Effects of Phonetic Training on the Perception and Production of /i:/-/ɪ/ and /æ/-/ʌ/ by Catalan/Spanish Learners of English

Cristina Aliaga-García
Universitat de Barcelona

Abstract

Cross-language differences in vowel perception and production have shown clear limitations in the accuracy with L2 phonetic segments are perceived and produced by native speakers of Romance languages. The present study investigates Catalan/Spanish learners' ability to learn to discriminate and produce the English tense-lax (/i:/-/ɪ/) and front-central (/æ/-/ʌ/) vowel contrasts through a six-week phonetic training, given their difficulties to use and access to L2 spectral and durational information. A minimal-pair AX vowel discrimination task and F1-F2 and duration measures in vowels elicited through a delayed repetition task were used to assess learners' gains in perceptual and productive ability, respectively, before (pre-test) and after (post-test) training. Accuracy in vowel discrimination was found to increase significantly, whereas in production only modest accuracy gains were obtained. These results suggest that, despite a more accurate perception of L2 vowels, learners still produced /i:/-/ɪ/ and /æ/-/ʌ/ with no significant spectral differences at post-test but rather a durational contrast that is larger than in L1 English.

1. Introduction

Studies on second language (L2) speech learning in naturalistic settings have shown that learners are not able to produce L2 speech authentically across a number of segmental (and suprasegmental) phonetic dimensions. Approaches to phonological acquisition such as Flege's (1995) Speech Learning Model, have shown that one of the factors determining the degree of accuracy in L2 sound perception and

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production is the nature of the interaction between the learner's L1 and L2 phonetic systems, characterised by phonetic category assimilation and dissimilation (Flege, forthcoming). Age is often also acknowledged a central role in explaining ultimate attainment in L2 speech. A major finding stemming from this research programme is that early learners —those who start L2 speech learning before the passing of critical period— tend to outperform late learners in the perception and production of L2 vowels (e.g. Piske *et al.*, 2002) and consonants (e.g. MacKay *et al.*, 2001). An explanatory account of the early-start advantage based on general neurological maturation (e.g. Scovel 1988), however, faces an important limitation in the fact that many contextual factors affecting L2 speech learning, such as amount and quality of L2 input or amount of L2 and L1 use, are confounded with the age at which learning began. Within this research context, studies measuring the differential effects of a stay-abroad term ("years of residence in the L2 speaking country") and an at-home period of formal instruction ("hours of instruction") on accuracy gains in L2 sound perception and production (e.g. Díaz-Campos, 2004; Fullana, 2005; Mora, forthcoming) provide a context where input effects may be observed in the short term, but controlling for input quality effects would require evaluating speech data that is not normally available for analysis.

Phonetic training studies constitute a research paradigm that has produced interesting results as regards input effects on L2 speech learning, often reporting the effectiveness of laboratory training in improving L2 pronunciation (e.g. Catford & Pisoni, 1970; Moyer, 1999). Such results have a bearing on crucial issues in L2 speech learning, such as the ability of late learners' perceptual and articulatory systems to remain adaptive to linguistic experience. The present paper, which is part of a larger project investigating phonetic training effects on L2 pronunciation, further explores this line of research by assessing phonetic training effects on advanced Catalan/Spanish learners' perception and production of English vowel contrasts.

2. Method

A total of 36 participants (32 females, 4 males) between the ages of 19 and 48 (mean age 21.62) took part in a pretest-posttest

experiment: two groups of bilingual Catalan/Spanish undergraduate students of English Philology (NNS; *N*=29) at the University of Barcelona —grouped into experimental (*N*=18) and control (*N*=11)— and a control group of NSs of British English (*N*=7) who provided base-line data. Only the experimental group went through a six-week phonetic training period, after which all groups did the same perception and production tasks again (post-test). The volunteering learners had been learning English formally for 8 years and had not had any previous phonetic training experience or experience abroad. The age at which they began learning English ranged from 8 to 12 (mean 9.15). They were given course credit for their participation.

Table 1. Design of the study

Participants		Pre-Test (T1: October 2006)	Phonetic Training (November-December 2006)	Post-Test (T2: December 2006)	*N*
NNS	Experimental	✓	✓	✓	18
	Control	✓	×	✓	11
NS Control		×	×	✓	7
Total					36

2.1. Perception and Production tasks

Learners' accuracy in vowel perception and production was assessed by means of a categorial AX discrimination task and a delayed sentence repetition task (see Table 2).

