Eastern Catalan Vowel Reduction is Characterized by Raising – Not Centralization

DYLAN HERRICK, University of Oklahoma

Abstract

This paper presents a quantitative study of vowel reduction in five Eastern dialects of Catalan, a Romance language spoken in northeastern Spain in the autonomous region of Catalonia. For each of the five dialects, the study: a) verifies the impressionistic descriptions reported in the literature, b) provides quantitative acoustic data for both the stressed and unstressed vowel inventories, and c) shows that Catalan vowel reduction is characterized primarily by raising (of the first formant; F1) and not centralization (or reduction of both the first and second formants; F1 and F2).

1. Introduction

The term 'vowel reduction' means something different for phoneticians and phonologists (on this point, see Herrick, 2003). Phoneticians typically define vowel reduction as a gradient tendency for vowels to centralize (or for the overall vowel space to shrink) due to various factors – the most common being shortened duration, speech rate, register, word size, stress and/or consonantal context. Phonologists, on the other hand, use vowel reduction to refer to the neutralization of vowel contrasts under stress-dependent conditions (Crosswhite, 1999). Thus, where phoneticians refer to a reduction in the size of the vowel space, phonologists refer to a reduction of the number of vowels in the vowel inventory.

Most phonologists feel that phonetic and phonological vowel reduction should be linked, and recent research (especially Barnes, 2002; Crosswhite, 1999, 2004; Flemming, 1995, 2004; Padgett, 2004; Padgett & Tabain, 2005) has attempted to make the link explicit by explaining phonological vowel reduction (roughly) as follows: (i) unstressed vowels are shorter in duration than stressed vowels; (ii) a decrease in duration makes it more difficult to achieve the jaw lowering necessary for low vowels (this results in considerable F1 formant undershoot for low vowels); (iii) F1 formant undershoot effectively raises the floor of the vowel space causing the overall vowel space to shrink (phonetic vowel reduction); (iv) in this shrunken vowel space, the perceptual distance between vowels also shrinks making neighboring vowels more easily confused; and (v) ultimately, this confusion leads to neutralization (phonological vowel reduction).

H. Sirai et al. (Eds.) *Studies in Language Sciences 6*. 227-241.
2007, Kurosio Publishers, Tokyo, Japan.

Phonetic vowel reduction allows for reduction along F1 (raising) and/or F2 (centralization); however, the phonological explanation above makes crucial reference only to the reduction of the first formant (raising)[1] – see points (ii) and (iii) in particular. This paper supports recent phonological theory by showing that the overall F1 range in unstressed position is reduced by roughly one third in five distinct varieties of Catalan – a Romance language spoken in North-Eastern Spain. Furthermore, these varieties show almost no centralization (reduction along F2) – a characteristic that distinguishes Catalan from languages like English which exhibit relatively strong centralization (reduction along F2; Moon & Lindblom 1994). Finally, even though this paper focuses exclusively on the reduction in the acoustic vowel space, the following section provides a brief background to the vowel inventories and neutralization patterns in Catalan.

1.1. Phonological Background

Catalan is traditionally divided into Eastern and Western varieties – Eastern varieties allow schwa in unstressed position while Western varieties do not. This paper examines five Eastern varieties (see Herrick, 2003 for a discussion of Western Catalan) – two belonging to Central Catalan (represented by speakers from the Bages and Girona regions) and three belonging to Balearic Catalan (represented by speakers from the cities of Palma, Lloseta, and Ciutadella).

Table 1. Standard Catalan (Bages Catalan) – A Vowel Inventory

a. Stressed vowels		b. Unstressed vowels	
i	u	i	u
e	o		
ɛ	ɔ	ə	
a			

Standard Catalan, which is represented here by speakers from the Bages region, allows seven vowels in stressed position (/i, e, ɛ, a, ɔ, o, u/) and three vowels in unstressed position (/i, ə, u/) as shown in Table 1. In unstressed position, rounded vowels surface as [u] while non-high, non-round vowels surface as [ə]. The other four varieties all vary slightly from this pattern in terms of their vowel inventories and / or neutralization patterns as detailed in Table 2 and the paragraph below. For more information on these varieties please see Herrick (2003), Mascaró (1976, 1983, 2002), Moll (1991), and Recasens (1986, 1991).

