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The Effects of Language Dominance in the Perception and Production of the Galician Mid Vowel Contrasts

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Abstract

Aims: This study investigates the perception and production of the Galician mid vowel contrasts by 54 early Spanish-Galician bilinguals in the cities of Vigo and Santiago (Galicia, Spain). Empirical data is provided to examine the role of language dominance in the perception and production of Galician mid vowel contrasts in order to determine whether the Galician vowel system is becoming more Spanish-like as a result of extensive contact with Spanish in urban areas. ***Methods:*** Perception and production data for each mid vowel contrast were collected in (1) binary forced-choice identification tasks, (2) AX discrimination tasks and (3) a reading-aloud task. ***Results:*** Results from binary forced-choice identification and AX discrimination tasks indicate that Spanish-dominant bilinguals have great difficulty in discriminating between these mid vowels while Galician-dominant subjects display a robust categorical identification of the two mid vowel categories. Acoustic analyses of their productions show that Galician-dominant bilinguals implement a Galician-specific /e/-/ɛ/ contrast but Spanish-dominant ones produce a single, merged Spanish-like front mid vowel. However, both language dominance groups seem to maintain a more robust /o/-/ɔ/ contrast. This asymmetry between front and back mid vowels is found in the productions of both language dominance groups. ***Conclusion:*** These results show that language dominance is a strong predictor of the production and perception abilities of Spanish-Galician bilinguals, and that only Galician-dominant subjects in these urban areas possess two independent phonetic categories in the front and back mid vowel space.

1 Introduction

A bilingual individual will use one language or another depending on factors such as the linguistic environment, the communicative purpose, language preference and language dominance. In order to sound native-like in both languages, bilinguals must develop two phonological systems and have the ability to produce and perceive acoustic

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targets that may be unique to each of their languages. One of the central questions of bilingual research has been to determine to what extent the bilingual's two phonological inventories influence each other and are interconnected and in what ways they remain independent, especially in comparison with the single system of monolinguals.

Research has shown that early bilinguals, who have either learned both languages from birth or during early childhood, are less likely to have a 'foreign' or L1-influenced accent than late bilinguals (DeKeyser, 2000; Flege et al., 1999b), that they produce and perceive L2 sounds more accurately (Baker and Trofimovich, 2005) and that they recognize more words in noise (Mayo et al., 1997; Meador et al., 2000). While most studies agree that early learners outperform late learners in various production and perception tasks, the source of age effects is still controversial (Flege and MacKay, 2004). The question that arises is whether early bilinguals maintain separate and independent phonetic systems due to early exposure and extensive experience with both languages, or their L1 and L2 sounds are interrelated and coexist in a common phonetic space, with the bilingual sound system being a combination of the two languages' segmental inventories (Flege 1987, 1995). In the second case, the bilingual sound system will, by consequence, be prone to cross-linguistic phonological transfer.

The present study investigates the phonological influence of Spanish on the acquisition of language-specific phonological categories in Galician, a Romance language spoken in northwestern Spain. It focuses on a group of early-onset, highly proficient Spanish-Galician bilinguals from the cities of Santiago and Vigo in Galicia, Spain. The main aim of this study is to examine whether L1 phonemic categories interact with the acquisition of L2-specific categories when L2 acquisition occurs at an early age. Specifically, this study examines the production and perception of language-specific phonemic categories by early bilingual individuals along a continuum of language dominance providing the opportunity to understand how bilinguals categorize and produce L1 and L2 sounds in a native-like manner, and to what degree we find an influence of the L1 on the acquisition of the L2. In other words, how susceptible are these bilinguals to phonological transfer, and how is this cross-linguistic influence modulated by language dominance?

1.1 Cross-Linguistic Phonological Influence

Jarvis and Pavlenko (2008) define cross-linguistic phonological influence as 'the ways in which a person's knowledge of the sound system of one language can affect that person's perception and production of speech sounds in another language' (p. 62). Phonological transfer at the segmental and suprasegmental levels has been reported in both production and perception from the L1 to the L2 (i.e. forward transfer), from the L2 to the L1 (i.e. reverse transfer) and from an L2 to an L3 (i.e. lateral transfer). This cross-linguistic influence plays an important role in provoking the percept of a discernable 'foreign accent' (Broselow, 1987; Cebrián, 2000; Cutler, 2002; Flege, 1987, 1991, 1992, 1993, 1995, 1997a, b; Flege et al., 1999a; Zampini, 1994).

The interaction between both languages of an early bilingual and the effects on bilingual production and perception are still under debate. Some studies on bilingual speech production have observed that early bilinguals produce and perceive L1 and L2 sounds free of interference (Flege et al., 1999a; Guion et al., 2004; Mack, 1989; Piske

et al., 2002), suggesting that early exposure helps to develop and maintain independent or separate phonetic systems. However, a number of studies suggest that these bilinguals do not necessarily produce native-like targets (e.g. language-specific contrasts) in the L2; rather, the bilinguals' combined or interrelated systems influence each other at a fine-grained acoustic level in speech production (Amengual, 2012; Flege et al., 1999a; Lleó et al., 2008; Mora and Nadeu, 2012; Simonet, 2014), and early and extensive exposure to a second language may not be sufficient to attain native-like phonetic abilities in the language (Bosch et al., 2000; Mora et al., 2011; Pallier et al., 1997; Sebastián-Gallés and Bosch, 2005; Sebastián-Gallés and Soto-Faraco, 1999; Sebastián-Gallés et al., 2005).

The most influential models in the area of L2 phonetic acquisition in recent decades are the Speech Learning Model (SLM; Flege, 1995) and the Perceptual Assimilation Model (PAM; Best, 1995). Both of these models hypothesize that the success in the acquisition of nonnative speech sounds can be predicted from the similarities between the native and nonnative target sounds. The SLM postulates that phonetic categories of the L1 and L2 coexist in a shared acoustic-phonetic space, and that early learners, as opposed to adult L2 learners, are capable of establishing additional phonetic categories for similar L2 sounds, as early learners' L1 phonetic categories are malleable while late learners' L1 categories are already fully developed. Thus, the SLM's interaction hypothesis predicts that the sounds of the L1 and L2 are less likely to interact in early bilinguals than in late bilinguals (Flege, 1992). Similarly, the PAM predicts that a nonnative phone may be perceptually assimilated to the native system, and crucially, the assimilation patterns displayed by the listeners will depend on the degree of similarity and discrepancy perceived between the native and nonnative sounds. However, it is still unclear if and how language dominance will impact the acquisition of language-specific sounds in the speech of bilinguals who have been exposed to the language at an early age.

1.2 Language Dominance

The usage patterns of a bilingual individual are likely to be associated with greater fluency, proficiency and dominance. Even though bilinguals may have a high level of proficiency in both languages, the perfectly balanced bilingual probably does not exist: bilinguals have a dominant or stronger language (Cutler et al., 1989; Flege et al., 2002). It is important to consider that language dominance and language proficiency, though conceptually overlapping in some respects, and easily conflated and often correlated, are different concepts (Birdsong, 2006). In the context of bilingualism, dominance 'refers to observed asymmetries of skill in, or use of, one language over the other' (Birdsong, 2014, p. 374). Language dominance covers many dimensions of language use and experience, such as proficiency, fluency, ease of processing, frequency of use or cultural identification.

Of special interest to this study, language dominance has been shown to be an important predictor of the L1-L2 interaction patterns in the speech production and perception of bilingual individuals. For instance, previous studies have shown that language dominance accounts for phonological transfer in production (Amengual, 2011, 2013, 2014, 2015; Bullock et al., 2006; Simonet, 2011, 2014), perception (Antoniou et al., 2012; Bosch et al., 2000; Pallier et al., 1997; Sebastián-Gallés and Soto-Faraco,

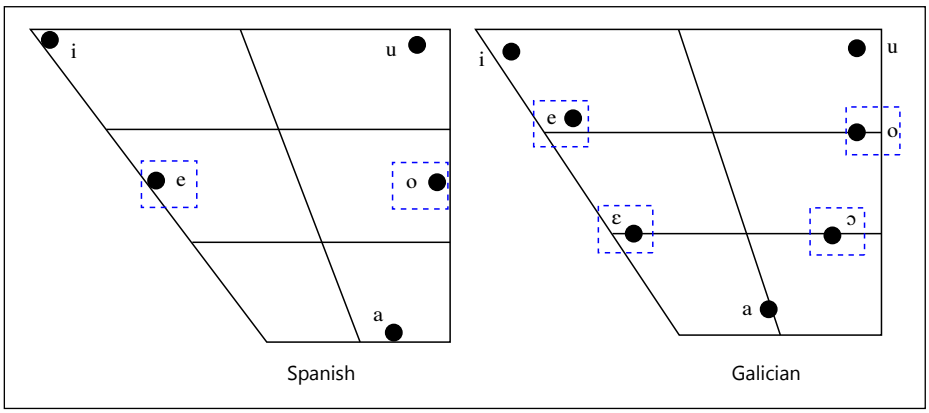

Fig. 1. Spanish and Galician vowel systems.

1999) and lexical storage (Amengual, in press; Pallier et al., 2001). Additionally, it has been found to influence code-switching patterns (Basnight-Brown and Altarriba, 2007), govern bilingual lexical memory representation (Heredia, 1997), affect language choice for self-directed and silent speech (Dewaele, 2004) and determine the language of mental calculations (Tamamaki, 1993).

A number of selection criteria have been used to classify bilingual individuals according to their language dominance, such as identification with speakers of a language and daily use of each language (Grosjean and Miller, 1994), scores on language assessment tests (Náñez and Padilla, 1995) and naming tests (Moreno and Kutas, 2005). This illustrates the divergent approaches that researchers have adopted when quantifying language dominance. In this study, we operationalize language dominance as a multifaceted, gradient and dynamic construct, and we employ the Bilingual Language Profile (BLP; Birdsong et al., 2012) by taking into account a variety of language-related variables (see section 2.1 for more details). The BLP has been used in recent studies to investigate language dominance effects on the production and perception abilities of speakers of several language pairs (Amengual, 2013, 2014, 2015, in press; Baird, 2014; Casillas, 2012; Simonet, 2014).

