

# Why are the Catalan contrasts between /e/-/ɛ/ and /o/-/ɔ/ so difficult for even early Spanish-Catalan bilinguals to perceive?

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## ABSTRACT

Previous research has shown that Catalan mid-vowel contrasts remain difficult for native Spanish adults to perceive, even those who began using Catalan as an L2 as young children. Here we tested 82 Spanish-Catalan bilinguals first exposed to their L2 by school age (3-6 years) who differed in self-reported use of Catalan. All participated in categorization and AXB discrimination tasks using four 10-step vowel continua. The endpoints of 2 high-mid vowel continua (/i/-/e/, /u/-/o/) were vowels that contrast in both Spanish and Catalan whereas those in the remaining 2 mid-mid vowel continua (/e/-/ɛ/, /o/-/ɔ/) were mid vowels that do not contrast phonemically in Spanish. We hypothesized that Catalan mid-vowels contrasts are difficult not only because of cross-language phonological differences between Spanish and Catalan, but also because these phonemic contrasts are phonetically “weak” as a result of several factors. All participants perceived the high-mid contrasts less categorically than the mid-vowel contrasts but the magnitude of the difference seemed to depend on frequency of Catalan use. While not excluding possible effects of even brief delays in exposure to vowel contrasts found in an L2, these findings suggested the importance of variations on overall amount of L2 exposure on the eventual L2 performance of bilingual adults.

KEYWORDS: vowel perception, experience, maturational constraints, Catalan, Spanish

## 1. Introduction

Age of onset of L2 learning strongly affects L2 speech production and perception. For example, age of learning differences yield strong effects on overall degree of perceived foreign accent (see Piske et al. 2001). Generally speaking, early learners outperform late learners in many different aspects of L2 speech perception and production. According to some, age effects are caused by a loss of cerebral plasticity during the course of normal maturation (DeKeyser 2000). Previous research has also demonstrated robust effects of experience, normally operationalized as amount and type of L1/L2 input received, on bilinguals' speech production and perception between L1 and L2 phones (Flege and Liu 2001; Bohn and Flege 1990; Flege et al. 1997). One possibility, at least for individuals who learn an L2 upon immigration to an L2-speaking country, is that increased experience using the L2 may gradually augment perceptual sensitivity to L1-L2

phonetic differences, or to differences between L2 sounds that are not contrastive in the L1. This might increase the likelihood of new categories being established for sounds found in the L2 but not the L1 which, in turn, may result in increased L2 production accuracy (Flege 1995, Flege 2002, 2007).

When do “age” effects first become evident? Research in Barcelona suggests that even “early” learners of an L2 may not become fully native-like. This research focused on contrasts between Catalan mid vowels (/e/-/ɛ/, /o/-/ɔ/) which are hypothesized to be perceptually difficult for native speakers of Spanish due to “single-category assimilation” patterns (Best and Tyler 2007). Importantly Catalan has two vowels (/e/, /ɛ/) where Spanish has just one, /e/ (Bosch et al. 2000). Perceiving two L2 vowels as a single L1 vowel may result in functional “deafness” to the contrast.

Research using a variety of techniques has shown that Catalan mid-vowel contrasts are difficult even for native speakers of Spanish who began learning Catalan as young children (Sebastián-Gallés and Soto-Faraco 1999; Sebastián-Gallés and Bosch 2005, Pallier et al. 1997; Sebastián-Gallés et al. 2005), leading these investigators to hypothesize that the L1 inevitably influences performance in a language learned later in life, even if the L2 is learned in early childhood. Here we investigated an alternate possibility, namely the nature of the Catalan vowel system rather than the effect of Spanish-Catalan phonological differences on perceptual learning.

There is reason to think that Catalan mid-vowel contrasts are less robust (Badia Margarit 1969, 1970; Recasens 1993) than contrasts between other pairs of Catalan vowels. Mid-vowel contrasts are not consistently realized in a relatively large number of words in the dialect of Catalan spoken in Barcelona, where the research just cited was carried out. Variation exists in how mid vowels are realized phonetically in dialects where mid vowels do contrast consistently (e.g. Eastern Catalan /'bɛwrə/ *beure* ‘to drink’ vs. Western Catalan /'bewrə/ (Carrera-Sabaté and Fernández-Planas 2005; Recasens and Espinosa 2006). In some sub-dialects of Eastern Catalan (e.g. Sitgetà) the /e/-/ɛ/ contrast is best characterized as having undergone a near-merger process (Recasens and Espinosa 2009). Moreover, the implementation of mid vowels may vary across lexical items in a single dialect (*res* ‘nothing’ /res/-/rɛs/). Also, there is a general tendency in Catalonia for young people to neutralize mid vowel contrasts, for example, to pronounce /ɛ/ with an [e]-quality vowel (Recasens 1993: 86) perhaps due to the influence of Spanish, which lacks such a contrast.