In the AX discrimination task, learners were presented 3 repetitions of 24 monosyllabic minimal pairs (e.g. *feel-fill*) pairs and 6 distractors (e.g. *wheel-wheel*) containing the vowel contrasts /iː-ɪ; æ-ʌ/ in a variety of phonetic environments (CVC, CVCC, CCVC and CCVCC), after a previous familiarization phase. The participants' task was to indicate whether the two stimuli in each of the randomized 90 word-pairs distributed in 6 sections of 15 trials were the *same* or *different*.

A delayed sentence repetition task was used to elicit and record learners' production of /i:, ɪ, æ, ʌ/, preceded by word-initial /p t b d/ in words in sentence-initial position:

A What is the the next word?
B BEACH is the next word.
A What is the the next word?
You _____ is the next word.

Table 2. Items in the perception and production tasks

	PERCEPTION: AX discrimination task				PRODUCTION: delayed sentence repetition task			
	Minimal pairs	Distractors	Repetitions	Items	Contexts	Words	Repetitions	Total
/i:/	11 (feet-fit)	3 (chip-chip)	3	42	4	2	3	24
/ɪ/					4	2	3	24
/æ/	13 (cap-cup)	3 (run-run)	3	48	4	2	3	24
/ʌ/					4	2	3	24
	Word-pairs for discrimination			90	Elicited vowels for F1-F2 and length measurement			96

The target contrasting vowels were selected on the basis of their relative difficulty for Catalan/Spanish learners of English. On the one hand, L1 Catalan and Spanish lack a tense-lax distinction for high vowels /i:/-/ɪ/ and have a vowel (/i/) closer to English /i:/ (Flege & Mackay, 2004). In addition to the quantitative (durational) and qualitative (spectral) relationship maintained between /i:/-/ɪ/, /i:/ is hypothesized to give little difficulty due to the variations it can undergo (long [/i:/] in an open syllable or before voiced consonant; shortened [/i/] before a voiced consonant). On the other hand, a front-back distinction for open/low vowels /æ/-/ʌ/ is also lacking in the L1 of participants, and therefore substituted by a relatively front /a/. The difficulty is further explained by the fact that length may not be as distinctive as in /i:/-/ɪ/ and the prejudice induced by the frequent orthographic spelling with <u> or <o>. The quality generally obtained

is thus a too fronted and lip-rounded vowel modified in the direction of the back sound /ɑ:/.

Given the inherent L1-L2 differences in vowel space and the language-specificity characterising speech perception, cross-language research has documented L2 learners' failure to detect subtle spectral differences between contrasting vowels which overlap a single L1 category and, consequently, their tendency to produce them without substantial durational or spectral difference, resulting in a merged L1-based category (single-category assimilation). Other studies have shown, however, non-native's over-reliance on durational cues (non-existing in L1) as a non-native strategy to perceive and produce vowel contrasts (Cebrián, 2006; Escudero, 2000), along with L2 vowels produced with formant frequency values intermediate to the values of NSs of the L1 and L2 (two-category assimilation) (Flege *et al.*, 1997).

Based on this evidence, the present study sets out to explore the extent to which the perception and production of English vowel contrasts by Catalan/Spanish late learners of English may be modified through a six-week phonetic training, which was predicted to improve learners' accuracy (1) in vowel discrimination through increased English-like sensitivity to cue weighting and (2) in the production of vowels through new phonetic categories formation and proper use of spectral/durational cues.

2.2. Phonetic Training

The experimental group participated in six two-hour group training sessions dealing with the English vowel system, particularly the spectral and durational dimensions distinguishing /i:/-/ɪ/ and /æ/-/ʌ/. Intensive practice based on various perceptual and productive tasks was preceded by a theoretical part consisting of articulatory visual description (tongue movement and lip-rounding), exposure to NS models and contrastive analysis. The learners received *immediate* or *trial-by-trial* feedback during the sessions, *cumulative* feedback at the end, and *weekly* feedback. Finally, group sessions were complemented with individual 15-minute sessions mainly based on computer-based visual feedback.