1.3 The Phonetic Variable: The Galician Mid Vowel Contrasts

The language-specific categories examined in this study are the Galician mid vowels. Spanish has a simple 5-vowel system, which is the most common number of vowel phonemes cross-linguistically (Hualde, 2005). As shown in figure 1, Spanish vowels contrast along two dimensions: along the height dimension, there are 2 high vowels (/i/ and /u/), 2 mid vowels (/e/ and /o/) and 1 low vowel (/a/), and along the frontedness/backness dimension, there are 2 front vowels (/i/ and /e/), 1 low back vowel (/a/) and 2 back rounded vowels (/u/ and /o/). In contrast, Galician has a 7-vowel system, with an additional contrast in height, distinguishing higher-mid vowels /e/ and /o/ from lower-mid vowels /ɛ/ and /ɔ/ in stressed syllables (Álvarez and Xove, 2002). Extant studies have shown that Galician exhibits 7 vowels in stressed and pretonic syllables, while in

nonfinal posttonic syllables, it exhibits only 5 vowels, lacking any occurrences of /ɛ/ and /ɔ/. In word-final syllables, the vowels are reduced to 3, which generally tend to be produced as higher and centralized, [ɪ], [ʊ] and [ɐ] (Molinos Castro, 2002; Regueira, 2007; Vidal Figueroa, 1997). It is worth noting that the acoustic spaces for the individual vowels of the Galician pairs /e/-/ɛ/ and /o/-/ɔ/ are different from the Spanish mid vowels /e/ and /o/ in the sense that the Spanish mid vowels /e/ and /o/ are acoustically between the Galician mid-high and mid-low categories. In other words, the phonological symbols /e/ and /o/ do not have the same phonetic content in Galician and Spanish: Spanish /e/ and /o/ have a higher F_1 than Galician /e/ and /o/ by virtue of being placed between the Galician mid-high and mid-low vowels in the vowel triangle (Álvarez and Xove, 2002; Vidal Figueroa, 1997).

The Galician vowel system provides the opportunity to test sounds that are susceptible to contact-induced change. There is a wealth of studies that have investigated the acquisition of language-specific mid vowel contrasts of other languages with extensive contact with Spanish, such as Catalan. Previous research in Barcelona suggests that early Spanish-Catalan bilinguals have difficulty distinguishing the Catalan mid vowel contrasts, and Spanish-dominant ones in particular are significantly less accurate than Catalan-dominant bilinguals in discriminating between the mid vowel contrasts (Bosch et al., 2000; Pallier et al., 1997; Sebastián-Gallés and Soto-Faraco, 1999). Furthermore, these Spanish-dominant bilinguals are neutralizing the Catalan mid vowels in their productions: the 4 Catalan mid vowels (/e/, /ɛ/, /o/ and /ɔ/) are merged into 2 Spanish-like mid vowel categories (/e/ and /o/). Importantly, these bilinguals have acquired both of their languages in early childhood, have many years of L2 experience and have attained a high proficiency in their L2.

The loss of the mid vowel contrasts in Catalan has been widely attributed to the influence of Spanish (Sebastián-Gallés and Soto-Faraco, 1999; Pallier et al., 2001). The sociolinguistic context of Galicia, with a historically strong presence of Spanish in the region, also favors the possibility of a simplification of the Galician vowel system. Previous impressionistic studies have described variation in the production of the Galician-specific mid vowel categories with an increasing shift towards the loss of the Galician mid vowel contrasts (Costas González, 1988; Regueira, 2008; Vidal Figueroa, 1997). The present study contributes to this line of research by experimentally testing the production and perception abilities of a relatively large number of early Spanish-Galician bilinguals residing in urban areas of Galicia. Additionally, this study investigates the effects of language dominance in the production and perception of these early bilinguals. Before we turn to our study and the analysis of the data, a note is in order regarding the sociohistorical background, which will help contextualize the current status of Galician.

1.4 Sociohistorical Background

Galego-Portugués was the language spoken in the region of Galicia when it became part of the Crown of Castile in the 12th century. At this point Galician started to differentiate itself from Portuguese but it also began to lose prestige and speakers as a consequence of the introduction of Spanish by the Castilian nobility, their servants, the clergy, civil and military administrators. Spanish became the language of prestige once members of the Spanish Crown moved to the region. The disdain of

Galician varieties in the following centuries grew and was soon associated with uneducated rural speakers (Freixeiro Mato, 1997; Lorenzo Suárez, 2009; Mariño Paz, 1998; Monteagudo, 1999; Ramallo, 2007).

When Spanish nationalist dictator Franco died in 1975, a period of transition from the dictatorship to a democratic constitutional monarchy led to the decentralization of power. This decentralization culminated with the 1978 Spanish Constitution, which recognized Galician, Catalan and Basque as co-official languages with Spanish in their respective regions. There has been a process of standardization of Galician after the *Lei de Normalización Lingüística* ('Law of Linguistic Normalization', Ley 3/1983). This has resulted in a widespread presence of both languages, with Galician making notable gains in the last 30 years. However, as a result of a long process of language shift (especially since the 16th century, when Spanish became the only official language of the kingdom), the most common language for everyday use in the largest cities of Galicia is still Spanish rather than Galician (Monteagudo and Santamarina, 1993), and the number of Galician speakers among the youth continues to decline even though they strongly support the maintenance and transmission of Galician (González González et al., 2007; Loureiro-Rodríguez et al., 2012; O'Rourke, 2011).

2 The Present Study

The present study investigates the perception and production of the Galician mid vowel contrasts (/ɛ/-/e/ and /ɔ/-/o/) by 54 early and highly proficient Spanish-Galician bilinguals from the cities of Vigo and Santiago in Galicia. The main goal is to examine the role of language dominance, which encompasses variables such as language use, language history, language proficiency and language attitudes in the perception and production of both Galician mid vowel contrasts. Therefore, this study aims to address the following questions: (1) Do bilinguals in Vigo and Santiago maintain the Galician mid vowel contrasts in their Galician productions? (2) Do Spanish-Galician bilinguals perceive the Galician mid vowel contrasts? And (3) are there differences in the production and perception patterns of these bilinguals based on language dominance?

2.1 Participants

A total of 54 Spanish-Galician bilinguals (26 females and 28 males) participated in the identification, AX discrimination and reading-aloud tasks. Participants were residents in the towns of Vigo (n = 29) and Santiago (n = 25). Each participant completed the BLP questionnaire (Birdsong et al., 2012). The BLP is an instrument for assessing language dominance through self-reports, and it produces a continuous dominance score and a general bilingual profile taking into account multiple dimensions: age of acquisition of the L1 and L2, frequency and contexts of use, competence in different skills and attitudes towards each language (Gertken et al., 2014). All of these factors are organized in 4 modules, which receive equal weighting (language history, language use, language proficiency and language attitudes).

The classification of participants as Spanish-dominant or Galician-dominant was determined by their responses to the questionnaire, which generated a language-specific

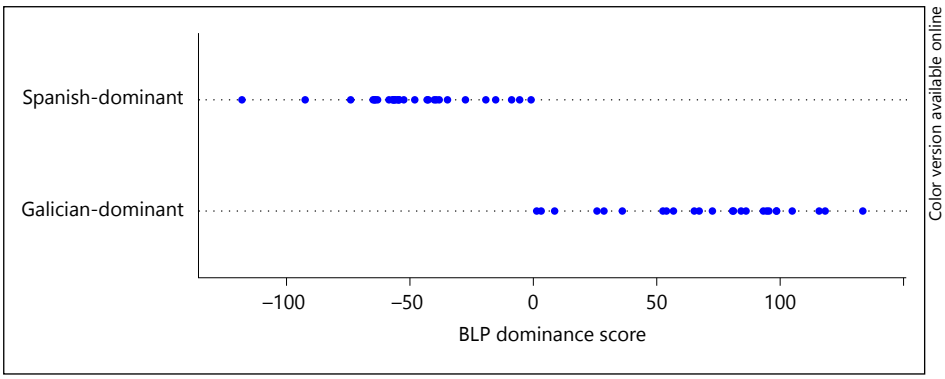

Fig. 2. Language dominance scores as a function of group according to the BLP.

Table 1. Age, age of exposure, accent self-ratings and typical daily use of both languages (means ± SD) for each language dominance group

	Galician-dominant	Spanish-dominant
Age, years	36.9±12.5	32.9±12
Age of exposure, years	GAL = 0.5±1.6 SPN = 1.6±2.7	GAL = 1.5±2.8 SPN = 0±0
Self-reported accent (1 = strongly accented; 9 = native-like)	GAL = 7.4±2.1 SPN = 3.8± 1.9	GAL = 5.1±1.7 SPN = 5.5±1.8
Typical daily use (1 = only Spanish; 9 = only Galician)	7.6±1.8	3.3±1.5

GAL = Galician; SPN = Spanish.

score for each module, a global score for each language and a global score of dominance. The point system was converted to a scale score with the Galician score subtracted from the Spanish score. Participants with negative points were classified as Spanish-dominant (n = 29), while participants with positive points were classified as Galician-dominant (n = 25). Dominance scores ranged from –118 (strongly Spanish-dominant) to 133 (strongly Galician-dominant). Figure 2 provides the distribution of the Spanish-dominant and Galician-dominant groups.

All participants were born, raised and educated in Vigo and Santiago, and they reported having extensive exposure to both languages on a daily basis. In addition, they used only Galician and/or Spanish in the household and were not native in any other language. The main differences between the Galician-dominant and Spanish-dominant groups were that the Spanish-dominant group was exposed earlier to Spanish and later to Galician than the Galician-dominant group, and also the Galician-dominant group reported a higher daily use of Galician than Spanish, and a more native-like accent in Galician in comparison to the Spanish-dominant group. Table 1 provides the language background for each language dominance group.

2.2 Experiment 1: Perception (Identification Tasks)

All participants completed a binary forced-choice identification task for each Galician mid vowel contrast (/e/-/ɛ/ and /o/-/ɔ/). A variety of perception tasks has been used in the literature to test the categorical perception of different groups of listeners, where a change in some variable along a continuum is perceived not as gradual but as instances of discrete categories (Eimas, 1963; Liberman et al., 1957; Macmillan, 1987; Repp, 1984, Van Hessen and Schouten, 1999). This experimental design typically entails the presentation of synthesized vowel stimuli along a continuum, ranging between two phonemic categories in equidistant increments from one stimulus to another. The main goal of the perception tasks in this study is to investigate if Spanish-Galician bilinguals in Vigo and Santiago are able to perceive an acoustic difference between the Galician mid vowel phonemic categories, and if there are differences in their perceptual abilities based on their language dominance.

