Current Issues in Linguistic Theory 335

The Phonetics-Phonology Interface

Representations and methodologies

JOHN BENJAMINS PUBLISHING COMPANY

Effects of Spanish use on the production of Catalan vowels by early Spanish-Catalan bilinguals*

Joan C. Mora, James L. Keidel & James E. Flege
Universitat de Barcelona / University of Sussex / University of Alabama at Birmingham

This study examined the production of Catalan vowels by 82 adults who had begun using both Spanish (S) and Catalan (C) at school age but differed in their self-reported percentage of Catalan use (11%=MostlyS, 40%=S/C, 63%=C/S, 86%=MostlyC). Bark-normalized Euclidean distances between the vowels /i/-/e/, /u/-/o/, /e/-/ɛ/ and /o/-/ɔ/ were computed to estimate the magnitude of between-vowel production differences. The results revealed an effect of Catalan use: the more frequently Catalan was used, the more open and less fronted — and thus the less Spanish-like — were productions of Catalan /ɛ/ and /ɔ/. Euclidean distances between /e/-/ɛ/ were greater for the MostlyC group than for the MostlyS and S/C groups, also indicating an effect of Catalan use. These findings suggest that Catalan /e/ and /ɛ/ are produced less successfully by early learners of Catalan who continue using Spanish often despite the fact that the second language (either Catalan or Spanish) was acquired in early childhood.

1. Introduction

A considerable amount of research on early bilingualism has investigated the plasticity of the perceptual system in second language (L2) learning. Some of this research has focused on perception of the Catalan mid-vowel contrasts /e/-/ɛ/ and /o/-/ɔ/ by various groups of bilinguals who spoke both Spanish and Catalan and who differed according to the way in which they became bilingual (simultaneous vs. sequential bilingualism) and which of the two languages was

* This study was funded by grants 2014DGR1089 and FFI2013-47616P to the first author. We would like to thank Cristina Aliaga, Eva Cerviño, and Mayya Levkina for their help in recruiting participants and in the acoustic analysis of the data. We would also like to thank two anonymous reviewers for their useful comments on an earlier draft of this article. Any errors remain our own.

DOI 10.1075/cilt.335.02mor

stronger (language dominance; see Pallier, Bosch & Sebastián-Gallés 1997, Bosch, Costa & Sebastián-Gallés 2000, Sebastián-Gallés, Echeverría & Bosch 2005, among others). The Spanish-Catalan interface has been of interest to researchers due in large part to differences between the vowel systems of the two languages. Spanish has a single mid-front vowel (/e/) in much the same portion of vowel space occupied by two mid-front Catalan vowels, /e/ and /ɛ/ (Bosch, Costa & Sebastian-Gallés 2000); similarly, Spanish has a single mid-back vowel (/o/) where Catalan has the two mid-back vowels /o/ and /ɔ/ (Simonet 2011). The primary question of interest addressed in this body of research is how bilinguals deal with an interesting cross-language difference of this kind. Will bilinguals who learned both languages as young children have three distinct mid-front vowels (Spanish /e/, Catalan /e/, Catalan /ɛ/)? Will two of the three vowels merge, assuming a position in vowel space that is different from the canonical vowels found in either Spanish or Catalan? And if there is no merger, will at least one member of the triad shift its position in vowel space in order to preserve phonetic contrast?

Previous research has shed important light on questions of this kind. For sequential bilinguals who learned first one language (Spanish or Catalan) and then the other, it seems that the two mid vowels of Catalan are likely to be perceived as being instances of the one mid Spanish vowel, a phenomenon referred to as 'single-category assimilation' (Best 1995, Best & Tyler 2007; see also Flege 1995, 2007). The existence of this underlying perceptual mechanism seems to result in measurable and apparently permanent differences between the bilinguals who have been studied and what might be considered to be the 'gold standard' of accuracy, that is, the performance of monolingual speakers of Spanish and monolingual speakers of Catalan (Sebastián-Gallés, Echevarría & Bosch 2005, Ramon-Casas et al. 2009, Bosch & Ramon-Casas 2011).

The Spanish-Catalan research has been carried out by several groups of researchers working in Barcelona, a city where bilingualism is widespread if not the norm. It is the context in which the two languages under investigation are used that sets apart the work in Barcelona examining Catalan mid vowels from other published research including, for example, the voluminous research examining acquisition of the English /r/-/l/ contrast by native speakers of Japanese (Yamada 1995, Iverson, Hazan & Bannister 2005, Hattori & Iverson 2009, among others). Although the acoustic difference between English /r/ and /l/ (rock vs. lock) is sufficiently robust to ensure that native English speakers rarely if ever perceptually confuse the two English liquids, Japanese speakers often misidentify English /r/ and /l/ even after years of English-language use; moreover, their own productions of /r/ and /l/ may be misheard by native English listeners. Importantly, however, the vast majority of the Japanese participants examined in published research became bilingual only long after their L1 (Japanese) was fully

established. Indeed, most of them learned English after the age of 10 years after leaving their home country and arriving in a predominantly English-speaking country.

Participants in the Barcelona research, on the other hand, have been tested where they were born and raised. They are typically individuals who acquired two languages simultaneously or else learned their 'second' language when they began attending primary school. Perhaps even more important than early exposure, these individuals have needed to use both languages throughout their scholastic experience and have habitually used both languages in many settings on a daily basis. It seems reasonable to suppose that most or all Japanese speakers of English studied to date in published research have remained dominant in their L1, Japanese (Flege, Takagi & Mann 1995). However, for research carried out in Barcelona, language dominance cannot simply be assumed. It is sometimes the case that the first language acquired by a bilingual remains her or his dominant language for life. However, it is plausible to think that in a city like Barcelona the 'second' language of a bilingual might later become dominant if it is used more frequently than the 'first' language for a long period of time.

Sebastián-Gallés, Echevarría & Bosch (2005) offered a developmental explanation for the difference in performance by sequential (Spanish-Catalan, Catalan-Spanish) and simultaneous bilinguals in Barcelona. These authors hypothesized that phonemic categories acquired early in life compromise the acquisition of new phonetic categories later in life despite early and extensive exposure to the L2 (for sequential bilinguals) and may compromise the categories of both languages in the case of simultaneous bilinguals. If so, then bilinguals who speak Catalan often and well should manifest some degree of difficulty with Catalan mid-vowel contrasts regardless of language experience.

One by now well-known finding for early bilinguals in Barcelona involves an asymmetry seen in lexical decision tasks. In such tasks, participants hear Catalan words containing the mid vowels /e/ and /ɛ/ (e.g., finestra /fiˈnestrə/ "window", galleda /gaˈʎɛdə/ "bucket") alongside Catalan non-words created by substituting the open mid vowel for the close mid vowel, and vice versa (e.g., finestra *[fiˈnɛstrə], galleda *[gaˈʎedə]). The participants' task is to decide whether each item they hear is or is not a Catalan 'word'. Typically more errors are made for non-words containing /e/ than /ɛ/. It seems that participants are less likely to correctly judge that a non-word with /e/ is a not a word because they are perceptually 'prepared' to tolerate mispronunciations of /ɛ/ as [e] (/gaˈʎɛdə/ mispronounced as *[gaˈʎedə]) than to tolerate mispronunciations of /e/ as [ɛ] (/fiˈnestrə/ mispronounced as *[fiˈnɛstrə]). This asymmetry has been observed even for Catalan-dominant bilinguals who exhibit a fully categorical perception of the /e/-/ɛ/ contrast at a phonetic level, that is, when the effect of lexical context cannot exert an influence on perceptual

decisions (Sebastián-Gallés, Echevarría & Bosch 2005, Bosch & Ramon-Casas 2011, among others).