Other factors may also contribute to a reduction of robustness in Catalan mid-vowel contrasts. One is low functional load. There are relatively few Catalan minimal pairs involving the contrast /e/-/ɛ/. Vowel reduction processes in unstressed syllables may neutralize /e/-/ɛ/ into /ə/, and there may be inconsistencies in the articulation of root vowel (e.g. *pes* /pɛs/ ‘weight’ vs. *peso* /'pezu/ ‘I weigh’, cf. *pesar* /pə'za/ ‘to weigh’). Finally, high-mid vowel contrasts

are often neutralized in the speech of native Spanish speakers of Catalan (Badia Margarit 1970). Thus foreign-accented input may further obscure the phonetic nature of Catalan mid vowel contrasts for those learning Catalan in Barcelona (Cortés et al. 2009, Larsson et al. 2008, Sebastián-Gallés et al. 2008).

Surprisingly little research has been carried out to test the hypothesis that a lack of robustness in Catalan mid vowel contrasts may help explain perceptual difficulties evidenced by early native Spanish learners of Catalan. A recent study by Mora and Nadeu (2009) compared two groups of Spanish-Catalan bilinguals. The members of both groups spoke Catalan from birth and were dominant in Catalan. The two groups differed only in terms of self-reported Catalan use. Neither group showed a fully categorical perception of /e/-/ɛ/, as suggested by the relatively low mean % correct discrimination rate in across-boundary stimuli pairs (70-76%). Interestingly, the less frequent users of Catalan showed significantly higher response latencies (RTs) when discriminating /e/-/ɛ/, suggesting experience-related effects on processing speed.

These preliminary findings are consistent with recent research on the impact of phonological variation on phoneme perception investigating the robustness of the French vowel contrast /e/-/ɛ/, which is in the process of merging in Northern France. Brunellière et al. (2009) tested French-speaking participants from Switzerland on the perception of the unstable /e/-/ɛ/ contrast vs. the stable /ø/-/y/ contrast by means of a same-different task using behavioural and electrophysiological (ERP) measures. Their ERP results show that the two contrasts were processed differently. Specifically, the stable /ø/-/y/ contrast was discriminated faster and better than the unstable /e/-/ɛ/ contrast. The ERP results were consistent with the behavioural data, which showed higher error rates and slower RTs for /e/-/ɛ/.

Taken together, findings from this and previous research on the Catalan mid-vowel contrasts call for further research on the degree of robustness of the mid-vowel contrasts and the effect of L1/L2 experience on bilingual vowel perception.

## 2. Method

This study assessed degree of perceptual robustness of the Catalan mid-vowel contrasts for Spanish-Catalan bilinguals who were exposed to their L2 (Spanish or Catalan) as young children and reported using both of their languages on a daily basis. It evaluated the effect of L1/L2 experience on the perception of two Catalan mid vowel contrasts and two other Catalan vowel contrasts which served as controls.

It was impossible to recruit a group of Catalan monolinguals in Barcelona under the age of 50 years owing to the pervasiveness of Spanish. However, careful participant screening and selection procedures yielded groups of bilinguals

who differed according to their frequency of Catalan use. We assumed that the Spanish-Catalan bilinguals who used Spanish (S) infrequently would most closely approximate a monolingual Catalan (C) group, had it been possible to recruit such a group. That being the case, the “mostly-C” group would show the most categorical perception of C mid vowel contrasts. All of the bilinguals participated in categorization and discrimination (AXB) perception tasks based on acoustic spectral continua and a production reading-aloud task. Owing to space limitations, just the perception results will be reported here.

### 2.1. Participants

A total of 82 Spanish-Catalan (S-C) bilinguals were selected from the 719 S-C bilinguals who responded to ads placed in public libraries located throughout Barcelona. A short telephone interview and a written linguistic background questionnaire provided the information for subsequent screening. All the selected participants were first exposed to Catalan before they went to school, or at the latest when they started school at the age of 5 or 6 years. All participants were born and raised in Barcelona. All reported being able to speak and understand both Catalan and Spanish.