2.2.1 Materials

The perception of the Galician mid vowel phonemes was investigated with the selection of two minimal pairs, one for each mid vowel contrast: /pe/ 'letter P' versus /pɛ/ 'foot', and /oso/ 'bear' versus /ɔso/ 'bone'. The experimental stimuli were obtained from the productions of a female native Galician speaker. The sound files were recorded in a sound-attenuated booth using a Shure SM10A dynamic head-mounted microphone and a solid-state digital recorder (Marantz PMD660), and digitized at 44 kHz and 16 bits. The formant frequency values (F_1, F_2, F_3) of the original recordings were synthesized into 2 series of 7 vowel stimuli along a continuum from /e/ to /ɛ/ and /o/ to /ɔ/ using Akustyk 1.9.2 (Plichta, 2012). The method to create the 7-step speech continua was based on PSOLA and LPC analysis/resynthesis methods. The formant trajectories between each minimal pair were automatically estimated and synthesized in 7 steps with an analysis window of 0.05 ms applied to a time step of 0.01 ms, as implemented in the speech continuum script included in the Akustyk plug-in for Praat (Plichta, 2012). The vowel tokens were manipulated so that all tokens had exactly the same vowel duration, and they were also normalized for peak intensity. If there was a DC offset, it was removed and the maximum amplitude was normalized to –0.5 dB at a project rate of 44 kHz. Figure 3 presents the formant values of the synthesized stimuli for each 7-step vowel continuum.

2.2.2 Procedure

Participants completed the forced-choice minimal-pair identification task for each mid vowel contrast using the stimulus presentation software SuperLab Pro 4.5 (Cedrus Corporation, 2012) on a Mac computer. Participants listened to the stimuli on a set of headphones at a self-adjusted volume in front of a computer display in a quiet room. Both verbal and written instructions throughout the experiments were provided in Galician to control for language mode and to minimize any cross-language activation (Antoniou et al., 2010, 2011, 2012, 2013; Ehrensberger-Dow and Jekat, 2005; Sunderman and Kroll, 2006). All participants were informed that they would listen to a set of words that matched one of two pictures that appeared on the screen (fig. 4) and that the task consisted of selecting which word they had just heard. After the researcher had given the instructions, the participants were asked to press the button box on a USB Response Pad (RB-730), which represented each member of the minimal pair, as

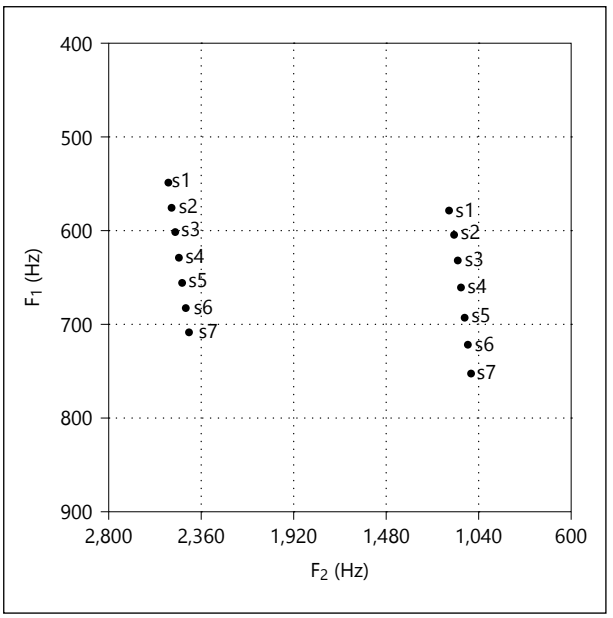

Fig. 3. Formant values (Hz) of the synthesized stimuli (s1–s7) along the /e/-/ɛ/ and /o/-/ɔ/ continuum.

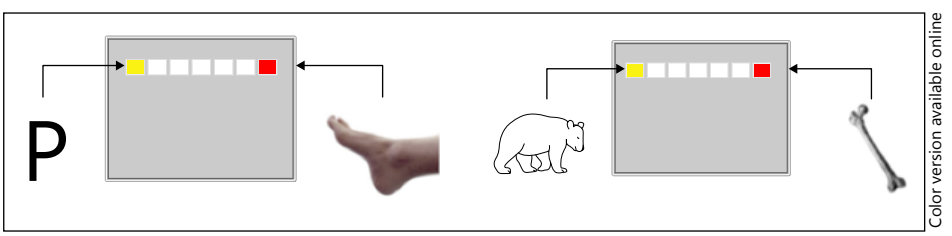

Fig. 4. Visual stimuli in the identification tasks.

fast and as accurately as possible after listening to each stimulus. Pictures were used rather than written words in order to avoid orthographic effects.

Each identification task (/e/-/ɛ/ and /o/-/ɔ/ contrast) was completed separately. For each mid vowel contrast, participants responded to 77 stimuli: 7 practice stimuli (1 full block of stimuli) + 70 randomized test stimuli (7 stimuli × 10 repetitions). After 5 blocks, the participants were invited to take a short break. In total there were 7 stimuli × 10 repetitions × 54 participants for each identification task, which resulted in 3,780 possible responses for each identification task. A nonresponse was recorded if the participant did not press a key in the 2-second interval allowed. There were a total of 24 nonresponses for the /e/-/ɛ/ identification task and 22 nonresponses for the /o/-/ɔ/ identification task.

The statistical analyses for the identification tasks consisted of a mixed design ANOVA for each mid vowel contrast, with language dominance (Spanish-dominant, Galician-dominant) and location (Vigo, Santiago) as between-subjects factors, stimulus

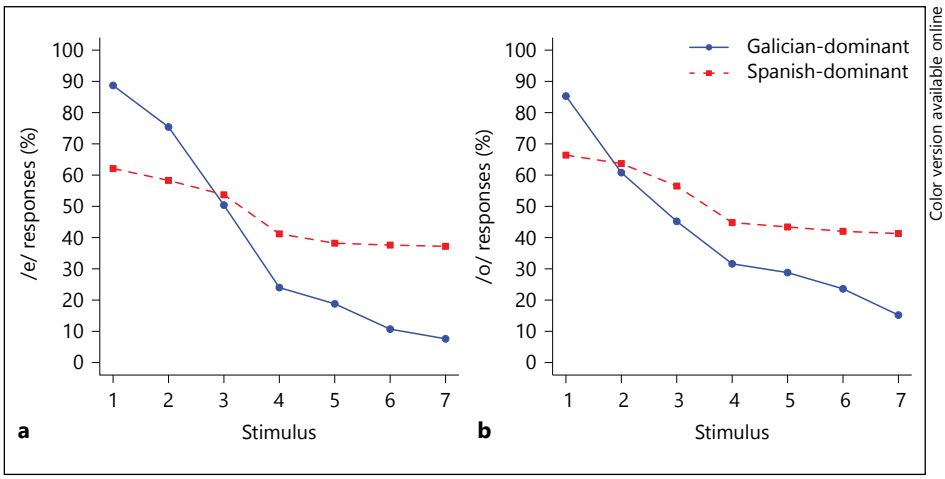

Fig. 5. Identification of stimuli along the /e/-/ɛ/ (**a**) and /o/-/ɔ/ (**b**) continuum.

(s1–s7) as within-subject factor and subject as the random term. In the analysis of the /e/-/ɛ/ data, the dependent variable was the proportion of /e/ responses (i.e. selection of the word *pe*, 'letter P'). The analysis of the /o/-/ɔ/ mid vowel contrast consisted of a mixed-model design with the same factors as in the /e/-/ɛ/ data. In this case, the dependent variable was the proportion of /o/ responses by selecting the word *oso* 'bear'. The interactions in each model were examined by means of Bonferroni-corrected, paired t tests, and the α-level was adjusted accordingly.

2.2.3 Results

Figure 5 shows the proportion of /e/ and /o/ responses as a function of language dominance, where the curves for Galician-dominant and Spanish-dominant bilinguals follow a different trajectory from s1 to s7. Specifically, the trajectory of the Galician-dominant group shows a clear categorization of 2 separate mid vowel categories demonstrating that these bilinguals perceive 2 distinct phonemes, whereas the trajectory of the Spanish-dominant group indicates that these bilinguals did not accurately identify the stimuli along the /e/-/ɛ/ and /o/-/ɔ/ continuum.

The repeated-measures ANOVA on the front mid vowel data yielded a main effect of stimulus [$F(6, 300) = 54.46$, $p < 0.001$] and language dominance [$F(1, 50) = 4.62$, $p < 0.05$], and an interaction between stimulus and language dominance [$F(6, 300) = 15.05$, $p < 0.001$], but there was not a significant effect of location [$F(1, 50) = 3.05$, n.s.]. In order to explore the interaction between stimulus and language dominance, a series of 7 two-sample, Bonferroni-corrected, paired t tests compared the responses of Spanish-dominant and Galician-dominant participants for each stimulus. The α-level was adjusted accordingly ($0.05/7 = 0.007$). These comparisons yielded significant differences in the responses between Spanish-dominant and Galician-dominant subjects for step 1 [26.66, $t(50) = 5.01$, $p < 0.001$], step 2 [17.09, $t(50) = 2.96$, $p < 0.001$], step 5 [–19.4, $t(50) = –3.16$, $p < 0.001$], step 6 [–26.9, $t(50) = –4.89$, $p < 0.001$] and step 7 [–29.64, $t(50) = –5.03$, $p < 0.001$]. These results show that there are differences in the way that each group identified the stimuli along the /e/-/ɛ/ continuum, with

Galician-dominant participants showing a categorical identification of two separate mid vowel categories while Spanish-dominant subjects had difficulties in categorizing the stimuli. Additionally, there were no differences between the groups that resided in Santiago and Vigo.

The back mid vowel data were also submitted to a repeated-measures ANOVA. The analysis yielded a main effect of language dominance [$F(1, 50) = 4.87$, $p < 0.05$] and stimulus [$F(6, 300) = 40.64$, $p < 0.001$] but not a main effect of location [$F(1, 50) = 0.70$, n.s.]. There was also a significant interaction between stimulus and language dominance [$F(6, 311) = 7.18$, $p < 0.001$]. Bonferroni-corrected pairwise comparisons examined the responses by each group for each step. The α-level was also adjusted to 0.007. These comparisons yielded significant differences in the responses between both groups for step 1 [–18.96, $t(50) = 2.96$, $p < 0.001$], step 6 [–18.46, $t(50) = –2.83$, $p < 0.001$] and step 7 [–26.17, $t(50) = –4.41$, $p < 0.001$]. These results also indicate that only the Galician-dominant bilinguals identified the stimuli along the continuum from /o/ to /ɔ/. This suggests that the perception of the back mid vowel contrast is robust for the Galician-dominant but not for Spanish-dominant subjects. Similarly to the front mid vowel data, there were no significant differences in the responses of speakers from Santiago and Vigo.