[1] Crosswhite (1999) proposes a non-unified account of phonological vowel reduction in which one type of vowel reduction (prominence enhancing vowel reduction) need not depend on raising.

Table 2. Summary Classification of the Five Varieties of Eastern Catalan

Region	Minor Variety	Number of stressed vowels	Number of unstressed vowels	stressed schwa	unstressed schwa
Bages	Central	7	3	no	yes
Girona	Central	6	3	no	yes
Palma	Balearic	8	4 (5)	yes	yes
Lloseta	Balearic	7	4 (5)	no	yes
Ciutadella	Balearic	8	3	yes	yes

Girona Catalan and Ciutadella Catalan share the same neutralization pattern (round vowels surface as [u]; non-high non-round vowels surface as [ə]). However, Girona Catalan allows only six stressed vowels (one less than Standard Catalan: the back mid vowels /ɔ/ and /o/ have merged into a vowel which is often transcribed with a capital 'O' due to its intermediate/ indeterminate height; see Recasens, 1986). On the other hand, Ciutadella Catalan allows eight vowels (allowing stressed schwa) and belongs to Balearic Catalan (Recasens, 1986, 1991). For Palma and Lloseta Catalan, the neutralization pattern differs considerably from Bages Catalan. In both of these Balearic varieties the mid back vowels /ɔ/ and /o/ surface as [o] in unstressed position (it would be [u] in Bages Catalan), and /e/ and /ɛ/ sometimes surface as [e] and sometimes as [ə] (there is considerable variation; Mascaró, 2002; Herrick, 2003). Palma and Lloseta Catalan also differ in their stressed vowel inventories; Lloseta allows seven and Palma eight vowels.

2. Methodology

For this study, three native speakers – all female college students between the ages of 18-25 – from each of the five regions were recorded uttering nonsense words within a carrier phrase. Because most Catalan speakers are bilingual Spanish speakers, "native speakers" were limited to those (i) who claimed to be native speakers (and use primarily Catalan in their daily life) and (ii) who reported that both their parents were native speakers of Catalan. A map indicating the hometown for each of the speakers is shown in Figure 1 below. Speakers 11-14 represent Bages Catalan (Standard Catalan), and speakers 31-33 represent Girona Catalan – both varieties of Central Catalan. Speakers 41-43 represent Palma Catalan, speakers 47-49 represent Lloseta Catalan, and speakers 51-53 represent Ciutadella Catalan (all varieties of Balearic Catalan).

Recordings were made of free speech, real words, and nonsense words, but only the nonsense words are analyzed here (because the real-word

lists could not be kept consistent between varieties). The nonsense words consisted of a list of verbs in 2nd person singular form in the shape /bVpes/ (where 'V' is replaced by the stressed vowels allowed in each variety).

Each word was uttered in a carrier phrase (shown in (1) below). Sentence (1a) forces the infinitival form in which the target vowel would be unstressed ([bV'pa]), and sentences (1b) and (1c) force the third person singular form in which the target vowel is stressed (['bVpa]). This allows for us to record ten repetitions of both the stressed and *corresponding* unstressed vowels for each speaker. For each variety, then, N=30 for each stressed vowel, and N=30 or more (in the case of neutralization) for each unstressed vowel.

(1) a. *la frase és sempre _____ a la nit* (the phrase is always __ at night)
b. *ell sempre _____ a la nit* (he…)
c. *ella sempre _____ a la nit* (she…)