3. Results and discussion

3.1. Effects of training on perception

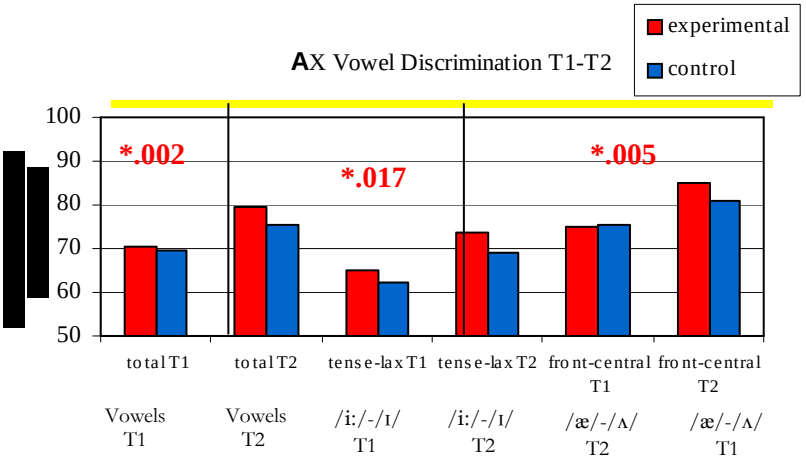
Mean percent correct discrimination scores were computed for each subject and vowel contrast (see Table 3). As expected, overall statistically significant differences were observed in the discrimination scores of the experimental group ($t(17)=-3.64$, $p=.002$), but not the control group, from T1 to T2, for both /i:/-/ɪ/ ($t(17)=-2.66$, $p=.017$) and /æ/-/ʌ/ ($t(17)=-3.32$, $p=.005$), which suggests that phonetic training had significant positive effects upon the learners' discrimination ability. A more detailed statistical analysis conducted for each of the vowel contrasts independently indicated similar amount of significant increase for the tense-lax (8.75%) and the front-central (9.65%) from T1 to T2, although /æ/-/ʌ/ was discerned at higher discrimination rates than /i:/-/ɪ/.

Despite the fact that the experimental group improved significantly in their ability to discern the vowel contrasts, the significant differences between NSs' and NNSs' performance observed at T1 ($t(23)=-6.27$, p=.000) persisted at T2 ($t(23)=-4.22$, $p=.000$), suggesting that Catalan/Spanish learners of English continued to perceive /i:-ɪ; æ-ʌ/ in a non-native-like manner after training (Figure 1).

Table 3. Mean percent correct vowel discrimination (*SD* in parenthesis) and significant differences (*) at α=.05

PERCEPTION % Correct discrimination		Total		/i:/-/ɪ/		/æ/-/ʌ/	
		T1	T2	T1	T2	T1	T2
NNS	Experi-mental group	70.45 (9.85)	*79.71 (9.07)	64.82 (12.26)	*73.57 (9.63)	75.21 (10.74)	*84.90 (11.19)
	Control Group	69.32 (9.87)	75.52 (7.89)	62.26 (14.04)	69.15 (9.56)	75.29 (11.60)	80.89 (8.06)
NS		95.04 (4.66)		95.67 (4.90)		94.51 (5.00)	

Figure 1. Mean percent correct vowel discrimination.



3.2. Effects of training on production

Accuracy in L2 vowel production was assessed by means of 6912 F1-F2 and 6912 duration measurements (96 words x 36 subjects x 2 data collection times) of each vowel. Formant frequencies were independently obtained by calculating the mean F1 and F2 in a mid-vowel space comprising 20 ms of the steady part of vocal fold vibration. Spectral contrasts were then calculated by measuring the distance between the F1 and F2 values of the contrasting vowels, independently. Vowel duration was measured (ms) from the first to the positive peak in the period portion of the signal, for each vowel and environment. Formant frequency analysis was expected to reveal significant differences between groups since training was likely to affect the degree of tongue height (F1) and the degree of tongue frontness/backness (F2), making learners produce the target vowels with more English-like frequency values (lower F1 values). The analysis of F1 and F2 differences between the two members of each vowel pair was expected to yield a larger distance between the contrasting vowels

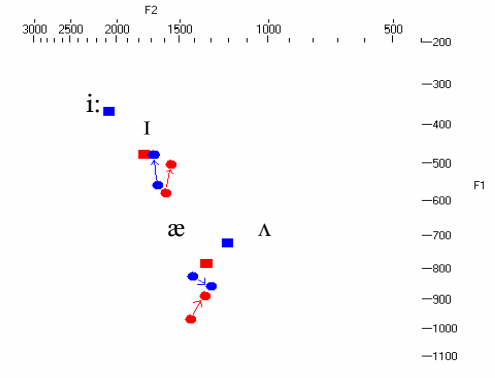
/i:/ and /ɪ/, and between /æ/ and /ʌ/, for the experimental group than for the control group at T2.