2.3 Experiment 2: Perception (AX Discrimination Tasks)

In order to further test the perception of these mid vowel contrasts and, specifically, to explore if there is a boundary where Galician-dominant and Spanish-dominant bilinguals separate both Galician-specific mid vowel categories, the same group of Spanish-Galician bilinguals completed AX discrimination tasks for each mid vowel contrast.

2.3.1 Materials

In this experiment, each participant is introduced to two stimuli and has to decide whether the two stimuli in a pair are acoustically the same or different (fig. 6). The stimuli were drawn from the same 7-step continua used in the previous identification tasks. For each of the 7 steps, a ‘same’ pair was created in which both sounds are acoustically identical (s1-s1, s2-s2, etc.) for a total of 7 ‘same’ pairs. Additionally, 5 ‘different’ pairs, which consisted of a combination of 2 different sounds in 2-step increments (s1-s3, s2-s4, etc.), were also created. The interstimulus interval was 1,000 ms, and the intertrial interval was 1,500 ms.

2.3.2 Procedure

Using the same equipment and experimental setting as in the identification tasks, participants listened to the ‘same’ and ‘different’ pairs, and were instructed to press either of the two buttons depending on whether they considered that they heard two acoustically identical sounds, or the sounds in the pair sounded different to them.

The ‘same’ and ‘different’ trials appeared in randomized order. For each condition (front and back mid vowels), participants responded to 108 trials: 12 practice trials (1 full block of ‘same’ and ‘different’ stimuli) + 96 randomized test trials (12 stimuli × 8 repetitions). Therefore, the experimental data consisted of 8 blocks of 12 randomized trials (7 ‘same’ and 5 ‘different’). After 4 blocks, the participants were invited to take

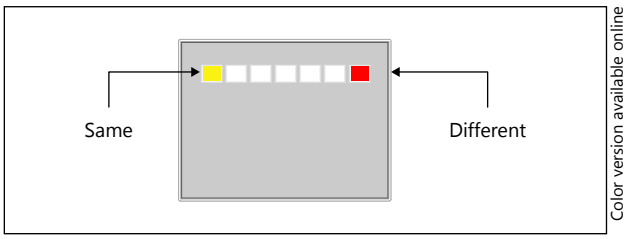

Fig. 6. Visual stimuli in the AX discrimination tasks.

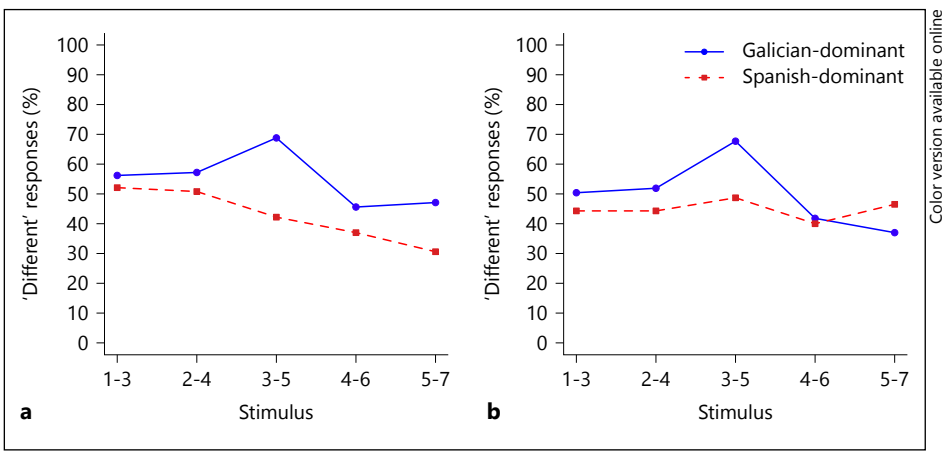

Fig. 7. Discrimination of the /e/-/ɛ/ (**a**) and /o/-/ɔ/ (**b**) 'different' pairs.

a short break. As there were 12 trials × 8 repetitions × 54 participants for each AX discrimination task, the total number of possible responses was 5,184 for each discrimination task. A nonresponse was recorded if the subject did not press a key in the 3-second interval allowed. There were a total of 46 nonresponses for the /e/-/ɛ/ discrimination task, and 61 nonresponses for the /o/-/ɔ/ discrimination task.

The /e/-/ɛ/ and /o/-/ɔ/ data were analyzed in two separate mixed design ANOVAs with language dominance (Spanish-dominant, Galician-dominant) and location (Vigo, Santiago) as between-subjects factors, stimulus (s1-s3, s2-s4, s3-s5, s4-s6, s5-s7) as within-subject factor and subject as the random term. The dependent variable in both ANOVAs was the proportion of correct responses (i.e. proportion of 'different' responses when the stimulus is 'different'), thus, only the 'different' stimuli were included in the analyses. The interactions were further explored in 5 Bonferroni-corrected paired t tests (α-level adjusted to 0.01).

2.3.3 Results

As shown in figure 7, Galician-dominant participants show a peak in their discrimination of the front and back mid vowels, for the s3-s5 stimulus pair. Conversely, this accuracy peak is not noted in the responses of the Spanish-dominant group.

The analysis of the /e/-/ɛ/ data yielded a main effect of stimulus [$F(4, 204) = 8.40$, $p < 0.001$] and language dominance [$F(1, 51) = 6.35$, $p < 0.05$] but not a significant

effect of location [F(1, 51) = 2.42, n.s.]. There was also a significant interaction between stimulus and language dominance [F(4, 204) = 2.77, $p < 0.05$]. Overall, Galician-dominant participants had a higher rate of correct responses than Spanish-dominant ones, but pairwise comparisons revealed that the only significant differences between groups was in their responses to stimulus pair s3-s5 [26.62, t(50) = 4.11, $p < 0.001$]. The analysis of the /o/-/ɔ/ data also revealed a main effect of stimulus [F(4, 212) = 6.08, $p < 0.001$], and there was a significant interaction between stimulus and language dominance [F(4, 212) = 3.65, $p < 0.01$]. However, there were no effects of language dominance [F(1, 51) = 0.96, n.s.] or location [F(1, 51) = 0.75, n.s.]. Even though Galician-dominant bilinguals had more correct responses than Spanish-dominant ones in stimulus pairs s1-s3, s2-s4 and s3-s5, this was not the case for stimulus pairs s4-s6 and s5-s7. Visual inspection of the data (fig. 7) also shows that there is an accuracy peak in stimulus s3-s5. In order to explore the interaction between language dominance and stimulus, Bonferroni-corrected paired t tests were used to compare the responses of both language dominance groups for each stimulus. These pairwise comparisons revealed that there were no significant differences between both groups in any of the stimuli except for stimulus s3-s5 [19.08, t(50) = 3, $p < 0.01$].

2.4 Experiment 3: Production (Reading-Aloud Task)

The production of the target Galician mid vowels in stressed position was elicited in a reading-aloud task. Participants were asked to name the experimental items embedded in short sentences.

2.4.1 Materials

The stimuli consisted of 60 experimental items that elicited the Galician mid vowels in stressed position (see Appendix 1 for the list of stimuli). Specifically, each sentence contained a target word that elicited a mid vowel in stressed position (e.g. *Hai unha **pera** no fruteiro* 'There is a **pear** in the fruit bowl'). The Galician utterances elicited the pronunciation of 15 target words for each Galician mid vowel, and each block appeared 3 times. Therefore, each participant produced 180 target productions for a total of 9,720 vowel measurements (54 participants × 180 target productions). Fourteen tokens were excluded due to recording errors or mispronunciations; as a result, the data set comprised a total of 9,706 measurements.

2.4.2 Procedure

The production task was conducted individually in a quiet room with participants comfortably seated in front of a computer display. The production data was obtained from a reading-aloud task. Participants were told that the study involved reading sentences on a computer screen and that their speech would be recorded for later acoustic analysis. Each sentence was presented on a computer screen, and participants were asked to read the sentences clearly and with a natural pace, speaking neither too quickly nor too slowly. The 60 sentences appeared in 3 repetitions and in random order. The speech samples were recorded using a head-mounted microphone (Shure SM10A) and a solid-state digital recorder (Marantz PMD660), digitized (44 kHz, 16-bit quantization) and computer-edited for subsequent acoustic analysis.

2.4.3 Acoustic Analysis

Vowels were segmented using synchronized waveform and spectrographic displays in Praat (Boersma and Weenink, 2014), version 5.3.18. The boundaries of each vowel were determined by examining the waveform, spectrogram and the intensity curve. Formant trajectories, especially the trajectory of the second formant (F_2), as well as intensity displays were taken as indicators of vowel onsets and offsets. The onset of the vowel was marked as the beginning of the first pitch period in which the F_2 was clearly visible (after stops and fricatives) or where the intensity was similar to that in the vowel's steady state (after nasals and laterals). The vowel offset was marked on the last pitch period in which F_2 was visible (before stops and fricatives), the beginning of the decline in intensity and the lowering of F_2 (before nasals and laterals). When the neighboring segment was an approximant, the onset and offset of the vowel were identified at the beginning of the transitional period between approximant and vowel. Vowel formant measurements (F_0, F_1, F_2) were automatically extracted at the center of the steady-state period of the vowel, together with the duration of the vowel (milliseconds) using a Praat script. Formant tracks were calculated with the Burg algorithm (Anderson, 1974) as built into the Praat program. The effective window length for the calculation was set at 25 ms and was maintained across tokens and speakers. The maximum number of formants to be located by the formant tracker was always 5, and the ceiling was set at 5.0 kHz for males and 5.5 kHz for females. These gender-specific formant ceilings reflect the different average vocal tract lengths of men versus women and were deemed appropriate after visual inspection of the sound files. The first author manually checked all measurements, and any errors resulting from the automatic formant tracking procedure were individually measured and corrected by hand. Formant values were extracted in hertz and were further converted to bark, using the hertz-to-bark function available in Praat. The Bark scale is a logarithmic psychoacoustic scale that ranges from 1 to 24, and is a measure of frequency based on the critical bandwidths of hearing believed to reflect human perception (Traunmüller, 1990; Zwicker, 1961).