The asymmetry just described might be due to the input received by the bilingual research participants. It seems likely, given the linguistic situation in Barcelona, that such individuals have heard correct renditions of Catalan words containing the target vowels of interest in the speech of individuals who are monolingual or near-monolingual in Catalan (e.g., galleda [gaˈʎɛdə] "bucket") and also Spanish-accented renditions of the same vowels produced by individuals who either learned Catalan late in life or were strongly Spanish-dominant bilinguals (*[gaˈʎedə]). One might hypothesize that a difference exists in how vowels are represented phonologically in the mental lexicon of bilinguals, on the one hand, and in the mental lexicon of monolinguals and near-monolinguals, on the other hand (Sebastián-Gallés et al. 2006, Larsson et al. 2008, Sebastián-Gallés et al. 2009). Such a difference might arise due to the phonetic material used to construct fairly abstract phonological representations.

This 'bilingual lexical representation' hypothesis can be illustrated with reference to the work of Sebastián-Gallés et al. (2009). These authors tested 32 Catalan-dominant Catalan natives' categorical perception of /e/ and /ɛ/ through a lexical decision task and a continuous discrimination task using /de/ and /dɛ/ syllables that had been produced by multiple speakers. This study replicated the /e/-/ɛ/ asymmetry seen in an earlier study (Sebastián-Gallés, Echevarría & Bosch 2005) in the lexical decision task and provided no evidence of difficulty or reduced performance in /e/-/ɛ/ discrimination. These results were also confirmed by electrophysiological measurements (ERP data and MMN discrimination). These authors found accented-input effects to be innocuous sub-lexically, producing no effects on the /e/-/ɛ/ contrast in terms of perceptual weakening.

Support for the bilingual lexical representation hypothesis was obtained by Bosch & Ramon-Casas (2011). These investigators examined production of the Catalan /e/-/ɛ/ contrast by groups of adults who all spoke Catalan at home (especially with their children) but who differed in early linguistic experience. The members of one group were raised in homes where only Catalan was routinely used (Catalan monolinguals, CM) whereas members of the other group (Spanish-Catalan bilinguals, SCB) grew up in homes where both Spanish and Catalan were used. Both groups distinguished /e/ and /ɛ/ in production. Importantly, however, whereas both groups produced /ɛ/ in a similar fashion, the SCB group evidenced a higher rate of mispronunciations (words in which /ɛ/ was realized as [e]) than the CM group. Perhaps having been exposed to Spanish from birth prevented the SCB group from developing stable phonological representations for /ɛ/, as Catalan infants as young as 5 months have been shown to be sensitive to vowel frequency differences in discriminating between two dialects of Catalan (see Ortega-Llebaria & Bosch,

this volume). These findings support the view of Larsson et al. (2008) (see also Sebastián-Gallés et al. 2006, 2009) that lexical plasticity is not dependent on phonetic changes affecting phonological categories in that, at the lexical level, the SCB participants in the Bosch & Ramon-Casas (2011) study mispronounced Catalan /ɛ/ as [e] at significantly higher rates than the CM participants, whereas at the phonetic level, both groups of participants did not differ in the acoustic realizations of the vowel categories /e/ and /ɛ/, which they produced contrastively.

Alternatively, one might hypothesize that the lexically-based /e/-/ɛ/ asymmetry described earlier is due to a phonological 'weakening' of Catalan mid-vowel contrasts that derives from system-internal factors such as low functional load, /e/-/ɛ/ reduction to /ə/ in unstressed syllables, and within-dialect variation (see Badia Margarit 1969, 1970, Recasens 1991, Recasens & Espinosa 2006, 2009, for a more detailed account). Moreover, the influence of Spanish — which has no mid-vowel contrasts — may be leading Catalan-dominant bilinguals to eliminate such contrasts in their phonological representations of Catalan words. Specifically, the influence of Spanish on Catalan might come about from daily exposure to the pronunciation of Catalan words with a Spanish accent in which Catalan mid-vowel contrasts are predictably reduced or eliminated.

Support for a 'weakening' hypothesis was obtained by Mora, Keidel & Flege (2011). These authors assessed the perceptual 'robustness' of the Catalan mid-vowel contrasts for Spanish-Catalan bilinguals who were first exposed to their non-native language (Spanish or Catalan) as young children and used both their languages on a daily basis. All participants tested were found to perceive contrasts between Catalan mid vowels (/e/-/ɛ/ and /o/-/ɔ/) less categorically than between high vs. mid vowels contrasts (/i/-/e/, /u/-/o/). The perceptual robustness of the /e/-/ɛ/ contrast was affected by amount of daily use of Catalan, suggesting that variation in L1/L2 experience affected their perceptual performance.

Support for a weakening hypothesis was also obtained by Mora & Nadeu (2012), who investigated the effect of L2 (Spanish) use on the perception and production of the /e/-/ɛ/ contrast by Catalan-dominant native speakers of Catalan. Those Catalan speakers who reported using Spanish more frequently than Catalan (and were thus potentially dominant in Spanish) were found to discriminate Catalan /e/-/ɛ/ less accurately and to produce Catalan /ɛ/ with a higher (more Spanish-like) tongue position. The effect of L2 use on L1 vowel production was larger in cognate than in non-cognate words, suggesting that extensive L2 experience in a language contact situation affected native sound categories. Mora & Nadeu (2012) suggested that Catalan speakers' long-term memory representation for /ɛ/ could have been modified, through extensive exposure to Spanish and Spanish-accented Catalan, so as to reflect the spectral features of Spanish-accented /ɛ/ in a merged phonetic category. Catalan speakers who were frequent users of Spanish evidenced

more /e/-like realizations of /ɛ/, reflecting the existence of this merged category. It is thus possible that the combined effect of extended exposure to Catalan spoken with a Spanish accent (by L1-Spanish speakers of Catalan) and to the speech of Catalan natives who had developed a merged category for /ɛ/ might be leading, among other factors, to the gradual weakening of the /e/-/ɛ/ contrast.

The weakening hypothesis being discussed here, if it continues to develop over time, may eventually culminate in what is usually called a historical sound change. Historical linguists have long believed that sound change arises through 'language contact', not necessarily through encounters between monolinguals but through interactions between two different languages in the minds of bilinguals. Indeed, what might once have been considered the province of historical linguistics is a study of bilingual speech examining Spanish-Catalan bilinguals in Majorca. Simonet (2010) investigated the patterns of L1-L2 interaction of Spanish and Catalan lateral /l/, which is distinctly darker in Majorcan Catalan than in Spanish. Simonet found that some Spanish-Catalan bilinguals (Spanish-dominant early bilingual females) had developed a single merged L1+L2 lateral category, producing identical laterals in their two languages. Similarly, in a study of the acoustics of the Catalan mid-back vowel contrast in Majorca, Simonet (2011) found that Spanish-dominant bilinguals failed to produce the Catalan /o/-/ɔ/ contrast, producing a single merged (/o/+/ɔ/) mid-back vowel instead, which differed from their Spanish /o/ and Catalan-dominant bilinguals' /o/ and /ɔ/.

