli previously described were embedded in Dutch carrier phrases, pronounced by a balanced Spanish-dutch bilingual. In this task listeners were told that they were hearing phrases taken from a Dutch text. Stimuli were enhanced to encourage Dutch perception by the inclusion of a variety of Dutch phonemes. Listeners were directed to choose from the 12 Dutch vowel categories presented to them. Results from the first task indicated that Dutch listeners at all levels of instruction used all three Dutch categories in their perception of the Spanish vowels, although no significant effect for experience was found.

The second task was designed to show that in the Spanish perception mode listeners would use the /I/ category less than in the Dutch perception mode. The same CVC stimuli used in the first task were embedded in Spanish carrier phrases and supplemented with 55 Spanish-sounding fillers. For this task, listeners were correctly told that the language they were hearing was Spanish but were instructed to listen with
“Dutch ears” and to classify the vowels as Dutch vowels. Results showed that listeners did in fact use /I/ less in the Spanish perception mode and further, that there is a reliable effect of experience on the extent of /I/ categorization ($r = -0.38; p < 0.005$). Furthermore, listeners at times actually used their ‘Spanish ears’ in the second task, despite instructions to do otherwise. The authors suggest this finding to mean that there is a low-level language-dependent perception mode.

The third task was a test of perceptual proficiency. Listeners heard the same 125 CVC stimuli and 55 Spanish-sounding fillers, and this time they were asked to identify the Spanish vowel category from the five Spanish vowels shown on the computer screen. As in the second experiment, the effect of experience was again found to be significant ($r = -0.57; p < 0.0001$). Specifically, as listeners increased in experience their identification of the boundaries between Spanish front vowels /i/ and /e/ became more native-like. Thus, with the results of the three tasks the authors were able to draw conclusions about their main hypothesis, that multiple category assimilation causes front vowel problems. The results of the third task of perceptual proficiency (test of listeners’ identification of vowel category boundaries) were plotted against the reduction of /I/ usage in the first two tasks. The authors found that boundary location correlated strongly with the degree of MCA reduction found between the Dutch and Spanish perception modes ($r = -0.62; p < 0.000001$). The authors offer these results as evidence of language-dependent low-level perception modes. Furthermore, the significant effects for experience underscore the changing
nature of Dutch listeners’ Spanish perception mode. It appears that with experience, listeners are able to accurately place vowel boundaries by getting rid of the extraneous /I/ category.

The design and results of the Dutch study are directly relevant to the present line of investigation. First, because the Dutch vowel inventory is similar to the English vowel inventory in the number of vowels they contain, the existence of a tense/lax distinction between some vowels, and the position of the vowels in the articulatory space, it is logical to investigate the possibility that English speakers would behave similarly to Dutch speakers in their manifestation of MCA for front vowels. In particular, do English speakers sometimes perceive Spanish /i/ as /i/ and sometimes as /I/? Second, because the Dutch study investigates the effect of experience on listeners’ ability to discard extraneous vowel categories it bears relevance to Research Question 3 of the present investigation.

The Dutch study is an examination of perception within particular language contexts. Specifically, perception is affected by the language that a listener thinks he is hearing. A later study by Boersma and Escudero (2004) explored further Dutch listeners’ perception of Spanish vowels and modeled, via an Optimality Theoretic formalization, the way in which a listener’s perception changes over time in lexicon-driven learning. In short, a listener matches incoming stimuli against the existing (and presumably correct) representations in her lexicon. In the case of a mismatch, where the listener perceives a category that her recognition system tells her is incorrect, the
plasticity of the listener’s perception grammar allows her to re-rank the appropriate constraints in order to maximize the likelihood that in the next instance there is no error. Furthermore, the Boersma and Escudero (2004) study modeled the way in which a learner adjusts her L2 perception, initially a copy of her L1 perception, so that over time it more closely approximates a native level of perception.

Both studies on Dutch listeners’ perception yielded important findings regarding the adjustments listeners make to their perception in varied language contexts and further, the way in which those modifications are made via changes in cue weighting made over time. The study proposed here will have as its experimental base the experimental design used in Escudero and Boersma (2002). However, this investigation will further refine the methods used in the Dutch study testing factors not tested in the previous studies. By acoustically modifying test tokens for duration, and degree of diphthongization, one of the goals of the current study is to further identify which cues are the strongest in listeners’ cue weighting. Previous research has shown that for English speakers duration is a strong cue (Fox, Flege & Munro, 1995) but without a direct comparison of duration with spectra quality and degree of diphthongization we cannot be really sure of what the strongest cues are. Therefore the design of the present investigation will include tests specifically created to test for the effect of these native cues on the perception of Spanish vowels.

Based on the difference in size of the English and Spanish vowel inventories, together with data from the sources previously reviewed, I can make some preliminary
predictions regarding patterns of transference from L1 English to L2 Spanish. I predict that English speakers, despite having a subset of “common” vowels that they initially transfer to L2 Spanish, will demonstrate flawed categorization of L2 vowel categories. I predict the cause for flawed perception to be the transfer of L1-based perception, which will in turn impede correct categorization of L2 vowels due to the overlap of phonetic categories in L1. I expect that high and mid front vowels as well as high and mid back vowels will be problematic, similar to the findings of Bradlow (1996).

The English subset: Additional characteristics

Previous research has shown duration to be an important cue for English perception (Fox, Flege and Munro, 1995). An example of the role of durational cues in English is the tense/lax distinction of vowels such as /i/ and /I/, /e/ and /ε/, /u/ and /º/, /o/ and /Ο/. Additionally, when the tense vowels occur in stressed syllables, they are diphthongized. The fact that the tense/lax distinction is a feature only for the vowels listed above can be explained by their location in the vowel space. Because the members of each pair are located close to one another in the articulatory space, the tense/lax distinction is an additional feature which provides a unique phonetic description for each vowel (Hammond, 2001). In some of the studies previously reviewed (Bradlow, 1996), comparisons of the tense English vowels (/i/, /e/, /o/ and /u/) to their Spanish counterparts were made only after filtering out the offglide present in the original English tokens. Personal observation has shown that English speakers transfer the diphthongization of their tense vowels to their production of Spanish /i/,
/e/, /o/ and /u/. Is this due only to an articulatory habit which must be overcome (because Spanish vowels are never diphthongized), or are English speakers insensitive to the cue given by the offglide? I think this is a question which cannot be answered correctly without a direct comparison of tokens differing only in duration and cued by the offglide.
Rationale and research questions

Summary of previous research limitations and rationale for the study

The foregoing summary of previous research in the field of second language perception has addressed several issues pertinent to the current investigation of English speakers’ perception of L2 Spanish vowels. Nevertheless, previous research leaves several avenues still to be explored and the purpose of the present research is to empirically address these issues.

The first goal of the current study is population-specific and regards the need for empirical research on the perceptual abilities of adult English speakers of L2 Spanish. With a few exceptions, this population has received little attention in L2 perception research relative to the amount of studies addressing perception of English by speakers of other languages. In the small number of additional studies of L2 perception focused on English and Spanish, the scenario was reversed; the participants under study were native speakers of Spanish tested on measures of English perception (Flege, 1991; Flege & Bohn, 1989, 1991; Flege, et al., 1994; Fox et al., 1995). At the time of this writing, only two published studies by Bradlow (1995, 1996) directly address the acoustic factors underlying English speakers’ perception of Spanish vowels. The present study will exclusively address the perceptual skills of adult native English speakers of L2 Spanish.

One of the core issues of the previous literature review was the acoustic comparison of the vowel systems of English and Spanish. The most notable difference
in the two systems is their respective sizes, with English having at least twice as many vowels in its inventory as Spanish. A very interesting finding of Bradlow (1996) was that native English speakers not only perceived Spanish stimuli in terms of their native vowel space, but when doing so, demonstrated difficulty with the perception of the /e/ - /i/ contrast due to the neighboring English /I/ category not found in Spanish. English listeners showed similar results with the /o/-/u/ contrast, where the complicating factor was the existence of their native /I/ category. The additional English categories can be problematic for the listener mapping L2 Spanish vowel categories to L1 English vowel categories. Support for this was found by Escudero and Boersma (2002), who cite evidence for multiple category assimilation by Dutch-speaking learners of Spanish. Although the L1 studied was not English, the similarities in size and the categories between the Dutch vowel system and the English vowel system are sufficient to warrant an investigation into whether English speakers of L2 Spanish are also challenged by what Escudero and Boersma refer to as the Subset Problem. The present study include tasks modeled after experiments used in Escudero and Boersma (2002) in order to determine if English speakers also show evidence of multiple category assimilation when perceiving Spanish vowels.

Apart from the difference in the size of these two systems, previous research has shown that native speakers of English and Spanish are sensitive to different acoustic components (Bradlow 1995, 1996). English, unlike Spanish, makes use of differences in duration and diphthongization to make vowel contrasts (Fox et al.,
A logical question therefore is whether English speakers depend on those native cues in their perception of Spanish vowels. This study will include a training component, described below, designed around these acoustic features in order to determine if listener perception of these cues can be improved and if that perception increases accuracy on assessment measures.

The foregoing literature review also highlighted the learner-specific factors involved in L2 perception. These included aptitude, motivation, social factors and time of exposure to L2. The last of these factors, time of exposure to L2, will play a central role in the present investigation. Previous studies have investigated the perceptual capacity of early (infant or pre-pubescent) learners as well as the perceptual abilities of learners who have been exposed to the L2 for a number of years. However, there is a paucity of studies which have detailed the perceptual ability of the adult learner at defined stages of second language acquisition. Little is known about the perception of beginning adult learners because previous studies which have in fact investigated beginning L2 learners have failed to adequately describe the amount L2 experience of their participants. Previous studies have either (1) failed to specify the time of exposure of subjects or (2) have assigned subjects with varying levels of exposure to the same experimental groups based upon other factors.

This investigation examines the effects of training on cross-language perception. Cross-language perception research has shown that developmental changes due to experiential influences might not be permanent (Werker, 1994).
Perceptual training studies conducted within the last two decades have found that adults can acquire varying levels of success on even difficult non-natives phonemes as a result of training (Jamieson & Morosan, 1986, 1989; Pisoni et al., 1982; Pisoni et al., 1994; Tees & Werker, 1984). The successful training studies are those in which phonological training involved shifting attention away from familiar cues and to unfamiliar cues (Francis et al., 2000). Therefore the present investigation attempts to train listeners on the cross-linguistic acoustic differences which may be perceptually unfamiliar to them.

In summary, the present investigation addresses what I consider to be the core issues involved in native English speakers’ perception and categorization of L2 Spanish phonemes. Do English speakers map Spanish vowels to a subset of their native vowel categories? What is the effect of amount of exposure on adult learners’ perception of L2 Spanish vowels? Is there a significant difference between levels of learners? Is there an effect of training on accurate L2 perception and specifically, is there a differential effect for training on vowel duration or vowel diphthongization?

**Contribution to existing literature**

The present study is clearly couched within the field of applied linguistics and as such has as its principle goal to add to current knowledge about the factors that influence second language acquisition, in this case L2 perceptual acquisition. Some of the important contributions of this study include investigation of learners at different levels of exposure and an examination of the effects of cross-linguistic acoustic
differences upon vowel perception. These are issues which in one way or another have not been thoroughly addressed in previous literature.

Beyond the anticipated contributions to applied studies, an important goal of this study is to test claims of theoretical studies which propose perception grammars (Boersma 1998, 1999; Boersma et al., 2003; Escudero & Boersma 2003) or filters (Hume & Johnson, 2001) which exert an influence on phonological systems. The importance of these studies to the present investigation is their view of perception as flexible and changing rather than a fleeting event in the speech chain. Kuhl’s model of the magnet effect is instructive but lacks the explanatory power that the aforementioned models have for explaining listener behavior over time. The view held for the present study is that L2 perception is not static and that even adult L2 perception can change and inform both the perception and production grammars. This view will be revisited in the final sections of this study as part of the discussion of experimental findings.

Research questions and hypotheses

This study is guided by the following research questions and hypotheses:

Research question 1:

Does native vowel inventory size have an effect on English speakers’ perception of L2 Spanish vowels? Specifically, do English speakers show evidence of Multiple Category Assimilation for Spanish front vowels?

Hypothesis 1:
The presence of additional English categories will affect correct identification of Spanish vowels and English speakers will show evidence of multiple category assimilation of Spanish vowels.

Research question 2:
Does increased exposure to Spanish have an effect on English speakers’ correct perception of Spanish vowels?

Hypothesis 2:
Increased experience with Spanish will positively affect English speakers’ correct perception of Spanish vowels. Participants with more experience with L2 Spanish will have statistically higher scores on tests of perception than will participants with less experience.

Research question 3:
Is there an effect of perceptual training on English speakers’ perception of Spanish vowels /i, e, o, u/? Specifically, is there an effect for vowel duration training and/or vowel diphthongization training? Does training have a differential effect on different Levels of listeners?

Hypothesis 3:
Perceptual training will have a positive effect on English speakers’ perception of Spanish vowels. Participants who receive perceptual training on the acoustic
differences between English and Spanish vowels will score significantly higher on perceptual tests than control subjects receiving training on other acoustic features.
Summary of the study

This summary briefly outlines the methodology to be used in this experiment. More detailed description will follow in sections dedicated to each phase of the experiment. Table 1 gives the overview of all phases of the experiment. In order to address the research questions listed above, native English-speaking participants will be required to perform a series of listening experiments designed to test their perceptual abilities in L2 Spanish. As one of the research questions here addresses the effect of perceptual training, it will be necessary to evaluate participants’ perception of Spanish vowels before as well as after training measures. This will be accomplished via Pre-test and Posttest measures.

The first Pretest, a test of Multiple Category Assimilation (MCA) was designed to evaluate English speakers’ perception of Spanish vowels in different perceptual modes. These tasks were partially modeled on the tasks used in Escudero & Boersma (2002) and in these tasks participants heard the five Spanish vowels presented in CVCV tokens but under separate conditions designed to elicit different perceptual modes. In the pilot study Pretest the MCA task consisted of three phases. The number of phases was changed for the full study, and an explanation for and about the change will follow in ensuing sections. The decision use CVCV syllable shapes was made in consideration of Spanish phonotactics, as CVCV syllable shapes are more common than CVC shapes in Spanish, and are permissible in English as well. The different perceptual conditions elicited in the pre-test tasks will be described in detail in the
pages to follow. The second part of the pilot Pretest consisted of a Language Identification task focused specifically on the vowels ‘common’ to English and Spanish, /i/, /e/, /o/ and /u/. The purpose of this task was to assess listener’s ability to correctly identify the vowels by language. This identification task utilized natural Spanish CVCV tokens to evaluate listeners’ reliance upon cues that are present in their native English vowels (longer duration, offglides cueing diphthongization) but absent in similar Spanish vowels. Pretest CVCV stimuli for both the MCA and Language Identification tasks are given in Table 6.

This study also contained a training component. During the training phase study participants were divided into a total of three groups by training condition. The Trained Test Groups received training on the acoustic differences between English and Spanish /i, e, o, u/ in terms of Vowel Duration and Vowel Diphthongization (Appendices A and B). The Trained Control Group received training on voiceless stop consonants /p, t, k/ Appendix C). Immediately following the training sessions both the Trained Test Groups and the Trained Control group performed A/X (“same/different”) Discrimination tasks which served as focused practice following their respective tutorials. A more detailed description of all tasks, including test tokens used and instructions to the listeners will be given in the following section on research design and methodology. Training stimuli are given in Tables 7 and 8.

In the Posttest, participants once again took the perception tests consisting of the Multiple Category Assimilation and the Language Identification tasks described
previously. The Posttest contained items identical to the pre-test measures but with a new randomized order of presentation in a split-block design. Posttest stimuli are given in Table 9.

**RESEARCH DESIGN AND METHODOLOGY**

The purpose of this chapter is to describe the methodology followed in the current study on adult perception of L2 Spanish vowels. This chapter will begin with a description of the participants under study. Next, the materials used to elicit measurements of perception will be described, as well as the phonemic structures chosen for the study and the rationale for their selection. The final sections will provide a description of the experimental tasks and the procedures followed in each.

**Participants**

The participants in this study were adult students enrolled in college-level Spanish courses. One hundred and eighty participants were divided into a total of nine groups according to levels of class placement (Beginner, Intermediate, Advanced) and Training (2 Trained Test Groups, 1 Trained Control Group). The level of class placement was balanced by the approximate number of hours of exposure to Spanish reported by each participant at the time of task administration. This information was determined by a questionnaire administered before participation in any of the experiments. The reason for balancing class placement with hours of exposure was to eliminate any between-subject inconsistency which might be overlooked in the course of placement in college-level Spanish courses. For example, if a student enrolled in
first semester Spanish revealed that he had significantly more hours of exposure to Spanish than the average student placed in his class level, it was therefore necessary to assign that student to a group which better matched his level of exposure.

The participants in this study met three basic criteria. First, all participants were native speakers of English, born and raised in the U.S., where English was the language spoken in the home during childhood and adolescence. The second criterion was that their exposure to Spanish first occurred during or after adolescence (age 13 or older). The third criterion required that participants had no prior instruction in Spanish phonetics. The Participant Questionnaire also ensured that participants had no history of hearing problems. Participants’ knowledge of other Romance Languages was also assessed via the Participant Questionnaire. An initial goal of this study was to ensure that participants had no knowledge of another Romance Language in order to prevent the uncontrolled influences of that knowledge upon listener perception. However, most college students have had exposure to a foreign language in high school, and the vast majority of those study a Romance Language. Therefore for this study the participants’ study or knowledge of other Romance Languages was measured via the Participant Questionnaire. This information was recorded and saved in the same data file in which assessment data was recorded. This information will be used in a future follow-up study which assesses the effect of experience with other languages as well as other variables upon perception of Spanish vowels.
Materials

The perceptual targets

The targeted phonemic structures in the present study include natural and edited natural tokens of Spanish vowels. The Pre-test and Posttest measures assessing MCA featured all five natural Spanish vowels, /a/, /i/, /e/, /o/, /u/. The Pre-test and Posttest Identification trials as well as the Discrimination and Identification trials of the Training phase focused on the four vowels ‘common’ to both English and Spanish, /i/, /e/, /o/, and /u/.

Rationale for selection of the perceptual targets

To begin, the acoustic comparison of English and Spanish vowels makes them an interesting topic of study. As stated previously in the section dedicated to acoustic properties of English and Spanish vowels, the “similar” vowels /i/, /e/, /o/, and /u/ are in fact acoustically unique in each language. English vowels are generally higher in F2 than the Spanish vowels and are also longer in duration than their Spanish counterparts (Table 3). Additionally, these four vowels in English are tense vowels with a diphthongized quality, a feature not characteristic of the Spanish vowels.

