3.5. Sequences of obstruent and lateral consonants

In this section, the sequences where laterals combine with obstruent consonants in C1 and C2 position will be analyzed. Section 3.5.1 presents the results for obstruent – lateral sequences and section 3.5.2 presents the results for lateral – obstruent sequences. Sections 3.5.3 and 3.5.4 analyze the effect of speaking rate and degree of overlap on voicing in these sequences.

3.5.1. Obstruent – lateral sequences

Figure 3.36 below presents the results for the sequences /k#l/ (test) and /g#l/ (control) for Catalan and English, and Figure 3.37 presents the results for the sequences /s#l/ (test) and /z#l/ (control). In both languages, onset of voicing in the test sequences seemed to be coordinated with the onset of the oral constriction for C2, although there could be asynchrony between oral and glottal gestures that could result in the presence of glottal vibration in the final portion of C1 or in some devoicing during the first third of C2. The data from the Catalan subject AN shows that there could be vocal fold vibration during the whole constriction for C1 in /k#l/ in faster speaking rates, which indicates that regressive assimilation of voicing may apply optionally in this sequence in Catalan. The results of One-way ANOVAs in Table XV below show that the sequences /g#l/ and /k#l/ did not have significantly different percentages of voicing in Catalan.

In fricative-lateral sequences, Figure 3.37 and Table XV show that the Catalan speaker AN displayed significantly more voicing in C1 in the voiced control sequence /z#l/ than in the test sequence /s#l/, whereas for speaker MJ the test and control sequences did not differ significantly due to this speaker's devoicing of coda fricatives.

In English, the voiced control sequences /z#l/ and /g#l/ had more voicing than the test sequences /s#l/ and /k#l/, except for speaker ME who showed absence of voicing in C1 in the voiced control sequence /z#l/.

In sum, concerning the direction and extent of voicing assimilation, complete regressive assimilation was found optionally in the Catalan sequence /k#l/ (for speaker AN, at faster rates), although the general pattern for the two languages seemed to be to coordinate onset of glottal vibration with onset of the oral constriction for C2. As in the case of obstruent – nasal sequences, obstruent – lateral sequences showed a rather stable

synchronization of onset of vocal fold vibration and onset of C2 constriction (*i.e.,* the onset of voicing is found around 0), and there was little interspeaker variability.

Table XV. Results of one-way ANOVA comparing percentage of voicing in sequences where laterals combined with obstruents. * = $p<.05$, ** = $p<.01$

Language	Sequence type	Mean	SD	N	Speaker	Sequences	ANOVA	*p*	Sig.
Catalan	/g#l/	-39.9	55	10	AN	/g#l/-/k#l/	F(1,19)=0.593	0.450	-
	/k#l/	-22.2	50.2	11					
	/g#l/	34.6	14.6	11	MJ		F(1,20)=3.588	0.072	-
	/k#l/	45	10.7	11					
	/z#l/	-18.7	14.1	10	AN	/z#l/-/s#l/	F(1,19)=10.778	0.0032	**
	/s#l/	-2.1	8.6	11					
	/z#l/	3.4	34	11	MJ		F(1,21)=2.662	0.117	-
	/s#l/	23	23	12					
	/l#g/	100	0	9	AN	/l#g/-/l#k/	F(1,18)=3975.33	0.0000	**
	/l#k/	19.3	5.6	11					
	/l#g/	77.6	32.4	11	MJ		F(1,18)=16.007	0.0008	**
	/l#k/	-16.7	9	9					
	/l#z/	73.5	40.3	9	AN	/l#z/-/l#s/	F(1,16)=40.329	0.0000	**
	/l#s/	-18	15.6	9					
	/l#z/	79.1	36.7	11	MJ		F(1,20)=40.337	0.0000	**
	/l#s/	-1	19.8	11					
English	/g#l/	-100	0	11	AL	/g#l/-/k#l/	F(1,18)=200.53	0.0000	**
	/k#l/	42.5	33.6	9					
	/g#l/	-58.3	51.5	12	ME		F(1,23)=37.366	0.0000	**
	/k#l/	30.7	10.5	13					
	/z#l/	-52	63.3	10	AL	/z#l/-/s#l/	F(1,17)=13.906	0.002	**
	/s#l/	27.2	6	9					
	/z#l/	36	16.6	12	ME		F(1,24)=0.960	0.337	-
	/s#l/	42	14.8	14					
	/l#g/	91.6	9	10	AL	/l#g/-/l#k/	F(1,18)=293.76	0.0000	**
	/l#k/	13.7	11.1	10					
	/l#g/	67.6	36	12	ME		F(1,22)=85.567	0.0000	**
	/l#k/	-40	18	12					
	/l#z/	100	0	9	AL	/l#z/-/l#s/	F(1,17)=304.191	0.0000	**
	/l#s/	21.3	13.5	10					
	/l#z/	73.6	35.4	10	ME		F(1,18)=41.632	0.0000	**
	/l#s/	-17.6	27.3	10					