Returning once again to research in Barcelona, most research on the Catalan mid vowels has examined groups of bilinguals who, while having little or no difficulty discriminating mid-vowel contrasts, do nevertheless, in lexical decision tasks, tend to misidentify as being a word various non-word stimuli created by substituting /ɛ/ for /e/ (e.g., Sebastián-Gallés et al. 2006, 2009, Larsson et al. 2008).

In the present study we examined groups of bilinguals who, in categorization and discrimination tasks based on vowel continua, tended not to perceive the contrasts between the mid Catalan vowels /e/-/ɛ/ and /o/-/ɔ/ in a way that might be expected for Catalan monolinguals (Mora, Keidel & Flege 2011).[1] These bilingual groups presented varying degrees of perceptual difficulty with the Catalan mid-vowel contrasts as a function of patterns of Catalan/Spanish use. These findings lead us to expect, for the same groups of bilinguals examined in the present study,

1. No Catalan 'monolinguals' may be said to exist after childhood in Catalonia, as it is not possible (or it is extremely rare) to find adult native speakers of Catalan unable to hold a conversation in Spanish. According to a recent survey (Institut d'Estudis Catalans 2011), 99.9% of the population in Catalonia understands Spanish and 99.8% speaks it, whereas Catalan is understood by 95.3% of the population but only spoken by 77.5%. Similarly, whereas 56.7% of the population learned Spanish as their L1, only 35.3% learned Catalan as their L1.

varying degrees of overlap and lack of robustness in the production of the Catalan mid-vowel contrasts. More specifically, we hypothesized that speaker groups using Catalan more often would present larger spectral distances in the production of the contrasting vowel pairs /e/-/ɛ/ and /o/-/ɔ/ than speaker groups using Spanish more often, whose productions of the mid vowels /ɛ/ and /ɔ/ were expected to present acoustic features approximating the spectral characteristics of Spanish /e/ and /o/.

2. Method

The Spanish-Catalan bilinguals tested here were born and raised in Barcelona and had experienced life-long immersion in a language contact situation. The main aim of this study was to assess how effectively the participants differentiated in production the Catalan mid-vowel contrasts /e/-/ɛ/ and /o/-/ɔ/. Formant frequencies were measured in mid vowels in frequently occurring Catalan words that were elicited through a read-aloud task. Spectral distance (SD) scores were obtained by calculating the Euclidean distance between the mid-front vowels (/e/-/ɛ/) and the mid-back vowels (/o/-/ɔ/). The SD scores (in Bark) were intended as a measure of between-vowel distance, and thus of degree of overlap in the acoustic vowel space: the larger the SD score, the smaller the overlap between neighbouring vowels and presumably the lesser likelihood of eventual perceptual confusion by listeners. Words containing high and low stressed Catalan vowels were also elicited in order to provide insight into the bilinguals' entire vowel space. It was expected that Spanish-Catalan bilinguals would differ in their SD scores as a function of amount of L1/L2 use for the mid-vowel contrasts, but not for the non-mid vowels, larger SD scores corresponding to higher frequency of use of Catalan.

2.1 Participants

The participants, whose perception of Catalan vowels has already been examined by Mora, Keidel & Flege (2011), were selected from a larger pool of 719 Catalan-Spanish bilinguals after careful pre-screening via telephone and examination of responses to a written background questionnaire. All participants retained for the study, 82 in total, were born and raised in Barcelona, spoke and understood Catalan and Spanish well, used both languages on a daily basis, and were first exposed to their L2 (either Catalan or Spanish) at no later than age 6. Participants were assigned to one of four groups as a function of their frequency of use of Catalan, which was computed through self-reported percentages of use of Catalan in several contexts (at home, at work, on social occasions, with relatives, with friends and overall).

The pervasive influence of Spanish in Barcelona (see above) made it impossible to recruit a group of Catalan monolinguals. It was assumed, however, that the group of Catalan-Spanish bilinguals who reported speaking Spanish the least frequently would most closely approximate the performance of a truly monolingual Catalan group (had we managed to recruit one). As summarized in Table 1, estimates of Catalan use were used to assign participants to one of four groups: mostly Spanish (Mostly-S, <25% Catalan use), Spanish-Catalan bilinguals (S/C: 30–50% Catalan use), Catalan-Spanish (C/S: 50–70% Catalan use), and mostly Catalan (Mostly-C: >75% Catalan use). About 1/3 of the bilingual participants reported having been exposed to both of their languages prior to the age of 6 years, but this varied both as a function of group assignment and language (see Table 1).

As already mentioned, Mora, Keidel & Flege (2011) examined the 82 participants' perception of the Catalan mid (/e/-/ɛ/, /o/-/ɔ/) and high-mid (/i/-/e/, /u/-/o/) vowel pairs. The earlier study revealed that all participants perceived the high-mid vowel contrasts more categorically than the mid-vowel contrasts, and that the degree of categoriality in the perception of the mid-vowel contrasts varied as a function of how frequently Catalan was used. We anticipated similar findings in the present vowel production study, that is, we expected that the participants who used Catalan more frequently would produce larger contrasts between Catalan mid vowels than those who used Catalan less frequently.

Table 1. Participants' characteristics (standard deviations in parentheses)

	Bilingual groups			
	Mostly S (n=15)	S/C (n=22)	C/S (n=26)	Mostly C (n=19)
Self-reported % C use	11 (8)	40 (7)	63 (6)	86 (8)
Chronological age at test (years)	30 (10)	32 (7)	32 (7)	35 (8)
Years of residence in Barcelona	30 (9)	31 (9)	32 (7)	34 (7)
L1 before schooling (% of participants)				
Catalan	6.7	0.0	34.6	90.0
Spanish	73.3	76.2	30.8	10.0
Catalan and Spanish	20.0	23.8	34.6	0.0

2.2 Procedures and analyses

Participants read a 158-word passage in Catalan at a normal speaking rate. By design, the passage included target words containing all seven stressed vowels of Catalan. Five words containing /i/, /a/ and /u/ were selected for analysis, whereas

there were eight words each containing the mid vowels /e/, /ɛ/, /o/ and /ɔ/. These words were selected for analysis only if the mid vowel of interest was stressed and the word occurred in a prosodically focused position in the text so as to avoid an unstressed realization of the target vowel in running speech. Also, insofar as possible, an attempt was made to balance consonantal context across the vowel pairs of interest (/e/-/ɛ/ and /o/-/ɔ/, see Appendix).

Participants were recorded while seated in a sound-proof booth at a 44.1kHz sampling rate using a Marantz PM660 recorder and a Shure SM68 microphone. Participants were first asked to read the passage silently once on their own and then once aloud to be recorded. In the hope of obtaining samples that would resemble natural speech, and in order to avoid possible speech monitoring effects caused by the perception tasks performed previously, participants were asked to focus on information contained in the text because they would later be required to answer questions regarding the content. Participants were then asked to read a similar passage in Spanish. Here we report only on the analyses of just the Catalan vowels.