It has been acknowledged that the raw formant frequencies of different speakers are not directly comparable because of interspeaker variation due to inherent anatomical differences (Clopper 2009; Disner 1980; Hindle 1978; Thomas 2002; Watt et al., 2010). Specifically, vocal tract length varies by gender and age, such that men, who typically have longer vocal tracts, tend to produce vowels at lower frequency ranges than women and children (Hillenbrand et al., 1995; Peterson and Barney, 1952). In order to minimize physiological interspeaker variation to permit accurate cross-speaker comparisons of formant data, a vowel-intrinsic bark distance normalization procedure was applied where B1−B0 represented vowel height, and B2−B1 the degree of vowel frontedness/backness (Baker and Trofimovich, 2005; Syrdal and Gopal, 1986; Tsukada et al., 2005).

Data sets of by-subject aggregates were created including the median B1–B0 and B2–B1 values over subjects as a condition of vowel (4 values per participant). The use of the median rather than the mean in the analyses of vowels has been claimed to reduce the effect of formant measurement errors (Escudero et al., 2009). The normalized vowel data were analyzed through mixed design ANOVAs with group (Spanish-dominant, Galician-dominant) and location (Santiago, Vigo) as between-subjects factors, vowel (/e/ and /ɛ/ for the front vowels; /o/ and /ɔ/ for the back vowels) as within-subject factors, and individual speaker as the random term. Additionally, interactions were further explored by analyzing the effects of vowel for each language dominance group separately in Bonferroni-adjusted pairwise comparisons.

2.4.4 Results

2.4.4.1 Front Mid Vowel Data (/e/ and /ɛ/)

The analysis of the height dimension (B1–B0) yielded a main effect of vowel [$F(1, 50) = 23.79$, $p < 0.001$] and language dominance [$F(1, 50) = 4.88$, $p < 0.05$] and a significant interaction between vowel and language dominance [$F(1, 50) = 8.77$, $p < 0.01$]. The height contrast between the higher-mid (/e/) and lower-mid (/ɛ/) vowel was produced in the expected direction. There was not a significant effect of location, and no interactions between language dominance and location, vowel and location or vowel, language dominance and location. The data were further explored by dividing the data set into 2 subsets as a function of language dominance. The significant interaction was examined by means of 2 separate paired t tests, and it was found that there were significant differences in the height dimension between /e/ and /ɛ/ produced by Galician-dominant participants [diff. = –0.33, $t(47) = –2.97$, $p < 0.01$] but not for Spanish-dominant ones [diff. = –0.09, $t(55) = –0.84$, n.s.].

The mixed-design ANOVA with the B2–B1 data as the dependent variable revealed a significant effect of vowel [$F(1, 50) = 21.93$, $p < 0.001$] but also a significant effect of language dominance [$F(1, 50) = 6.72$, $p < 0.05$], and a significant interaction between vowel and language dominance [$F(1, 50) = 9.33$, $p < 0.01$]. In order to explore the interaction, the production of the front mid vowels was investigated for each language dominance group separately. As shown in the analysis of the height dimension, Bonferroni-corrected pairwise comparisons yielded significant differences between Galician-dominant and Spanish-dominant participants. There were significant differences in the frontedness dimension between /e/ and /ɛ/ produced by Galician-dominant subjects [diff. = 0.41, $t(47) = 2.13$, $p < 0.05$] but not for Spanish-dominant ones [diff. = –0.1, $t(55) = 0.60$, n.s.]. These results indicate that there are differences based on language dominance: only the Galician-dominant subjects are producing robust /e/-/ɛ/ contrasts in Galician. Specifically, Galician-dominant participants, but not Spanish-dominant ones, produced robust height and frontedness differences between the front mid vowel categories.

2.4.4.2 Back Mid Vowel Data (/o/ and /ɔ/)

The analysis of the height dimension (B1–B0) yielded a main effect of vowel [$F(1, 50) = 104.5$, $p < 0.001$] but not for language dominance [$F(1, 50) = 1.68$, n.s.] or location [$F(1, 50) = 0.03$, n.s.]. Specifically, no statistical differences were found between the productions of Galician-dominant and Spanish-dominant participants, as they both maintained distinct back mid vowel contrasts. There was also a significant interaction between vowel and language dominance [$F(1, 50) = 12.42$, $p < 0.001$]. No other interactions were significant. The data were further explored by dividing the data set into 2 subsets as a function of language dominance. Pairwise comparisons indicated that there were significant differences in the height dimension between /o/ and /ɔ/ produced by both Galician-dominant [diff. = –0.46, $t(47) = –4.27$, $p < 0.001$] and Spanish-dominant subjects [diff. = –0.22, $t(55) = –2.12$, $p < 0.05$]. The mixed-design ANOVA with the B2–B1 data as the dependent variable revealed a significant effect of vowel [$F(1, 50) = 59.21$, $p < 0.001$] but not for language dominance [$F(1, 50) = 0.69$, n.s.] or location [$F(1, 50) = 1.84$, n.s.]. No other interactions were significant. These results show that both Spanish-dominant and Galician-dominant subjects in Santiago and Vigo maintained the back mid vowel contrast in their productions, even though this contrast seems to be more robust for the Galician-dominant participants.

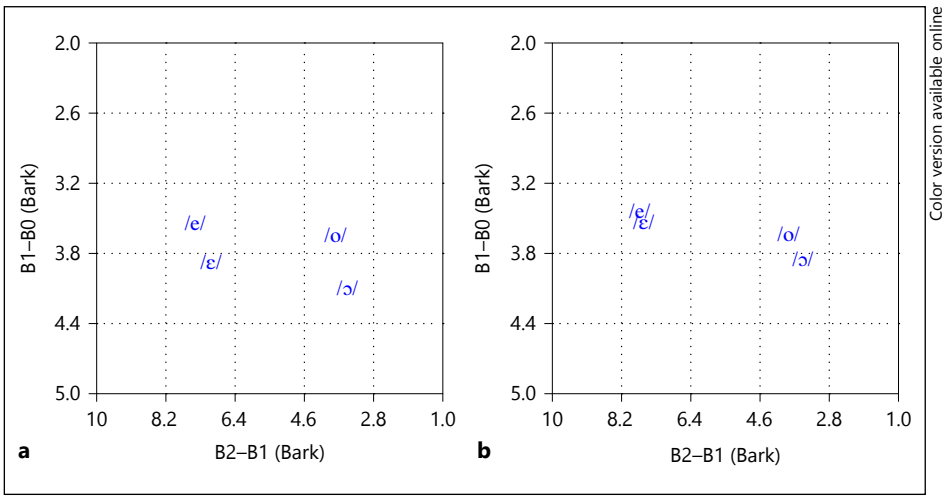

Fig. 8. Bark-converted height (B1–B0) and frontedness (B2–B1) vowel charts plotting the Galician front and back mid vowels produced by Galician-dominant (**a**) and Spanish-dominant (**b**) bilinguals.

Figure 8 displays two B1–B0 × B2–B1 vowel charts plotting the Galician front and back mid vowels produced by 54 Spanish-Galician bilinguals. Inspection of these vowel plots suggests that Galician-dominant bilinguals implement a Galician-specific /e/-/ɛ/ contrast but Spanish-dominant ones produce a single, merged Spanish-like front mid vowel. However, both language dominance groups seem to maintain a more robust /o/-/ɔ/ contrast. In other words, the distinction between the front mid vowels for Galician-dominant participants seems to be less robust than for the back mid vowels. This asymmetry between front and back mid vowels is found in the productions of both language dominance groups.

Because the analysis on group averages may obscure distinct patterns of between-speaker variation, further analyses were carried out to investigate the extent to which the mid vowel contrasts are realized for each individual speaker. In order to investigate the individual variation in the production patterns of these bilinguals, the data were analyzed for their Pillai score, which is a measure for the degree of merger (Hall-Lew, 2010; Hay et al., 2006; Sloos, 2013). The Pillai score is an output of a multivariate analysis of variance that represents the degree of overlap between 2 vowel clusters. In addition to maintaining information about the vowel token cluster distribution, the Pillai score also accounts for phonological environment. The Pillai score representing the vowel cluster difference between /e/-/ɛ/ and /o/-/ɔ/ was calculated for each individual speaker, in which the higher the Pillai score, the lower the degree of overlap, and larger distinction, between the two vowel clusters (see Appendix 2). Following Sloos (2013), Pillai scores with a significance value >0.05 are treated as a distinction, and Pillai scores with a significance value <0.05 are treated as a neutralization. These results confirm that more Spanish-Galician bilinguals are neutralizing the front mid vowels in their productions (Galician-dominant subjects: 7/25 = 28%; Spanish-dominant subjects: 19/29 = 65.5%) than the back mid vowels (Galician-dominant subjects: 2/25 = 8%; Spanish-dominant subjects: 13/29 = 44.8%).

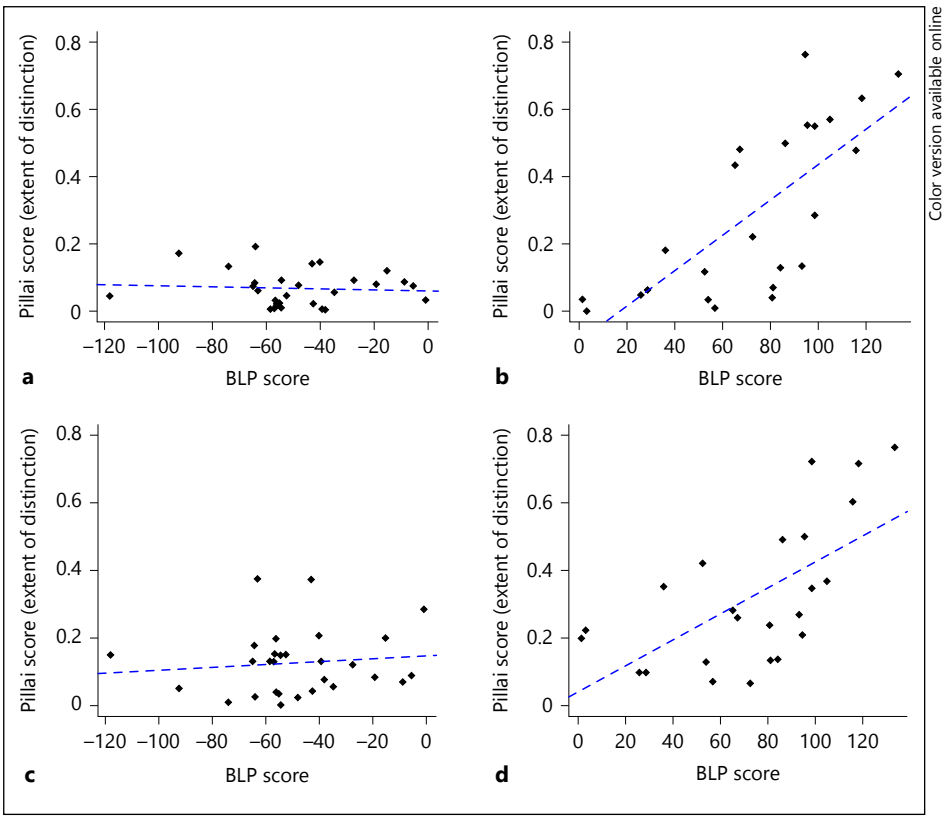

Fig. 9. Individual Pillai scores as a measure of front and back mid vowel merger plotted as a function of a speaker's BLP score. **a**, **b** /e/-/ɛ/. **c**, **d** /o/-/ɔ/. Fitted lines for Spanish-dominant (**a**, **c**) and Galician-dominant (**b**, **d**) bilinguals.