Secondly, evidence from Bradlow (1996) indicates that the presence of a neighboring vowel category in L1 English is problematic for correct perception of L2 Spanish categories. English speakers showed a relatively high degree of uncertainty in their identification of Spanish /e/, often mapping it to English /I/. English speakers also showed uncertainty in their identifications of Spanish /u/-/o/ stimuli due to the
influence of neighboring categories (/ /) in their L1 acoustic space. These results suggest that L2 sounds are perceived in terms of the L1 vowel space and that listeners may make no adjustments to their perception in order to match the category locations indicated by the stimuli. A similar pattern of perceptual behavior has been revealed by studies of Dutch learners of Spanish (Escudero and Boersma, 2002). This study found evidence for multiple category assimilation in Dutch speakers who perceived three categories where the target language (Spanish) only had two. The authors refer to this pattern as the “subset problem”, where the target language contains a subset of the L1 categories and the challenge for the learner is to discard the L1 category not used in the L2. Due to similarities between the Dutch and English vowel systems in regards to the size and nature of their vowel inventories, it is plausible that English speakers will perform similarly to the Dutch speakers in the Escudero and Boersma study and will experience difficulty discarding the extraneous English category when confronted with Spanish vowel categories.

The Independent Variables

Exposure to L2

To test the effect of L2 exposure on vowel perception, adult L2 Spanish learners were drawn from three different levels of college-level Spanish courses – Beginning, Intermediate and Advanced. Participants drawn from these levels completed questionnaires designed to confirm his or her level of exposure. Such measures were necessary in order to avoid a scenario in which a student’s class
placement may not accurately reflect his amount of exposure to Spanish at the time of the experiment.

**Perceptual training**

The second independent variable under investigation in this study was perceptual training. Because cross-language perception research of approximately the last two decades has increasingly shown positive effects of perceptual training on listeners’ ability to shift attention to critical cues in the L2, one of the goals of this study was to add to this body of research by incorporating a training component. Participants in this study were divided into three groups based upon the explicit acoustic training they received on the acoustic factors of interest in this study. Two thirds of participants were divided into two Trained Test Groups and were trained on the acoustic parameters of duration and diphthongization respectively, with a vowel tutorial presenting the qualitative differences between English and Spanish vowels in terms of these parameters. The remaining third of participants were assigned to the Trained Control Group and received training on non-aspiration of stop consonants /p/, /t/, and /k/, a phonetic feature unrelated to the acoustic parameters of interest here but nevertheless valid in a study of L2 Spanish perception. Following the training sessions, both the Trained Test and Trained Control participants performed follow-up A/X (“same/different”) Discrimination tasks on their respective acoustic features. These tasks are described in greater detail in the following sections “Experimental Tasks” and “Description of Task Stimuli and Procedure”. The assignment of
participants to training groups was made at random and participants were equally
divided between the three groups. As with any investigation centered upon data
collected by university students, factors such as class scheduling, the timing of testing
within the semester and the ever-present threat of subject attrition due to waning
motivation contributed to the decision to limit the training period to one experimental
session. Although extending training over many days or even weeks would likely
yield numerous benefits (Logan and Pruitt, 1995), the factors cited above as well as
practical considerations regarding remuneration limits dictate the duration of the
training period. All training was delivered by computer using E-Prime software on PC
stations in a language laboratory, and at the beginning of each training session
participants were given a short introduction to the acoustic parameter that was the
target of that session.

The Experimental Tasks

The section which follows outlines the Training tutorials, Discrimination tasks
and Identification tasks which were used in the study. Included in this section is
information regarding the participant groups, creation of test stimuli and the order of
administration of the tasks. The Research Design Overview is given in Table 1.

General description of tasks

Vowel tutorial

Participants in the Trained Test Groups were given short tutorials, delivered by
computer, which gave brief but sufficient information regarding the nature of Spanish
and English vowels and in particular how they differ acoustically. The acoustic parameters under study here, duration and diphthongization, were explained in the tutorials in as simple a manner as possible. In other words, the tutorials were not intended to be a crash course in phonetics but rather served the purpose of introducing listeners to the existence of these parameters and to train participants to listen for these features in the tasks which follow. The tutorials presented the vowel inventories of both languages and were focused on the four ‘similar’ vowels /i/, /e/, /o/ and /u/.

Trained Test participants were divided into two separate training groups: Duration Training Diphthongization Training. In these training sessions listeners began with a tutorial which presented the feature being trained (Appendices A & B). Participants in the Trained Control Group followed the same procedure, but were instead given a tutorial focused upon unaspirated Spanish /p,t,k/ (Appendix C). The training tutorial lasted approximately 20 minutes.

**A/X Discrimination task**

Following the tutorial, participants’ perceptual sensitivity was trained via an A/X (“same/different”) Discrimination task. In an A/X Discrimination task, listeners heard two stimuli in each trial. The first stimulus (“A”) was held constant and the listener’s job was to determine if the variable comparison stimulus (“X”) was the same as or different than the first stimulus. A/X Discrimination tasks have been used in speech perception research to assess the limits of the listener’s sensory capacity (Logan and Pruitt, 1995). Additionally, A/X discrimination training has been used in VOT
studies (Carney et al., 1977) and in training studies on Japanese listeners learning the
/r/ - /l/ distinction, where changing F3 along a continuum in some cases helped
listeners perceive the distinction (Strange and Dittmann, 1984). In the present study,
the A/X Discrimination task was used to focus listeners’ perception on a model
stimulus through repeated play of that stimulus and comparison of other, acoustically
modified stimuli to the model. Listeners were told in the task instructions that the first
stimulus presented was representative of the parameter being trained (a Spanish vowel
of appropriate duration, for example) and to decide if the second stimulus was the same
as or different from the first. Thus with this design, listeners had repeated exposure to
a model stimulus as well as multiple opportunities to hear other, non-model stimuli.
The goal of this task was to train listeners to discriminate vowels in a continuum of
synthetically edited vowels, always reinforcing the model stimulus. Listeners from
both the Test Groups and the Control Group performed the A/X Discrimination task
following the tutorial for each acoustic parameter/feature trained. The procedure for
creating the stimuli for the A/X Discrimination tasks is detailed in “Preparation and
administration of task stimuli” in the pages to follow.

Listeners also received feedback after each response in the A/X Discrimination
task. If listeners gave a correct response they saw “Correct, good selection!” on their
screen. If listeners made an incorrect judgment, the feedback they received was more
specific. For example, if the listener perceived as equal two vowels of different
durations, the feedback was “Incorrect. The second vowel was longer than the first.”
The exact wording of the feedback changed according to task, so that for the different acoustic parameters trained in this study - duration and diphthongization for the Test Group, aspiration for the Control Group – listeners received feedback which specifically addressed the parameter being trained.

The A/X Discrimination task trained one vowel at a time, such that listeners heard all stimuli for one vowel (/i/ of different durations, for example) before continuing on to the next vowel. This design was intended to provide concentrated listening practice as part of the training experience and also to reduce the potential for cognitive overload which might result from presenting more than one vowel per discrimination set.

**Preparation and administration of task stimuli**

**Native speaker recordings and measurements**

The tasks in this experiment utilized both natural and edited natural CVCV productions of native English and Spanish speakers. The Discrimination task in the Training segments used the CVCV productions of one female native Spanish speaker, modified by the acoustic parameters of interest. The MCA and Language Identification tasks used in the Pre-, Post- and Delayed Posttests utilized natural Spanish and English CVCV stimuli. The MCA task used the natural CVCV productions of one native female Spanish speaker, while the Language Identification task featured natural CVCV stimuli produced by multiple native speakers of each language (10 English, 10 Spanish).
Ten native female Spanish speakers and ten native female English speakers recorded three repetitions of all CVCV stimuli used in this study. Information regarding the age and geographic origin of the native speaking informants is given in Table 2. All speakers were directed to say each of the target CVCV stimuli in the carrier phrase “Escucha la palabra CVCV” (Spanish speakers) or “Hear the word CVCV” (English speakers). Each speaker repeated this carrier phrase three times. These productions were used to calculate the speakers’ average vowel duration and transitional F2 (diphthongization) values. The native speaker recordings were also used to analyze the aspirated stop consonants which are the focus of the Trained Control group training tasks. Individual speaker averages for the above parameters were averaged for each language in order to create a ‘snapshot’ of the values of the target stimuli for both English and Spanish. These values are given in Tables 3-5.

The acoustic averages just described formed the basis for the acoustic modifications made to the training and test stimuli used in this study. The sections to follow will describe the acoustic preparation and modification required for the specific phases of the study. All acoustic work was done using Praat 4.6 acoustic software (Boersma & Weenink, 2007).

**Duration Discrimination stimuli (Test Group)**

Following the tutorial on the durational difference between English and Spanish vowels, listeners in the Test Group performed an A/X Discrimination task. The stimuli in this task were edited natural Spanish CVCV items recorded by one
female native Spanish speaker. These natural Spanish stimuli were modified in such a way that they approximated the quality of English vowels by being increasingly longer in duration. All target vowel stimuli appeared in the /s_sa/ context, a phonotactically permissible CVCV frame in both English and Spanish. The vowel duration

Discrimination task included three target vowel stimuli: 1) a target Spanish vowel of average duration, 2) a target Spanish vowel increased in duration and 3) a target vowel further increased in duration. The exact duration of these stimuli was derived from the averaged productions of the 10 native English and 10 native Spanish speakers. Figure 5 lists the duration of the three stimuli for each target vowel in the Duration Discrimination task. The ‘average’ vowel duration reflects the average duration of the native Spanish speakers’ productions of these vowels in the /s_sa/ context. The durations of the two lengthened stimuli were determined by the measurements made of the native English speakers’ vowels in the /s_sa/ context. Specifically, the longest vowel is representative of the native English speakers’ production of the /s_sa/ stimuli, while the intermediate vowel has a duration that is intermediate between the average Spanish vowel duration and the average English vowel duration in the /s_sa/ context.

INSERT FIGURE 5 ABOUT HERE

In the discrimination task listeners heard five repetitions of each of the three different vowel durations, for a total of 60 discrimination stimuli (/i,e,o,u/ x 3 durations each x 5
repetitions = 60 observations). The Discrimination task presented all the repetitions of one vowel, followed by all repetitions of another vowel, and so on, until listeners heard all four target vowels. Additionally, listeners received feedback as described in the previous section “A/X Discrimination task”. Participants spent an average of 20 minutes on this task.

Diphthongization Discrimination stimuli (Test Group)

Following the tutorial focused on the undiphthongized quality of Spanish vowels, (Appendix B), listeners in the Test Group performed an A/X Discrimination task. Once again, the stimuli in this task were edited natural Spanish CVCV items recorded by one female native Spanish speaker, here modified in such a way that they approximated the quality of English by having increasing degrees of F2 offglides. The F2 transitions of the CVCV stimuli were determined by the average F2 transitions of the native English speakers’ vowels in the /f_fa/ context (Table 4). The English speakers’ F2 transitions were measured in two ways. The first measurement determined the percentage of the vowel, in its final portion, that contained an F2 transition. The second measurement was made for the amount of change in Hertz for the F2 of each target vowel. These values determined by these measurements were then used to create the stimuli for the Discrimination task. In this task there were three types of target stimuli for each target vowel: 1) a CVCV stimulus with an undiphthongized target Spanish vowel, 2) a CVCV stimulus with a target Spanish vowel modified to include a partial F2 offglide and 3) a CVCV stimulus modified to
include a full F2 offglide such as would occur in the tense English vowels /i, e, o, u/.

Figure 6 gives the F2 transitions of the stimuli for each target vowel in the Diphthongization Discrimination task.

INSERT FIGURE 6 ABOUT HERE

In the discrimination task listener heard five repetitions of each of the three different F2-modified stimuli, for a total of 60 discrimination stimuli (/i,e,o,u/ x 3 F2 transitions each x 5 repetitions = 60 observations). The Discrimination task presented all the repetitions of one vowel, followed by all repetitions of another vowel, and so on, until listeners heard all four target vowels. Additionally, listeners will receive feedback as described in the previous section “A/X Discrimination task”. Listeners spent approximately 20 minutes on this task.

Aspiration Discrimination (Control Group)

Following the tutorial focused on the unaspirated quality of Spanish stop consonants /p/, /t/ and /k/, (Appendix C), listeners in the Control Group performed an A/X Discrimination task which mirrored the format of the A/X Discrimination tasks performed by the two Test Groups previously described. The stimuli in this task were edited natural Spanish CVCV items recorded by one female native Spanish speaker, here modified in such a way that they approximated the quality of English stop consonants by having increasing amounts of aspiration. In this task there were three
types of target stimuli for each target vowel: 1) a CVCV stimulus with an unaspirated initial Spanish stop consonant, 2) a CVCV stimulus with partial aspiration added to a target Spanish stop consonant and 3) a CVCV stimulus with full aspiration added to the target Spanish stop consonant. The degrees of aspiration were derived from the averaged productions of the 10 native English and native Spanish speakers in the /__afa/ context (Table 5). Figure 7 gives the degree of aspiration added to the initial consonants of the Spanish CVCV stimuli in this task.

INSERT FIGURE 7 ABOUT HERE

In the discrimination task listeners heard five repetitions of each of the three consonant realizations (different degrees of aspiration), for a total of 45 discrimination stimuli (/p,t,k/ x 3 modifications each x 5 repetitions = 45 observations). The Discrimination task presented all the repetitions of one voiceless stop, followed by all repetitions of another voiceless stop, and so on, until listeners heard all three target stops. Additionally, listeners received feedback as described in the previous section “A/X Discrimination task”. Listeners spent an average of 20 minutes on this task.

Language Identification task (Pre-/Post-/Delayed Posttest)

The Language Identification task utilized natural productions of both native English and native Spanish speakers. From each speaker’s repeated productions of the
target stimuli one good production was selected. A ‘good’ production met several criteria. First, that the intonation of the word was for the most part equal to the intonation of other speakers’ productions of the same word. Second, that the word had a good acoustic quality: of sufficient intensity to be audible and without any acoustic ‘clipping’ that would be distracting to the listeners. Each speaker’s ‘good’ production was then edited to ensure that the duration of the target vowel was correct according to the averages derived from all speakers, as described previously. Therefore the duration of the target vowel of each speaker’s ‘good’ production was measured and, if found to be too long or too short was modified accordingly so that the duration of target vowels in all CVCV stimuli were balanced across speakers.

Lastly, some editing was required for the final vowel in all CVCV stimuli in the Discrimination and Language Identification tasks. All CVCV test stimuli feature final /a/ (Spanish) or /A/ (English). While these categories are perceptually similar, they are not equal. Although participants will be directed to attend to the first vowel of each stimulus and not the final vowel, the possibility exists that a perceptive listener might notice the difference in final vowels. In the Language Identification tasks, this could lead an astute listener to make language identifications on the basis of the final vowel rather than the first. One way to control for such a scenario would be to create an ‘intermediate’ vowel using F1 and F2 values that are intermediate between the F1 and F2 values for Spanish /a/ and English /A/, and to then use that vowel in all CVCV stimuli, English and Spanish. The problem with such an approach is that, with Praat
software, such modification requires a certain degree of synthesis and the final product does not sound completely natural. Therefore in the final editing for the Language Identification task, the final /a/ or /Α/ was edited for duration only. The final /a/’s of all Spanish speakers’ productions were measured and the average duration of the final /a/ was used as a base measurement for both Spanish and English CVCV stimuli. As an additional safeguard, in the initial recordings the English speakers were coached on their production of the final /Α/, being told to pronounce the ‘ah’ sound and to avoid the ‘uh’ sound of the schwa which occurs in English unstressed vowels. Therefore, while the final English /Α/ and the final Spanish /a/ are not equal, their perceptual similarity may be enhanced by editing for them for duration and additionally, by the fact that listeners will be directed to attend to the first, not the final vowel of all CVCV stimuli in the study.

Administration of the tasks

All tasks administered during the study were delivered on computer. E-Prime data collection and analysis software was used to deliver test measures to participants. When the coding of all measures into E-Prime was complete, the experiment was run in a language classroom equipped with PC’s at individual learning stations. All participants were equipped with earphones at their individual stations in order to prevent disturbance from other PC stations or from ambient noise. A qualified computer programmer coded all measures into E-Prime. The next section explains in more detail the nature of the tasks and the stimuli featured in each. All assessment
measures (Pre-, Post- and Delayed Posttests) will be delivered in a split-block design of three configurations. In each assessment task one third of participants saw response options that were arranged on their screen in a manner different from that on the screens of the other two thirds of participants. All groups heard stimuli in randomized order in all assessment tasks.

**Assessment Tests**

**Familiarization session**

Prior to the administration of pre-test measures all participants completed a brief familiarization session designed to familiarize them with the vowels featured in the response options of the assessment tasks and the “listen and match” procedure of the experimental portion of the study. The familiarization session was delivered via a PowerPoint presentation installed on each PC in the language lab. Participants were introduced to model words which are similar to the CVCV response options they would see in the test measures (example: MEESA, MESSA, etc.), accompanied by real English words which contained the same vowel sound (example: MEESA…..GEESE). Participants were told to read the example words carefully to familiarize themselves with the vowel sounds of the model words. Participants then clicked on a series of ten sound links which played actual English words to be matched to one of the model words. All listeners were given an answer sheet on which to record their responses. The last screen of the familiarization session gave listeners the answers and they were instructed to review their answers and circle any incorrect responses before submitting.
their answer sheets. The researcher reviewed answers at a glance and participants who recorded wrong responses were given the opportunity to see their mistakes and ask questions if necessary before beginning the Pretest.

Pretests

Pre-test 1: Test of Multiple Category Assimilation

The first pre-test will assessed the degree to which English speakers perceive a binary contrast in Spanish (/e/ - /i/ for example) as more than two categories in English. The purpose here was to determine how often English speakers mistakenly perceive native vowel categories when listening to Spanish vowels. Specifically, would they show evidence of Multiple Category Assimilation? To accomplish this, the Pretest used here was modeled after measures used in Escudero & Boersma (2002), described in the earlier section, “Difficulties presented by the English subset”. In this pre-test participants heard natural Spanish vowels embedded in CVCV syllables of the form /b_sa/ but were given different sets of instructions designed to elicit different modes of perception. The consonants /b/ and /s/ of the CVCV syllables were selected because they are both permissible in their respective positions in the CVCV shape according to the phonotactics of both English and Spanish.