Vowel measurements (*f*0, F1, F2) were taken manually at the midpoint of the steady-state portion of the vowel tokens selected for analysis using the Praat acoustic analysis software (Boersma & Weenink 2009). To reduce the effect of variations in vocal tract size, frequency values were converted from Hertz (Hz) to Barks (B), and then a bark-distance normalization procedure (Syrdal & Gopal 1986) was used to provide speaker-independent estimates of vowel height.[2] The difference, in Barks, between F1 and *f*0 (B1-B0) estimated degree of vowel height, whereas the difference between F2 and F1 (B2-B1) estimated degree of vowel frontness-backness (see Bohn & Flege 1990, Flege, Bohn & Jang 1997, Baker & Trofimovich 2005).

In order to assess the degree of robustness of the /e/-/ɛ/ and /o/-/ɔ/ contrasts in production across subject groups, we computed (for every subject) the Euclidean distances or spectral distance (SD) scores between the mean B1-B0 and B2-B1 values (Flege, Bohn & Jang 1997).[3] Subjects speaking Catalan more frequently were predicted to show less overlap between pairs of mid Catalan vowels, which would also be expected to result in relatively larger SD scores between contrasting

2. Vowel frequencies (Hz) were converted to Bark (B) using the formula $Z_i = 26.81/(1+1960/F_i) - 0.53$, where F_i is the frequency value in Hz for a given formant *i* and Z the frequency in Bark (Traunmüller 1997).

3. Euclidean distances (SD scores) were calculated by means of the following formula, where *Va* and *Vb* are the two vowels for which the Euclidean distance is calculated:

$$\sqrt{((VaB2 - B1) - (VbB2 - B1))^2 + ((VaB1 - B0) - (VbB1 - B0))^2}$$

mid vowels as well as larger differences in vowel height (B1-B0) and/or frontness/backness (B2-B1). These subjects were also expected to obtain higher B1-B0 values for /ɛ/ and /ɔ/, indicating a lower tongue position clearly differing from the much higher articulation typical of Spanish /e/ and /o/, as well as lower B2-B1 values for /ɛ/, indicating a less fronted tongue position than that of Spanish /e/. However, subjects speaking Spanish more frequently were expected to obtain lower B1-B0 and higher B2-B1 values for Catalan /ɛ/ and /ɔ/, indicating a more Spanish-like articulation for these vowels with height and frontness values closer to Spanish /e/ and /o/.

3. Results

The mean vowel height (B1-B0) and frontness/backness (B2-B1) values of the Catalan mid vowels (/e/, /ɛ/, /ɔ/, /o/) obtained by the four groups of bilinguals are shown in Table 2. Differences in tongue position varied systematically mainly for the mid vowels /ɛ/ and /ɔ/, which were realized with a higher, more fronted (i.e., more Spanish-like) tongue position by bilinguals who spoke Spanish most of the time than by bilingual groups with a higher frequency of Catalan use. The B1-B0 and B2-B1 measures were submitted to a mixed design ANOVA with *participant group* (MostlyS, S/C, C/S, MostlyC) as the between-subjects factor and *vowel* (/i/, /e/, /ɛ/, /ɔ/, /o/, /u/) as the within-subjects factor. This analysis yielded a significant main effect for *vowel* ($F(3, 76)=71.3$; $p<.001$) and a non-significant main effect for *participant group* ($F(3, 78)=71.3$; $p=.457$). However, a significant *vowel* x *subject group* interaction ($p=.005$) indicated that between-group differences in vowel production were dependent on vowel type, as /ɛ/ and /ɔ/ varied consistently as a function of participant group: groups made up of participants using Catalan more frequently (MostlyC and C/S) produced vowels that were more open and less fronted (i.e., less Spanish-like) than groups consisting of individuals who spoke Spanish more frequently (MostlyS and S/C).

We next explored SD scores for every vowel contrast as a function of participant group. For the mid-vowel contrasts /e/-/ɛ/ and /o/-/ɔ/ SD scores were observed to increase consistently with greater frequency of Catalan use (Table 3). We assessed SD score differences in the realization of the vowel contrasts /i/-/e/, /e/-/ɛ/, /u/-/o/ and /o/-/ɔ/ as a function of *subject group* (MostlyS, S/C, C/S, MostlyC) by submitting SD scores to a series of one-way ANOVAs (independently for every vowel contrast). SD scores were found to differ significantly according to *participant group* for the mid-front contrast /e/-/ɛ/ ($F(3, 78)=5.79$; $p=.001$), but did not reach significance for the /o/-/ɔ/ contrast

Table 2. Bark (B) distance scores of the Catalan mid vowels (standard deviations in parentheses)

		Bilingual groups			
		Mostly S	S/C	C/S	Mostly C
Mid open /e/	Height (B1-B0)	3.33 (0.31)	3.23 (0.45)	3.37 (0.33)	3.13 (0.39)
	Front/Back (B2-B1)	8.09 (0.50)	8.47 (0.63)	8.32 (0.64)	8.70 (0.41)
Mid open /ɛ/	Height (B1-B0)	3.58 (0.49)	3.62 (0.49)	3.87 (0.52)	3.92 (0.48)
	Front/Back (B2-B1)	7.50 (0.49)	7.63 (0.68)	7.25 (0.83)	7.31 (0.51)
Mid close /o/	Height (B1-B0)	3.52 (0.44)	3.40 (0.50)	3.54 (0.43)	3.36 (0.53)
	Front/Back (B2-B1)	5.51 (0.61)	5.32 (0.71)	5.28 (0.55)	5.41 (0.52)
Mid open /ɔ/	Height (B1-B0)	3.87 (0.42)	3.79 (0.34)	3.94 (0.43)	4.15 (0.44)
	Front/Back (B2-B1)	4.54 (0.49)	4.31 (0.42)	4.23 (0.38)	4.15 (0.46)

($F(3, 78)=1.98$; $p=.123$). Tukey post-hoc tests revealed that MostlyC participants produced the mid-front vowel contrast /e/-/ɛ/ with significantly greater spectral distances than the MostlyS ($p=.001$) and the S/C ($p=.028$) groups (the MostlyS-S/C, MostlyC-C/S and S/C-C/S comparisons did not reach significance). For the high-mid vowel contrasts the main effect of *participant group* reached significance in the case of /i/-/e/ ($F(3, 78)=3.18$; $p=.028$), because the MostlyC group presented significantly lower SD scores than the MostlyS group (Tukey $p=0.29$). This was due to the MostlyC group's much larger spectral distance between /e/ and /ɛ/, which effectively reduced the spectral distance between /i/ and /e/ (see Figure 1). The participant groups did not differ in SD scores for /u/-/o/ ($F(3, 78)=0.10$; $p=.957$).