As figure 9 shows, the Pillai score is in general smaller for Spanish-dominant bilinguals (negative BLP score) than for Galician-dominant bilinguals (positive BLP score). The correlation between language dominance as reported in the BLP and Pillai scores of the /e/-/ɛ/ contrast was not significant for the Spanish-dominant bilinguals ($n = 29$, d.f. = 27, $r = -0.07$, $R^2 = 0.005$, n.s.); however, there was a significant positive correlation for the Galician-dominant group ($n = 25$, d.f. = 23, $r = 0.72$, $R^2 = 0.53$, $p < 0.001$). In addition, correlations between BLP score and Pillai score of the /o/-/ɔ/ contrast also yielded a nonsignificant correlation for the Spanish-dominant group ($n = 29$, d.f. = 27, $r = 0.10$, $R^2 = 0.01$, n.s.), but a highly significant positive correlation for the Galician-dominant group ($n = 25$, d.f. = 23, $r = 0.63$, $R^2 = 0.39$, $p < 0.001$). These results indicate that participants with higher BLP scores (i.e. more Galician-dominant) show even less overlap between the two mid vowel clusters. Based on the information provided by the BLP, most Spanish-dominant bilinguals have neutralized their mid vowels into a single, merged Galician mid vowel, while a higher proportion of Galician-dominant bilinguals maintained a clear distinction between the mid vowel categories. Furthermore, those Galician-dominant speakers

with a higher BLP score (i.e. more extremely Galician-dominant) were found to maintain a lower degree of overlap, and thus a larger distinction between these mid vowel contrasts.

3 Discussion

The present study examined the perception and production of the Galician mid vowel contrasts (/e/-/ɛ/ and /o/-/ɔ/) by 54 Spanish-Galician bilinguals along a continuum of language dominance, in the cities of Santiago and Vigo (Galicia, Spain). There is a lack of experimental studies that investigate the perception and acoustic realization of the Galician mid vowels, and these mid vowel contrasts have been especially understudied in comparison to other comparable bilingual communities that speak a minority language that is in contact with Spanish (e.g. Catalan). One of the main contributions of the present study is to provide empirical data to examine the role of language dominance in the perception and production of both Galician mid vowel contrasts and to determine whether the Galician vowel system is becoming more Spanish-like as a result of extensive contact with Spanish in the Galician urban areas.

This study posed several questions regarding the perception abilities of Spanish-Galician bilinguals: Are these bilinguals able to perceive the acoustic difference between the Galician mid vowels? Do these bilinguals have 2 mid vowel phonemes in their phonetic inventory where Spanish has 1? And are there differences in the perception patterns of these bilinguals based on language dominance? The aim of the identification and AX discrimination tasks was to focus on the potential difficulties that Spanish-Galician bilinguals face in identifying the Galician mid vowel contrasts, and specifically to examine the effects of language dominance in the identification of the mid vowel categories by Spanish-dominant and Galician-dominant bilinguals. The results from the identification tasks show that only Galician-dominant bilinguals consistently and accurately identify synthesized stimuli along a continuum, and as a result perceive 2 distinctive phonemes in the mid vowel phonetic space. The Galician-dominant group identified the synthesized stimuli along the /e/-/ɛ/ and /o/-/ɔ/ continuum in a categorical manner. In contrast, Spanish-dominant subjects had great difficulties in identifying the stimuli as either containing a higher or a lower mid vowel. The results from the AX discrimination tasks also reveal that the Galician-specific mid vowel contrasts were significantly more difficult to perceive for Spanish-dominant bilinguals. Galician-dominant participants were found to distinguish different word pairs more accurately in the boundary that separates both phonemic categories. The peak in their discrimination performance indicates that Galician-dominant bilinguals had a higher accuracy when discriminating the s3-s5 pair, suggesting that this region is the point of partition into the two separate mid vowel categories. This peak was absent in the responses of Spanish-dominant subjects. The identification and discrimination curves of the Galician-dominant group match the expected perception pattern typically found in categorical perception studies (Eimas, 1963; Liberman et al., 1957; Mattingly et al., 1971; Miyawaki et al., 1975).

These results confirm that there are significant differences in the perceptual abilities of Spanish-dominant and Galician-dominant bilinguals suggesting that only the Galician-dominant subjects demonstrate a heightened sensitivity due to the phonemic discrimination between both mid vowel categories while Spanish-dominant bilinguals

are unable to perceive the distinctive mid vowel phonemes in Galician. Additionally, there seems to be a difference between the front and back mid vowels: in the AX discrimination task there were significant differences between groups in the perception of the front mid vowel contrast but the difference between groups in the responses to the back mid vowel contrast was not as robust. Taken together, these results suggest that early Spanish-Galician bilinguals in the towns of Santiago and Vigo are not all able to perceive the contrast between the Galician /e/-/ɛ/ and /o/-/ɔ/ categories. Language dominance appears to be a strong predictor as the results in the identification and AX discrimination tasks suggest that only the Galician-dominant participants possess two independent phonetic categories in the mid vowel space, and as a result perceive both Galician-specific categories despite the overlap with one phonetic category in their nondominant language (i.e. Spanish). On the other hand, Spanish-dominant bilinguals seem to have great difficulty in identifying the stimuli as either a higher or lower mid vowel in both the front and back mid vowel space. These results are comparable to the reported difficulties of Spanish-dominant bilinguals in Barcelona with regard to the acquisition of Catalan-specific categories (Pallier et al., 1997; Sebastián-Gallés and Soto-Faraco, 1999).

The reading-aloud task investigated the acoustics of the Galician mid vowels and compared the productions of Galician-dominant and Spanish-dominant bilinguals. The main question addressed was the following: do Spanish-dominant and Galician-dominant bilinguals in Vigo and Santiago maintain the Galician mid vowel contrasts in their productions? More specifically, do these Spanish-dominant bilinguals produce the Galician-specific mid vowel contrasts? The analyses of the normalized formant data provide evidence that the productions of the Galician mid vowels also differ as a function of language dominance. The results indicate that Galician-dominant bilinguals produce robustly different Galician /e/-/ɛ/ and /o/-/ɔ/ contrasts in both acoustic height and frontedness. Interestingly, the acoustic analyses also demonstrate that Spanish-dominant subjects produced acoustically distinct back mid vowels, even if they neutralized the front mid vowel contrast. This asymmetry was also found for Galician-dominant bilinguals: the distinction between the front mid vowels was also less robust than for the back mid vowels. Additionally, analyses of individual data showed that the degree of dominance in Spanish affected the acoustic distance maintained between both phonemes in their productions. Specifically, the Pillai score, which measures the degree of merger between both mid vowel clusters, significantly correlates with the bilinguals' degree of Galician language dominance. For Spanish-dominant subjects there was no significant correlation between the degree of overlap of the mid vowel clusters and the degree of Spanish dominance, as most Spanish-dominant participants neutralized the mid vowel contrast. However, there was more variation in the Galician-dominant group with respect to the mid vowel distinction in production: there was less overlap between the mid vowel categories and, thus, a more robust distinction, as a function of being more Galician-dominant.

Early learners have been reported to be more successful than late learners in acquiring the phonological system of an L2. This success seems to be limited by the performance of Spanish-dominant Spanish-Galician bilinguals in Vigo and Santiago. The results of this study indicate that the production and perception of the Galician mid vowel contrasts by Spanish-Galician bilinguals, who have been exposed to both languages from a very early age, is modulated by language dominance. Spanish-dominant bilinguals have great difficulties distinguishing between these vowels and do not

consistently maintain the contrasts in their productions. A different pattern is found in the acoustic realization of Galician-dominant bilinguals: the Galician-specific /ɛ/ and /ɔ/ categories appear to be robustly maintained in their productions, and they also seem to have no difficulties perceiving these distinct mid vowel categories.

For the most part, speech production and perception have been investigated independently (Fowler and Galantucci, 2005). Even though there is an undeniable link between production and perception, it is still unclear which role each of these skills plays in relation to the dominant and nondominant sound systems of bilingual individuals: which skill is first mastered, and whether one conditions the other. Pisoni (1995) states that production and perception reflect the properties of a unitary articulatory event and speakers produce precisely the same acoustic differences that are distinctive in perceptual analysis. Following the same idea, Liberman and Mattingly (1985) espouse the view that production and perception are different sides of the same coin. Some researchers assume that perception conditions production (Edwards, 1974; Ingram, 1976; Menyuk, 1977; Neufeld, 1988; Rochet, 1995) such that L2 learners can only produce L2 sounds accurately if they perceive them accurately. As a result, an increase in performance in production is necessarily preceded by an increase in perception, with previous work showing that training listeners to perceive nonnative speech sounds results in improved production (Bradlow et al., 1997; Lengeris and Hazan, 2010). In contrast, others maintain that production can precede perception (Brière, 1968; Goto, 1971; Sheldon and Strange, 1982). For instance, experimental studies with Japanese late learners of English have shown that their production of English /r/ and /l/ was better than their perception (Goto, 1971; Sheldon and Strange, 1982). The results of the present study seem to align with the latter view, showing that even though Spanish-dominant bilinguals have great difficulties in perceiving the mid vowel contrasts, they fared somewhat better in the production task. This scenario, especially with regard to the back mid vowel contrast, points to an example of a near-merger situation 'where speakers consistently report that two classes of sounds are ''the same'', yet consistently differentiate them in production at a better than chance level' (Yu, 2007, p. 187). These findings add to the previous observations claiming that 'we cannot rule out the possibility that changes in production occur first, or that they occur in the absence of corresponding changes in perception' (Flege et al., 1997, p. 467).