As shown in Table 1, participants were assigned to one of four groups based on self-reported percent of use of Catalan (%C) in several contexts (at home, at work, on social occasions, with relatives, with friends, and overall). To facilitate discussion, these bilingual groups will be referred to as “mostly Spanish” (< 25% Catalan use), “S/C” (30-50% Catalan use), “C/S” (50-70% Catalan use), and “mostly Catalan” (> 75% Catalan use). Participants also differed as to which language (L1) they were exposed to before schooling age (3-6): exposed only to Catalan before schooling age (“C”,  $N=28$ ), exposed both to Catalan and Spanish simultaneously before schooling age (“C+S”,  $N=17$ ) and exposed only to Spanish before schooling age (“S”,  $N=37$ ).

Table 1. Characteristics of the 4 groups; “S” and “C” refer to Spanish and Catalan, respectively. SDs in parentheses.

	Mostly-S (n=15)	S/C (n=21)	C/S (n=26)	Mostly-C (n=20)
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 age (3-6)	C=1; C+S=3; S=11	C=0; C+S=5; S=16	C=9; C+S=9; S=8	C=18; C+S=0; S=2

## 2.2. Method and analyses

The stimuli used in both identification and discrimination tasks were drawn from 4 synthetic vowel continua: two high-mid vowel continua (/i/-/e/, /u/-/o/) with mid vowel endpoints that contrast in both Spanish and Catalan and two mid-mid vowel continua (/e/-/ɛ/, /o/-/ɔ/) with mid vowels that contrast phonemically only in Catalan. In each, F1, F2 and F3 frequencies varied in 10 steps whereas vowel duration and F4 were held constant (289 ms, 3570 Hz). For example, in the /e/-/ɛ/ continuum, F1 ranged from 450-580 Hz, F2 from 1840-1700 Hz, and F3 from 2570-2430 Hz. The endpoints of two continua were both mid vowels, /e/-/ɛ/ and /o/-/ɔ/. In the other two continua (/i/-/e/ and /u/-/o/), one endpoint was a mid vowel, the other was a high vowel. A total of 120 stimuli were presented for forced-choice in the identification task (4 continua x 10 stimuli x 3 repetitions; ITI=2 sec.). The AXB discrimination task was designed with a 2-step resolution and contained 256 stimuli (8 triads x 4 orders x 4 continua x 2 repetitions; ISI=1 sec, ITI=1.5 sec). DmDx display software was used to run both experiments in a quiet room in a session lasting about 45 min. The participants heard the stimuli over headphones and selected one of two response alternatives shown on a computer screen. These stimuli in both tasks were presented in fully randomized blocks (one per continuum). The order in which the continua were tested was counterbalanced across the participants in each group.

Several measures were derived from responses to the identification (ID) and discrimination (DIS) tasks for each continuum. The ID measures included the estimated location of the 50% crossover from one response category to the other (i.e., the “boundary”), the width of the category boundaries, the overall amount of change from one response category to the other (spectral effect scores), percent correct ID, and difference scores computed for pairs of stimuli that did/did not straddle the boundary. The DIS measures included overall percent correct, and percent correct for pairs of stimuli that did/did not straddle category boundaries. Correlations were computed to explore effects of language use as well as the relation between identification and discrimination. A multiple regression analysis was used to compare the contribution of language use and L1 independent variables to explaining the ID and DIS scores. Finally, a mixed-design ANOVA was used to test for a possible interaction between Group (4 levels: Mostly S, S/C, C/S, Mostly C) and Vowel Continuum (4 levels, 2 representing contrasts found in Spanish as well as Catalan).

## 3. Results

We began by exploring whether %C use was correlated with the various outcome measures obtained for high-mid contrasts. Of the 28 tests performed (14 variables

x 2 continua), only 2 reached significance ( $p < 0.05$ ). When the same tests were carried out for the two mid-mid vowel contrasts, 8 correlations reached significance at the .05 level (and 4 at the 0.01 level). These mostly involved boundary width and spectral effect scores measures for the /e/-/ɛ/ contrast, suggesting that accuracy in the perception of this contrast is related to amount of use of Catalan.