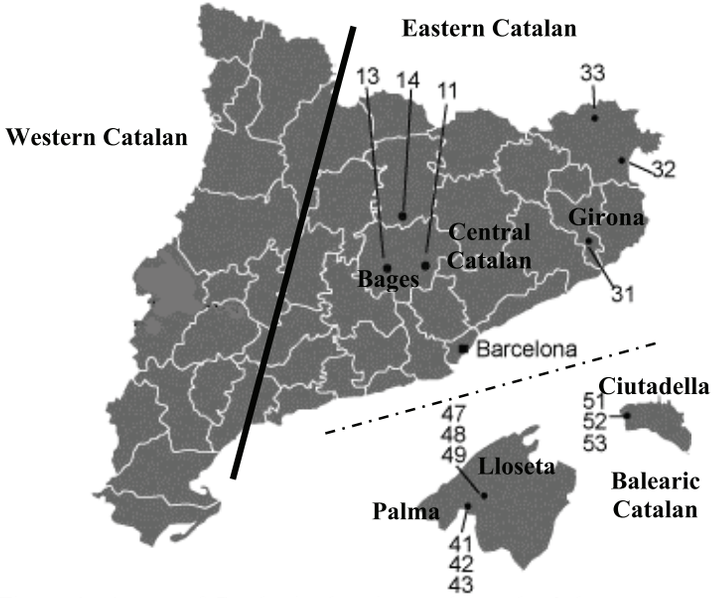

Figure 1. A map of Catalonia showing each speaker's hometown

All recordings were made in Catalonia on a DAT recorder, digitized at 44.1kHz, low pass filtered below 6000Hz, and analyzed using the PRAAT (Boersma & Weenik, 2002) phonetics software package (LPC analysis, 25ms window). All 2040 tokens were measured for F1-F3 (the first three formants). The location for measurements was made as shown in (2).

(2) The location for formant measurements was determined as follows:
(i) if F1 had a single peak, F1-F3 were measured at the point where F1 reached its peak
(ii) if no unique max could be found for F1 (if F1 contained multiple peaks or if F1 were a constant cline), the measurement was made at the peak (or valley) of F2;
(iii) if there was no unique max or min for F2, the measurement was made at the mid-point of the vowel (as determined by eye).

3. Results

3.1. Descriptive Results

In this section, I present tables of averaged data for the first three formants (F1-F3) for each of the five varieties of Catalan followed by F1 x F2 vowel plots. The data has been presented in *Equivalent Rectangular Bandwidth* – a perceptual scale which models human hearing in a similar but superior way to the BARK scale (Moore & Glasberg, 1996; for measurements in the more familiar Hertz scale, see Herrick, 2003). Finally, each data cell in the tables below contains two numbers – the first number is the average value in ERB, and the second number (below it) is the standard deviation for that cell (e.g. in Table 3, stressed F1 for /i/ has an average of 9.3 ERB, with a standard deviation of 0.9).

3.2. Discussion and Analytical Results

There are two points I would like to make in this section. First, the data presented in the following tables are consistent (in terms of the number of vowel phonemes, the neutralization patterns, and, in the case of the Balearic varieties, the relatively open/low quality of the low-mid vowels /ɛ/ and /ɔ/) with the impressionistic descriptions found in the Catalan literature (for phonetically oriented descriptions see Recasens, 1986, 1991; and for phonologically oriented descriptions see Mascaró, 1983, 2002; Wheeler, 1979). Furthermore, the F1 x F2 vowel plots for Bages Catalan (Standard Catalan) show strong similarities to previously published acoustic data (Recasens, 1986; Planas, 2000) – the primary differences being attributable to the fact that this study reports data for female speakers while the other two studies report data for male speakers (who have a lower F0 and more compact vowel space). Further comparison of vowel plots for the other varieties is impossible due to the lack of previous (published) quantitative acoustic data (though see Montoya 1998 for a vowel plot of Balearic Catalan). (For further details on these points, please see Herrick, 2003.)

The second point is that for all five of the varieties described in the previous section, the data show a reduction of the F1 range (raising) in unstressed vowels which is greater than 40% while the reduction of the

Table 3. Bages Catalan Data (in ERB)