Formant frequency analysis showed no significant differences overall in L2 vowel production as a result of phonetic training (see Table 4 and Figure 2), and revealed significant differences between experimental and NS control groups at T1 and T2, especially for the tense-lax contrast. In general, learners produced the target vowels with significantly higher F1 values than NSs, indicating that tongue position for L2 vowels was too low in the mouth. A closer inspection of F1 and F2 values revealed, however, modest gains as regards the production of the tense-lax contrast on the part of the experimental group, but not the control group. Paired-samples t-tests showed that, in all cases, NNSs produced /i:/ ($t(16)=2.74$, $p=.015$) and /ɪ/ ($t(16)=2.38$, $p=.030$) with significantly lower F1 values, indicating that vowels were produced with greater vowel height after training. On the other hand, no significant T1-T2 differences were found for the F1 and F2 values of /æ/ and /ʌ/ ($p>.05$).

Table 4. Mean F1-F2 measures of vowels and significant differences (*) at $\alpha=.05$

Mean F1-F2		/ i:/		/ɪ/		/æ/		/ʌ/	
		F1	F2	F1	F2	F1	F2	F1	F2
Expe-rimen-tal	T1	541.34	1590.17	553.86	1617.22	928.66	1401.03	803.21	1350.85
	T2	*515.41	1623.22	*525.03	1555.67	908.33	1353.83	787.96	1326.73
Con-trol	T1	547.52	1647.18	546.99	1691.54	890.47	1420.49	816.47	1337.45
	T2	*495.79	1745.44	503.03	1787.44	879.85	1394.31	*773.97	1350.02
NS		376.36	2260.67	476.07	1648.54	814.83	1404.33	657.93	1223.74

Figure 2. F1-F2 vowel formant plot for the English vowels pronounced by NSs (■ ■) and NNSs (● ●) at T1 and T2, with arrows showing amount and direction of change

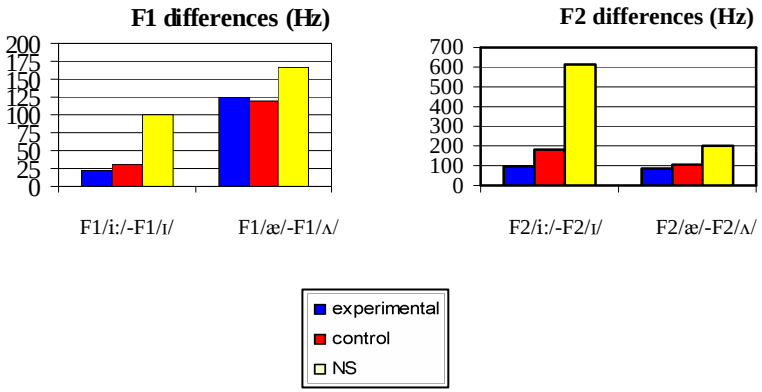


Statistical analysis of the quality differences between the target vowel categories revealed significant differences between the experimental and NS groups for the F1 (t(23)=-4.03, p=.001) and F2 (t(7.07)=-2.47, p=.043) values of /i:/-/ɪ/, suggesting that, unlike NSs, Catalan/Spanish learners did not rely on quality differences to implement the /ɪ/-/i:/ contrast but did it in a non-native way to produce /æ/-/ʌ/ (see Table 5 and Figure 3).