Table 3. Spectral distance (SD) scores between Catalan high-mid and mid vowels (standard deviations in parentheses)

		Bilingual groups			
		Mostly S	S/C	C/S	Mostly C
Front Vs	high-mid /i/-/e/	2.32 (0.47)	2.17 (0.69)	2.31 (0.61)	1.81 (0.48)
	mid-mid /e/-/ɛ/	0.76 (0.57)	1.00 (0.73)	1.29 (0.69)	1.63 (0.55)
Back Vs	high-mid /u/-/o/	1.42 (0.38)	1.50 (0.63)	1.49 (0.52)	1.43 (0.41)
	mid-mid /o/-/ɔ/	1.06 (0.59)	1.14 (0.56)	1.26 (0.61)	1.51 (0.61)

Mean B1-B0 (vowel height) and B2-B1 (frontness/backness) values for the seven stressed vowels of Catalan (/i/, /e/, /ɛ/, /a/, /ɔ/, /o/, /u/) as produced by the

four bilingual groups are plotted on the normalized Bark-converted F1-F2 vowel space in Figure 1. Interestingly, while the acoustic features of the corner vowels /i/, /u/ and /a/ are very similar for all bilingual groups, relatively large differences between bilingual groups exist in the case of the mid vowels, /e/, /ɛ/ and /ɔ/ in particular. As shown in Table 3, it is for the mid-front and mid-back vowels (Figure 2) that participant groups obtain different SD scores, larger spectral distances corresponding to participant groups using Catalan more frequently; MostlyC speakers present the largest spectral distance between contrasting mid vowels, particularly between the mid-front vowels /e/ and /ɛ/.

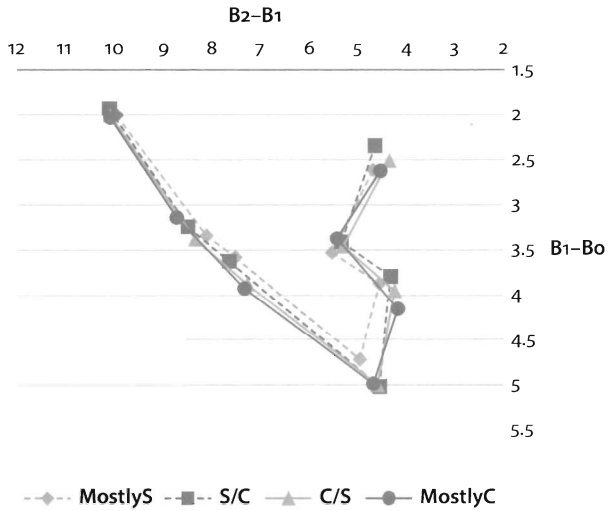

Figure 1. Spectral distances (Bark) between the seven stressed vowels of Catalan

These results indicate that the Catalan vowels /e/ and /ɛ/ were realized less distinctively by early bilingual speakers using Spanish more frequently than by early bilingual speakers using Catalan more frequently. However, the mean group differences in SD scores obtained (Figure 3) may be attributed to either between-group differences in frequency of Catalan use or to a difference in the distribution of the bilingual participants within each one of the groups. That is, greater frequency of Catalan use may correspond to larger SD scores between /e/ and /ɛ/, or to bilingual groups using Catalan more frequently having a larger number of participants with well established distinct categories for /e/ and /ɛ/. These participants would consequently be producing larger SD scores between /e/ and /ɛ/ than participants in bilingual groups using Catalan less frequently. Sebastián-Gallés, Echevarría & Bosch (2005), for example, found different distributions for each

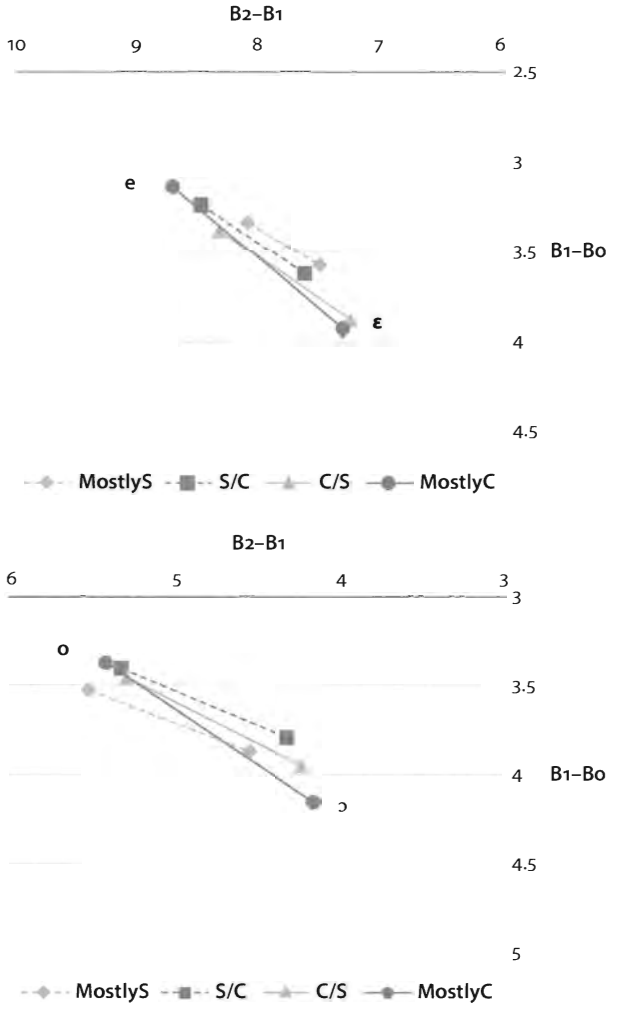

Figure 2. Spectral distances (Bark) between /e/-/ɛ/ (top) and /o/-/ɔ/ (bottom)

type of bilingual in four groups of Spanish-Catalan bilinguals significantly differing in their ability to identify /e/-type and /ɛ/-type non-words in a lexical decision task: some Spanish-dominant bilinguals were found to perform within the range of Catalan-dominant bilinguals. We tested this possibility by examining the individual data.

The analysis of the individual SD scores revealed that MostlyC bilinguals produced larger acoustic contrasts (i.e., had higher SD scores) than did the MostlyS group (Figure 4). However, some members of the MostlyS group produced spectral distances between /e/ and /ɛ/ that fell within the range of SD scores obtained

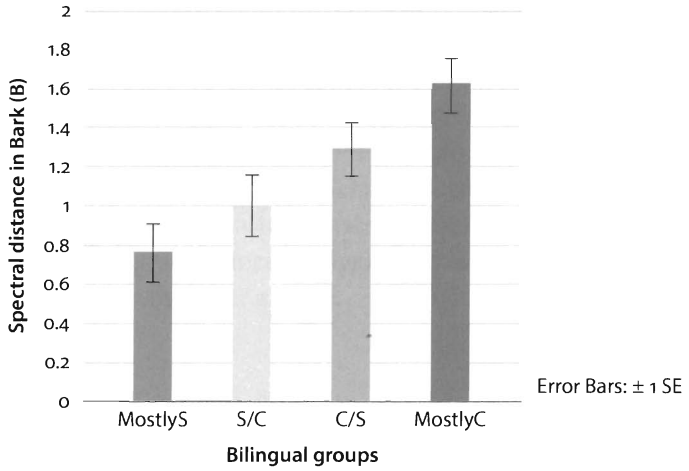

Figure 3. Spectral distances (Bark) between /e/ and /ɛ/

by the MostlyC bilinguals. Thus, it appears that individual participants within each one of the groups tended to either merge or contrastively produce the mid-front vowel contrast. The differences in scores between the MostlyC and the MostlyS bilingual groups may be accounted for by assuming that most participants in the MostlyC bilingual group are likely to have developed two distinct phonetic representations for /e/ and /ɛ/, whereas most of the bilinguals in the MostlyS group may have not succeeded in creating a distinct phonetic category for Catalan /ɛ/. This would explain why the MostlyS group's /e/-/ɛ/ SD scores were significantly smaller than those by MostlyC bilinguals, and probably indicates that MostlyS bilinguals realize /e/ and /ɛ/ as a single merged /e/-/ɛ/ category.