As the MCA Pretest evaluated perception under different perception modes, participants received instructions which varied slightly from one phase of the task to the next. In Phase 1 participants heard Spanish vowels in CVCV items and were asked to classify the vowels according the English vowel categories. They were not told that
the items contain Spanish vowels. In the first phase of the MCA pre-test, the CVCV “words” were embedded in an English sentence of the type “Hear the word ____. ”
Participants identified the vowel they heard by choosing from the ten English vowel categories presented to them in example words. Response options were written orthographically rather than phonetically transcribed due to the requirement that participants be untrained in phonetics. All participants were familiarized with the screen and response procedure on Day 1 during the brief familiarization session designed to introduce participants to the look of the experiment and the response method. Participants received the following instructions:

“In this task you will hear a series of invented words. These words have been extracted from English sentences pronounced by a female English speaker. As you hear each word, listen carefully to the FIRST vowel of the word. Identify that vowel by finding the same sound in one of the English words that you see at the bottom of the screen. Indicate your choice by clicking on the word which contains the same vowel as the word that you hear. The words on your screen are very much like the words you learned in the short practice session.”

Participants heard the CVCV stimuli /bisa/, /besa/, /bosa/, /busa/ and /basa/ and simultaneously saw the target response items, along with the distractors /prasa/, /krasa/, and /trasa/, on their computer screens. Participants indicated what they heard by clicking on the matching CVCV item:
Listeners heard ten repetitions of each stimulus and six repetitions of each
distractor for a total of 68 stimuli in the first phase of the MCA pretest. Table
12 gives a quantitative breakdown of these stimuli.

The second phase of the MCA pretest will be a test of Spanish perceptual
proficiency. In this phase listeners were told that they were hearing Spanish vowels
and were told to match the items they heard to the five Spanish vowel categories
shown on the screen. In Phase 2 the Spanish CVCV items were delivered in the
Spanish carrier phrase “Escucha la palabra ____.” The instructions were as follows:

“In this task you will hear a series of invented words. These words have
been extracted from Spanish sentences read by a female Spanish
speaker. Identify the Spanish word you hear by matching it to one of
the Spanish words on your screen. Indicate your choice by clicking on
the word which matches what you hear.”

As this phase of the MCA task asks participants to choose only from Spanish vowels
categories, the selection set will be reduced to only those items which match the
Spanish target vowels, in CVCV stimuli, plus the distractors /prasa/, /trasa/ and /krasa/:

<table>
<thead>
<tr>
<th>basa</th>
<th>krasa</th>
<th>besa</th>
<th>prasa</th>
<th>bisa</th>
</tr>
</thead>
<tbody>
<tr>
<td>bosa</td>
<td>trasa</td>
<td>busa</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Once again, listeners will hear ten repetitions of each target stimulus and six repetitions of each distractor for a total of 68 stimuli in the Phase 2 of the MCA pretest. MCA Pre-test stimuli are given in Table 12.

Lastly, for each phase of the MCA pre-test participants will be asked to indicate their degree of certainty for each response, using the values given in the following scale:

| Unsure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Sure |

In the perception research reviewed thus far, there seems to be no universally preferred pre-test cut-off score to determine which participants should be eliminated before beginning the experimental phase. The exact cutoff score was determined following examination of the distribution of Pretest. A more thorough description of the cutoff criterion and data cases included in the final data analysis will be given in the “Results of the full-scale study” section later in this paper.

Pre-test 2: Language identification

Following the MCA tasks participants performed an identification task which required them to identify the language and vowel category of the tokens they heard. Identification tasks have been used in perception research to assess development of non-native phonological categories when the L2 category changes as a function of variation in stimulus. Specific examples are VOT studies training the development of
voiced/voiceless categories (Pisoni et al., 1982; Jamieson and Morosan, 1986, 1989), and the /∞/ - /l/ distinction, notoriously difficult for Japanese speakers (Logan et al., 1991). The use of an identification task here addresses one of the central issues of this investigation, the ability of English speakers to accurately perceive Spanish vowels as categories which are acoustically unique from their native English ‘equivalents’. In this task subjects heard CVCV stimuli played through their headphones. The playlist of stimuli contained four target vowels, (/i/, /e/, /o/ and /u/), both English and Spanish, but in randomized order. Subjects were instructed to attend to the target vowel in each item and to indicate both the language to which the test item belonged and the vowel category. Participants received the following instructions:

“In this task you will hear one-syllable invented words extracted from sentences read by multiple female Spanish and English speakers.

Listen very carefully to the FIRST vowel in each word and decide if the word contains an English vowel or a Spanish vowel. On your screen you will see two lists of words; one English list and one Spanish list. For each word you hear, find the word which matches what you hear and click on it. Remember that these are invented words and any resemblance to real words is coincidental. Therefore please base your choice solely on the quality of the first vowel of each word.”
Listeners heard ten repetitions of each target stimulus and 5 repetitions of each distractor (/pafa/, /tafa/, /kafa/) for a total of 110 stimuli (2 languages x 4 target stimuli x 10 repetitions = 80 stimuli + 2 languages x 3 distractors x 5 repetitions = 30 stimuli). All stimuli in the Language Identification test were presented in randomized order and in a split-block design. The items in the Language Identification task consisted of natural Spanish and English CVCV tokens produced by multiple native Spanish and English speakers (10 English, 10 Spanish). In this task stimuli were not varied along the parameters of duration or diphthongization as specified for the A/X Discrimination task. Rather, stimuli were representative of “average” productions of the English and Spanish target vowels. A breakdown of these stimuli is given in Table 12.

Throughout the duration of the Identification Pretest, the listener’s computer screen showed the set of all possible response options, displayed in such a way that the listener was required to select not only the language of the stimuli they heard but also the vowel category. Listeners were presented with the following response set for each stimulus of the Identification Pretest:

<table>
<thead>
<tr>
<th>English</th>
<th>Spanish</th>
</tr>
</thead>
<tbody>
<tr>
<td>tahfa</td>
<td>bifa</td>
</tr>
<tr>
<td>beefa</td>
<td>kafa</td>
</tr>
<tr>
<td>pahfa</td>
<td>befa</td>
</tr>
<tr>
<td>bayfa</td>
<td>tafa</td>
</tr>
</tbody>
</table>

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In addition to identifying the language and category of each stimulus, subjects were also asked to give a rating of their certainty regarding their choice. The certainty scale was the same scale used for the MCA tasks previously described:

<table>
<thead>
<tr>
<th>Unsure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Sure</th>
</tr>
</thead>
</table>

**Posttest and delayed posttest**

The posttests used in this study took the same form as the first and second pretests (test of Multiple Category Assimilation, Language Identification task) described above. The purpose of the posttest was to measure any change in perceptual ability occurring in any of the groups during the Experimental Phase as a result of the training condition. It is hypothesized that subjects from the Trained Test Group will perform better on the posttest, showing 1) less instances of multiple-category assimilation and 2) a higher percentage of correct identification of stimuli by language. The items on the posttests were presented in a different random order from the items in the pretests and experimental trials. Two weeks after the administration of the posttest,
a delayed posttest was administered. The format of the delayed posttest was the same as that of the immediate posttest but with a new randomized order of presentation.

**Procedure**

Table 1 provides an overview of the experimental design used in this study. Profile questionnaires (Appendices E, F and G) were distributed to participants in this study through their Spanish classes and were returned completed when participants reported to the lab on Day 1. On Day 1 all participants completed the familiarization tasks which served to acquaint them with the computer application that delivered the experimental tasks. Participants listened to sample playlists containing items not contained in pre- or posttests and not in experimental trials. In the familiarization tasks participants heard CVCV stimuli similar to the CVCV items in this study. Participants performed a short (10-item) practice task similar to the MCA Pretest and Posttests. This test was scored for statistical analysis, but listeners’ answers were analyzed to make certain that all participants were comfortable with the response process, the appropriate response keys and the categories represented by the responses. Furthermore, participants were given the opportunity to check their answers against the correct answers provided immediately after the familiarization task. Listeners spent an average of ten minutes to complete the familiarization task. As in all experimental conditions, participants heard stimuli through headphones at individual PC stations. Day 1 ended with the MCA and Language Identification Pretests, lasting an average of 20 minutes each.
Day 2 was devoted to training sessions for participants in the Trained Test (Duration and Diphthongization Training) and Trained Control (Aspiration) groups. The training day included the training tutorial and A/X Discrimination task. Following the training sessions participants performed the MCA and Language Identification Immediate Posttests. Listeners spent approximately 15-20 minutes on each of these tasks.

Fourteen days after the administration of the MCA posttest (Day 3) all participants took the Delayed MCA and Language Identification Posttests. The Delayed Posttests included the same CVCV items as in the Pretest and Posttest, but with a new randomized order of presentation. At the conclusion of Day 3 all subjects completed follow-up questionnaires designed to record their opinions of the experiment as a whole and offer them the opportunity to reflect on the ease or difficulty of the tasks.

Data recording and analysis

This section will describe the response choices offered to the listeners for each of the tasks and the means by which the listeners will record their responses.

Pretest and Posttests MCA

The response choices for the different phases of the MCA pretest and posttest differed slightly to reflect the different perceptual conditions which each phase will attempt to elicit. For the first phase, listeners heard English CVCV stimuli but were told that the stimuli were Spanish items and to identify the English vowel category by
selecting the English “word” on the screen which best matched what they heard. As
the MCA tasks were modeled on the tasks used in Escudero and Boersma (2002), the
response choices also followed that design. Therefore in the first task listeners chose
from the ten response categories (English vowel categories) presented to them.

In the second phase of the MCA pretest and posttest, listeners were told that
they were hearing Spanish stimuli and were told to match them to the five Spanish
“words” they saw at the bottom of the screen. Therefore this final task offered only
five response choices corresponding to the five Spanish vowel categories.

E-Prime software logs the stimuli presented in each trial as well as the listener’s
response to that stimulus. When all data collection was complete each listener’s
stimulus-response pattern was analyzed in order to determine whether a given stimulus
elicited a particular response pattern from the listener.

Pretest/Posttest Language Identification

In the Pretest and Posttest Language Identification tasks, the vowels were the
vowels “common” to English and Spanish - /i,e,o,u/ - therefore the number of response
choices totaled eight (4 English categories, 4 Spanish categories). In these tasks,
listeners were told to identify the language of each stimulus presented to them and to
also identify the vowel category. Once again, the E-Prime data reports were analyzed
in an effort to identify the stimulus-response pattern. For example, did listeners more
frequently choose the English category /e/ or / / when presented with Spanish /e/?

A/X Discrimination (Training)
In the training segments listeners performed discrimination tasks which asked them to compare a test stimulus (“X”) to a fixed stimulus (“A”). The goal of the A/X Discrimination task was to provide focused practice following the training segments and did not figure into the statistical analyses necessary for answering the research questions. This stimulus-response data will be analyzed in a follow-up study for the purpose of uncovering any correlation that may exist between discriminatory skill and the Language Identification tasks and Posttests which follow in the test design.

Pilot study

Participants

In September of 2007 a pilot study was conducted with students from three levels of Spanish courses at The Georgia Institute of Technology. The original participant pool consisted of ten students of Spanish, but the data collected from one subject was lost due to a fatal programming error in the training session. The data from a second subject was eliminated when it was revealed she had more experience with Spanish than was disclosed in early screening measures, experience sufficient to skew her data. The final number of pilot participants was therefore reduced to eight, and subjects were randomly assigned to one of the treatment groups given in Table 10.

INSERT TABLE 10 ABOUT HERE
Procedure

The testing procedure followed for the pilot study was the same as the procedure proposed for the full study (Table 1), with a few exceptions. Pilot participants completed the familiarization session individually, rather than as a group as proposed for the full study. The familiarization session was delivered in a Powerpoint presentation, with sound links included, and participants recorded their answers to the 10-item ‘quiz’ on a piece of paper which was then submitted for verification before the first experimental session. All but two subjects received perfect scores on the familiarization session quiz. The two subjects who did not receive perfect scores missed only item each, and both reported that their errors were errors of handwriting only, that when they reviewed the correct responses they realized that their written responses were not the responses they intended to record. All participants reported having a clear understanding of the task and found the category matching process to be straightforward and easy.

Following the familiarization session, all pilot subjects performed the MCA and Language Identification Pre-Tests. Two days later participants performed the training sessions to which they were randomly assigned (Duration, Diphthongization, or Aspiration). The MCA and Language ID immediate posttests followed, in some cases after a two-day delay after the training session. This was due to several factors, among them student schedule conflicts and the need to administer Posttests during times when the language lab was available during a period of tight scheduling. Delayed posttests
were delivered one week after immediate Posttests. This timing constituted another change from the proposed procedure. Lastly, all pilot participants were given a feedback questionnaire upon completion of Delayed Posttests. The questionnaire was designed to allow participants to comment on the ease or difficulty of each of the tasks they completed, as well as to make general comments on the experiment in general.

Pilot study descriptive results

With such a small sample it is not possible to conduct a statistical analysis on the pilot results, therefore the following sections will review the overall trends for the eight pilot participants across assessment tests.

Multiple Category Assimilation

In Phase 1 of the Pre-test most listeners most frequently mapped Spanish /e/ to English ///. In the Phase 1 Posttest the degree of mapping to English // decreased, with a corresponding increase for Spanish /e/ to English /e/ mapping, for listeners 1, 2, and 8, all participants assigned to one of the two test groups. Listener 5 from the Aspiration training group also showed similar results. In Delayed Posttests, however, listeners returned to more frequent mapping from Spanish /e/ to English ///. Listener patterns of /i/ mapping were not as expected in Phase 1 of the MCA test. In the Pre-test, when listeners heard Spanish stimuli but were told they were hearing English CVCV stimuli (in an English carrier phrase), listeners frequently mapped Spanish /i/ to English /i/. With the exception of Listener #3, there was relatively little mapping of
Spanish /i/ to any other English category, namely to English /I/. Listener mapping patterns changed from Pre-test to Posttest, however, with listeners showing more instances of mapping Spanish /i/ to English /I/. In the Phase 1 Delayed Posttest listener mapping patterns were similar to those of the Posttest.

In the Phase 2 Pre-test listeners show more frequent Spanish /e/ to English /e/ mapping than in Phase 1. This would make sense if in fact they are listening with “English ears” as instructed in Phase 2. Phase 2 Delayed Posttests still show that most participants return to more instances of mapping Spanish /e/ to English /e/ under the instructions to listen with “English ears”. However, two of the listeners in the Duration Training group show their highest number of instances of mapping Spanish /e/ to English /e/, perhaps indicating an inability to suppress the Spanish perceptual mode even when instructed to listen with “English ears”. Phase 2 of the MCA task was removed after the Pilot study and thus will not be used in the full-scale study.

The third phase of the MCA tests was an assessment of Spanish vowel perception. Listeners heard Spanish CVCV stimuli and were instructed to match the stimuli to the five Spanish vowel categories on the screen. In general, listener mapping patterns for all four Spanish vowels were highly accurate, with most listeners accurately matching stimuli to vowel categories in 25 out of 25 trials. One Intermediate listener scored noticeably lower than others in the Pre-test (16/25) but dramatically improved in the Posttest and Delayed Posttest (24/25, 25/25 respectively).
Language Identification

Five of the eight participants showed gains from Pretest to Posttest, and one subject increased in identification accuracy in the Delayed Posttest. However, results must be taken with caution as two of the five subjects were control subjects who were trained on consonant aspiration. This increase may be due to practice effects from the Identification task included in the training segment for the pilot but which will be removed for the full-scale study.

In order to determine whether the increases noted above corresponded to increases in accuracy for a given language or vowel, an item-by-item analysis of each participant’s data was conducted. The very interesting finding was that the gains in identification accuracy were generally limited to English stimuli. Listener performance on Spanish stimuli appeared to change little from Pre-test to Posttest to Delayed Posttest, and often the change marked a decrease, rather than an increase in accuracy. It is important to note at this point that because the Language ID task consisted of only five repetitions per vowel, an ‘increase’ or ‘decrease’ may mean a change of only one or two more correct or incorrect responses from one assessment test to the next. However, the increased accuracy for English stimuli only raises questions about what might be occurring in listeners’ perception that makes English vowel stimuli more easily identifiable than Spanish vowel stimuli. Is it possible that it is easier to perceive the features trained in the experiment than it is to not perceive them? It is
impossible to answer the question with pilot data only, but if the trend is found in the full-scale study it will be a question worthy of further investigation.

**Pilot study feedback**

Upon completion of the Delayed Posttests all participants completed a brief questionnaire. The questionnaire asked for listener opinions regarding the ease or difficulty of each task, clarity of instructions and sound quality in the various tasks. When asked to comment on the difficulty of the MCA tasks, half of the participants indicated that the task was challenging for them. Most of the comments were centered upon the similarity between English and Spanish /i, e, o, u/, as indicated by the following responses:

“[It was] difficult sometimes telling the difference between sounds ‘ee’ and ‘i’, ‘a’ and ‘ah’, ‘oo’ and ‘u’.”

“‘oo’ and ‘u’….they both sounded very similar.”

“‘Some vowels were confusing, [for example] ‘boofa’ and ‘bufa’.”

“baysa/bessa was sometimes hard to distinguish.”

Another participant found MCA Phase 2 to be challenging:

“It was difficult to use English ears when the [carrier] sentence was in Spanish.”

No participant reported problems or complaints with the sound quality or sound volume for any of the tasks. Most participants found all task instructions to be clear. In only one case did a participant find the training task (Discrimination) to be unclear.
at first, but indicated that the immediate feedback given helped her to realize her mistake and she then scored correctly on the remaining items.

The questionnaire also asked for feedback regarding the speakers’ voices used for the Identification tasks, in particular if the listener ever associated a particular voice with either English or Spanish so that he/she consistently identified the language of stimuli by that voice. A few of the participants reported associating certain voices with certain languages. However, one listener explained further that although she determined a particular voice was “English”, that she really could not be sure if the association was correct.

Lastly, one participant gave some informative metalinguistic feedback. After completing the diphthongization training she noted that the experiment made her consider her own production, saying “I realize that’s probably how I sound when I speak Spanish”, referring to the examples of diphthongized English vowels she had heard in the training session.

**Differences between pilot study and full-scale study**

Some changes were made to the design of the full study upon the conclusion of the pilot. The first change to be implemented to the full-scale study was to remove the Language Identification task from the training segments. Previous versions of the proposed experimental design called for the Language Identification task to follow the tutorial and Discrimination (“A/X”) task in each training segment. As the Language Identification task in the training segment was similar in design to the Language
Identification task in the assessment tests, it was decided that the Language Identification task should be removed from the training segments due to the risk of practice effects upon the posttest results. However, because the decision was made just before the first scheduled pilot session there was no time to make the necessary adjustments to the experimental programming, and the pilot participants did complete the training sessions with the Language Identification task included.