Average Data for Speakers 11, 13, 14

	Stressed			Unstressed			
	F1	F2	F3	F1	F2	F3	
i	9.3	23.5	25.0	9.6	23.0	24.4	i
	(0.9)	(0.4)	(0.7)	(0.4)	(0.4)	(0.5)	
e	10.8	22.2	24.6		{realized as [ə]}		
	(0.4)	(0.8)	(0.4)				
ɛ	13.2	21.5	24.7		{realized as [ə]}		
	(0.2)	(0.4)	(0.4)				
a	14.8	18.7	24.3	12.7	17.7	23.8	ə
	(0.4)	(0.7)	(0.4)	(0.9)	(0.9)	(0.4)	
ɔ	13.5	16.6	24.2		{realized as [u]}		
	(0.5)	(0.7)	(0.6)				
o	11.2	15.4	24.3		{realized as [u]}		
	(0.3)	(0.3)	(0.7)				
u	9.9	13.6	24.2	9.9	14.3	24.0	u
	(0.8)	(0.4)	(0.9)	(0.4)	(0.7)	(0.8)	

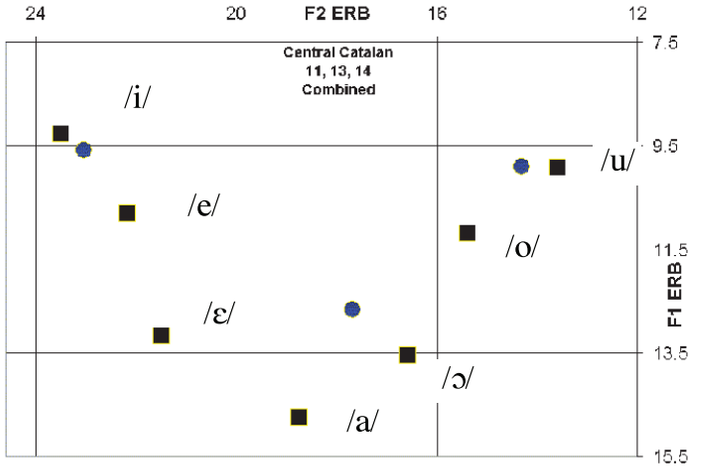

Figure 2. F1 x F2 vowel plot for Bages Catalan

Table 4. Girona Catalan Data (in ERB)

Averages for Speakers 31, 32, 33

	Stressed			Unstressed			
	F1	F2	F3	F1	F2	F3	
i	9.3	23.3	25.0	9.5	22.9	24.6	i
	(0.8)	(0.5)	(0.8)	(0.6)	(0.7)	(0.8)	
e	10.3	22.0	24.4		{realized as [ə]}		
	(0.3)	(0.6)	(0.4)				
ɛ	13.1	21.3	24.4		{realized as [ə]}		
	(0.2)	(0.5)	(0.4)				
a	14.6	19.0	23.4	12.1	17.9	24.0	ə
	(0.3)	(0.5)	(0.5)	(0.6)	(0.6)	(0.5)	
	12.0	15.7	23.8		{realized as [u]}		
	(0.7)	(0.9)	(0.7)				
u	10.2	14.3	23.9	10.2	14.5	23.6	u
	(0.7)	(1.0)	(0.8)	(0.3)	(0.7)	(0.9)	