On the basis of this assumption we further investigated the SD scores for the /e/-/ɛ/ contrast by assigning participants to one of three groups according to a perceptual measure of the degree of categoriality in the perception of the /e/-/ɛ/ contrast that was obtained earlier in the study by Mora, Keidel & Flege (2011). A perceptual 'Spectral Effect Score' (SES) was calculated by subtracting the mean proportion of /e/ responses obtained at steps 1 and 2 of the /e/-/ɛ/ continuum from the mean proportion of /e/ responses obtained at steps 9 and 10 of the /e/-/ɛ/ continuum (Flege, Bohn & Jang 1997). The resulting SES scores estimated the size of the perceptual effect of changing vowel quality from /e/ to /ɛ/. A SES score of 1.0 indicated a complete change in perception from one vowel category to the other, whereas a SES of 0.0 would indicate a complete inability to perceptually note a change from one vowel to the other. Participants were thus assigned to one of three /e/-/ɛ/ perception groups: HighSES (*mean*=1.0, *sd*=0.0, n=25), MidSES

(*mean*=0.72, *sd*=0.13, n=32) and LowSES (*mean*=0.21, *sd*=0.14, n=25) and their corresponding production SD scores were examined accordingly. The participants who readily perceived a difference between /e/-/ɛ/ (HighSES) were found to produce SD scores (in Bark) for the /e/-/ɛ/ contrast that were larger (*mean*=1.56, *sd*=0.6) than those produced by the participants who perceived only moderately well the difference between /e/-/ɛ/ (MidSES, (*mean*=1.21, *sd*=0.7), who in turn produced larger between-vowel differences than did the participants who had difficulty perceiving the difference between /e/-/ɛ/ (LowSES group, *mean*=0.82, *sd*=0.5).

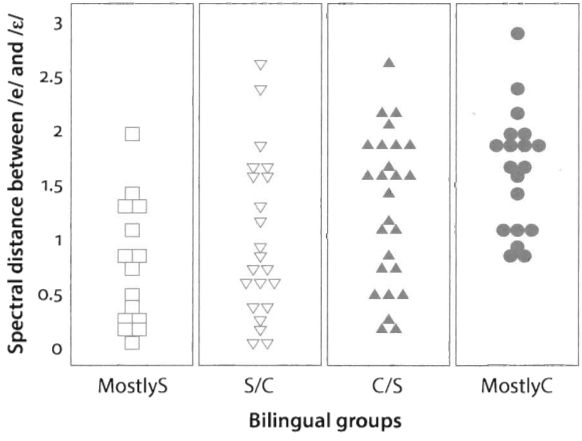

Figure 4. Individual spectral distances between /e/ and /ɛ/

The SD scores were then submitted to a one-way ANOVA with SES groups (HighSES, MidSES and LowSES) as the between subjects factor. This yielded a significant main effect of SES group ($F(2, 79)=7.74$; $p=.001$). Tukey post-hoc tests revealed that the HighSES group obtained significantly larger SD scores than the LowSES group ($p=.001$), but the MidSES group did not differ from either the HighSES or the LowSES groups ($p=.125$ and $p=.079$, respectively) in SD scores. These results indicated that bilingual participants who perceived the /e/-/ɛ/ contrast more categorically (HighSES) had probably developed two distinct phonetic categories for /e/ and /ɛ/ and consequently produced the contrast with larger SD scores, that is, they realized the vowels /e/ and /ɛ/ more distinctly, whereas bilingual participants who perceived the /e/-/ɛ/ contrast less categorically (LowSES) had probably not formed two different phonetic categories for /e/ and /ɛ/ and thus produced these vowels less distinctly.

We tested the association between degree of categoriality in perception and spectral distance in production by comparing the distribution of

HighSES bilinguals (who produced the /e/-/ɛ/ contrast with relatively large SD scores) and LowSES bilinguals (who produced the /e/-/ɛ/ contrast with relatively small SD scores) across the four bilingual groups determined on the basis of frequency of Catalan use (MostlyS, S/C, C/S, MostlyC). A Pearson's Chi-Square test indicated that in the MostlyC and C/S groups there was a significantly larger number of HighSES bilinguals (66% and 64.3%, respectively) than LowSES bilinguals (33.3% and 35.7%), and the opposite distribution was found within the S/C and MostlyS groups ($\chi^2(3)=11.54$, $p=.009$). This finding confirmed that the proportion of bilinguals who perceive the /e/-/ɛ/ contrast categorically and produce it with a distinct spectral difference is significantly larger in those participant groups that used Catalan more frequently (MostlyC and C/S) than in those who used Spanish more frequently (S/C and MostlyC).

4. Discussion and conclusions

The present study investigated the production of the Catalan mid-front and mid-back vowel contrasts by four groups of Spanish-Catalan bilinguals differing in the self-reported frequency of daily use of Catalan. The language dominance of participants was not assessed, but it seems reasonable to think that those who used Catalan most of the time were Catalan dominant whereas those who used Spanish most of the time were dominant in that language. The four groups were found to differ significantly in vowel production, specifically, in their ability to distinguish the mid-front vowels /e/ and /ɛ/. In particular, Spanish-Catalan bilinguals using Catalan most of the time (the "MostlyC" group) were found to produce larger spectral differences between /e/ and /ɛ/ than did other bilinguals who used Catalan less often. This finding for vowel production parallels results of an earlier study with the same participants which examined vowel perception (Mora, Keidel & Flege 2011), where performance also varied as a function of frequency of daily use of Catalan. The present findings for vowel production are also similar to the results obtained by Mora & Nadeu (2012). These authors found that native speakers of Catalan (born and raised in Catalan-speaking homes and who had learnt Spanish after the age of 4–5) using Spanish more frequently had a more Spanish-like acoustic target in the production of Catalan /ɛ/, suggesting that extensive L2 experience affected their native Catalan sound categories in production.

Unlike the L1-Catalan Catalan-dominant population examined by Mora & Nadeu (2012), the participants in the present study represented a continuum of language use patterns. Here, self-reported use of Catalan ranged from an average

of just 11% daily use of Catalan for the "MostlyS" group to an average of 86% for the "MostlyC" group. This wide variation in the use of Catalan (and a corresponding wide range of Spanish use) reflects the linguistic reality of Barcelona, and is likely to index very important differences in amounts of exposure to the kinds of Catalan that bilingual speakers experience in Barcelona. In particular, one might infer that individuals living in Barcelona are likely to be exposed to heterogeneous forms of Catalan input because Catalan is spoken by a range of speakers whose own learning experiences and daily contact patterns differ importantly. Specifically, we infer that the participants in this study had often heard Catalan spoken with a Spanish-accent, where the neutralization of mid-front vowels occurs frequently, and that this may constitute one of the sources of the perceptual 'weakening' of the mid-vowel contrasts in their perception of Catalan.