In general significant positive correlations showed that the subjects' ID and DIS scores (ID scores mainly) for the /e/-/ɛ/ contrast (as opposed to /i/-/e/, /u/-/o/ and /o/-/ɔ/) varied as a function of %C use. Because the /i/-/e/ and /u/-/o/ contrasts exist both in Catalan and Spanish and are more robust than the mid vowel contrasts, little variation in performance (ID and DIS tasks) was found among participants as a function of L1/L2 experience. Significant correlations between ID and DIS scores were found in particular for the /e/-/ɛ/ contrast. In general, and for all vowel contrasts, significant correlations between ID and DIS measures were relatively weak ( $r < .5$ ). For the /e/-/ɛ/ contrast, ID measures capturing the degree of categoricity in the perception of the contrast generally correlated significantly with discrimination scores, suggesting that speakers who perceived the /e/-/ɛ/ contrast more categorically also discriminated the contrast more accurately (particularly in across-boundary pairs drawn from the continuum).

### 3.1. Identification

Category boundaries were generally located between steps 5 and 6 for the /i/-/e/ and /u/-/o/ continua, and between steps 4-5 for the /o/-/ɔ/ continuum. The /e/-/ɛ/ boundary occurred between steps 2 and 3 ( $mean = 2.7$ ) for Mostly-S, indicating substantially more /e/ than /ɛ/ responses. The boundary width (the range of stimuli between the 0.25 and 0.75 proportion of identification of the closer vowel in each continua) was narrower, indicating a more rapid change from one category to another (and thus more nearly "categorical" perception), for the two high-mid vowel contrasts (1.0-1.5 stimuli) than for the two mid-mid vowel contrasts (3.3-4.0 stimuli). The boundaries were also narrower for /o/-/ɔ/ (2.3-3.2 stimuli) than for /e/-/ɛ/ (3.4-4.0 stimuli). A tendency was observed for category width to become narrower as use of Catalan increased, particularly for the mid-mid vowel contrasts. Finally, lower slope coefficients (obtained through curve fitting by means of logistic regression) indicated steeper ID functions (more categorical perception) for high vowels than for mid vowels and for back vowels than for front vowels.

Identification scores were submitted to mixed between-within ANOVAs with Contrast (4 levels: /i/-/e/, /e/-/ɛ/, /u/-/o/ and /o/-/ɔ/) as the within subjects factor and %C groups (4 levels: mostly-S, S/C, C/S, mostly-C) and L1 (C, C+S and S) as between-subjects factors. The main effect of Contrast did not reach significance for the boundary location measure ( $F(3, 70)=2.54, p=0.63$ ), but the Contrast

factor was found to be significant for the boundary width measures ( $F(3, 76)=54.2, p<0.01$ ; no significant Contrast x %C interaction,  $p=.937$ ) and the identification function slope coefficients ( $F(3, 74)=12.3, p<0.01$ ; the Contrast x %C interaction was non-significant,  $p=.519$ ). Further Bonferroni-adjusted pairwise comparisons revealed that for both the boundary width and the slope measures, all vowel contrasts, except /i/-/e/ vs. /u/-/o/, differed significantly at the  $p<.01$  level.