A second major change made to the experimental design regards the MCA task. The design implemented in the pilot study included a third phase of the MCA task, a phase in which listeners were instructed to “listen with English ears”. In the pilot this phase occurred between the two phases that were part of the final full-scale study. In consideration of post-pilot feedback and discussion with committee members regarding the goals of the study, the original second phase of the MCA task was eliminated, leaving just two phases: Phase 1, in which listeners map Spanish CVCV stimuli to English CVCV response options, and Phase 2, a straightforward test of Spanish perceptual proficiency (originally Phase 3).

Other major changes were in part a result of the elimination of the second MCA phase. The elimination of this task, combined with the observation that pilot participants completed all assessment and training measures more quickly than anticipated, prompted the decision to increase the number of stimuli in the assessment trials. Tables 7-9 give the number of stimuli in Pilot study assessment and training tasks. Table 12, by comparison, details the revised number of stimuli used in the MCA
and Language Identification tasks of the Full-Study (no change was made to the number of stimuli in the Discrimination task of the training session). Furthermore, as seen in Table 12, distractor stimuli not appearing in the pilot study were added to both the MCA and Language Identification measures (Pre-, Post- and Delayed), constituting another reason for the difference in stimuli between the pilot and full-scale experiments. The purpose of distractors in an experiment of this design is to temporarily take the listener’s focus away from the target stimuli and thereby reduce the likelihood that he will deduce the purpose of the task.

A final major difference between the pilot and full-scale experiment regards the change in the confidence rating scale used in both the MCA and Language Identification tests. The scale used in the pilot study was a Lichert scale of only five degrees and included descriptors such as “very sure” and “very unsure” at the extremes, descriptors which were potentially confusing to participants. Upon consultation with committee the scale was changed to remove the descriptors attached to the numbers and in addition, the scale was increased to seven degrees with the descriptor “Unsure” placed at the low end of the scale (“1”) and “Sure” placed at the high end (“7”), as shown in the previous section on “Assessment Tests”.

Other changes made to the full-scale study regards programming details. The first change was to link the test sounds in the discrimination task of the training segments. In the pilot listeners were instructed to click on two different play buttons in order to hear the stimuli and to then discriminate one from the other based on the target
acoustic feature of the training segment. Due to the very real possibility that the elapsed times between the first and second clicks would vary from one participant to the next, and the likelihood that this variability could be a confounding variable in the study, the discrimination stimuli were linked for each trial for use in the full-scale study. The second change regards one of the first screens in the duration and diphthongization tutorials. Listeners were instructed to click on example words to hear them played, and after more detail was given they were instructed to go back and play the words again. Initial programming required that the listener play these words twice before being permitted to continue to the next screen. However, the same sound-linked words appear on the following screen, effectively meaning that the listeners would hear these words three times in the tutorial. This observation prompted the decision to reduce the number of required plays to two. Therefore the programming was adjusted so that the first screen showing these words required that they be played at least once before continuing to the next page.

RESULTS OF THE FULL-SCALE STUDY

Full-scale study scoring and statistical procedures

Before running the appropriate statistical tests it was necessary to determine which pretest cases were to be included in the final analysis. The design of the present study is complicated, including more than one assessment task (MCA task, Language Identification task), featuring more than one phase (MCA) or multiple target stimuli to be analyzed. The previous literature does not suggest a cutoff score for a design of this
type, therefore after an examination of the distribution of scores the decision was made to use a cutoff of 80%. A lower percentage would eliminate too great a number of participants, thus weakening the statistical analysis. A higher percentage, such as 90%, would preserve yet more participants but leave little room for significant improvement in post-treatment measures. In this study listeners heard ten repetitions of each target item, therefore a cutoff of 90% would mean that an “improvement” in posttest or delayed posttest measures would only consist of one more right answer. Has this study allowed for a higher number of stimuli repetitions, a cutoff of 90% might have been more acceptable.

Research question 1

Does native vowel inventory size have an effect on English speakers’ perception of L2 Spanish vowels? Specifically, do English speakers show evidence of Multiple Category Assimilation for Spanish front vowels?

In this task participants were asked to categorize the Spanish stimuli they heard according to English vowel categories (Phase 1) or Spanish vowel categories (Phase 2). The review of results which follows will be focused primarily upon the data collected from Phase 1, as this phase directly addresses the effect that a larger English inventory may have upon participants’ perception of Spanish front vowels. Data from Phase 2 will be briefly discussed for comparative purposes only.
Front vowel mapping

A one-way ANOVA was run on the data collected for the MCA Pre-test in order to determine any difference that might exist between participants at different levels at onset. ANOVA results revealed listeners to be comparable, as there was no significant difference between groups, $F(2, 119) = 1.046, p = .354$ on the /besa/ stimulus nor on the /bisa/ stimulus, $F(2,97) = .153, p = .858$, the two target stimuli of the MCA Pretest.

Table 13 lists the descriptive statistics for Phases 1 and 2 of the MCA pretest. Table 13 includes descriptive statistics for all five stimuli in the task, even though the present study addresses front vowels /e/ and /i/ only. Several observations are to be made from this data. Glancing across the Phase 1 stimuli one notes the higher means for /basa/, /busa/ and /bosa/. Conversely, lower pretest means are found for /besa/ and /bisa/, the target stimuli in this study. The descriptive statistics for Phase 2 show that participants at all levels achieved high accuracy for categorizing all Spanish vowels. Therefore, by comparing Phase 1 and Phase 2 results it is clear that straightforward Spanish vowel perception (Phase 2) is not problematic for most listeners, while perception of Spanish vowels amidst the background of multiple L1 English categories (Phase 1) is more difficult.
Multiple Category Assimilation: Mapping of Spanish /e/ and /i/

A second and very important part of the MCA assessment task is to determine not only IF participants exhibit MCA for front vowels, but if their responses tend toward a particular vowel response. Based on the literature reviewed earlier (Bradlow 1996; Escudero & Boersma 2002), it was hypothesized at the outset of the study that the existence of the categories /æ/ and /I/ in the English vowel space would interfere with correct perception of Spanish vowels, and that participants would map Spanish /e/ to English /æ/ and would also map Spanish /i/ to English /I/, perhaps with lesser frequency. In the organization and coding of data collected in this study, special care was taken to tally the number of times participants did in fact make the responses cited above. In other words, when listeners did not map Spanish /e/ to English /e/ or when they did not map English /i/ to Spanish /i/, how frequently did they choose the response category of English /æ/ or /I/, respectively? The paragraphs which follow review the results for these specific response patterns.

Results of a one-way ANOVA revealed no significant difference between levels of learners on MCA of /e/ to /æ/, $F(2,119) = .113, p = .893$, nor on MCA of /i/ to /I/, $F(2.97) = 1.469, p = .235$. Table 14 displays the descriptive statistics for MCA for participants at all levels. Once again, these results indicate the number of times that listeners, when not mapping Spanish /e/ to English /e/, mapped to English /æ/ instead. It is notable that the mean for all levels reached a minimum of .85 and in some cases a maximum of .95 percent. Put in different terms, participants in this study mapped
Spanish front vowels /e/ and /i/ to English front vowels /ɛ/ and /ɪ/ with notably high frequency in the MCA Pretest. There were a few cases in which these Spanish front vowels were mapped to other categories among those offered by the response options in the task. However these instances were few and in some cases the responses given were for vowels so unrelated to the target vowels as to raise the supposition that perhaps those participants simply mis-keyed their responses. While the means indicate a high frequency of this mapping pattern, a one-way ANOVA performed on the Pretest data reveal no significant difference between groups.

**Research question 2**

Does increased exposure to Spanish have an effect on English speakers’ correct perception of Spanish vowels?

**Language Identification**

To determine the effect of level of exposure, a 3x3 repeated measures ANOVA was conducted on data collected in the Language ID tests, with level of exposure (Beginning, Intermediate, Advanced) as the between-subject factor and time as the within subject factor. Results show a significant main effect for Level only for Spanish /bufa/, \( F(2,118) = 5.204, p = .007 \) but for none of the other three Spanish stimuli. Post hoc analyses revealed that the main effect for Level was due to the significant contrasts.
between Beginner\((M = .536)\) and Intermediate listeners, \((M = .653, S.D.)\) and between Beginner and Advanced listeners \((M = .663)\). There were no significant interactions found for any of the Spanish stimuli. There was, however, a significant main effect for Time for two of the four Spanish stimuli in this study, for /bifa/, \(F(2,332) = 5.339, p = .005\) and for /bufa/, \(F(2,236) = 13.755, p = .000\). The significant effect of Time means that the treatment overall (rather than Level specifically) was effective. The magnitude of the effect size in the population was a large one for Spanish /bufa/ (partial eta squared = .104) and a medium one for Spanish /bifa/ (partial eta squared = .062).

ANOVA results for the English stimuli reveal no significant main effect for learner Level or interaction between Time x Level, for any of the four English stimuli. There appears to be a trend toward significance for Level for English /befa/, \(F(2, 138) = 2.510, p=0.058\) and English /bufa/, \(F(2, 124) = 2.691, p=0.072\), but the significance is not realized as the effect does not reach the pre-determined alpha level of .05 for either stimulus. A significant main effect for Time was found for English /bifa/, \(F(2,302) = 19.808, p = .000\), indicating the effectiveness of Treatment overall, rather than learner Level, on Language Identification measures. The effect size in the general population would be a medium one (partial eta squared = .116). No significant main effects or interactions were found for the remaining English stimuli.

Tables 15 and 16 display the descriptive statistics for the Language ID measures for Spanish and English CVCV stimuli, respectively. Despite the lack of significance for Level for almost all of the stimuli, as previously reported, the means
listed in Tables 15 and 16 do show that for most stimuli, Spanish and English, increase in means corresponds to an increase in learner Level. Figure 8 graphically displays the performance of participants at all levels, on all stimuli from Pretest to Delayed Posttest.

A few trends are observable in Figure 8. First, the participants in the Intermediate group performed in a generally consistent manner, improving from Pretest to Delayed Posttest. The stimuli which mark an exception to this pattern are Spanish /bifa/ and English /bufa/.

Another interesting pattern is observable for the Advanced group. Advanced participants were consistent in their means increases or maintenance from Pretest to Delayed Posttest for English stimuli /befa/ and /bofa/. In contrast, their identification of English /bifa/ and /bufa/ is marked by decline from Posttest to Delayed Posttest. Discussion on a possible explanation for this pattern will be presented following this section on experimental results.

Test of Multiple Category Assimilation

As with the analysis of Research Question 1, the results of the MCA assessment for Research Question 2 must be discussed in two respects. The first
regards the frequency with which the Spanish front vowels /e/ and /i/ were matched to the nearest English equivalents /e/ and /i/. No significant main effect for Level was found for /besa/, $F(2,119) = .768, p = .466$, nor for /bisa/, $F(2,97) = 6.22, p = .539$. Likewise, no significant interactions between Time x Level were found for either /besa/, $F(4,238) = .741, p = .565$, nor for /bisa/, $F(4,194) = .512, p = .727$. However, ANOVA results of a repeated measures ANOVA reveal a significant main effect for Time for /besa/, $F(2,238) = 19.853, p = .000$, indicating that listeners improved their categorization of the /e/ vowel in response to the treatment experience overall, rather than in response to their Level of L2 exposure. The effect size in the population would be large, as indicated by the partial eta squared value of .143. No significant main effect for Time was found for /bisa/, $F(2,194) = 1.866, p = .158$.

Table 17 displays the descriptive statistics for listener mapping for the front vowel stimuli /besa/ and /bisa/. Table 17 and Figures 9 and 10 show the notable increase in mapping English /e/ to Spanish /e/ that was achieved by the Beginning group relative to the other Levels, although for /bisa/ Beginner accuracy was not sustained for the Delayed Posttest. One very interesting finding is that the Advanced listeners mapped English /e/ and /i/ to Spanish /e/ and /i/ with the lowest frequency compared to the listeners at the other levels. In other words, the Advanced listeners exhibited MCA more frequently than listeners with less exposure to Spanish.

INSERT TABLE 17 ABOUT HERE

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MCA: Mapping of /e/ to / /

A second important point in the analysis of the MCA results regards the observed mapping patterns for front vowels. The question of interest here is “When listeners did not map Spanish /e/ to English /e/, how frequently did they instead map Spanish /e/ to English //? In the MCA Pretest, participants frequently mapped Spanish /e/ to English //. In the Posttest and Delayed Posttest measures, the incidences of categorization of Spanish /e/ to English // decreased consistently for all three levels of learners. However, results of a repeated measures ANOVA show no significance for the independent variable of Level, $F(2,119) = .074, p = .929$, nor for the interaction between Time x Level, $F(2,119) = .016, p = .984$. Results do however reveal a significant main effect for Time, $F(2,238) = 16.207, p = .000$. Figure 11 shows the decline for all groups in the mapping of Spanish /e/ to English //. Table 17 once again displays the descriptive statistics for participants’ categorization of the Spanish front vowels /e/ and /i/. Increases in /e/>/e/ mapping for /besa/ are observable for all Levels from Prestest to Delayed Posttest. Therefore it can be seen that the decline in mapping from Spanish /e/ to English // (Figure 11) corresponds to increased instances of mapping Spanish/e/ to English /e/, as seen earlier (Table 17).
MCA: Mapping of /i/ to /I/

When listeners did not map Spanish /i/ to English /i/ in the MCA task, how often did they choose English /I/ instead? In the MCA Pretest, participants frequently mapped Spanish /i/ to English /I/. In the Posttest, the incidences of categorization of Spanish /i/ to English /I/ decreased consistently for Beginning and Intermediate participants, however from Posttest to Delayed Posttest participants at the Intermediate and Advanced levels showed increased mapping of Spanish /i/ to English /I/ (Figure 12). Results of a repeated measures ANOVA show no significance for the independent variable of Level $F(2,97) = .359, p = .699$, nor for the interaction between Time x Level, $F(4, 194) = 1.071, p = .372$. Results do however reveal a significant main effect for Time, $F(2,194) = 6.514, p = .002$. Figure 12 shows the pattern of mapping of Spanish /i/ to English /I/ for participants at all three levels. Table 17 displays the descriptive statistics for participants’ categorization of the Spanish front vowels /e/ and /i/ (the mapping of Spanish front vowel /e/ or /i/ to its nearest English equivalent /i/ rather than to the English vowel /I/). Therefore it can be seen that the declines in mapping from Spanish /i/ to English /I/ (Figure 12) correspond to increased mapping accuracy (Table 17) for the Beginner group, while the reverse is true for Intermediate and Advanced participants who reverse their response pattern from Posttest to Delayed Posttest.
Research question 3

Is there an effect of perceptual training on English speakers’ perception of Spanish vowels /i, e, o, u/? Specifically, is there a significant effect for vowel duration training and/or vowel diphthongization training? Does training have a differential effect on different Levels of listeners?

Language Identification

In order to determine the effectiveness of the perceptual training measures, a 3 x 3 x 3 (Training Group x Learner Level x Time) repeated measures ANOVA was performed on RQ3. Analyses were conducted on both Spanish CVCV stimuli and English CVCV stimuli.

Results of a repeated measures ANOVA show no significant main effects for Training for any of the Spanish Language Identification stimuli. Among the Spanish stimuli, a significant main effect for Level was found only for /bufa/ $F(2,112) = 5.859, p = .004$. Post hoc Scheffé tests reveal the difference to be attributable to contrasts between the Beginning group ($M = .535$) and the Intermediate group ($M = .658$) and between the Beginning group and the Advanced group ($M = .672$). No significant interactions were found for any of the Spanish stimuli. However, a significant main effect for Time was found for /bofa/, $F(2,150) = 6.995, p = .001$, partial eta squared = .085; /bufa/ $F(2,224) = 12.425, p = .000$, partial eta squared = .1; and /bifa/ stimuli $F(2,330) = 4.973, p = .007$, partial eta squared = .029. These results point to the
effectiveness of the treatment experience in general on Spanish /bofa/, /bufa/ and /bifa/, with a small to medium effect size in the general population. Table 18 displays the descriptive statistics for the Language Identification, Spanish stimuli by Training group and learner Level.

Repeated measures ANOVA results for English stimuli show no significant main effects for Training for any of the four stimuli. A significant interaction of Training x Level was found only for /bofa/, $F(4,65) = 2.758, p = .035$. However, a significant main effect for Time was found for three of the four stimuli: /befa/, $F(2,264) = 40.908, p = .000$, partial eta squared = .237; /bifa/, $F(2,290) = 20.32, p = .000$, partial eta squared = .123; and /bofa/, $F(2,130) = 15.716, p = .000$, partial eta squared = .332. Therefore for English /befa/, /bofa/ and /bifa/, the treatment experience overall, rather than Training or Level specifically, was more effective in increasing listener Language Identification accuracy. Table 19 displays the descriptive statistics for the Language Identification tests by Training group and learner Level.

INSERT TABLE 18 ABOUT HERE

INSERT TABLE 19 ABOUT HERE

Figure 13 presents a comparison of Language Identification means for Training groups in Pre-, Post- and Delayed Posttests. Spanish and English stimuli are shown in a side-by-side comparison. The principle difference to be noted regards the higher means for English stimuli /befa/, /bifa/ and /bofa/ in comparison to similar Spanish
stimuli. Of these three stimuli, correct listener identification was sustained in the Delayed Posttest for /befa/ and /bofa/. Additionally, Figure 13 shows that the improvement for English /befa/ and /bofa/ stimuli is slightly higher for the group Trained in vowel Diphthongization.

In summary, Figure 13 shows that where perceptual training resulted in higher posttest means, the increases were observed for English, rather than Spanish stimuli. A possible reason for these observed results will be offered in the discussion to follow.

Test of Multiple Category Assimilation

As Pretest results from the test of Multiple Category Assimilation (MCA) show, participants frequently assigned the Spanish front vowel categories /e/ and /i/ to more than one English category. This portion of the results section reviews the effects of Training on Posttest and Delayed posttest MCA measures in terms of first, the frequency of listener mapping of Spanish /e/ and /i/ their English equivalents and secondly, the frequency of MCA of those same vowels (/e/>/ /i/ or /e/>/I/).