In addition to comparing groups using ANOVA techniques, a careful analysis of individual participants was undertaken. The results of these analyses were interpreted to mean that more participants who usually spoke Catalan developed two distinct phonetic categories and thus clearly distinguished Catalan mid-front vowels, whereas, in turn, a smaller proportion of the participants who used Catalan less frequently were able to develop two distinct categories for Catalan /e/ and /ɛ/. These results underscore the importance of frequency of language use — and presumably the kind of phonetic input received — as a contributing factor in the development of phonetic categories for bilingual speakers in situations of language contact. However, it is important to note that a considerable proportion of speakers assigned to one of the four different groups of bilinguals on the basis of their frequency of use of Catalan appeared to produce the mid-front vowel contrast with comparable spectral distance values (Figure 4), thus indicating relatively large inter-subject variation within each one of the bilingual groups. For example, a few of the bilingual speakers who used Catalan most of the time (MostlyC) were found to produce /e/ and /ɛ/ with spectral distance scores that approximated the mean spectral distance scores of the bilinguals that used Spanish most of the time (MostlyS). This suggests that high frequency of use of Catalan *promotes* the development of two distinct categories for the Catalan mid-front vowels, but does not in itself guarantee that such categories will be formed. It is plausible to think that extensive exposure to varying degrees of Spanish-accentedness in the mid-front Catalan vowels as produced by speakers with different patterns of use of Catalan and Spanish may have prevented some MostlyC speakers from developing fully distinct categories for these vowels. It is also possible that what really matters is actual input, and that having participants estimate their frequency of language use represents only a distant proxy for actual measures of phonetic input over their lifetime.

In summary, the overall picture that emerges from the Catalan mid-vowel data in the present study is that of a combination between individual speakers' patterns of usage of Catalan and Spanish and variation in the type of Catalan input received, which may explain the lack of robustness in perception of the mid-vowel contrasts found by Mora, Keidel & Flege (2011) as well as the differences in the degree of contrastiveness of these vowels in production by the four bilingual groups in the present study.

These findings suggest that bilinguals' patterns of language use in adulthood over extended periods of time in a situation of language contact may have effects on the production of native vowel categories. The fact that Catalan /e/ and /ɛ/ appear to be realized less distinctively by early bilingual speakers using Spanish more frequently than by early bilinguals mostly using Catalan suggests that such patterns of use may provide a source for the perceptual 'weakening' of the mid-vowel contrasts in Catalan through exposure to input that does not consistently provide listeners with fully distinct realizations of the mid-front vowels /e/ and /ɛ/.

References

Badia Margarit, Antoni Maria. 1969. "Algunes mostres de les igualacions ɛ=e and ɔ=o en el català parlat de Barcelona". *Sons i fonemes de la llengua catalana* ed. by Antoni Maria Badia Margarit, 97–103. Barcelona: Publicacions de la Universitat de Barcelona.

Badia Margarit, Antoni Maria. 1970. "Les vocals tòniques *e* i *o* en el català de Barcelona. *Sons i fonemes de la llengua catalana* ed. by Antoni Maria Badia Margarit, 141–190. Barcelona: Publicacions de la Universitat de Barcelona.

Baker, Wendy & Pavel Trofimovich. 2005. "Interaction of Native- and Second-Language Vowel System(s) in Early and Late Bilinguals". *Language and Speech* 48:1.1–27. DOI: 10.1177/00238309050480010101

Best, Catherine T. 1995. "A Direct Realist View of Cross-Language Speech Perception". *Speech Perception and Linguistic Experience: Issues in cross-language research* ed. by Winifred Strange, 171–204. Baltimore, Md.: York Press.

Best, Catherine T. & Michael D. Tyler. 2007. "Nonnative and Second-Language Speech Perception: Commonalities and complementarities". *Language Experience in Second Language Speech Learning: In honor of James Emil Flege* ed. by Ocke-Schwen Bohn & Murray J. Munro, 13–34. Amsterdam & Philadelphia: John Benjamins. DOI: 10.1075/lllt.17.07bes

Boersma, Paul & David Weenink. 2009. *Praat: Doing phonetics by computer: Version 5.1.05* (http://www.praat.org/) (Retrieved on May 1, 2009).

Bohn, Ocke-Schwen & James E. Flege. 1990. "Interlingual Identification and the Role of Foreign Language Experience in L2 Vowel Perception". *Applied Psycholinguistics* 11:3.303–328. DOI: 10.1017/S0142716400008912

Bosch, Laura, Albert Costa & Núria Sebastián-Gallés. 2000. "First and Second Language Vowel Perception in Early Bilinguals". *European Journal of Cognitive Psychology* 12:2.189–221. DOI: 10.1080/09541446.2000.10590222

Bosch, Laura & Marta Ramon-Casas. 2011. "Variability in Vowel Production by Bilingual Speakers: Can input properties hinder the early stabilization of contrastive categories?". *Journal of Phonetics* 39:4.514–526. DOI: 10.1016/j.wocn.2011.02.001

Flege, James E. 1995. "Second Language Speech Learning: Theory, findings, and problems". *Speech Perception and Linguistic Experience: Issues in cross-language research* ed. by Winifred Strange, 233–277. Baltimore, Md.: York Press.

Flege, James E. 2007. "Language Contact in Bilingualism: Phonetic system interactions". *Laboratory Phonology 9* ed. by Jennifer Cole & José Ignacio Hualde, 353–382. Berlin: Mouton de Gruyter.

Flege, James E., Ocke-Schwen Bohn & Sunyoung Jang. 1997. "Effects of Experience on Non-Native Speakers' Production and Perception of English vowels". *Journal of Phonetics* 25:4.437–470. DOI: 10.1006/jpho.1997.0052

Flege, James E., Naoyuki Takagi & Virginia Mann. 1995. "Japanese Adults can Learn to Produce English /r/ and /l/ Accurately". *Language and Speech* 38:1.25–55.

Hattori, Kota & Paul Iverson. 2009. "English /r/-/l/ Category Assimilation by Japanese Adults: Individual differences and the link to identification accuracy". *Journal of the Acoustical Society of America* 125:1.469–479. DOI: 10.1121/1.3021295

Institut d'Estudis Catalans. 2011. *Coneixements i usos del català a Catalunya el 2010: Dades del baròmetre de la comunicació i la cultura.* [Knowledge and Use of Catalan in Catalonia in 2010: Data from the Communication and Culture Barometer]. Barcelona: Institut d'Estudis Catalans.

Iverson, Paul, Valerie Hazan & Kerry Bannister. 2005. "Phonetic Training with Acoustic Cue Manipulations: A comparison of methods for teaching English /r/-/l/ to Japanese adults. *Journal of the Acoustical Society of America* 118:5.3267–3278. DOI: 10.1121/1.2062307

Larsson, Johan P., Fátima Vera-Constán, Núria Sebastián-Gallés & Gustavo Deco. 2008. "Lexical Plasticity in Early Bilinguals does not Alter Phoneme Categories. I: Neurodynamical modelling". *Journal of Cognitive Neuroscience* 20:1.76–94. DOI: 10.1162/jocn.2008.20004

Mora, Joan C., James L. Keidel & James E. Flege. 2011. "Why Are the Catalan Contrasts between /e/-/ɛ/ and /o/-/ɔ/ So Difficult for Even Early Spanish-Catalan Bilinguals to Perceive?". *Achievements and Perspectives in the Acquisition of Second Language Speech: New Sounds 2010* ed. by Magdalena Wrembel, Małgorzata Kul & Katarzyna Dziubalska-Kołaczyk, vol. II, 183–193. Frankfurt am Main: Peter Lang.