Table 5. Distance between the F1-F2 measures of /i:/-/ɪ/ and /æ/-/ʌ/

Differences between phonetic categories		/i:/-/ɪ/		/æ/-/ʌ/	
		F1	F2	F1	F2
Experimental	T1	22.74	96.67	125.44	86.02
	T2	29.94	180.32	120.37	105.62
Control	T1	37.06	103.54	82.22	143.54
	T2	30.78	118.73	105.88	67.11
NS		99.70	612.13	165.90	200.26

Figure 3. Spectral contrast (F1 and F2 differences) in /i:/-/ɪ/ and /æ/-/ʌ/

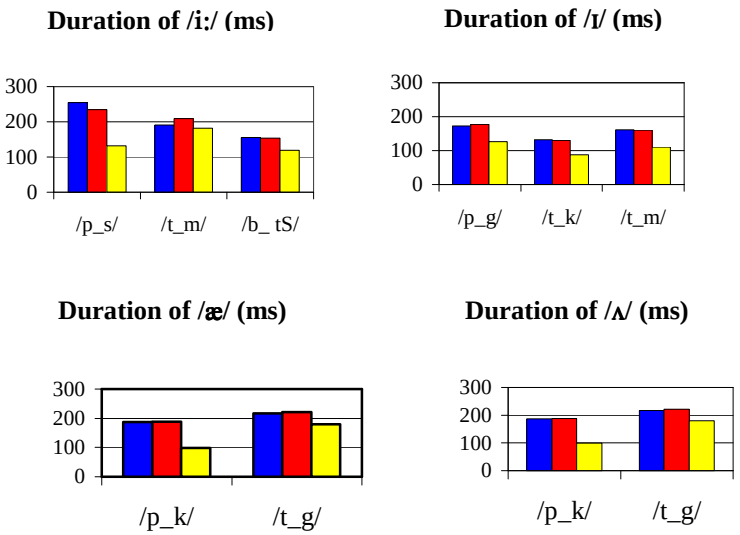


On the other hand, length was consistently used as a vowel differentiation cue by learners, especially for /i:/-/ɪ/. In all cases, the experimental and control groups produced L2 vowels with significantly larger contrasting duration than NSs and t-tests revealed no significant differences between L2 production at T1 and T2, which suggests that phonetic training did not affect learners' over-reliance on durational cues in L2 vowel production in the direction of a more English-like cue weighting (see Table 6 and Figure 4).

Table 6. Mean duration of /i: ɪ æ ʌ/

Mean Duration (ms)		/i:/			/ɪ /			/æ/		/ʌ/	
		/p_s/	/t_m/	/b_ tʃ/	/p_g/	/t_k/	/t_m/	/p_k/	/t_g/	/p_n/	/t_k/
Experimental	T1	254.17	190.54	155.03	172.3	132.82	160.94	187.37	217.30	171.63	153.90
	T2	234.56	*209	153.87	176.52	131.03	160.26	188.72	221.59	180.43	145.43
Control	T1	200.43	196.12	146.20	149.87	124.83	157.71	176.79	199.94	177.18	139.62
	T2	206.37	202.64	153.26	162.57	134.11	162.44	198.20	219.19	192.62	144.31
NS		131.75	181.60	119.23	126.56	87.95	110.62	98.48	180.13	123.72	86.16

Figure 4. Mean duration (ms) of /i:/, /I/, /æ/ and /ʌ/



4. Conclusion

The present study investigated the effects of phonetic training on the perception and production of two target L2 sound pairs by bilingual Catalan/Spanish learners of English. The two L2 sound pairs were vowel phonemes contrasting primarily in quality (/i:/-/ɪ/, /æ/-/ʌ/), but also exhibiting durational differences (/i:/ and /æ/ are longer than /ɪ/ and /ʌ/, respectively) and are known to present difficulty for Catalan/Spanish learners of English. The results suggest that the input administered through phonetic training had differential effects on the subjects' perception and production of /i:/-/ɪ/ and /æ/-/ʌ/. Percent correct discrimination scores for /i:/-/ɪ/ and /æ/-/ʌ/ were found to increase significantly after training, which suggests that learners had learnt to attend to English acoustic cues (durational and, presumably, spectral cues) in perception. It is concluded, however, that a six-week phonetic training may not be long enough to produce the same gains in perception and production. Accuracy in vowel production, as measured through F1 and F2 frequency values, did not improve significantly as a result of training, which was found not to have an effect either on learners' reliance on duration differences to produce the /i:/-/ɪ/ and /æ/-/ʌ/ vowel contrasts. Experience effects on cue reliance in L2 vowel perception and production should be further investigated.

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