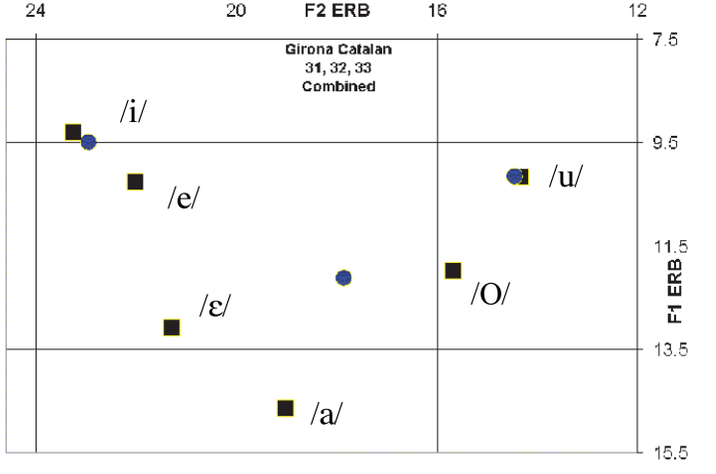

Figure 3. F1 x F2 vowel plot for Girona Catalan

Table 5. Palma Catalan Data (in ERB)
Averages for Speakers 41, 42, 43

	Stressed			Unstressed			
	F1	F2	F3	F1	F2	F3	
i	8.9	23.0	24.5	9.0	22.4	24.1	i
	(0.5)	(0.9)	(0.8)	(0.4)	(1.2)	(0.9)	
e	11.2	21.6	24.1	11.7	20.4	24.0	e[2]
	(0.4)	(1.0)	(0.6)	(0.4)	(1.2)	(0.6)	
ɛ	13.6	21.0	24.1	{realized as [ə]}			
	(0.4)	(0.8)	(0.5)				
ə	11.8	17.7	23.7	{realized as [ə]}			
	(0.4)	(0.5)	(0.6)				
a	14.5	18.8	23.4	11.5	17.6	23.1	ə
	(0.7)	(0.8)	(0.5)	(0.8)	(0.5)	(0.8)	
ɔ	13.6	17.0	23.4	{realized as [o]}			
	(0.5)	(0.4)	(0.4)				
o	11.3	15.7	23.8	11.4	15.9	23.4	o
	(0.4)	(0.5)	(0.5)	(0.5)	(0.4)	(0.7)	
u	9.7	14.1	23.6	9.7	14.6	23.4	u
	(0.2)	(0.7)	(0.8)	(0.6)	(0.4)	(0.8)	

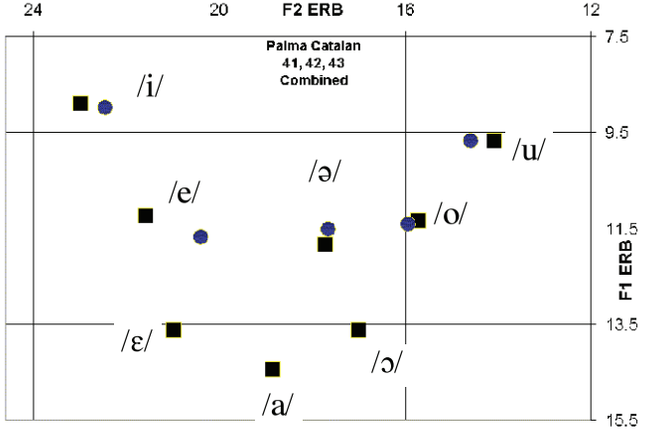

Figure 4. F1 x F2 vowel plot for Palma Catalan

[2] Reduction to [e] in Palma (and Lloseta) Catalan is complicated – under certain conditions /e, ɛ, ə/ reduce to [e] not [ə] (see Herrick, 2003 and references therein).

Table 6. Lloseta Catalan Data (in ERB)
Averages for Speakers 47, 48, 49

	Stressed			Unstressed			
	F1	F2	F3	F1	F2	F3	
i	8.7	23.5	25.3	8.7	23.1	24.6	i
	(0.4)	(0.7)	(0.8)	(0.3)	(0.9)	(0.9)	
e	10.4	22.5	24.5	11.2	21.5	23.8	e[3]
	(0.4)	(0.7)	(0.5)	(0.1)	(0.2)	(0.1)	
ɛ	13.4	21.4	24.4	{realized as [ə]}			
	(0.4)	(0.6)	(0.5)				
a	14.8	19.3	23.6	11.0	18.2	24.1	ə
	(0.3)	(0.7)	(0.3)	(0.5)	(1.5)	(0.4)	
ɔ	14.1	17.7	23.5	{realized as [o]}			
	(0.3)	(0.6)	(0.5)				
o	11.3	15.1	24.5	11.2	15.5	24.2	o
	(0.4)	(0.5)	(0.6)	(0.3)	(0.6)	(0.6)	
u	9.8	13.6	24.4	9.4	13.8	24.2	u
	(0.3)	(0.7)	(0.7)	(0.3)	(0.5)	(0.6)	