The SLM (Flege, 1995) proposes that success in L2 production depends on the establishment of new phonetic categories for the L2 segments, and critically, this success is based on the perceived similarity or dissimilarity between the L2 sound and any existing L1 category. As stated in Flege (1995, p. 367), 'the more distant from the closest L1 sound an L2 is judged to be, the more likely it is that L2 learners – regardless of age – will establish a new category for the L2 sound'. The SLM establishes that a 'new phone scenario' and a 'similar phone scenario' depend on whether the difference perceived by the learner between an L2 sound and its closest L1 sound is large enough. To explain the perception and production difficulties of Spanish-dominant bilinguals, the SLM would hypothesize that similar but not identical L2 sounds and L1 phonemic categories are particularly difficult to perceive and produce. In this case, the Galician and Spanish mid vowels constitute a case of phonetic category assimilation making the acquisition of the Galician mid vowel contrasts particularly difficult, and as such would be primary targets for contact-induced change.

The PAM (Best, 1995) postulates that a nonnative phone may be assimilated in one of three ways: (1) as a good or poor exemplar of a native phonological segment

(categorized), (2) as unlike any single native phoneme as the nonnative sound will fall somewhere in between native phonemes (uncategorized), or (3) as a nonlinguistic speech sound (nonassimilated) that does not resemble any native phoneme. The PAM proposes that both the native phonology and the goodness of fit of the nonnative sounds play a crucial role in the way nonnative phonetic contrasts are perceived. In other words, the ease with which nonnative contrasts are perceived varies depending on how they are perceptually assimilated by the native perceptual system. The difficulty of Spanish-dominant bilinguals in perceiving these Galician-specific mid vowel contrasts would be a consequence of these mid vowels being 'incorrectly' assimilated as a merged Spanish-like mid vowel. It is important to note that the PAM was designed to make predictions for learners with no prior linguistic experience with the target language, whereas the SLM is concerned with ultimate attainment and as such makes predictions about advanced learners, therefore matching more closely with the phonetic abilities of the early and highly proficient Spanish-Galician bilinguals that participated in this study.

The PAM adopts a direct realist approach to speech perception (Fowler, 1986, 1994, 1996), which takes articulatory gestures as the direct primitives of speech perception and posits linked perception and production systems predicting that the perception and production abilities of an individual speaker are directly related. By contrast, the SLM adopts a psychoacoustic theory of speech perception (Diehl, 1987; Neary, 1990; Ohala, 1996) assuming that the acoustic properties of the speech signal are the primitives of speech perception. This model proposes that at least some of the representations underlying speech perception and production are different, and as a result perception and production of L2 sounds are not directly related. Given that the perception and production of the Galician mid vowels by these early Spanish-Galician bilinguals do not seem to reflect the properties of a unitary articulatory event, our results are more easily explained by the SLM. However, neither of these models can fully account for the asymmetry found in the perception and production of front and back mid vowel contrasts.

A typological explanation could also be adopted to explain the difficulties of Spanish-dominant bilinguals to accurately perceive and produce the Galician mid vowel targets. Previous research on the simultaneous acquisition of two phonological systems has argued that complex and marked phenomena in one language may tend to be permeated by the other language if this is simpler and less marked (Lleó and Rakow, 2005). In Lleó et al. (2008), the authors identify the Catalan mid vowels as being vulnerable to Spanish influence due to two related phenomena: markedness and complexity. The notion of markedness is considered to be intimately related to frequency, with unmarked entities being more frequent than marked entities. In the case of vowel systems, having 2 degrees of height within the mid vowels is less frequent than having just 1 degree (Maddieson, 1984), and following this notion in a context of extensive language contact the Galician vowel system would be more marked and complex than the Spanish one, and as a result prone to simplification from a 7-vowel to a 5-vowel system by merging the mid vowel contrasts.

The results of the present study could also be a result of language internal factors, such as the lack of robustness of the Galician mid vowel contrasts. The differences between the front and back mid vowel categories for both language dominance groups seem to support this hypothesis, since the front mid vowel contrast may be harder to maintain than the back mid vowel contrast due to there being more variability in the

pronunciation of the front mid vowels, and not just due to the potentially linguistically 'marked' vowel system of Galician. This explanation has been used to account for the loss of the Catalan mid vowel contrasts in Barcelona (Mora et al., 2011; Mora and Nadeu, 2012). Specifically, there may be a low functional load due to the fact that there are few minimal pairs in the language, and these Galician mid vowels vary across and even within dialects of Galician. For instance, the first vowel in '-ente' is generally articulated as /e/ in western and northern areas of Galicia whereas it is typically pronounced as /ɛ/ in the rest of Galicia (e.g. *dente* 'tooth' ['den.te]/['dɛn.te], or *semente* 'seed' [se.'men.te]/[se.'mɛn.te]). Similarly, other lexical items exhibit analogous variation in the back mid vowel set. Such is the case of *ollo* 'eye', which is produced as ['o.ʎo] in western and northern areas but as ['ɔ.ʎo] in the rest of the territory (Regueira, 2010).

Flege (2007) argues that the quantity and quality of L2 input received by an L2 learner are important determinants of the ultimate degree of attainment in an L2. A plausible explanation for the different production and perception patterns found between Galician-dominant and Spanish-dominant bilinguals in Vigo and Santiago is that these bilinguals vary crucially as a function of the (accented) input that they receive. Galician-dominant and Spanish-dominant bilinguals in this study differ in the amount of input in Galician that they receive with the Galician-dominant group reporting a higher daily use of Galician than Spanish, and a more native-like accent in Galician in comparison to the Spanish-dominant group (table 1). In this case, more instances of acoustically distinctive Galician mid vowels are available in the input that Galician-dominant bilinguals receive whereas Spanish-dominant ones are more exposed to Spanish and to input in Galician containing merged mid vowels, where Galician /ɛ/ words and /ɔ/ words are produced closer to /e/ and /o/, respectively. Therefore, Spanish-dominant bilinguals in particular may receive highly variable and inconsistent Galician input, which in terms of the Galician mid vowels leads to difficulties in the acquisition of the contrasts. In fact, Vidal Figueroa's (1997) results in his impressionistic study, where he compares the vowel productions of two Galician varieties and the Spanish variety spoken in Vigo, is in consonance with this hypothesis. Vidal Figueroa found that speakers of the (Galician) *traditional Vigo dialect* maintain the mid vowel contrasts while speakers of the *educated urban Galician*, merged them into a single, Spanish-like vowel in the front and back mid vowel region. His results show that the sound system of the educated urban Galician is not acoustically distinct from the Spanish spoken in the region. These results are not surprising if we consider what groups are representative of each variety. The traditional Vigo dialect is the Galician variety spoken by individuals who understand but do not regularly use Spanish in their daily lives. This is the variety spoken mostly by older people from the peripheral areas. The educated urban Galician is the variety spoken by individuals who use Galician on a daily basis (but in many cases Spanish is considered their dominant language). This group, which probably matches the Spanish-dominant bilinguals in this study, is integrated mostly by college-educated individuals and also individuals with a strong presence in the community and the media, including leaders of political organizations and unions, writers and TV actors (Vidal Figueroa, 1997).

These results question the existence of the mid vowel contrasts in the vowel inventory of modern urban Spanish-dominant Galician speakers, but more studies are still necessary to determine if we are witnessing change in progress, and if there are age differences in the maintenance or simplification of the Galician mid vowels. Furthermore,

if urban Galician is undergoing dialectal leveling and is converging with Spanish, it still remains to be seen if these Galician-specific mid vowels are maintained in the speech of bilinguals in rural areas. Future studies on the status of the Galician mid vowels will also shed light on an issue of linguistic identity in this bilingual community and answer the following question: is the production and perception of the Galician-specific mid vowel contrasts (/ɛ/-/e/ and /ɔ/-/o/) still considered necessary in order to sound native-like in Galician? Even if prescriptivists and grammarians consider the maintenance of the mid vowel contrasts to be necessary, is a Galician speaker considered to be less 'authentic' for not using these Galician-specific vowel contrasts? Follow-up sociolinguistic studies (e.g. matched guise tests) should be able to provide answers to these questions by capturing the attitudes of these bilinguals towards the use and maintenance of the Galician-specific mid vowel contrasts.

4 Conclusions

The present study investigated the Galician mid vowel (/e/-/ɛ/ and /o/-/ɔ/) perception and production of two groups of early Spanish-Galician bilinguals from the cities of Santiago and Vigo, where Spanish and Galician are co-official. The results from the binary forced-choice identification and AX discrimination tasks show that there are significant differences in the perceptual abilities of Spanish-dominant and Galician-dominant bilinguals suggesting that only the Galician-dominant ones demonstrate a heightened sensitivity due to the phonemic discrimination between both mid vowel categories while Spanish-dominant subjects are unable to perceive the distinctive mid vowel phonemes in Galician. Data from the reading-aloud task indicate that Galician-dominant bilinguals produce robustly different Galician mid vowel contrasts but the productions of Spanish-dominant individuals suggest that many of these early bilinguals residing in urban areas of Galicia have difficulties maintaining two independent phonetic categories in the mid vowel space. The acoustic analyses also show that Spanish-dominant bilinguals produced acoustically distinct back mid vowels, even if they neutralized the front mid vowel contrast. This asymmetry was also found for Galician-dominant bilinguals: the distinction between the front mid vowels was also less robust than for the back mid vowels. While much work remains to be done to more completely understand the interaction between the phonemic categories of both languages of the bilingual individual, this study has contributed new data to the study of language dominance and the relationship between the production and perception abilities of a relatively understudied group of early and highly proficient bilinguals.