3.5.2. Lateral – Obstruent sequences

The coordination of glottal gestures with supraglottal gestures in the Catalan and English sequences /l#k/ and /l#s/ and the control sequences /l#g/ and /l#z/ is displayed in Figures 3.38 and 3.39. It can be observed that, in the voiced control sequences, both consonants were implemented with vocal fold vibration although voicing could die out before the release of C2 due to mechanical devoicing. Again, it can be observed that in Catalan there tends to be devoicing of coda obstruents in the voiced control sequences (see Figures 3.36 and 3.37) but not so much in onset obstruents (see Figures 3.38 and 3.39). In the test sequences /l#k/ and /l#s/ offset of vocal fold vibration seemed to be coordinated with the onset of the oral constriction for C2 in both languages.

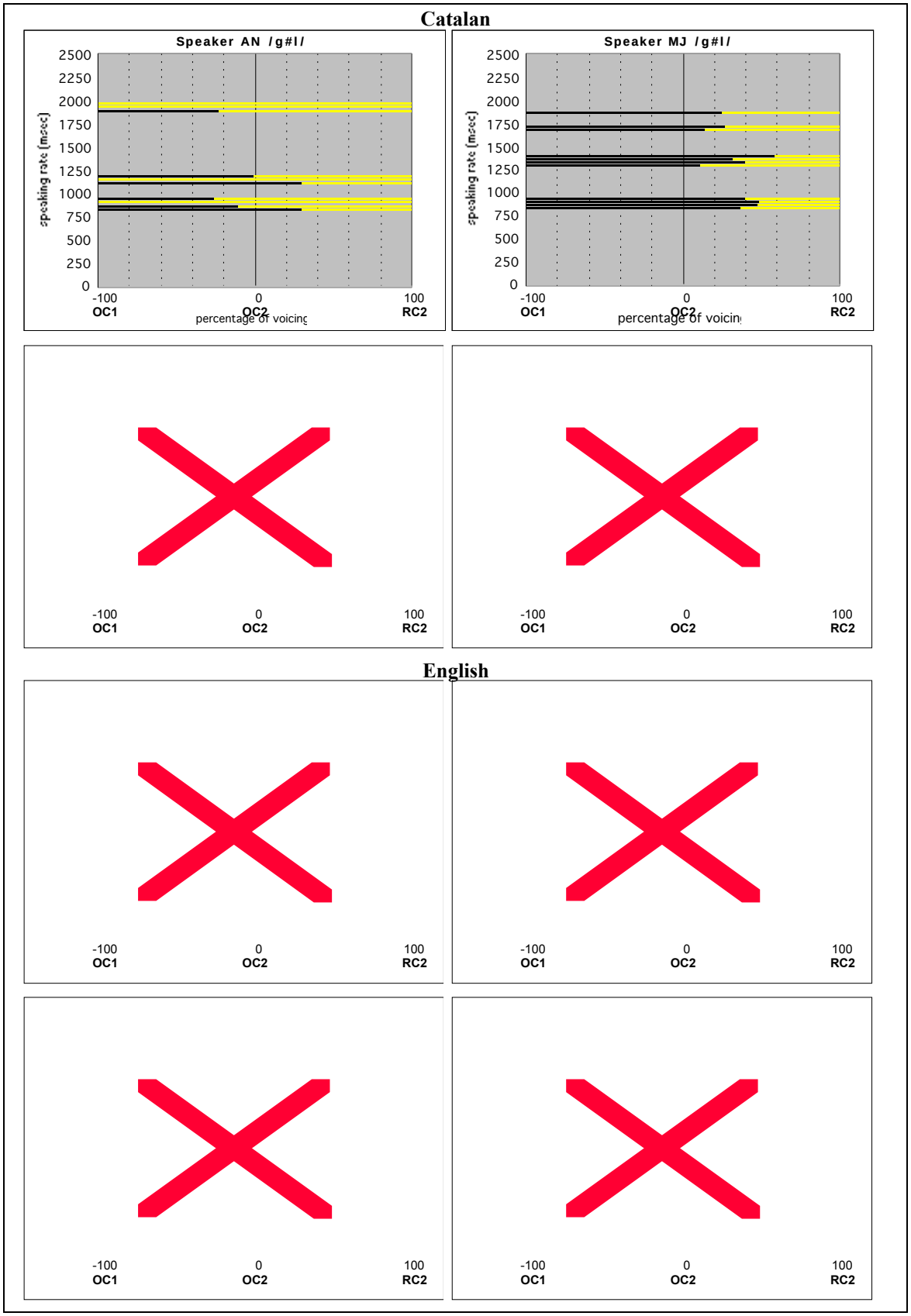

Figure 3.36. Vocal fold vibration in the consonant sequences in 'mag lent, big lap' (/g#l/) and 'Mac lent, thick lap' (/k#l/) in Catalan and English. The yellow lines represent vocal fold vibration and the black lines represent absence of vocal fold vibration. Speaking rate appears on the ordinate and percentage of voicing in relation to supraglottal gestures appears on the abscissa. OC1 stands for onset of C1, OC2 stands for onset of C2 and RC2 stands for release of C2. Each line represents one observation.