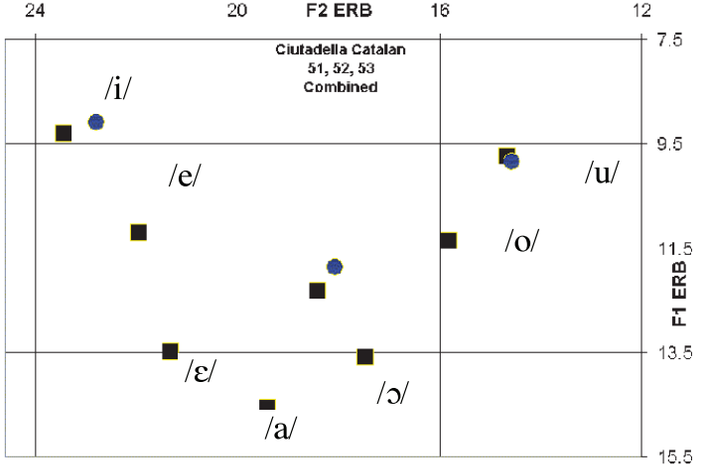

Figure 5. F1 x F2 vowel plot for Lloseta Catalan

[3] Reduction to [e] in Lloseta (and Palma) Catalan is complicated – under certai conditions /e, ɛ, ə/ reduce to [e] not [ə] (see Herrick, 2003 and references therein).

Table 7. Ciutadella Catalan Data (in ERB)
Average data for Speakers 51, 52, 53

	Stressed			Unstressed			
	F1	F2	F3	F1	F2	F3	
i	9.3	23.4	25.0	9.1	22.8	24.3	i
	(0.3)	(0.3)	(0.5)	(0.5)	(0.5)	(0.5)	
e	11.2	21.9	24.7	{realized as [ə]}			
	(0.4)	(0.7)	(0.5)				
ɛ	13.5	21.3	24.8	{realized as [ə]}			
	(0.2)	(0.6)	(0.4)				
ə	12.3	18.4	24.2	{realized as [ə]}			
	(0.3)	(0.9)	(0.4)				
a	14.6	19.4	24.0	11.9	18.1	23.9	ə
	(0.4)	(0.7)	(0.5)	(0.4)	(0.6)	(0.4)	
ɔ	13.6	17.5	24.2	{realized as [u]}			
	(0.4)	(0.5)	(0.6)				
o	11.4	15.8	24.4	{realized as [u]}			
	(0.6)	(0.5)	(0.4)				
u	9.7	14.7	24.4	9.8	14.6	24.3	u
	(0.4)	(0.6)	(0.5)	(0.5)	(0.9)	(0.6)	

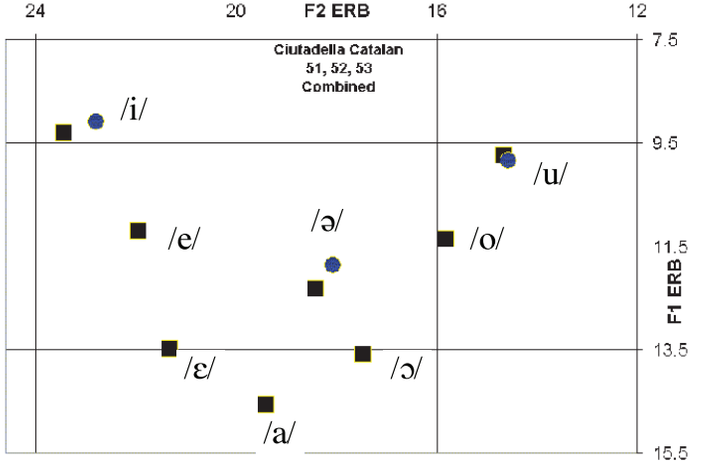

Figure 6. F1 x F2 vowel plot for Ciutadella Catalan

F2 range (centralization) never exceeds 12%. The conclusion we must draw from this is that vowel reduction in Eastern Catalan is characterized primarily by raising and *not* centralization. The reduction data for each variety is provided in Table 8 below.

Table 8. The Degree of Reduction for F1 and F2 (Averaged Data)

Region	Averaged Data	
	F1 decreases	F2 decreases
Bages	44%	12%
Girona	51%	7%
Palma	52%	12%
Lloseta	59%	6%
Ciutadella	47%	6%
TOTAL	51%	9%

In Table 8, the decrease in F1 has been determined by subtracting the total range of F1 for the vowels in unstressed position (typically /i/ and /ə/) from the total range of F1 for stressed vowels (typically /i/ and /a/). To facilitate comparison between varieties, this difference is then represented as a percent (rather than a raw value). (*Mutatis mutandis* for F2.)