Results of a repeated measures ANOVA show no significant main effect for Training for /e/>/e/ mapping for the stimulus /besa/ \( F(2,113) = .160, p = .852 \), nor significant interactions for Time x Training \( F(2,113) = .980, p = .378 \). However, results of a repeated measures ANOVA on front vowel mapping do reveal a significant main effect for Time for /besa/, \( F(2,226) = 18.607, p = .000 \). In simpler terms, the type of Training does not significantly influence listeners’ pattern of mapping Spanish /e/ to
English /e/, but over time there is a general rise in the frequency of this mapping for all Training groups. Regarding Spanish /bisa/, ANOVA results revealed no significant main effects for Training $F(2,91) = 1.1765, p = .177$ or for Time $F(2,182) = 1.085, p = .365$. Lastly, no significant interaction was found for Training x Time, $F(4,182) = 1.543, p = .192$. Table 20 displays the descriptive statistics for pre-, post- and delayed posttests for Phase 1 of the MCA test, by Training group and learner Level. Listeners’ patterns of /i/>/i/ mapping are much less consistent than observed for /e/>/e/ mapping.

MCA: Mapping of /e/ to //

As previously reviewed, participants in this study showed a high degree of MCA for the Spanish front vowels /e/ and /i/ in Phase 1 of the Pretest. In Posttests the mapping of /e/ to / / decreased and there was much more frequent mapping of Spanish /e/ to English /e/, or to the response option “baysa”. Results of a repeated measures ANOVA performed on the MCA assessment measures show no significant main effects for Training $F(2,119) = .992, p = .374$. There were no significant interactions for Time x Training $F(2,119) = .08, p = .923$. However, results of a repeated measures ANOVA reveal significant main effects for Time, $F(2,238) = 16.501, p = .000$, for the decrease in instances of /e/ to / / mapping. Table 21 displays the descriptive statistics for MCA of Spanish /e/ to English / / by Training group, in Pre-, Post- and Delayed Posttests. Figure 14 graphically displays the performance by Training and Level on Pre-, Post- and Delayed Post measures and clearly shows the reduced /e/ to / /

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mapping for all groups and the greater decrease in MCA for those in the Duration Training group.

**MCA: Mapping of /i/ to /I/**

In the MCA Pretest there was also a high incidence of MCA of Spanish /i/, most often to the English vowel /I/, or to the response option “bissa”. A repeated measures ANOVA performed on MCA assessment measures shows no significant main effects for Training $F(2,97) = .927, p = .399$ on the decreased instances of /i/ to /I/ mapping. However, Results of a repeated measures ANOVA do reveal a significant main effect for Time $F(2,194) = 5.077, p = .007$. Table 21 displays the descriptive statistics for instances of MCA of /i/ to /I/. Figure 15 graphically displays the performance by Training and Level on Pre-, Post- and Delayed Post measures. Listeners in the Duration and Diphthongization groups showed the greatest decline in MCA, although the decline was not sustained in the delayed posttest.

**DISCUSSION AND CONCLUSION**

The discussion of the findings of this study will follow, for the most part, the same format as that used in the Results section. The first section will discuss the findings for Multiple Category Assimilation (Research Question 1). This will be
followed by a discussion of the effects of learner level on Spanish vowel perception (Research Question 2). Lastly, this section will review the findings on effects of Training on Spanish vowel perception (Research Question 3). The purpose of this section is to go beyond a quantitative review of the results as previously presented and to propose explanations for what has been observed.

Research question 1

Does native vowel inventory size have an effect on English speakers’ perception of L2 Spanish vowels? Specifically, do English speakers show evidence of Multiple Category Assimilation for Spanish front vowels?

The participants in this study clearly exhibited MCA for Spanish front vowels /e/ and /i/. Phase 1 required participants to listen to Spanish CVCV stimuli and to match them to the English category on the screen which they thought best matched the vowel of the first syllable of the word they heard. Table 14 indicates the percentage of responses for which participants mapped (i.e. matched) Spanish /e/ or /i/ to English / / or /I/, respectively, in the Pretest. While percentages are high for all groups, an unanticipated finding is that the Intermediate and Advanced groups, rather than the Beginning group, showed a greater degree of MCA for the Spanish /i/ vowel.

This task utilized all five Spanish vowel categories embedded in the CVCV stimuli, although as stated, only /e/ and /i/ are the target vowels of this study. However, it is worth repeating the observation from the Results section that of the five stimuli featured in the task, it was the target stimuli /besa/ and /bisa/ which participants
most frequently mapped incorrectly. This could suggest that there is a feature of these vowels which makes correctly mapping them to ‘equivalent’ English vowels difficult. Based on previous literature (Bradlow 1996, Escudero & Boersma 2002) it was anticipated that these vowels would be the most likely to cause perceptual mapping confusion and that category mapping might result in the mapping to the additional English categories /æ/ and /I/.

In the analysis of the MCA data a count was kept of every instance in which a listener mapped Spanish /e/ to English /æ/ or when he mapped Spanish /i/ to English /I/.

Results indicated that in fact listeners did initially favor English /æ/ and /I/ as category responses for Spanish /e/ and /i/. While no significant main effect was found for any of the stimuli, the consistently high means for MCA lend support to previous findings by Bradlow (1996), whose data showed that the presence of the vowel categories /æ/ and /I/ in the English vowel space was shown to interfere with accurate perception of Spanish vowels /e/ and /i/. The findings here are also supportive of Escudero & Boersma’s (2002) study of Dutch speaking learners of Spanish, who were also shown to map Spanish vowels to Dutch vowels that have no ‘equivalent’ in Spanish. The results of the Pretest-Phase1 stand in clear contrast to the results of the Pretest-Phase 2, in which participants showed high degrees of accuracy in a basic test of Spanish vowel perception. This contrast is displayed in Table 13. The fact that participants did not have difficulty with Phase 2 would lend support to the assertion that the means for
Pretest-Phase 1 are in fact indicative of the more problematic perception of Spanish /e/ and /i/. The MCA task will be discussed further when effects of Training are discussed in the pages to follow.

Research question 2

Does increased exposure to Spanish have an effect on English speakers’ correct perception of Spanish vowels?

Language Identification data

Figure 8 plots Spanish and English Lang ID scores side-by-side for comparison. In several cases the groups performed as hypothesized, where the Advanced group gains were higher than those of the Intermediate, whose gains were in turn higher than those of the Beginning group. This pattern can be observed for Spanish /bifa/ and /bufa/ and for English /befa/, /bifa/, and /bofa/. In terms of both the means and the relationship between Levels (higher means for Advanced than for Intermediate and so on), one can observe that data are more consistent for the English stimuli than for the Spanish stimuli. That is to say, for English /befa/, /bifa/ and /bofa/, means are seen to increase with learner level and with time. While this also occurs for Spanish /bifa/ and /bufa/, it is fair to say that the occurrence of this pattern for three of the four English stimuli constitutes a measure of improvement over the two stimuli in which the pattern is observed for Spanish. Why do English stimuli more than Spanish stimuli elicit responses which increase in accuracy over time, an increase which parallels increase in learner exposure to L2?
The parallel between the increases in accuracy for English stimuli and increases in level of exposure may indicate that listeners with more experience in the L2 are more sensitive to the acoustic differences between ‘similar’ vowels. Because the data show greater increases in accuracy for English stimuli as opposed to Spanish stimuli, the logical question is whether these listeners are sensitive to the acoustic cues present in English vowels (duration, diphthongization) but less sensitive to the absence of those cues in similar Spanish vowels. In the absence of more data and more importantly, additional significant data for Level this hypothesis can only remain a hypothesis. However this is a trend which was observed in the pilot and in a prior unpublished study, therefore future studies to test this hypothesis are certainly warranted.

**MCA data**

Comparing the two cases of MCA, Spanish /e/ to English / / mapping and Spanish /i/ to English /I/ mapping, results indicate that the Beginning and Intermediate participants show the greatest degree of reduction in their instances of MCA. An important finding in this task is that the Advanced group did not conform with the hypothesis made at the outset of the study in that this group did not achieve higher means for front vowel categorization. As Figures 9 and 10 clearly show, the mean accuracy of responses for the Advanced group was lower than that of the other two levels. A look at the data for instances of MCA (/e/ to / / mapping and /i/ to /I/ mapping) in Figures 11 and 12 shows once more that the Advanced group does not
show greater achievement than the other two groups in terms of reducing the instances of MCA. Furthermore, the Intermediate group is shown to perform as well as or better than the Advanced group.

It is not entirely clear why Advanced participants would not be the leading achievers in this study. Participant profile questionnaires revealed the Advanced students to have not only more exposure to Spanish but also more out-of-class exposure and more study abroad exposure as well. Is it possible that these participants exhibit a type of perceptual fossilization? In other words, that exposure beyond a certain point (e.g. Intermediate) does not contribute to the improvement of one’s perceptual acuity? This is merely supposition without further data on a much larger scale, but is a question that could easily be transformed into a follow-up study.

Research question 3

Is there an effect of perceptual training on English speakers’ perception of Spanish vowels /i, e, o, u/? Specifically, is there a significant effect for vowel duration training and/or vowel diphthongization training? Does training have a differential effect on different Levels of listeners?

Language Identification data

Results of the Language ID task suggest that Time exerts more of an effect on learner gains than does Training. The training task as well as the assessment tasks in this study required the listener to engage in concentrated and, perhaps more importantly, repetitive listening to target stimuli. It may be that the repetitive listening
alone was helpful to the listeners in this study. While the phenomenon of practice effects is often considered a negative occurrence in experimental studies, it may be possible to view the effect of Time in a positive light when looking at it from a pedagogical perspective. If the listeners in this study improved perceptual skill due to repeated listening alone, this may suggest that a strategy of introducing repeated and concentrated listening to target sounds would be effective in the language classroom. This does not mean comprehensible input alone, but rather time dedicated to aural input that is structured and repetitive.

There are two potential sources of the ineffectiveness of the training measures. The first potential source is the limited amount of time allotted for the training measures. Listeners in this study completed their training in one session, with most listeners spending approximately 25 minutes to complete both the tutorial and the discrimination task that followed. The second potential source for the lack of significant findings for the training measures may be the discrimination task used. It may have been ineffective to present listeners with a task that was different from the assessment measures. As listeners in all training groups performed a discrimination task as part of their training, it is impossible to know on the basis of this data alone if the discrimination task was the source of the problem. A potential follow-up study would look more closely at learner performance on training measures and how that performance correlates with performance on tasks of perception over time (Pre-, Post- and Delayed Posttest measures).
Another point of note regards the difference in listener performance on Spanish and English stimuli. The findings reviewed in the results section suggest that the greater relative improvement for participants in this study occurred with English stimuli. While the objective of the training measures were to improve listeners’ perception of Spanish vowels, the fact that they made greater gains in identifying (in the case of the Language ID task) English stimuli is nevertheless an interesting point of discussion. As discussed in the literature review on the acoustic properties of English and Spanish ‘equivalent’ vowels, English tense vowels are longer in duration than their Spanish counterparts and feature an F2 offglide that lends the diphthongized character to them. A possible explanation for the gains made for English stimuli as opposed to Spanish stimuli is that participants are able to attend to the cues present in English tense vowels, but are not as skilled at attending to the absence of those clues for the similar Spanish vowels. This is an important point to consider: in learning to accurately perceive L2 vowels which are similar to L1 vowels, does the listener first go through a phase of learning to perceive the unique qualities of the L1 vowels? If so, does this eventually lead to the ability to perceive the absence, or perhaps difference, of certain cues in L2 vowels?

MCA data

As with the Language ID data, the only significant finding in the MCA data was the main effect of Time. However, the decrease in instances of MCA for Spanish vowel /e/ was noticeable for all Training groups and Levels, including the Aspiration
(control) group (Fig. 14). In the /i/ to /I/ mapping data (Figure 15), the most change occurred in the group trained in Duration, while the data for the Aspiration group patterned as expected, showing little improvement (little decrease in MCA) from Pretest to Posttest.

Without significant findings on the effectiveness of Training groups it is only possible to comment on the trends indicated by the means and the patterns which emerge in the data just reviewed, which all point to a definite change in vowel categorization responses and specifically, a reduction of MCA. It may be that, as with the Language Identification data, changes in listener responses are attributable to time spent engaged in the task and the concentrated and repetitive listening required to complete the task.

Relevance of findings to previous literature

The L1 vowel inventory and L2 vowel perception

The present study adds to the findings of previous studies which have found the L1 vowel inventory to exert an influence on L2 vowel perception. Bradlow (1996) found that native English speakers not only perceived Spanish stimuli in terms of their native vowel space, but when doing so, demonstrated difficulty with the perception of the /e/ - /i/ contrast due to the neighboring English /I/ category not found in Spanish. Escudero and Boersma (2002) found that Dutch speaking learners of Spanish exhibited multiple category assimilation for Spanish front vowels due to vowel categories present in the Dutch inventory not present in the Spanish inventory. One goal of the
present study has been to test the findings of the Bradlow study in part by using methods similar to those used by Esucudero & Boersma. This study has also sought to add to previous findings by exploring the effects of perceptual training and in particular, the training of perception of the acoustic parameters of duration and diphthongization, parameters which are present in English tense vowels but absent in their ‘equivalent’ Spanish counterparts.

Findings from the MCA task are supportive of the previous literature. Participants at all levels did exhibit MCA for Spanish front vowels /e/ and /i/, mapping them to English /æ/ and /i/ with high frequency. This mapping pattern did decrease for all levels after training, but lack of significant results for the independent variable of Training, coupled with significant main effects for Time indicate that the improvement may be due to practice alone. Furthermore, results of this study do not support the hypothesis that increased exposure to Spanish improves a listener’s categorical perception, or in the case of the present study, the ability to avoid multiple category assimilation.

The present study also included a Language Identification task designed to test listener’s ability to correctly identify Spanish and English ‘similar’ vowels on the basis of the acoustic cues that characterize the English tense vowels but not their Spanish ‘equivalents’. Findings indicated that English stimuli are more often correctly identified than Spanish stimuli. This finding raises the possibility that perhaps listeners
find it easier to detect the presence of cues in English vowels rather than the absence of those cues in Spanish.

Theoretical implications

The influence of L1 English on L2 Spanish perception

One of the aims of this study has been to add to our knowledge of how L1 perception influences L2 perception. The findings of this study do not dispute the assertions of previous literature that the L2 perception grammar begins as a clone of the L1 perception grammar (Boersma and Escudero, 2004; Escudero and Boersma, 2002).

Nevertheless, a review of some of the previous literature is warranted here in light of some of the observations made in this study, for the purpose of placing this study in the body of existing research.

Boersma (1999) proposes a separate perception grammar that works in concert with the production grammar. The model proposed by Boersma (Figure 2) is not specific to L2 learning but will be referenced here as this discussion references the occurrences that take place as the listener applies L1 perception to L2 perception. Two aspects of the model in particular merit consideration; the role of the lexicon and the job of the perception grammar in L2 perception.

Boersma (1999) explains how, in the initial stages of L2 acquisition, the learner’s recognition system may lead to incorrect mapping to lexical items. In that event, the L2 lexicon will inform the perception system of the error, thereby raising a
type of ‘flag’ so that in the future errors of that type are less likely. After enough of such events and in the ideal scenario, the learner will adjust the perception system so that similar errors are no longer made. Put in the terms of this study, if the listener hears the Spanish vowel /e/ in the initial stages of L2 Spanish acquisition, he will map to one of the vowel categories for which he already has underlying representation, most likely English /e/ or /æ/. In the ideal scenario, the listener will gradually adjust his L2 perception grammar so that underlying forms more closely approximate the appropriate L2 forms. In the present study the pattern observed for most listeners was one in which listeners at all levels mapped Spanish /e/ to English /æ/ very frequently in the pretest and to a lesser degree in posttest measures. Does this pattern suggest that listeners who change their mapping pattern from one assessment measure to the next, in as few as two days later, have already adjusted the perception grammar? This is not likely the case. In Boersma and Escudero’s Dutch study (2004) the authors propose an algorithm which requires much more time and instances of erred perception in order to arrive at a more native-like L2 perception. It is more likely that the perceptual grammar is acting in an efficient manner by assigning the perceptual input (the acoustic input received by the listener) to an already established (L1) category that is the closest match. Boersma’s model for a separate perception grammar (Figure 2) assumes a perfect underlying form (underlying form = perceptual specification, here a vowel expressed in terms of its acoustic properties), an assumption which may be incorrect if we are to believe that L2 perception begins as a copy of L1 perception. It is not clear
how the model accounts for the intermediate time in L2 acquisition when, in the ideal case, native-like L2 categories are being formed. Do the new L2 categories reside within the L1 perception grammar until there are enough of them for the listener to form a complete L2 perception grammar or does the creation of the first L2 category constitute the new grammar?

The data from this study support the theory that L2 perception begins as a copy of L1 perception. For example, listeners showed a high frequency of mapping Spanish /e/ to English / / in the Pretest, indicating that the perceptual grammar is still grounded in and influenced by L1. At the time of the Delayed Posttest, this MCA pattern decreased with time but was still evident at frequencies of roughly fifty percent, signifying that even after training and multiple exemplars, listeners were still influenced by L1 in their responses. Furthermore, in the Language Identification task, the finding that listeners became more adept at identifying English, rather than Spanish stimuli, could be an indication that listeners found it easier to access L1 categories based on specific cues than to access L2 categories which did not possess those cues.

**Time of exposure and L2 perception**

L2 perception theory has suggested that the perception grammar possesses a degree of plasticity that allows the learner to progress from an initial copy of the L1 perception grammar to a more and more native-like L2 perception grammar (Escudero and Boersma, 2003, 2004). Listener performance on the MCA measures in this study support those theories, as participants of all levels exhibited a change in their patterns.
of mapping L2 to L2 front vowels. However, based on the data from this study there are two comments to be made regarding the effect of time of exposure on the plasticity of the perception grammar. First, while the results of this study showed that listeners did in fact exhibit a change in front vowel mapping patterns, learners with more exposure did not show significantly more change than listeners with less exposure. Second, the reduction of MCA was not drastic for any group, suggesting that for at least a short-term experiment there are limits to the adjustments that can be made by the perception grammar. Similar observations can be made for the Language Identification data. While the Advanced listeners did often show higher means (i.e. higher identification accuracy), their means were often virtually equaled by those of the Intermediate listeners, suggesting once again that being an Advanced listener does not ensure a greater ability to modify the perception grammar in response to training and practice. Also, as previously observed for MCA data, the changes observed for all listeners were not drastic, where means on Post and Delayed Posttests were often within ten percent of Pretest means. Therefore once again it appears that for short-term training the degree of plasticity of the perception grammar is small.

Pedagogical implications

The findings of this study raise some issues that are of practical importance to language instructors. The independent variables in this study – Perceptual Training and Level of Exposure to L2 – represent two of the most common concerns for instructors interested in finding ways to evaluate and perhaps improve listeners’ L2
perception: how to train perception and how to tailor that training to students of
different levels.