Mora, Joan C. & Marianna Nadeu, M. 2012. "L2 Effects on the Perception and Production of a Native Vowel Contrast in Early Bilinguals". *International Journal of Bilingualism* 16:4. 484–500. DOI: 10.1177/1367006911429518

Ortega-Llebaria, Marta & Bosch, Laura. 2015. "A Look at Prosodic, Rhythmic and Segmental Properties in Utterances from Two Catalan Dialects". This volume.

Pallier, Cristophe, Laura Bosch & Núria Sebastián-Gallés. 1997. "A Limit on Behavioral Plasticity in Speech Perception". *Cognition* 64:3.B9-B17. DOI: 10.1016/S0010-0277(97)00030-9

Ramon-Casas, Marta, Daniel Swingley, Núria Sebastián-Gallés & Laura Bosch. 2009. "Vowel Categorization during Word Recognition in Bilingual Toddlers". *Cognitive Psychology* 59:1.96–121. DOI: 10.1016/j.cogpsych.2009.02.002

Recasens, Daniel. 1991. *Fonètica descriptiva del català: Assaig de caracterització de la pronúncia del vocalisme i consonantisme del català al segle XX*. Barcelona: Institut d'Estudis Catalans.

Recasens, Daniel & Aina Espinosa. 2006. "Dispersion and Variability of Catalan Vowels". *Speech Communication* 48:6.645–666. DOI: 10.1016/j.specom.2005.09.011

Recasens, Daniel & Aina Espinosa. 2009. "Dispersion and Variability in Catalan Five and Six Peripheral Vowel Systems". *Speech Communication* 51:3.240–258. DOI: 10.1016/j.specom.2008.09.002

Sebastián-Gallés, Núria, Sagrario Echeverría & Laura Bosch. 2005. "The Influence of Initial Exposure on Lexical Representation: Comparing early and simultaneous bilinguals". *Journal of Memory and Language* 52:2.240–255. DOI: 10.1016/j.jml.2004.11.001

Sebastián-Gallés, Núria, Antoni Rodríguez-Fornells, Ruth de Diego-Balaguer & Begoña Díaz. 2006. "First- and Second-Language Phonological Representations in the Mental Lexicon". *Journal of Cognitive Neuroscience* 18:8.1277–1291. DOI: 10.1162/jocn.2006.18.8.1277

Sebastián-Gallés, Núria, Fátima Vera-Constán, Johan P. Larsson, Albert Costa & Gustavo Deco. 2009. "Lexical Plasticity in Early Bilinguals does not Alter Phoneme Categories. II: Experimental evidence". *Journal of Cognitive Neuroscience* 21:12.2343–2357. DOI: 10.1162/jocn.2008.21152

Simonet, Miquel. 2010. "Dark and Clear Laterals in Catalan and Spanish: Interaction of phonetic categories in early bilinguals". *Journal of Phonetics* 38:4.663–678. DOI: 10.1016/j.wocn.2010.10.002

Simonet, Miquel. 2011. "Production of a Catalan-Specific Vowel Contrast by Early Spanish-Catalan Bilinguals". *Phonetica* 68:1–2.88-110. DOI: 10.1159/000328847

Syrdal, Ann K. & Hundrai S. Gopal. 1986. "A Perceptual Model of Vowel Recognition Based on the Auditory Representation of American English Vowels". *Journal of the Acoustical Society of America* 79:4.1086–1100. DOI: 10.1121/1.393381

Traunmüller, Hartmut. 1997. *Auditory Scales of Frequency Representation*. (http://www.ling.su.se/staff/hartmut/ bark. htm) (Retrieved on November 11, 2007).

Yamada, Reiko A. 1995. "Age and Acquisition of Second Language Speech Sounds: Perception of American English /ɹ/ and /l/ by native speakers of Japanese". *Speech Perception and Linguistic Experience: Issues in cross-language research* ed. by Winifred Strange, 305–320. Baltimore, Md.: York Press.

Appendix: The reading-aloud task in Catalan

Orthographic transcription

Ens estan prenent el pèl i no és just. Es pensen que som cecs, i muts, i estúpids. Un pis de segona mà de menys de trenta metres quadrats és una cosa que ningú no vol, però ja no és un fet insòlit. Ja fa temps que la gent no sap què fer per accedir a un pis decent, perquè no s'ho pot permetre, en especial persones amb un sou baix i sense poder econòmic, com per exemple gent jove; però ningú no es queixa. El problema és que, segons la llei, aquests pisos no es poden vendre. Per això el regidor Jordi Mestres va dir que cal més control, perquè no n'hi ha prou, i s'hauria de tancar més l'aixeta dels beneficis d'alguns. "El que s'ha de fer és posar una multa a aquells propietaris que amb tota la mala fe posin a la venda un pis sense que aquest compleixi les mínimes condicions per viure-hi bé.

Phonetic transcription

The underlined words were selected for acoustic analysis (target vowels appear in **bold**). "/" indicates a tone unit boundary.

[ənz əsˈtan pɾəˈnen əl ˈpɛl i no ez ˈʒust/əs ˈpɛnsən kə som ˈseks/i ˈmuts/i əsˈtupits/um ˈpis də seˈɣonə ˈma ðə ˈmɛɲz də ˈtɾɛntə ˈmɛtrəs kwəˈðɾats/ez unə ˈkɔzə kə ninˈgu no ˈβɔl/pɾɔ ʒa no ez uɲ ˈfet inˈsɔlit/ˈʒa ˈfa ˈtemps kə lə ˈʒen no ˈsap kɛ ˈfe pər əksəˈði ə un ˈpis dəˈsen/pərkɛ no su ˈpɔt pərˈmɛtrə/ən əspəˈsjal pərˈsonəz əmb un ˈsɔw ˈβaʃ i sensə puˈðɛr əkuˈnɔmik/kɔm pər əgˈzemplə ˈʒen ˈʒoβə/pɾɔ ninˈgu no əs ˈkeʃə/əl pɾuˈβlɛmə es kə seˈɣons lə ˈʎɛj/əkɛts ˈpizuz no əs ˈpɔðən ˈbɛndɾə/pər əˈʃɔ əl rəʒiˈðo ˈʒɔɾði ˈmɛstrəs βa ˈði kə ˈkal mes kunˈtrəl/pərkɛ ˈno ni a ˈpɾɔw/i sauˈɾiə ðə təɲˈka ˈmes ləˈʃɛtə dəlz bənəˈfisis dəlˈɣuns/əl kə ˈsa ðə ˈfe es puˈza unə ˈmultə ə əˈkɛʎz pɾupiəˈtaɾis kə əm ˈtotə lə ˈmalə ˈfɛ ˈpɔzin ə lə ˈβɛndə um ˈpis sensə ke əˈkɛt kumˈplɛʃi ləz ˈminiməs kundiˈsions pər ˈβiwɾə i ˈβe]