A potential problem with the data as portrayed in Table 8 is that by using the average data for each vowel, it ignores the difference in variation shown between some vowels. In particular, schwa often shows more variation than other vowels, and it is possible that the variation among different tokens of schwa – when compared to the variation shown by stressed vowel tokens – could decrease the degree to which we find reduction. In fact, when we measure the degree of reduction between stressed and unstressed vowels using the ranges of *tokens* (not averaged values) the total amount of reduction decreases.

An alternative, and stricter, measure of reduction is possible if we use the token measurements for all vowels rather than the averaged data for the vowels. This method compares the maximal range of tokens for stressed position with the maximal range of tokens for unstressed positions, and it should show a slightly different picture since it is possible that the token-based range would show a different – probably lesser – degree of reduction. For example, if the greater variability of schwa resulted in a large increase to the F1 range for unstressed vowel tokens while the range of the stressed vowel tokens remained roughly the same, then, as a consequence, the degree of raising found would decrease.

Table 9 illustrates the decrease found for F1 and F2 when comparing the maximal F1 range for all stressed vowel tokens with the maximal F1 range for all unstressed vowel tokens. As suspected, the degree of the decrease

Table 9. The Degree of Reduction for F1 and F2 (Token Data)

Region	Averaged Data	
	F1 decreases	F2 decreases
Bages	29%	6%
Girona	38%	4%
Palma	42%	13%
Lloseta	50%	5%
Ciutadella	35%	-6%
TOTAL	39%	4%

Table 10. Reduction of F1 and F2 in Unstressed Tokens for Each Speaker

Speaker	Based on individual tokens	
	F1 decrease	F2 decrease
Bages 11	20%	19%
Bages 13	43%	2%
Bages 14	25%	-4%
Girona 31	26%	7%
Girona 32	49%	4%
Girona 33	38%	1%
Palma 41	43%	25%
Palma 42	36%	5%
Palma 43	47%	8%
Lloseta 47	57%	1%
Lloseta 48	38%	14%
Lloseta 49	56%	0%
Ciutadella 51	42%	0%
Ciutadella 52	30%	-6%
Ciutadella 53	33%	-12%

in range for F1 (the degree of raising) shrinks when using the token-based measure. Overall, the degree of F1 raising is 39% by this measure while it was 51% using the vowel averages shown in Table 8.

Surprisingly though, the conclusion that Eastern Catalan vowel reduction is characterized by raising (a decrease in F1) and not centralization (a decrease in F2) is only strengthened by the data in Table 9. The reason for this is twofold; first, although the degree of reduction for F1 shrinks when using the token ranges, the same is also true for F2 (only 4% with the token measure). Second, the decrease along F2 is *not consistent* – in fact, the F2 range even shows an increase for Ciutadella Catalan when we use this measure.

When we look at the data speaker-by-speaker in Table 10 (instead of

the three speaker averages for each variety), the result is strengthened even more. Of the fifteen speakers, three actually show an *increase* in the range of F2 for unstressed vowels, while two show no change, and the remainder vary considerably in the degree to which F2 decreases. The range of F1 for unstressed vowel tokens, on the other hand, shows a consistent and considerable decrease for *all* fifteen speakers.

4. Conclusion

The data Tables 3-7 and vowel plots in Figures 2-6 provide quantitative acoustic data for the stressed and unstressed vowel inventories of Catalan. They also verify the impressionistic descriptions for each variety found in the literature. The reduction tables (Tables 8-10) show that there is a consistent decrease in the range of the first formant (F1) for unstressed vowels regardless of whether the measurements are calculated based on average ranges (Table 8) or token ranges (Tables 9 and 10). Further examining the vowel plots and data tables shows that this decrease is due to *raising* of vowel height with no (or very little) lowering of vowels (in other words a decrease in the maximum F1 values with almost no change in the minimum F1 values). Conversely, there is neither a consistent nor considerable decrease in the range of F2 for unstressed vowels, and the combination of these factors leads to the inescapable conclusion that vowel reduction in Eastern Catalan is characterized by *raising* and not *centralization*.