Appendix 1: List of Stimuli Included in the Production Task

/e/
(1) *Puxen no* ***peto*** *os cartos.* 'I put the money in the piggybank'
(2) *Ana ten un* ***neno*** *pequeno.* 'Ana has a little boy'
(3) *O noso* ***cortello*** *está limpo.* 'Our stable is clean'
(4) *Hai unha* ***pera*** *no fruteiro.* 'There is a pear in the fruit bowl'
(5) *Teñen o* ***percebe*** *moi caro.* 'Their barnacles are very expensive'
(6) *O primo é* ***pequeno*** *coma ti.* 'Our cousin is as small as you'

(7) *Pescamos con **rede** no mar.* 'We fish with a net in the sea'
(8) *Hai un **penedo** grande.* 'There is a big stone'
(9) *Unha **abella** picoume no dedo.* 'A bee stung my finger'
(10) *Pedro ten unha **pega** na casa.* 'Pedro has a jay at home'
(11) *Eu poño a **mesa** despois.* 'I will set the table later'
(12) *O siamés ten **pelo** curto.* 'The Siamese cat has short hair'
(13) *Ten **medo** ás meigas.* '(S/he) is afraid of witches'
(14) *Esa **presa** leva muita auga.* 'This dam holds a lot of water'
(15) *Usan a **seda** para facer fío.* '(They) use silk to make thread'

/ɛ/
(1) *Calquera **guerra** é cruel.* 'Any war is cruel'
(2) *A farmacia é **preto** da casa.* 'The pharmacy is close to the house'
(3) *Comprei **terra** con fertilizante.* 'I bought soil with fertilizer'
(4) *A lareira é de **pedra** natural.* 'The fireplace is made of natural stone'
(5) *O rapaz está **cego** de amor.* 'The boy is blinded by love'
(6) *O portal é de **ferro** fundido.* 'The gate is made of cast iron'
(7) *Temos unha **festa** mañán.* 'We have a party tomorrow'
(8) *Os avós tiveron **sete** fillos.* 'Our grandparents had seven children'
(9) *Pedro é **grego** por parte de nai.* 'Pedro is Greek on his mother's side'
(10) *Ten unha ferida na **perna** esquerda.* '(S/he) has a wound in his/her left leg'
(11) *Muitos morreron de **peste** negra.* 'Many died from the Black Death'
(12) *A casa **vella** vendeuse.* 'The old house was sold'
(13) *A miña **neta** chega hoxe.* 'My granddaughter arrives today'
(14) *Compramos unha **moneca** de trapo.* 'We bought a rag doll'
(15) *Dorme a **sesta** sempre.* '(S/he) always takes a nap'

/o/
(1) *Tenho **doce** irmáns.* '(I) have twelve siblings'
(2) *En Galicia hai **toxo** branco.* 'In Galicia there is white gorse'
(3) *Ardeu o **monte** do veciño.* 'Our neighbor's lot burned'
(4) *Comprei un **toro** de peixe.* 'I bought a fish filet'
(5) *Teño un gato **fermoso** da Persia.* 'I have a beautiful Persian cat'
(6) *O irmán **xeitoso** casouse.* 'The handsome brother married'
(7) *Ten un **mozo** de Lugo.* 'She has a boyfriend from Lugo'
(8) *O camiño **pedroso** é mais longo.* 'The stone path is longer'
(9) *Esa é a **boca** da cova.* 'That is the cave's entry'
(10) *Escoitamos aventuras do **lobo** de mar.* 'We hear about the adventures of the sea lion'
(11) *Ten **todo** o piso limpo.* 'The entire floor is cleaned'
(12) *Comprei unha **bola** de pan.* 'I bought a loaf of bread'
(13) *É unha **ponte** romana.* 'It is a Roman bridge'
(14) *O meu **avó** padece do corazón.* 'My grandfather has a heart condition'
(15) *Aquí o **raposo** come as galiñas.* 'Here the fox eats our chicken'

/ɔ/
(1) *Ramón é un **home** simpático.* 'Ramón is a nice man'
(2) *Esa árbore ten **ocas** as polas.* 'That tree has hollow branches'
(3) *Este **xoves** é festivo.* 'Next Thursday is a holiday'
(4) *Paco ten **porco** para matanza.* 'Paco has a pig ready to be slaughtered'
(5) *Teño un **ovo** da nosa galiña.* 'I have an egg from our hen'
(6) *A miña **sogra** foise.* 'My mother-in-law left'
(7) *O neno é **forte** coma un touro.* 'The boy is as strong as a bull'
(8) *A sua **morte** foi triste.* 'His death was sad'
(9) *Esta **roda** está picada.* 'This tire is flat'
(10) *Esta **porta** está fechada.* 'This door is locked'

(11) *Ten un **golpe** na perna.* '(S/he) has a bruise on her/his leg'
(12) *Aqui o **solo** é alcalino.* 'Here the soil is alkaline'
(13) *Ese **corvo** comeu o peixe.* 'That crow ate the fish'
(14) *Comprei unha **pota** para o caldo.* 'I bought a pot to make stew'
(15) *Comprei unhas **botas** de goma.* 'I bought rubber boots'

Appendix 2: Pillai Scores and Their Significance Value for Each Speaker

Pillai scores with a significance value >0.05 are treated as a distinction (DIST) and Pillai scores with a significance value <0.05 are treated as a neutralization (NEUT).

No.	BLP	Dom.	Location	Pillai (/e/-/ɛ/)	Sig.	Merger/ split	Pillai (/o/-/ɔ/)	Sig.	Merger/ split
SF06	56.77	GAL	S	0.009	0.685	NEUT	0.071	0.062	NEUT
VM03	72.55	GAL	V	0.221	0.0001	DIST	0.066	0.075	NEUT
VF08	80.73	GAL	V	0.04	0.206	NEUT	0.238	0.0001	DIST
VM09	53.94	GAL	V	0.034	0.031	DIST	0.129	0.005	DIST
VF11	67.20	GAL	V	0.481	0.0001	DIST	0.26	0.0001	DIST
VM12	104.89	GAL	V	0.57	0.0001	DIST	0.368	0.0001	DIST
VF14	25.79	GAL	V	0.048	0.151	NEUT	0.098	0.020	DIST
VM16	133.49	GAL	V	0.705	0.0001	DIST	0.764	0.0001	DIST
VF17	95.45	GAL	V	0.553	0.0001	DIST	0.5	0.0001	DIST
VM18	94.54	GAL	V	0.763	0.0001	DIST	0.209	0.001	DIST
VF20	28.61	GAL	V	0.063	0.082	NEUT	0.098	0.020	DIST
VF21	115.79	GAL	V	0.478	0.0001	DIST	0.603	0.0001	DIST
VM22	3.17	GAL	V	0.00004	0.998	NEUT	0.223	0.0001	DIST
VF24	98.53	GAL	V	0.55	0.0001	DIST	0.722	0.0001	DIST
VM25	8.63	GAL	V	0.234	0.0001	DIST	0.345	0.0001	DIST
VM28	86.18	GAL	V	0.499	0.0001	DIST	0.491	0.0001	DIST
SF13	52.49	GAL	S	0.117	0.008	DIST	0.421	0.0001	DIST
SM17	84.18	GAL	S	0.129	0.005	DIST	0.137	0.003	DIST
SM18	65.20	GAL	S	0.434	0.0001	DIST	0.282	0.0001	DIST
SM19	1.36	GAL	S	0.035	0.254	NEUT	0.199	0.0002	DIST
SM21	118.24	GAL	S	0.633	0.0001	DIST	0.716	0.00001	DIST
SF22	81.1	GAL	S	0.07	0.063	NEUT	0.134	0.004	DIST
SM23	93.18	GAL	S	0.134	0.004	DIST	0.269	0.00001	DIST
SF24	98.53	GAL	S	0.285	0.0001	DIST	0.347	0.00001	DIST
SM25	36.05	GAL	S	0.181	0.004	DIST	0.352	0.00001	DIST
SM01	–27.51	SPN	S	0.092	0.064	NEUT	0.121	0.007	DIST
SM02	–118.06	SPN	S	0.045	0.168	NEUT	0.15	0.002	DIST
SM03	–64.03	SPN	S	0.192	0.0002	DIST	0.026	0.358	NEUT
SF04	–56.22	SPN	S	0.017	0.511	NEUT	0.198	0.0002	DIST
SF05	–43.04	SPN	S	0.141	0.003	DIST	0.373	0.0001	DIST
SF07	–56.67	SPN	S	0.032	0.285	NEUT	0.153	0.001	DIST
SF08	–42.59	SPN	S	0.022	0.415	NEUT	0.043	0.190	NEUT
VM01	–64.3	SPN	V	0.084	0.035	DIST	0.178	0.0006	DIST
VF02	–92.45	SPN	V	0.172	0.0007	DIST	0.051	0.137	NEUT
VM04	–55.13	SPN	V	0.024	0.389	NEUT	0.035	0.255	NEUT
VF05	–40.14	SPN	V	0.146	0.002	DIST	0.207	0.001	DIST
VF06	–48.04	SPN	V	0.077	0.047	DIST	0.024	0.400	NEUT
VM07	–54.40	SPN	V	0.092	0.025	DIST	0.002	0.907	NEUT

No.	BLP	Dom.	Location	Pillai (/e/-/ɛ/)	Sig.	Merger/ split	Pillai (/o/-/ɔ/)	Sig.	Merger/ split
VM10	–38.14	SPN	V	0.004	0.844	NEUT	0.077	0.067	NEUT
VM13	–74.01	SPN	V	0.133	0.004	DIST	0.01	0.423	NEUT
VM15	–34.78	SPN	V	0.056	0.109	NEUT	0.056	0.114	NEUT
VF23	–8.8	SPN	V	0.087	0.030	DIST	0.07	0.064	NEUT
VF26	–54.49	SPN	V	0.01	0.682	NEUT	0.149	0.002	DIST
VF27	–63.11	SPN	V	0.061	0.088	NEUT	0.375	0.0001	DIST
VF29	–52.49	SPN	V	0.046	0.163	NEUT	0.151	0.002	DIST
VF30	–19.25	SPN	V	0.08	0.061	NEUT	0.084	0.067	NEUT
SF09	–64.93	SPN	S	0.074	0.053	NEUT	0.131	0.004	DIST
SM10	–56.13	SPN	S	0.022	0.414	NEUT	0.04	0.208	NEUT
SF11	–15.26	SPN	S	0.12	0.007	DIST	0.2	0.0002	DIST
SF12	–0.91	SPN	S	0.033	0.275	NEUT	0.285	0.00001	DIST
SF14	–57.03	SPN	S	0.008	0.733	NEUT	0.13	0.006	DIST
SM15	–39.32	SPN	S	0.006	0.782	NEUT	0.131	0.004	DIST
SM16	–58.49	SPN	S	0.006	0.783	NEUT	0.131	0.005	DIST
SM20	–5.54	SPN	S	0.075	0.051	NEUT	0.089	0.060	NEUT

Dom. = Dominance; GAL = Galician-dominant; SPN = Spanish-dominant; S = Santiago; V = Vigo.

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