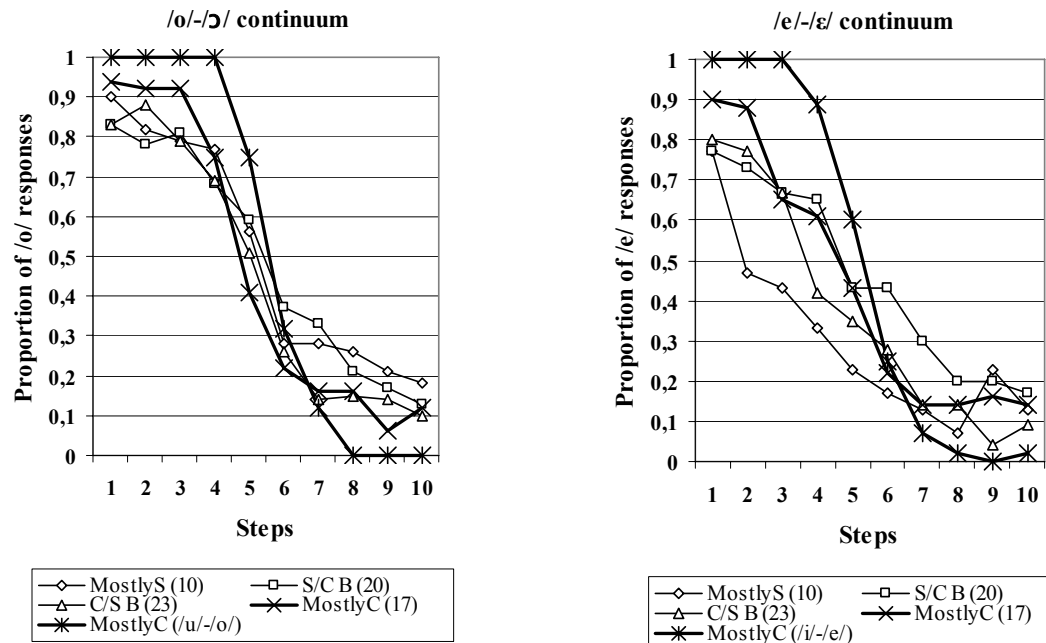
These findings indicated that Spanish-Catalan bilinguals perceived high-mid and mid-mid vowel contrasts in a significantly different way, mid-mid vowel contrasts being perceived less categorically than high-mid vowel contrasts. However, the ANOVAs failed to reveal a significant main effect of %C- or L1-related differences observed in boundary location, boundary width and slope ( $p=.418, p=.463, p=.265$ , respectively).

An examination of spectral effect scores (SESs: the difference in number of /i/, /e/, /u/ and /o/ responses for the first two and the last two stimuli in the /i/-/e/, /e/-/ɛ/, /u/-/o/ and /o/-/ɔ/ continua, respectively) revealed a similar pattern of results. The SESs were found to be much lower for mid-mid than for the high-mid vowel contrasts, indicating much shallower ID function curves (Table 2). SESs scores varied systematically as a function of subject group for both mid-mid vowel contrasts, participants who used Catalan more often showing a more substantial shift in judgments as the result of spectral changes (larger SES scores and thus steeper curves, indicating more categorical perception of the contrast) than those who used Catalan relatively seldom. Because of the difficulty in the perception of the Catalan mid-mid vowel contrasts, several participants obtained almost linear or even reversed ID functions (MostlyS=26.7%; S/C B=13.6%; C/S B=15.4%; MostlyC=10.5%). However, even when such participants were removed from the data analyses (cf. Flege et al. 1997) the same pattern of results were obtained (Figure 1). A mixed ANOVA on SESs yielded a significant main effect for Contrast ( $F(3, 76)=28.4, p<.01$ ), the Contrast x %C and Contrast x L1 interactions, and the main effects of %C ( $p=.235$ ) and L1 ( $p=.114$ ) were non-significant.

Table 2. Spectral effect scores (steps 1-2 minus step 9-10). SDs in parentheses.

SES	high-mid			mid-mid				
	Mostly S	S/C	C/S	Mostly C	Mostly S	S/C	C/S	Mostly C
FRONT Vs	100 (<1)	98 (6)	96 (14)	99 (4)	16 (50)	42 (63)	57 (55)	61 (50)
BACK Vs	99 (4)	100 (0)	99 (3)	100 (0)	44 (72)	58 (50)	63 (54)	69 (52)

Figure 1. /e/-/ɛ/ and /o/-/ɔ/ ID functions (with /i/-/e/ and /u/-/o/ ID functions from MostlyC included for comparison). The numbers in brackets indicate number of subjects per group (only participants with semi-categorical functions are included).



In general, the ID scores obtained were consistent with a difference in the degree of categorality in perception between high-mid and mid-mid vowel contrasts. The effect of L1/L2 experience on the perception of the mid-mid vowel contrasts did not reach significance for these ID measures, despite the consistent tendency observed for Spanish-Catalan bilinguals with higher %C use to perceive the mid-mid vowel contrasts more categorically. A multiple regression analysis assessing the ability of the %C and L1 factors to predict participants' SESs revealed that %C (but not L1) made the strongest unique (significant) contribution to explaining SESs in the case of the front mid-mid vowel contrast ( $p=.035$ ), explaining 6.76% of the variance in the SESs.