Acknowledgments

I wish to express my special thanks to those who participated in this research project and generously gave their time for the interviews.

References

Barnes, J. A. (2002). *Positional neutralization: A phonologization approach to typological predictions*. Unpublished doctoral dissertation, University of California, Berkeley, Berkeley.

Boersma, P., & Weenink, D. (2002). *Praat*. [Computer Software]. Available from http://www.praat.org.

Crosswhite, K. (1999). *Vowel reduction in Optimality Theory*. Unpublished doctoral dissertation, University of California, Los Angeles, Los Angeles.

Crosswhite, K. (2004). Vowel reduction. In B. Hayes, R. Kirchner, & D. Steriade (Eds.), *Phonetically based phonology* (pp.191-231). Cambridge: Cambridge University Press.

Flemming, E. (1995). *Auditory representations in phonology*. Unpublished doctoral dissertation, University of California, Los Angeles, Los

Angeles.
Flemming, E. (2004). Contrast and perceptual distinctiveness. In B. Hayes, R. Kirchner, & D. Steriade (Eds.), *Phonetically based phonology* (pp. 232-276). Cambridge: Cambridge University Press.
Herrick, D. (2003). *An acoustic analysis of phonological vowel reduction in six varieties of Catalan*. Unpublished doctoral dissertation, University of California, Santa Cruz, Santa Cruz.
Mascaró, J. (1976). *Catalan phonology and the phonological cycle*. Unpublished doctoral dissertation, Massachusetts Institute of Technology, Cambridge.
Mascaró, J. (1983). *La fonologia catalana i el cicle fonològic* [Catalan and the phonological cycle]. Universitat Autònoma de Barcelona, Bellaterra, Spain. (Revised Catalan version of *Catalan phonology and the phonological cycle*, by J. Mascaró, 1976, Unpublished doctoral dissertation, Massachusetts Institute of Technology, Cambridge)
Mascaró, J. (2002). El sistema vocàlic: Reducció vocàlica [The vowel system: Vowel reduction]. In J. Solà et al. (Eds.), *Gramàtica del català contemporani* (pp. 89-123). Barcelona: Editorial Empúries.
Moll, F. de B. (1991). *Gramàtica històrica catalana* [A historical grammar of Catalan]. València: Universitat de València.
Montoya Abat, B. (1998). Mesures estadístiques acústiques del canvi fonològic en el vocalisme balear [A statistical phonetic account of the changes in the Balearic vowel system]. *Revista de Llengua i Literature*, 75-91.
Moon, S.-J., & Lindblom, B. (1994). Interaction between duration, context, and speaking style in English stressed vowels. *JASA, 96,* 40-55.
Moore, B., & Glasberg, B. (1996). A revision of Zwicker's loudness model. *Acta Acustica, 82*, 335-345.
Padgett, J. (2004). Russian vowel reduction and Dispersion Theory. *Phonological Studies, 7*, 81-96.
Padgett, J., & M. Tabain. (2005). Adaptive dispersion theory and phonological vowel reduction in Russian. *Phonetica, 62, 14-54.*
Planas Morales, S. (2000). *Identificació de les vocals tòniques del català* [Identifying the tonic vowels of Catalan]. Unpublished doctoral dissertation, Universitat de Barcelona, Barcelona.
Recasens, D. (1986). *Estudis de fonètica experimental del català oriental central* [Experimental phonetic studies of Central-Eastern Catalan]. Barcelona: l'Abadia de Montserrat.
Recasens, D. (1991). *Fonètica descriptiva del català* [Descriptive phonetics of Catalan]. Barcelona: Institut D'Estudis Catalans, Biblioteca Filològica XXI.
Sanders, N. (2003). *Opacity and sound change in the Polish lexicon*. Unpublished doctoral dissertation, University of California, Santa Cruz, Santa Cruz.
Wheeler, M. (1979). *Phonology of Catalan*. Oxford: Basil Blackwell.
Wheeler, M., Yates, A., & Dols, N. (1999). *Catalan: A comprehensive grammar*. London: Routledge.