The data from this study shows that learners at different levels of exposure do
not necessarily possess differing levels of perceptual skill. There are two points to be
made here. First, increased exposure to L2 does not guarantee more accurate
perceptual skill, as noted at the outset of the study in the MCA Pretest. Secondly,
increased exposure to L2 does not ensure more improvement in posttest measures, as
evidenced by the Beginners in this study who often showed greater degrees of
improvement over time, as observed with some of the Language Identification stimuli.

Results for this study repeatedly found significant main effects for Time but
few significant main effects for Training or Level. While this is a drawback for a study
designed to show positive effects for Training and Level of exposure to L2, it may be a
finding that has positive pedagogical implications. Classroom training on vowel
perception is accomplished in a variety of ways, if accomplished at all due to demands
on classroom time. The findings of this study suggest that repetitive listening exercises
may lead to increased perceptual acuity. In other words, for language classrooms that
make time for explicit instruction of L2 sounds, a presentation of L2 vowels that is
frequent and repetitive may lead to increased accurate perception. The key would
seem to be an emphasis on repetition and on the use of a method which demands
purposeful listening, for identification or discrimination or some similar objective.
Furthermore, the findings of this study may lead one to challenge the widely-held
belief that comprehensible input of sufficient quantity is enough to raise the listeners’ awareness of the differences between L1 and L2 sounds and that, for the really successful learners, it may be enough to eventually lead to native-like production as well. As seen here, the Advanced listeners were not always the most skilled listeners and in fact scored below Intermediate and even Beginning listeners on some tasks.

The final observation regards the differences noted in Language Identification between Spanish and English stimuli, and the finding that improvement was most often found for English stimuli. It may be the case that listeners learn to attend to the cues present in English vowels but find it more difficult to perceive the absence of those cues in similar Spanish vowels. Many Spanish textbooks in current use make parallels to similar English tense vowels when teaching some of the Spanish vowels. If the patterns found in this study have any implications for pedagogical practice, they may suggest that textbooks which seek to teach the distinction between ‘similar’ English and Spanish vowels may err in that methodology. Such an approach assumes that the terms commonly used in textbooks, such as “tense”, “short”, “long”, etc. are clear descriptors for native English speakers. It might be argued that writers of language textbooks should increase to an extent their focus on the quality of English vowels rather than rely on the assumption that relative terms such as “more tense” are meaningful to the listener who may not perceive the tense quality of his L1 (here, English) vowels.
Limitations of the study

This section presents a number of limitations which can be found in this study as well as suggestions for improving upon these limitations in future research.

The first limitation regards the number of participants in this study. For some groups in some tasks the cell size was lower than the desired size for analysis by ANOVA. This downsizing of cells occurred despite strong recruitment and an initial participant pool of over two hundred participants. However, as the design of this study sought to determine change in perceptual skill over time, it was necessary to evaluate Pretest data and eliminate a certain number of cases that did not meet the cutoff criterion for inclusion in the study. This procedure lowered the overall pool of participants, a number which was then lowered even further when participants were divided by level of exposure and randomly assigned to training groups. The small number of some cells may be a contributing factor to the lack of significant effects for some variables, as significance is strongly related to sample size. In future studies an increased number of participants would of course increase the strength of the results and therefore the ability to more accurately generalize the findings of the present study to the general population. An increase in the sample size could be accomplished by extending the time period for data collection by an additional three to six months and by conducting another round of participant recruitment and data collection. For this study data was collected over two semesters, but a third semester of data collection would have been impossible due to the timeline of completion for this investigation.
Other limitations can be found in the training tasks used in this study. The first limitation regards the time allotted for the perceptual training tasks. In the present study all participants completed the treatment phase in one session, spending an average of twenty minutes to complete the tutorial and discrimination task before continuing to the immediate posttest. The choice to restrict the treatment phase to one session was made in an effort to keep the total time of the experiment manageable for full-time college students, with the ultimate goal of avoiding the ever-present threat of participant attrition. Previous research has shown that extending the training period over multiple sessions has a positive effect (Lisker, 1970; Pisoni et al., 1982). This limitation was even noted by one participant, who after completing all sessions initiated a discussion of the purpose of the study and the expected outcomes.

Regarding the training phase, one participant noted that “…more than one day of training would be good…” This observation is certainly an insightful one, and in future studies the training period should be extended to cover more than one experimental session. Another possibility to improve upon the training phase would be to introduce another experimental group, one which receives combined training in both vowel duration and diphthongization. The immediate and delayed posttest results of that group could then be directly compared to the results of the groups receiving only one type of training, a comparison which might lead to a better understanding of what constitutes successful perceptual training. A second potential limitation of the training
phase concerns the use of a discrimination task for training listeners to perceive differences in vowel duration and vowel diphthongization.

Two comments can be made regarding the discrimination task utilized in the Training portion of this study. First, it is a potential limitation that participants perform a discrimination task in the training phase but do not perform a similar task in the assessment tasks (Pre, Post or Delayed). Stated another way, it could be considered a limitation that the assessment tasks require participants to perform a task that is different from that on which they receive training. This limitation could be corrected in future studies in one of two ways. First, a discrimination task without feedback could be integrated into the assessment tasks. Alternatively, the training could utilize not a discrimination task but rather a task that closely approximates the format and objectives of the MCA and Language ID portions of the assessment tasks. The second limitation of the discrimination task regards a potential argument that could be made against the design of the task itself. It could be argued that the discrimination task trains audition rather than perception. When viewed separately from the tutorial and instructions which precede it, it might in fact seem that the discrimination task does nothing more than focus listeners’ attention on the length and degree of diphthongization of the target vowels. However, because participants must first complete the tutorial which explains these acoustic differences between English and Spanish vowels, and because they are explicitly told in the instructions in the discrimination task that the first stimulus of each pair represents a standard production
of the target Spanish vowel, the task is in fact designed to train language-specific vowel perception.

As a final point regarding the limitations of the present study, it might also be argued that the use of human voices for the stimuli in this study is a drawback. Human vocal characteristics range in quality from person to person in much the same way that fingerprints vary from person to person. Physical attributes such as vowel tract size, shape and size of the articulators such as the tongue and teeth, moisture or dryness as well as changes wrought upon the vocal tract by habits such as smoking can all contribute the unique quality of a speaker’s voice. A potential criticism of the use of naturally produced stimuli in this study might be that participants would attend to particular vocal characteristics of the speakers and, after identifying that speaker as a speaker of English or Spanish, would then continue to make that same identification based upon vocal quality rather than the quality of the target vowels. The decision to include multiple speakers of both languages was made in an effort to control for this problem. The alternative to using naturally produced stimuli is to use synthesized stimuli, either synthesized target vowels embedded in the naturally produced ‘words’ or stimuli entirely synthesized. However, the use of synthesized stimuli is also problematic and perhaps even more problematic than the use of naturally produced stimuli. It is possible that participants’ unfamiliarity with synthesized speech might require a certain level of additional cognitive effort which could detract from their ability to focus on the target acoustic differences. Therefore while arguments might be
made against the use of human voices in a study of this type, the use of naturally produced stimuli was a wiser approach for the present study when the pros and cons just given are all taken into consideration.

Future Research

The present study marks a solid beginning for questions related to the study of L2 vowel perception. The design of this study and its size will allow for several follow-up studies and opportunities to examine in greater depth some of the issues that have been raised here. The first follow-up will be a more detailed study of the training task. The data collection software used for this study tracked listener responses during the discrimination task, responses which can be analyzed and coded in order to study listener’s interaction with the task and specifically, whether or not accuracy improved as the task progressed. This data can also be linked to data obtained from a post-experiment questionnaire. In the questionnaire participants answered questions regarding their thoughts on the purpose of the experiment, their rankings of the helpfulness of the training, etc. Analyzing responses in this way may shed more light on the findings on training obtained in the present study.

A long-term goal is to explore the link between L2 perception and production. The present study and those which will follow are a necessary beginning to a line of research directed towards finding not only the link between L2 perception and production but also the factors which facilitate L2 perception. In such a line of research questions regarding the cognitive skills and personal attributes of the L2
learner can also be explored. In summary, this study marks a first step in what is hoped to be a long line of research on L2 perception and production.
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Figure 1. Hume & Johnson’s general model of the interplay of external forces and phonology (2001, p.13).
Figure 2. Boersma’s grammar model of functional phonology (1999, p. 1)
Figure 3: The English Vowel Inventory (Hammond, R. 2001)
Figure 4. The Spanish Vowel Inventory (Hammond, R. 2001)
Figure 5. Spanish CVCV Stimuli in the Duration A/X Discrimination Task

<table>
<thead>
<tr>
<th>CVCV</th>
<th>‘Average’ stimulus</th>
<th>1st lengthened stimulus</th>
<th>2nd lengthened stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>/sisa/</td>
<td>105ms</td>
<td>115ms</td>
<td>125ms</td>
</tr>
<tr>
<td>/sesa/</td>
<td>115ms</td>
<td>135ms</td>
<td>155ms</td>
</tr>
<tr>
<td>/sosa/</td>
<td>120ms</td>
<td>135ms</td>
<td>150ms</td>
</tr>
<tr>
<td>/sus/a/</td>
<td>100ms</td>
<td>115ms</td>
<td>130ms</td>
</tr>
</tbody>
</table>

Figure 6. Spanish CVCV Stimuli in the Diphthongization A/X Discrimination Task

<table>
<thead>
<tr>
<th>CVCV</th>
<th>0 F2 change stimulus</th>
<th>Measure of partial F2 change stimulus</th>
<th>Measure of full F2 change stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>/fifa/</td>
<td>0 Hz</td>
<td>247 Hz</td>
<td>495 Hz</td>
</tr>
<tr>
<td>/fe/f/a/</td>
<td>0 Hz</td>
<td>195 Hz</td>
<td>390 Hz</td>
</tr>
<tr>
<td>/fo/f/a/</td>
<td>0 Hz</td>
<td>192 Hz</td>
<td>385 Hz</td>
</tr>
<tr>
<td>/fu/f/a/</td>
<td>0 Hz</td>
<td>200 Hz</td>
<td>400 Hz</td>
</tr>
</tbody>
</table>

Figure 7. Spanish CVCV Stimuli in the Aspiration A/X Discrimination Task

<table>
<thead>
<tr>
<th>CVCV</th>
<th>0 aspiration stimulus</th>
<th>Partial aspiration stimulus</th>
<th>Full aspiration stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>/pafa/</td>
<td>12 ms</td>
<td>41 ms</td>
<td>70 ms</td>
</tr>
<tr>
<td>/ta/f/a/</td>
<td>15 ms</td>
<td>47 ms</td>
<td>80 ms</td>
</tr>
<tr>
<td>/kafa/</td>
<td>25 ms</td>
<td>52 ms</td>
<td>80 ms</td>
</tr>
</tbody>
</table>
Figure 8. Language ID Means by Learner Level for Spanish and English Stimuli
Figure 8. Language ID Means by Learner Level for Spanish and English Stimuli

Language ID: Spanish /bifa/

Language ID: English /bifa/
Figure 8. Language ID Means by Learner Level for Spanish and English Stimuli

Language ID: Spanish /bofa/

Language ID: English /bofa/
Figure 8. Language ID Means by Learner Level for Spanish and English Stimuli

Language ID: Spanish /bufa/

Language ID: English /bufa/
Figure 9. Front Vowel Mapping by Learner Level for Spanish /besa/
Figure 10. Front Vowel Mapping by Learner Level for Spanish /bisa/

Front Vowel Mapping: Spanish /bisa/

Mean Responses

Beg

Interm

Adv

Pretest  Posttest  Delayed Posttest
Figure 11. MCA of /e/ to / / by Learner Level
Figure 12. MCA of /i/ to /I/ by Learner Level

![Graph showing MCA of /i/ to /I/ by Learner Level](image)

Mean Percentage of MCA

<table>
<thead>
<tr>
<th>Level</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Delayed Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Figure 13. Language Identification by Training Group: Spanish and English Stimuli

Language ID: Spanish /bɛfa/

Language ID: English /bɛfa/

Mean Responses

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

Pretest Posttest Delayed Posttest

Duration
Diphth.
Aspiration

Duration
Diphth.
Aspiration
Figure 13. Language Identification by Training Group: Spanish and English Stimuli

Language ID: Spanish /bifa/

Language ID: English /bifa/
Figure 13. Language Identification by Training Group: Spanish and English Stimuli
Figure 13. Language Identification by Training Group: Spanish and English Stimuli

Language ID: Spanish /bufa/

Language ID: English /bufa/
Figure 14. MCA for Spanish /e/ by Training Group

MCA /e/ > /ɛ/: Training and Level

- Pretest
- Posttest
- Delayed Posttest
Figure 15. MCA for Spanish /i/ by Training Group

MCA /i/ > /I/: Training and Level

- Pretest
- Posttest
- Delayed Posttest
Table 1. Research Design Overview.

<table>
<thead>
<tr>
<th>DAY</th>
<th>GROUP(S)</th>
<th>TASK</th>
</tr>
</thead>
</table>
| 1   | All      | Day 1 Study:  
|      |          | Questionnaire  
|      |          | Familiarization session  
|      |          | MCA Pre-test, Identification trials Pre-test |

▷ 2 day interval ◷

| 2   | Duration Training | Tutorial: Vowel Duration  
|     |                  | A/X Discrimination task |
|     | Diphthong. Training | Tutorial: Vowel Diphthongization  
|     |                  | A/X Discrimination task |
|     | Aspiration Training | Tutorial: Stop aspiration  
|     |                  | A/X Discrimination task |
| All |                  | MCA Posttest, Identification trials Posttest  
|     |                  | Follow-up Questionnaire |

▷ 14 day interval ◷

| 3   | All      | Delayed MCA Posttest, Identification trials Posttest |

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Table 2. Native Speaker Informant Profiles

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Language</th>
<th>City/Country of Origin</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.R.</td>
<td>English</td>
<td>Ft. Lauderdale FL</td>
<td>30</td>
</tr>
<tr>
<td>A.K.</td>
<td>English</td>
<td>Columbus OH</td>
<td>29</td>
</tr>
<tr>
<td>A.G.</td>
<td>English</td>
<td>Seattle WA</td>
<td>27</td>
</tr>
<tr>
<td>T.S.</td>
<td>English</td>
<td>Columbus OH</td>
<td>27</td>
</tr>
<tr>
<td>L.G.</td>
<td>English</td>
<td>Atlanta GA</td>
<td>34</td>
</tr>
<tr>
<td>A.S.</td>
<td>English</td>
<td>Evanston IL</td>
<td>26</td>
</tr>
<tr>
<td>R.S.</td>
<td>English</td>
<td>Blacksburg VA</td>
<td>24</td>
</tr>
<tr>
<td>M.G.</td>
<td>English</td>
<td>San Francisco CA</td>
<td>45</td>
</tr>
<tr>
<td>P.F.</td>
<td>English</td>
<td>Pittsburgh PA</td>
<td>35</td>
</tr>
<tr>
<td>K.C.</td>
<td>English</td>
<td>Fort Lauderdale FL</td>
<td>32</td>
</tr>
<tr>
<td>R.G.</td>
<td>Spanish</td>
<td>Puerto Rico</td>
<td>38</td>
</tr>
<tr>
<td>P.F.</td>
<td>Spanish</td>
<td>Spain</td>
<td>35</td>
</tr>
<tr>
<td>O.A.</td>
<td>Spanish</td>
<td>Mexico</td>
<td>40</td>
</tr>
<tr>
<td>L.C.</td>
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<td>Mexico</td>
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<tr>
<td>S.J.</td>
<td>Spanish</td>
<td>Argentina</td>
<td>45</td>
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<td>M.P.</td>
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<td>Spanish</td>
<td>Spain</td>
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<tr>
<td>E.A.</td>
<td>Spanish</td>
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<td>L.G.</td>
<td>Spanish</td>
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<tr>
<td>Y.S.</td>
<td>Spanish</td>
<td>Mexico</td>
<td>35</td>
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</table>
### Table 3. English and Spanish Vowel Durations

<table>
<thead>
<tr>
<th>Vowel</th>
<th>CVCV</th>
<th>Language</th>
<th>N</th>
<th>Mean duration (ms)</th>
<th>Std. Dev.</th>
<th>t</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>/e/</td>
<td>/befa/</td>
<td>English</td>
<td>10</td>
<td>165</td>
<td>22</td>
<td>4.667</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spanish</td>
<td>10</td>
<td>125</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>/efa/</td>
<td>English</td>
<td>10</td>
<td>156</td>
<td>24</td>
<td>4.437</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spanish</td>
<td>10</td>
<td>115</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/fesa/</td>
<td>English</td>
<td>10</td>
<td>161</td>
<td>25</td>
<td>3.94</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spanish</td>
<td>10</td>
<td>120</td>
<td>23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>/sesa/</td>
<td>English</td>
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<td>156</td>
<td>25</td>
<td>4.17</td>
<td>0.000</td>
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<tr>
<td></td>
<td>Spanish</td>
<td>10</td>
<td>115</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
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Table 4. Average English F2 Transitions

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Table 5. English and Spanish Stop Consonant Aspiration

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<th>Std. Dev.</th>
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Table 6. Pilot Study Pretest Stimuli

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<th>ENGLISH stimuli</th>
<th>Repetitions</th>
<th>Total English CVCV items</th>
<th>SPANISH stimuli</th>
<th>Repetitions</th>
<th>Total Spanish CVCV items</th>
<th>Total CVCV items</th>
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<td>/i,e,o,u,a / x 5</td>
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Table 7. Pilot Study Vowel Duration and Diphthongization Training Stimuli (Test Group)

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<th>Repetitions</th>
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Table 8. Pilot Study Stop Consonant Aspiration Training Stimuli (Control Group)

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<th>Repetitions</th>
<th>Total Spanish CVCV items</th>
<th>Total CVCV items</th>
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### Table 9. Pilot Study Posttest Stimuli

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<th>Repetitions</th>
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Table 10. Pilot Study Participants by Level and Group

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<td>Beginner</td>
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Table 11. Language Identification: Spanish and English Target Stimuli Identified Correctly in Pilot Pre-, Post-, Delayed Posttests

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201
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Table 14. Front Vowel MCA in Pretest, by Level of Exposure

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Table 15. Descriptive Statistics: Language ID Spanish CVCV Stimuli by Level of Exposure

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Table 21. Descriptive Statistics: MCA for Spanish /e/ and /i/ by Training Group

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Appendix A: Vowel Duration Tutorial (Test Group)

As a native speaker of English you are well familiar with the English vowels. When you learned to read and write you probably learned that there are five vowels – a, e, i, o, u. You probably also learned that there are “short” vowels and “long” vowels. And you may have learned that combinations of vowels create new sounds. The words which follow exemplify vowel sounds featured in most varieties of English. Click on each word to hear the vowel sounds.