### 3.2. Discrimination

Three main vowel DIS measures were used: Mean percent correct discrimination across all vowel pairs in the continuum (DIS\_1), mean percent correct discrimination in across-category pairs (stimuli pairs 4-6 and 6-7) where a discrimination peak is predicted on the basis of the category boundary location (DIS\_2), and mean percent correct discrimination in within-category pairs (DIS\_3). In general the DIS scores reflect the ID data and follow a very similar



pattern in that high-mid vowel contrasts were discriminated more accurately than mid-mid vowel contrasts. Back vowel pairs were discriminated more accurately than front vowel pairs (Table 3).

Table 3. Discrimination scores (% correct). *SDs* in parentheses.

DIS	high-mid				mid-mid				
	Mostly S	S/C	C/S	Mostly C	Mostly S	S/C	C/S	Mostly C	
1	FRONT	64,4 (7)	67,1 (10)	68,5 (9)	70,4 (10)	58,5 (10)	64,4 (8)	62,8 (9)	63,5 (13)
	BACK	72,6 (10)	72,7 (9)	72,4 (12)	75,4 (8)	67,7 (8)	68,1 (10)	72,1 (12)	73,7 (10)
2	FRONT	67,9 (19)	70,1 (15)	65,8 (17)	72,7 (14)	53,6 (16)	63,7 (14)	63,4 (13)	64,2 (20)
	BACK	79,1 (13)	79,5 (13)	78,8 (14)	81,9 (10)	75,0 (13)	71,2 (16)	77,2 (20)	79,9 (15)
3	FRONT	63,3 (6)	66,1 (11)	69,3 (9)	69,7 (11)	60,1 (11)	64,6 (9)	62,6 (9)	63,2 (12)
	BACK	70,4 (11)	70,4 (10)	70,2 (12)	73,2 (8)	65,2 (8)	67,1 (10)	70,3 (10)	71,7 (10)

DIS scores were submitted to mixed between-within ANOVAs with Contrast (4 levels: /i/-/e/, /e/-/ɛ/, /u/-/o/ and /o/-/ɔ/) as the within subjects factor and %C groups (4 levels: mostly-S, S/C, C/S, mostly-C) and L1 (C, C+S, S) as the between-subjects factors. Main effects for Contrast were found to be significant for the three discrimination measures ( $F(3, 76)=36.3, p<0.01$  for DIS\_1;  $F(3, 76)=26.8, p<0.01$  for DIS\_2 and  $F(3, 76)=7.77, p<0.01$  for DIS\_3), no significant Contrast x %C or L1 interactions or main effects for %C and L1 were significant. Bonferroni-adjusted pairwise comparisons revealed that for the DIS measures, differences in percent correct discrimination between /u/-/o/ and /o/-/ɔ/ were significant at the  $p<.05$  level, and at the  $p<.01$  level for differences between /i/-/e/ and /e/-/ɛ/. This suggests, in line with the ID data, that Spanish-Catalan bilinguals discriminated high-mid and mid-mid vowel contrasts significantly differently, mid-mid vowel contrasts (/e/-/ɛ/ in particular) being discriminated at a lower percent correct rates.

#### 4. Conclusion

This study set out to investigate a possible source for the often reported difficulty of early Spanish-Catalan bilinguals' perceptual difficulty with the Catalan mid-vowel contrasts /e/-/ɛ/ and /o/-/ɔ/ other than those attributable to differences in

early vs. late exposure to Catalan, or the interaction of the L1/L2 phonological subsystems of Catalan/Spanish bilinguals, all of which have already been extensively researched (e.g. Sebastián-Gallés and Bosch 2005). We hypothesized, on the basis of linguistic evidence in previous research on the instability of the /e-/ɛ/ contrast, that the Catalan mid-vowel contrasts /e-/ɛ/ and /o-/ɔ/ are phonetically “weak”, when compared to the high-mid vowel contrasts /i-/e/ and /u-/o/. We tested this hypothesis by having 4 groups of Spanish-Catalan speakers differing in the amount of Catalan spoken daily (Mostly-S, S/CB, C/SB, Mostly-C) participate in categorical identification and discrimination tasks based on mid (/e-/ɛ/ and /o-/ɔ/) and high (/i-/e/ and /u-/o/) vowel continua. The results show that all Spanish-Catalan bilinguals perceived the high-mid vowel contrasts more categorically than the mid-mid vowel contrasts, and the size of the difference seemed to be consistently affected, in the case of the mid-mid vowel contrasts, by how frequently Catalan was used. Spanish-Catalan bilinguals using Catalan more often perceived the “weak” mid vowel contrasts more categorically.

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