Peter pity paper petty Patty poochie pushy pony pauper poppy puppy

English spelling is variable, so even though words like “pushy” and “puppy” are spelled with the letter ‘u’, their vowel sounds are different. Go back and play these words again.

Next you will see both the example words and the phonetic symbols for their vowels. Do not be alarmed if the symbols are foreign to you, and do not try to learn them. Concentrate only on the sound of the vowels. Listen once more to the English example words:
Now I will ask you to consider the Spanish vowels. When you began to learn Spanish you learned that it is a language of five vowels – a, e, i, o, u. However, in Spanish, unlike in English, there are no “short” or “long” vowels. Listen once more to the vowels in the following words. Again, don’t try to memorize the phonetic symbols.

\[
\begin{array}{cccc}
/i/ & /e/ & /u/ & /o/ & /a/ \\
\text{pita} & \text{pepa} & \text{pucha} & \text{pone} & \text{papi} \\
\text{(plant)} & \text{(seed)} & \text{('caramba')} & \text{(he/she ‘puts’)} & \text{('Daddy')} \\
\end{array}
\]

As a student of Spanish you may have also been told that the five Spanish vowels are very similar to some of the English vowels – remember Peter, paper, poochie, pony and poppy? It is true that those five English vowels and the five vowels of Spanish are similar. But they are also different in very important ways. You will now hear two short tutorial segments, each of which will present one qualitative difference between English and Spanish vowels. Each segment will focus on only FOUR of the five Spanish vowels - /i/, /e/, /o/ and /u/ - and will also give you short listening activities that will allow you to put into practice what you learn.
Vowel Duration Training

One important qualitative difference between Spanish and English vowels is that they differ in duration. Spanish vowels are typically shorter than English vowels. Listen to the vowels and example words which follow. Spanish and English examples are presented side by side. Click on each vowel and word to hear them played and compare their duration. You can play each word up to three times.

Spanish /i/: \textit{pita}  
English /i/: \textit{Peter}

Now listen to another Spanish-English vowel comparison. Again, play each up to three times if you need.

Spanish /e/: \textit{pepa}  
English /e/: \textit{paper}

Hear is the third vowel. Listen and compare again:

Spanish /u/: \textit{pucha}  
English /u/: \textit{poochie}

And now hear and the compare the last vowel.

Spanish /o/: \textit{pone}  
English /o/: \textit{pony}
PRACTICE LISTENING ACTIVITY

“As you have just learned, Spanish vowels are typically shorter than English vowels. With that in mind, you will now complete an easy listening task designed to train your ear to the appropriate duration of Spanish vowels. In this task you will hear PAIRS of SPANISH words produced by a female native Spanish speaker. The words will have the general form “S__SA”, and one of the four vowels from this lesson will occupy the blank. With each pairing, LISTEN CAREFULLY TO THE VOWEL WHICH FILLS THE BLANK.

In each pair of Spanish words, the FIRST word will contain a vowel whose duration is appropriate for Spanish. **Listen very carefully to both words and if the vowel in the SECOND word has the same duration as the vowel in the first word, click the word ‘SAME’ on your screen. If the vowel in the second word is not equal in duration, click the word ‘DIFFERENT’.

After you indicate your answer the computer will tell you if you are correct. This feedback should help you complete the task. You will practice listening to ONE VOWEL at a time, repeated over several examples, before proceeding to another ‘S__SA’ word containing another vowel, and so on, until you have had the opportunity to hear words containing all four vowels.
Begin now with the first set of ‘S_SA’ words. You may play the paired items up to three times.”
Appendix B: Vowel Diphthongization Tutorial (Test Group)

Let’s review. When you learned to read and write you probably learned that there are five vowels – a, e, i, o, u. You probably also learned that there are “short” vowels and “long” vowels. And you may have learned that combinations of vowels create new sounds. The words which follow exemplify the vowel sounds featured in most varieties of English. Click on each word to hear the vowel sounds.

Peter pity paper Petty Patty poochie pushy pony pauper poppy puppy

English spelling is variable, so even though words like “pushy” and “puppy” are spelled with the letter ‘u’, their vowel sounds are different. Go back and play these words again.

Listen once more to the English example words. This time you will see both the example words and the phonetic symbols for their vowels. Do not be alarmed if the symbols are foreign to you, and do not try to learn them. Concentrate only on the sound of the vowels.

/i/ Pete /I/ pity /e/ paper /E/ petty /{/ Patty
Now I will ask you to consider the Spanish vowels. When you began to learn Spanish you learned that it is a language of five vowels – a, e, i, o, u. However, in Spanish, unlike in English, there are no “short” or “long” vowels. Listen to the underlined vowels in the following words. Again, don’t try to memorize the phonetic symbols.

/i/                     /e/                     /u/                    /o/                    /a/

pita  pepa  pucha  pone  papi

(plant)               (seed)           (‘caramba’)      (he/she ‘puts’)    (‘Daddy’)

As a student of Spanish you may have also been told that the five Spanish vowels are very similar to some of the English vowels – remember Peter, paper, poohie, pony and poppy? It is true that those five English vowels and the five vowels of Spanish are similar. But they are also different in very important ways. The following segment will teach you one of these differences. You will focus on only FOUR of the five Spanish vowels - /i/, /e/, /o/ and /u/ - and you will have short listening activities that will allow you to put into practice what you learn.

One important qualitative difference between English and Spanish vowels regards a feature called “diphthongization”. You may know the term “diphthong” to mean two vowels which combine to make a new sound. In the case of the four English vowels
you are studying today – /e, i, o, u/-, “diphthongized” refers to a tensing of the vowel in the final milliseconds of its duration. Consider the tense vowels in the words “Peter”, “paper”, “pony” and “poochie”. The vowel in the word “paper” may be the easiest example to begin with. Click on the word “paper” to see if you can hear this transition. Play it up to three times if you would like.

paper

Did you hear the transition? At the end of the vowel you hear something like the sound /y/, as in ‘pay’. Now listen to all four vowels in the same words you have seen. Click on all of them, as many times as you would like, and try to hear the diphthongization of each vowel. Note that the vowels in “Peter” and “paper” end in a sound that is something like the /y/ sound. The vowels in “pony” and “poochie” end in a sound something like the /w/ sound. This is noted for you in the superscripts, below.

Peter  paper  pony  poochie

Now consider the Spanish vowels. Spanish vowels are NOT diphthongized. The vowel in the word “pepa”, which to you may seem similar to the vowel in “paper”, does not have that same acoustic transition at the end of the vowel. The Spanish vowels maintain their sound throughout their duration without growing tenser at the
end as the tense English vowels do. Click on the Spanish words below and listen to the sounds of each vowel.

\[
\text{pi\text{ta} pepe pone pucha}
\]

Again, English tense vowels are diphthongized but Spanish vowels are not. It is important to try to hear this difference. To help you do that, listen to the following vowels and example words which follow. Both a Spanish vowel and then an English vowel are presented side by side with example words for each. Listen for the tensing that occurs at the end of the English vowels but is absent in the Spanish vowels. Click on each word to hear their vowel sounds. You can click each word up to three times. Don’t be alarmed by the presence of the phonetic symbols and don’t try to learn them; concentrate only on the sound of the vowels.

Spanish /i/: \text{pita} \hspace{1cm} \text{English /i/: Peter}

Now listen to another Spanish-English vowel comparison. Again, play each up to three times.

Spanish /e/: \text{pepa} \hspace{1cm} \text{English /e/: paper}
Hear is the third vowel. Listen and compare again:

Spanish /u/: **pucha**  
English /u/: **poochie**

And now hear and the compare the last vowel.

Spanish /o/: **pone**  
English /o/: **pony**

**PRACTICE LISTENING ACTIVITY**

“As you have just learned, Spanish vowels are NOT diphthongized. With that in mind, you will now complete an easy listening activity designed to train your ear to the undiphthongized quality of Spanish vowels. In this activity you will hear PAIRS of SPANISH words produced by a female native Spanish speaker. PLEASE NOTE that these words have been created using speech software, so do not be surprised if they sound a little unnatural. The words will have the general form “F__FA”, and one of the four vowels from this lesson will occupy the blank. With each pairing, LISTEN CAREFULLY TO THE VOWEL WHICH FILLS THE BLANK.

In each pair of Spanish words, the FIRST word will contain a vowel that, appropriately for Spanish, is not diphthongized. **Listen**
very carefully to both words and if the vowel in the SECOND word has the same undiphthongized quality, click on the word ‘SAME’ on your screen. If NOT, click on the word ‘DIFFERENT’.

After you indicate your answer the computer will tell you if you are correct.

This feedback should help you complete the task. You will practice listening to ONE VOWEL at a time, repeated over several examples, before proceeding to another ‘F_FA’ word containing another vowel, and so on, until you have had the opportunity to hear words containing all four vowels.

Begin now with the first set of ‘F_FA’ words. You may play the paired items up to three times.”
The Spanish and English alphabets are almost the same in terms of the letters they contain. There are of course a few Spanish consonants that do not exist in English, but for the most part the Spanish alphabet as you learned it is very similar to that of English. In this computer lesson you will learn how some of the “same” consonants are pronounced slightly differently in the two languages, and you will learn how to better tune your ear to these differences.

First consider the English consonant sounds /p/, /t/, and /k/. These sounds are characterized by a feature called aspiration. This means that when the sounds are produced at the beginning of a word or syllable, a small puff of air is released as the sound is made. You can test this yourself. If you hold your hand in front of your mouth and make the sound “pa”, you will feel a small puff of air following the sound /p/.  Take a moment now to try it yourself. Put your hand in front of your mouth and say “pa”.

Did you feel the puff of air? This also occurs when you make the sounds /t/ and /k/. Repeat the same test you just performed for /p/, but this time make the sounds “ka” and “ta”.

Did you get the same result as before, a little puff of air?
As mentioned before, Spanish also contains the consonant sounds /p/, /t/ and /k/, but unlike their counterparts in English, these sounds are NOT accompanied by the little puff of air. These consonants in Spanish are characterized as unaspirated. Before you perform your test again, take a moment to listen to the following syllables being pronounced in English and in Spanish. Click on each syllable, up to three times, and see if you can hear the difference between the aspirated quality of the English consonants and the unaspirated quality of the Spanish consonants.

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<tr>
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<td><strong>ta</strong></td>
</tr>
<tr>
<td><strong>ka</strong></td>
<td><strong>ka</strong></td>
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</tbody>
</table>

Did you hear how the English syllables are aspirated, while the Spanish syllables, in contrast, are unaspirated?

Now take a moment to try the “puff test” as you produce the Spanish syllables /pa/, /ta/ and /ka/. Repeat /pa/, /ta/, and /ka/ to yourself, and see if you can make these sounds without producing the puff after the consonant.
Did it work? Now just listen to the following Spanish words and see if you can hear their unaspirated quality. Click to play each word, up to three times if you need. The /k/ sound in Spanish is almost always spelled with the letter ‘c’, as in the examples below.

- **pasa** (move, occur)
- **tasa** (rate)
- **casa** (house)
- **papa** (potato)
- **tapa** (top)
- **capa** (cape)

Now listen to some of these words again, and compare them to English words. Listen for the unaspirated quality of the Spanish consonants compared to the aspirated quality of the English consonants.

<table>
<thead>
<tr>
<th>Spanish</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>papa</strong></td>
<td><strong>pop</strong></td>
</tr>
<tr>
<td><strong>tapa</strong></td>
<td><strong>top</strong></td>
</tr>
<tr>
<td><strong>capa</strong></td>
<td><strong>cop</strong></td>
</tr>
</tbody>
</table>

Did you hear the difference? Now try to pronounce the unaspirated Spanish words quietly to yourself. Click each one if you need to hear the model.

- **papa**
- **tapa**
- **capa**
Okay, from this point on you will work on trying to perceive the difference between English and Spanish consonant sounds /p/, /t/ and /k/ on the basis of what you have just learned about aspiration. The segments that follow will consist of listening activities that focus on the unaspirated quality of these Spanish consonants.

**PRACTICE LISTENING ACTIVITY**

“As you have just learned and heard, the Spanish consonant sounds /p/, /t/ and /k/ are **unaspirated**, unlike their English counterparts which are **aspirated**. With that in mind, you will now complete an easy listening task designed to train your ear to the **unaspirated** quality of the Spanish sounds /p/, /t/ and /k/. In this activity you will hear **PAIRS** of **SPANISH** words produced by a female native Spanish speaker. The words will have the general form “__AFA”, and one of the consonant sounds from this lesson will occupy the blank. With each pairing, **LISTEN CAREFULLY TO THE CONSONANT SOUND THAT FILLS THE BLANK.**

In each pair of Spanish words, the first word will contain a consonant sound that is **unaspirated**, as is appropriate for these sounds in Spanish. **Listen very carefully to both words and if the consonant in the SECOND word has the same unaspirated quality as the**
consonant in the first word click ‘SAME’ on your screen. If NOT, click on the word ‘DIFFERENT’.

After you indicate your answer the computer will tell you if you are correct. This feedback should help you complete the task. You will practice listening to ONE CONSONANT at a time, repeated over several examples, before proceeding to another “__AFA” word containing another consonant, and so on, until you have had the opportunity to hear words containing all three consonant sounds from this tutorial. Begin now with the first set of ‘__AFA’ words. You may play the paired items up to three times.”
Participant ID ______________________ Instructor ______________________

Dear Participant: You have been asked to participate in this research study because you are a native English speaker and Beginning Spanish student enrolled in a college-level Spanish course. As such, it is assumed that you began the course with no prior knowledge of Spanish. In order that I, the researcher might better understand your performance on tasks in this study, please answer the following questions truthfully and to the best of your ability.

Personal and Learning History

1. Does your current Spanish course constitute your first exposure to Spanish? Yes No

If answering “No”, please answer items A-D below. Circle or write your answer.

A. Where were you first exposed to Spanish?
   Middle School  High School  College  Other ________________

B. When did this exposure occur? Within the…..
   last year or semester  last 2 years  last 3 years  last 4 years
   other _____________?

C. How long did the exposure occur (how many days, weeks, months, years)?

D. Did the exposure take place
   in the classroom  with family  with friends  other ________________?

E. Have you had explicit instruction in Spanish pronunciation or phonetics?
   Yes  No
   If answering yes, please indicate the source of instruction:
   Lecture & Practice  Workbook & Practice  Other ________________

2. Do you have any history of hearing problems? Yes  No
   If answering “yes”, please describe the nature of the problem and how it is/was treated.

230
Other Languages

1. Do you have knowledge of Latin or any other Romance Language? Circle any that apply.

   Latin       French       Portuguese       Italian       Catalan       Romanian

For each language selected above please indicate the skills and amount of experience you possess:

<table>
<thead>
<tr>
<th>Language (fill in blank)</th>
<th>Speaking Skills</th>
<th>Reading Skills</th>
<th>Writing Skills</th>
<th>Comprehension Skills</th>
<th>Amount of experience (weeks / years)</th>
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<tr>
<td>1. __________</td>
<td>Intermediate</td>
<td>Intermediate</td>
<td>Intermediate</td>
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<td>Advanced</td>
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<td>2. __________</td>
<td>Basic</td>
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<td>Basic</td>
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Please continue ➔
2. Please also indicate your skill level, if any, in any of the following languages: Classical Greek, Hebrew, Serbo-Croatian, Swahili, Maori, Basque, or Japanese.

<table>
<thead>
<tr>
<th>Language (fill in blank)</th>
<th>Speaking Skills</th>
<th>Reading Skills</th>
<th>Writing Skills</th>
<th>Comprehension Skills</th>
<th>Amount of experience (weeks / years)</th>
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<tbody>
<tr>
<td>1. ___________</td>
<td>Basic</td>
<td>Basic</td>
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<td>Intermediate</td>
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<td>2. ___________</td>
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<td>3. ___________</td>
<td>Basic</td>
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</table>
Appendix E: Background Questionnaire, Intermediate Spanish

Participant ID ______________________ Instructor ______________________

Dear Participant: You have been asked to participate in this research study because you are a native English speaker and Intermediate-level Spanish student enrolled in a college-level Spanish course. In order that I, the researcher might better understand your performance on the tasks in this study, please answer the following questions truthfully and to the best of your ability.

Personal and Learning History

1. Circle the option which best answers the question or fill in the appropriate answer where provided.

   Where were you first exposed to Spanish?
   Middle School    High School    College    Other __________________

   When did this exposure occur? Within the……
   last year    last 2 years    last 3 years    last 4 years    other ____________?

   Did exposure take place
   in the classroom    with family    with friends    other _______________?

2. How many high school Spanish classes did you take? Please fill in the following:

   _____________ classes, over a period of _________ semesters / ________ year(s).

3. How many semesters of college Spanish have you had (at current institution or combined with other)?

   Please circle  1    2    3    4    5    6    7    8

   Please indicate which course you are currently taking: ______________________

4. Have you had explicit instruction in Spanish pronunciation or phonetics?

   Yes    No

   If answering yes, please indicate the source of instruction:
   Lecture & Practice    Workbook & Practice    Other ______________
5. Do you have any history of hearing problems?  Yes  No

If answering “yes”, please describe the nature of the problem and how it is/was treated.

Other Languages

1. Do you have knowledge of Latin or any other Romance Language? Circle any that apply.
   Latin  French  Portuguese  Italian  Catalan  Romanian

For each language selected above please indicate the skills and amount of experience you possess:

<table>
<thead>
<tr>
<th>Language (fill in blank)</th>
<th>Speaking Skills</th>
<th>Reading Skills</th>
<th>Writing Skills</th>
<th>Comprehension Skills</th>
<th>Amount of experience (weeks / years)</th>
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<tbody>
<tr>
<td></td>
<td>Basic Intermediate Advanced</td>
<td>Basic Intermediate Advanced</td>
<td>Basic Intermediate Advanced</td>
<td>Basic Intermediate Advanced</td>
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<tr>
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<td>Basic Intermediate Advanced</td>
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<td>3. __________</td>
<td>Basic Intermediate Advanced</td>
<td>Basic Intermediate Advanced</td>
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</table>

Please continue ➔
2. Please also indicate your skill level, if any, in any of the following languages: *Classical Greek, Hebrew, Serbo-Croatian, Swahili, Maori, Basque, or Japanese.*

<table>
<thead>
<tr>
<th>Language (fill in blank)</th>
<th>Speaking Skills</th>
<th>Reading Skills</th>
<th>Writing Skills</th>
<th>Comprehension Skills</th>
<th>Amount of experience (weeks / years)</th>
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<tbody>
<tr>
<td>1. ____________</td>
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<td>2. ____________</td>
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</table>
Appendix F: Background Questionnaire: Advanced Spanish

Participant ID ______________________ Instructor ______________________

Dear Participant: You have been asked to participate in this research study because you are a native English speaker and Advanced-level Spanish student enrolled in a college-level Spanish course. In order that I, the researcher might better understand your performance on the tasks in this study, please answer the following questions truthfully and to the best of your ability.

**Personal and Learning History**

1. **Circle** the option which best answers the question or fill in the appropriate answer where provided.

   Where were you first exposed to Spanish?
   - Middle School
   - High School
   - College
   - Other ________________

   When did this exposure occur? Within the.....
   - last year
   - last 2 years
   - last 3 years
   - last 4 years
   - other __________?

   Did exposure take place
   - in the classroom
   - with family
   - with friends
   - other ________________?

2. How many **high school Spanish classes** did you take? Please fill in the following:
   _____________ classes, over a period of _________ semesters / ________ year(s).

3. How many semesters of **college Spanish** have you had (at current institution or combined with other)?
   - Please circle 1 2 3 4 5 6 7 8

   Please indicate which course you are currently taking: ______________________

4. Have you had explicit instruction in Spanish pronunciation or phonetics?
   - Yes
   - No
   If answering yes, please indicate the source of instruction:
   - Lecture & Practice
   - Workbook & Practice
   - Other ________________
5. Do you have any history of hearing problems?  Yes   No

If answering “yes”, please describe the nature of the problem and how it is/was treated.

**Other Languages**

1. Do you have knowledge of Latin or any other **Romance Language**?  Circle any that apply.

<table>
<thead>
<tr>
<th>Language (fill in blank)</th>
<th>Speaking Skills</th>
<th>Reading Skills</th>
<th>Writing Skills</th>
<th>Comprehension Skills</th>
<th>Amount of experience (weeks / years)</th>
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<tr>
<td>1._________</td>
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Please continue ➔
2. Please also indicate your skill level, if any, in any of the following languages: Classical Greek, Hebrew, Serbo-Croatian, Swahili, Maori, Basque, or Japanese.

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<tr>
<th>Language (fill in blank)</th>
<th>Speaking Skills</th>
<th>Reading Skills</th>
<th>Writing Skills</th>
<th>Comprehension Skills</th>
<th>Amount of experience (weeks / years)</th>
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</table>
Appendix G: Georgetown University IRB Approval

Georgetown University Institutional Review Board

Date: July 9, 2007

Principal Investigator: Leslie Gordon
Spanish and Portuguese
2977 Fairhaven Circle
Atlanta GA 30305

From: Sam Rigby
Analytical Writer
Institutional Review Board

Title: Factors Affecting English Speakers’ L2 Spanish Vowel Perception

IRB#: 2007-215

Action: Granted
Response to contingencies from review of May 24, 2007
Category I
Exemption

The above referenced project was deemed to be exempt from review by the Institutional Review Board with the following category:

1. X Research conducted in established or commonly accepted educational settings, involving normal educational practices. Examples include:
   a) Research on regular and special education instructional strategies, OR
   b) Research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

This exemption is in accordance with Title 45 of the Code of Federal Regulations Part 46.102 (d) "a systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge" as well as Part 46.102 (f) "a living individual about whom an investigator (whether professional or student) conducting research obtains (1) data through intervention or interaction with the individual or (2) identifiable private information".

3900 Reservoir Road, N.W. Washington, DC 20057
202-687-6153 202-687-4847 fax/atl
Appendix H: Georgetown University Informed Consent Form

GEORGETOWN UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

PROJECT TITLE

“Factors Affecting English Speakers’ L2 Spanish Vowel Perception”

PROJECT DIRECTOR

Dr. Alfonso Morales-Front
Department of Spanish and Portuguese, Georgetown University

PRINCIPAL INVESTIGATOR        TELEPHONE

Leslie Gordon, MS      (404) 210-6815

The Georgetown University Institutional Review Board (IRB) has approved this research project. For information on your rights as a research subject, call the Institutional Review Board office at 202-687-1506.

INTRODUCTION

You are invited to consider participating in a research study to investigate second language (Spanish) vowel perception. This form will describe the purpose and nature of the research, its possible risks and benefits, other options available to you, and your rights as a participant in the study. Please take whatever time you need to discuss the study with your family and friends, or anyone else you wish to. The decision to participate, or not to participate, is yours. If you decide to participate, please be sure to sign and date the last page of this form.

WHY IS THIS RESEARCH STUDY BEING DONE?

In this research study, we are investigating English speakers’ perception of Spanish vowels.
For English speakers, the Spanish vowels are initially easy to learn because they are similar to some native English vowels. However, the Spanish vowels are acoustically unique and the purpose of this study is to evaluate the ability of native English speakers to hear and/or be trained to hear the distinct features of Spanish vowels.
HOW MANY PEOPLE WILL TAKE PART IN THE STUDY?

About 135 people will take part in the full study. Prior to the full study about 20 people will take part in a pilot of the experimental measures. Participants in the study are referred to as “subjects.” Subjects will be students enrolled in Spanish courses at the Georgia Institute of Technology and the investigational measures will be conducted at the Georgia Institute of Technology.

WHAT IS INVOLVED IN THE STUDY?

In this study you will complete simple listening experiments delivered by computer. You will report to a language laboratory over a series of 5 days. You can expect to spend about an hour each day. On the first day you will turn in a questionnaire that helps the researcher know the nature of your background in Spanish. You will also spend a short time practicing some practice exercises so that you will be familiar with the look of the exercises, the response keys, etc. Over the next two days you will be given tutorials that target specific features of the Spanish sound system. On those days you will also complete listening exercises which allow you to put into practice what you have been taught. In the last two sessions you will complete exercises which will measure what you have learned in the previous sessions. The table on the next page outlines the breakdown of the days you will spend in this project.

You will be assigned to one of 3 research groups (A, B, or C). A computer will determine your group through a process that is much like picking names out of a hat. This process is called randomization. Your chance of being in any group is 1 in 3.

<table>
<thead>
<tr>
<th>DAY</th>
<th>GROUP</th>
<th>TASK</th>
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<tr>
<td>1</td>
<td>A</td>
<td>Participant questionnaire</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Familiarization session</td>
</tr>
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<td></td>
<td>C</td>
<td>MCA Pre-test, Identification trials Pre-test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 day break</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>Tutorial: Vowel Duration</td>
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<tr>
<td></td>
<td></td>
<td>Discrimination task: Duration</td>
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<tr>
<td></td>
<td></td>
<td>Language Identification task</td>
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<tr>
<td></td>
<td>B</td>
<td>Tutorial: Aspirated /p,t,k/</td>
</tr>
<tr>
<td></td>
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<td>Discrimination task</td>
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</table>
**HOW LONG WILL I BE IN THE STUDY?**

We expect that you will be in the **full study** for five sessions, over a period of 3 weeks, for a total of 5-6 hours. If you are a participant in the **pilot study only**, you will participate in four sessions over a period of one week.

The investigators or sponsors may stop the study or take you out of the study at any time they judge it is in your best interest (e.g., if you experience an injury or if you do not comply with the study plan) or for a variety of other reasons. They can do this without your consent.

You can stop participating at any time. However, if you decide to stop participating in the study, we encourage you to talk to the researcher first. If you withdraw from the

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<td>B</td>
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<td>† 14 day break †</td>
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<td>B</td>
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<td>C</td>
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</tbody>
</table>
study you will not be eligible for the class assignment credit that has been offered to you.

WHAT ARE THE RISKS OF THE STUDY?

There are no known risks associated with participation in this study.

ARE THERE BENEFITS TO TAKING PART IN THE STUDY?

It is reasonable to expect the following benefits from this research: improved perceptual ability in Spanish. However, we cannot guarantee that you will personally experience benefits from participating in this study. If you do experience this benefit, we cannot guarantee that it will last beyond the experiment, although it is our hope that it will. Others may benefit in the future from the information we obtain in this study. Specifically, the information obtained in this study may be applied to methods used in Spanish classrooms.

This research study does not provide treatment for any disorder or condition. Should subjects request such treatment, they will be referred to treatment alternatives outside this study.

WHO CAN PARTICIPATE IN THE STUDY?

This study is designed for university students enrolled in Beginning, Intermediate and Advanced Spanish courses. Your suitability for this study will be determined by your class placement and the information you provide on the participant questionnaire.

WHAT ABOUT CONFIDENTIALITY?

Your name will not be used when data from this study are published.

Every effort will be made to keep your research records and other personal information confidential. All electronic data (score reports, statistical measures) will be stored in a secured file on the researcher’s personal computer. Any measures completed on paper (subject profiles, debriefing questionnaire) will be stored in a locked file cabinet. However, we cannot guarantee absolute confidentiality.

Individuals from the Georgetown University IRB, other Georgetown University offices, Federal regulatory agencies, and The Georgia Institute of Technology may look at records related to this study, both to assure quality control and to analyze data.
Your name and any material that could identify you will remain confidential except as may be required by law.

We will take the following steps to keep information about you confidential, and to protect it from unauthorized disclosure, tampering, or damage: You will be assigned an identification code so that your performance will be kept anonymous and confidential. Only the researcher will maintain the data that is collected, and no data will remain on lab computers after the completion of the experiment. The data you provide will have no negative impact on your class performance.

**WILL I BE PAID FOR PARTICIPATING?**

You will not be financially compensated for your participation in this study. However, if you complete the full study you will receive compensation for your participation in the form of assignment credits in your Spanish course. You may contact your Spanish professor for the details pertinent to your class.

**WHAT IF I GET INJURED DURING MY PARTICIPATION?**

Researchers will make every effort to prevent study-related injuries. If you are injured or become ill while you are in the study, you will receive emergency medical care. The costs of this care will be charged to you or to your health insurer. No funds have been made available by Georgetown University or its affiliates, the District of Columbia, or the Federal government to compensate you for a study-related injury or illness.

**WHAT ARE MY RIGHTS AS A RESEARCH PARTICIPANT?**

Participation in this study is entirely voluntary at all times. You have the right not to participate at all or to leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with Georgetown University or any of its employees.

If you decide to leave the study, the procedure is: Notify the researcher, Leslie Gordon, in person or by email at lg113@mail.gatech.edu. If you withdraw from the study you will not be eligible for the class assignment credits which you have been offered.

**WHOM DO I CONTACT IF I HAVE QUESTIONS OR PROBLEMS?**
Call Leslie Gordon at 404-210-6815 during regular business hours if you have questions about the study, any problems, unexpected physical or psychological discomforts, any injuries, or think that something unusual or unexpected is happening.

Call the Georgetown University IRB Office at 202-687-1506 during regular business hours if you have any questions about your rights as a research participant.

**Statement of Person Obtaining Informed Consent**

I have fully explained this study to the subject. I have discussed the study’s purpose, its procedures, its possible risks and benefits, and the voluntary nature of participation. I have invited the subject to ask questions and have answered any questions that the subject has asked.

________________________________________ __________________________
Signature of Person Obtaining Informed Consent  Date

**Consent of Subject (or Legally Authorized Representative)**

I have read the information provided in this Informed Consent Document (or it was read to me by ________________________________).

My questions were answered to my satisfaction.

I voluntarily agree to participate in this study.

________________________________________ __________________________
Signature of Subject  Date

________________________________________ __________________________
Signature of Legally Authorized Representative  Date
Upon signing, the subject or the legally authorized representative will receive a copy of this form, and the original will become part of the subject’s research record.
Appendix I: Georgia Institute of Technology IRB Approval

Office of Research Compliance
Atlanta, Georgia 30332-0420 U.S.A.
Phone 404.894.6944
Fax 404.385.2081
irb@gatech.edu
iacuc@gatech.edu
biosafety@gatech.edu
exportcontrol@gatech.edu

Protocol: H07182
Funding Agency: N/A
Review Type: Exempt
Title: Factors Affecting English Speakers' Perception of L2 Spanish Vowels
Number of Subjects: 135
Number Enrolled: N/A

July 27, 2007

Dr. Leslie S. Gordon
Modern Languages
Mail Code 0375

Dear Dr. Gordon:

The Institutional Review Board (IRB) has carefully considered the referenced protocol. Your approval is effective as of July 26, 2007. The proposed procedures are exempt from further review by the Georgia Tech Institutional Review Board.

Project qualified for exemption status under 45 CFR 46.101b.1.

Inclusion of minors in this study is acceptable in accordance with 45 CFR 46.404.

Per 45 CFR 46.116 (d) this study qualifies for a waiver of parental permission.

Thank you for allowing us the opportunity to review your plans. If any complaints or other evidence of risk should occur, or if there is a significant change in the plans, the IRB must be notified.

If you have any questions concerning this approval or regulations governing human subject activities, please feel free to contact Dr. Phillip Sparling, IRB Chair, at 404/894-3402, or me at 404 / 894-6942.

Sincerely,

Melanie Clark, CIP
IRB Administrator

Enclosure
cc: (without enclosure)
Dr. Phillip Sparling, IRB Chair
Appendix J: Georgia Institute of Technology Informed Consent Form

Georgia Institute of Technology
Project Title: “Factors Influencing Native English Speakers’ Perception of L2 Spanish Vowels”
Investigators: Leslie Gordon
Consent title: 05/03/07v1
Research Consent Form

You are being asked to be a volunteer in a research study. You are encouraged to take your time in making your decision. If you have questions you may address them to the researcher, Leslie Gordon, at lg113@mail.gatech.edu.

Purpose:
The purpose of this study is to explore the factors which influence native English speakers’ perception of sounds acquired in a second language (Spanish). Approximately 120 students are expected to participate in this study. Georgia Tech students in Beginning, Intermediate and Advanced Spanish courses are eligible for participation in this study.

Procedures:
If you decide to be in this study, your part will involve:

In this study you will complete simple listening experiments delivered by computer. You will report to a language laboratory over a series of 5 days. You can expect to spend about an hour each day. On the first day you will turn in a questionnaire that helps the researcher know the nature of your background in Spanish. You will also spend a short time practicing some practice exercises so that you will be familiar with the look of the exercises, the response keys, etc. Over the next two days you will be given tutorials that target specific features of the Spanish sound system. On those days you will also complete listening exercises which allow you to put into practice what you have been taught. In the last two sessions you will complete exercises which will measure what you have learned in the previous sessions. The table on the next page outlines the breakdown of the days you will spend in this project.

You will be assigned to one of 3 research groups (A, B, or C). A computer will determine your group through a process that is much like picking names out of a hat. This process is called randomization. Your chance of being in any group is one in 3.
<table>
<thead>
<tr>
<th>DAY</th>
<th>GROUP</th>
<th>TASK</th>
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<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>Participant questionnaire</td>
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<tr>
<td></td>
<td>B</td>
<td>Familiarization session</td>
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<td></td>
<td>C</td>
<td>MCA Pre-test. Identification trials Pre-test</td>
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<td>2 day break</td>
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<td>2</td>
<td>A</td>
<td>Tutorial: Vowel Duration</td>
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<td>Discrimination task: Duration</td>
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<td></td>
<td>Language Identification task</td>
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<td>B</td>
<td>Tutorial: Aspirated p,t,k/</td>
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<td>Discrimination task</td>
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<td>Language Identification Task</td>
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<td>1 day break</td>
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<tr>
<td>3</td>
<td>A</td>
<td>Tutorial: Vowel Diphthongization</td>
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<td></td>
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<td>Discrimination task: Diphthongized vowels</td>
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<td>Language Identification Task</td>
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<td>B</td>
<td>Tutorial: Spirantized B, A, /</td>
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<td>4</td>
<td>A</td>
<td>MCA Posttest. Identification trials Posttest</td>
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<td></td>
<td>B</td>
<td>Follow-up Questionnaire</td>
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<td>14 day break</td>
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<td>5</td>
<td>A</td>
<td>Delayed MCA Posttest. Identification trials Posttest</td>
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**Risks/Discomforts (Mandatory Section)**

The following risks/discomforts may occur as a result of your participation in this study:
The risks involved are no greater than those involved in daily activities such as attending class. The activities in this study will be administered via computer and through headphones, and the risk therein is no greater than those involved in any daily use of a computer monitor or headphones.

**Benefits (Mandatory Section)**
The following benefits to you are possible as a result of being in this study:
You may benefit from being in this study by learning important characteristics about the second language (Spanish) which you are currently studying. It is the hope of this researcher that you will
learn from the tasks you complete as part of this research and will apply your learning to your future use of Spanish.

Compensation to You
Participants in this study will receive extra credit in their Spanish course. Extra credit will take the form of bonus points on homework or quiz grades, as decided by instructors at each level. Extra credit will be prorated for subjects who do not complete the study. You may contact your Spanish professor for the details pertinent to your class.

For students not wishing to participate in the study, alternative assignments will be available. The type of assignment will naturally vary by course level and will be approved by all participating instructors. Alternatives may include a reading or writing assignment or oral presentation for more advanced classes. Alternative extra credit activities will require the same amount of time (6-8hours) that research participants will spend in the study.

Confidentiality
The following procedures will be followed to keep your personal information confidential in this study: The data that is collected about you will be kept private to the extent allowed by law. To protect your privacy, your records will be kept under a code number rather than by name. Your records will be kept in locked files and only study staff will be allowed to look at them. Your name and any other fact that might point to you will not appear when results of this study are presented or published.

To make sure that this research is being carried out in the proper way, the Georgia Institute of Technology IRB may review study records. The Office of Human Research Protections may also look at study records.

Costs to You
There are no costs to you as a participant in this study.

In Case of Injury/Harm
If you are injured as a result of being in this study, please contact Leslie Gordon at telephone (404) 888-9842. Neither the Principal Investigator nor Georgia Institute of Technology have made provision for payment of costs associated with any injury resulting from participation in this study.

Subject Rights

Consent Form Approved by Georgia Tech IRB: July 26, 2007 - Indefinite
- Your participation in this study is voluntary. You do not have to be in this study if you don't want to be.
- You have the right to change your mind and leave the study at any time without giving any reason, and without penalty.
- Any new information that may make you change your mind about being in this study will be given to you.
- You will be given a copy of this consent form to keep.
- You do not waive any of your legal rights by signing this consent form.

Questions about the Study or Your Rights as a Research Subject

- If you have any questions about the study, you may contact Leslie Gordon at telephone (404) 869-9842.
- If you have any questions about your rights as a research subject, you may contact Ms. Melanie Clark, Georgia Institute of Technology at (404) 894-6942.

If you sign below, it means that you have read (or have had read to you) the information given in this consent form, and you would like to be a volunteer in this study.

__________________________

Subject Name

Subject Signature  Date

Signature of Person Obtaining Consent  Date

Consent Form Approved by Georgia Tech IRB: July 26, 2007 - Indefinite

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