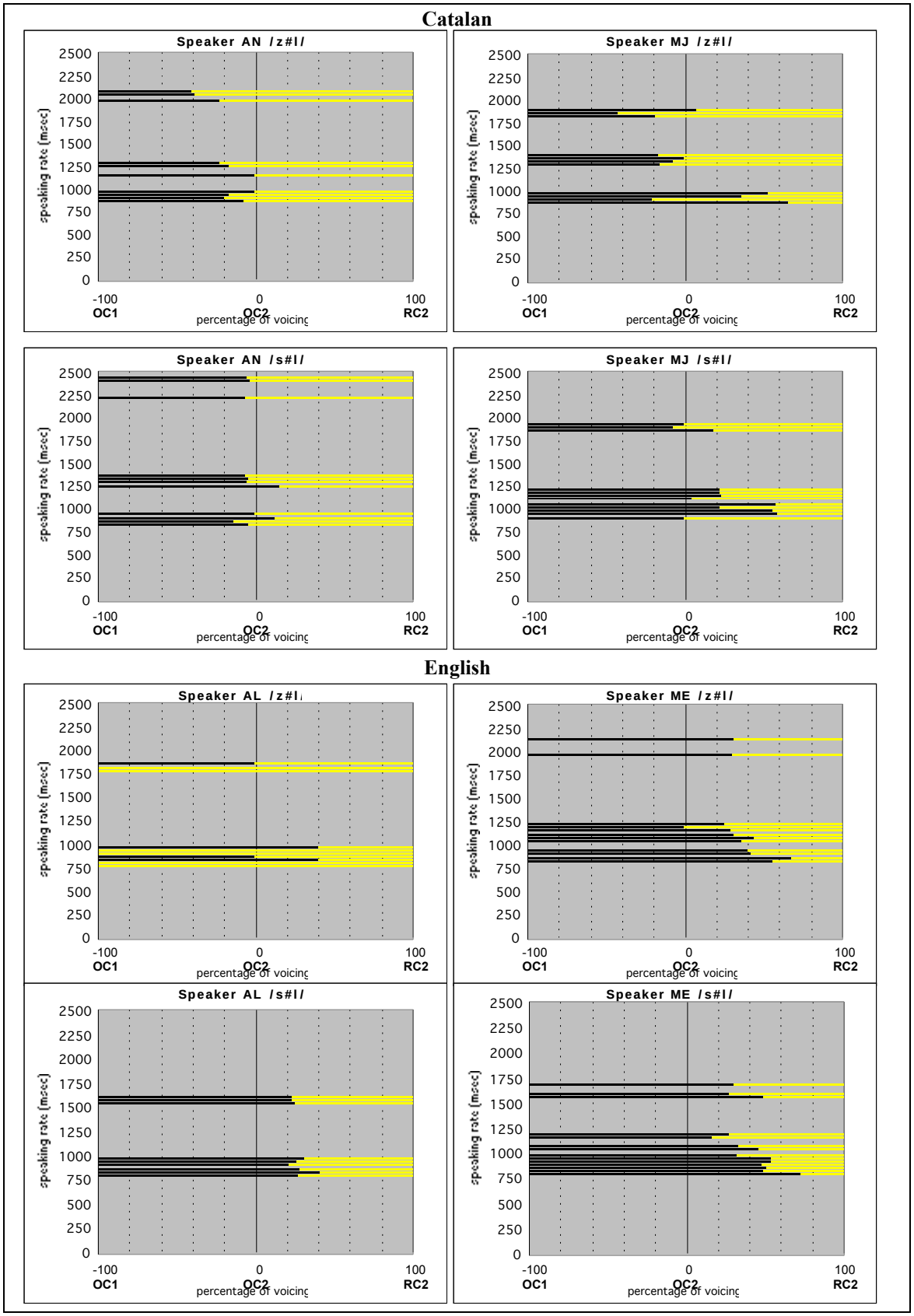

Figure 3.37. Vocal fold vibration in the consonant sequences in 'ga**s l**ent, hi**s l**ap' (/z#l/) and 'pa**s l**ent, thi**s l**ap' (/s#l/) in Catalan and English. The yellow lines represent vocal fold vibration and the black lines represent absence of vocal fold vibration. Speaking rate appears on the ordinate and percentage of voicing in relation to supraglottal gestures appears on the abscissa. OC1 stands for onset of C1, OC2 stands for onset of C2 and RC2 stands for release of C2. Each line represents one observation.

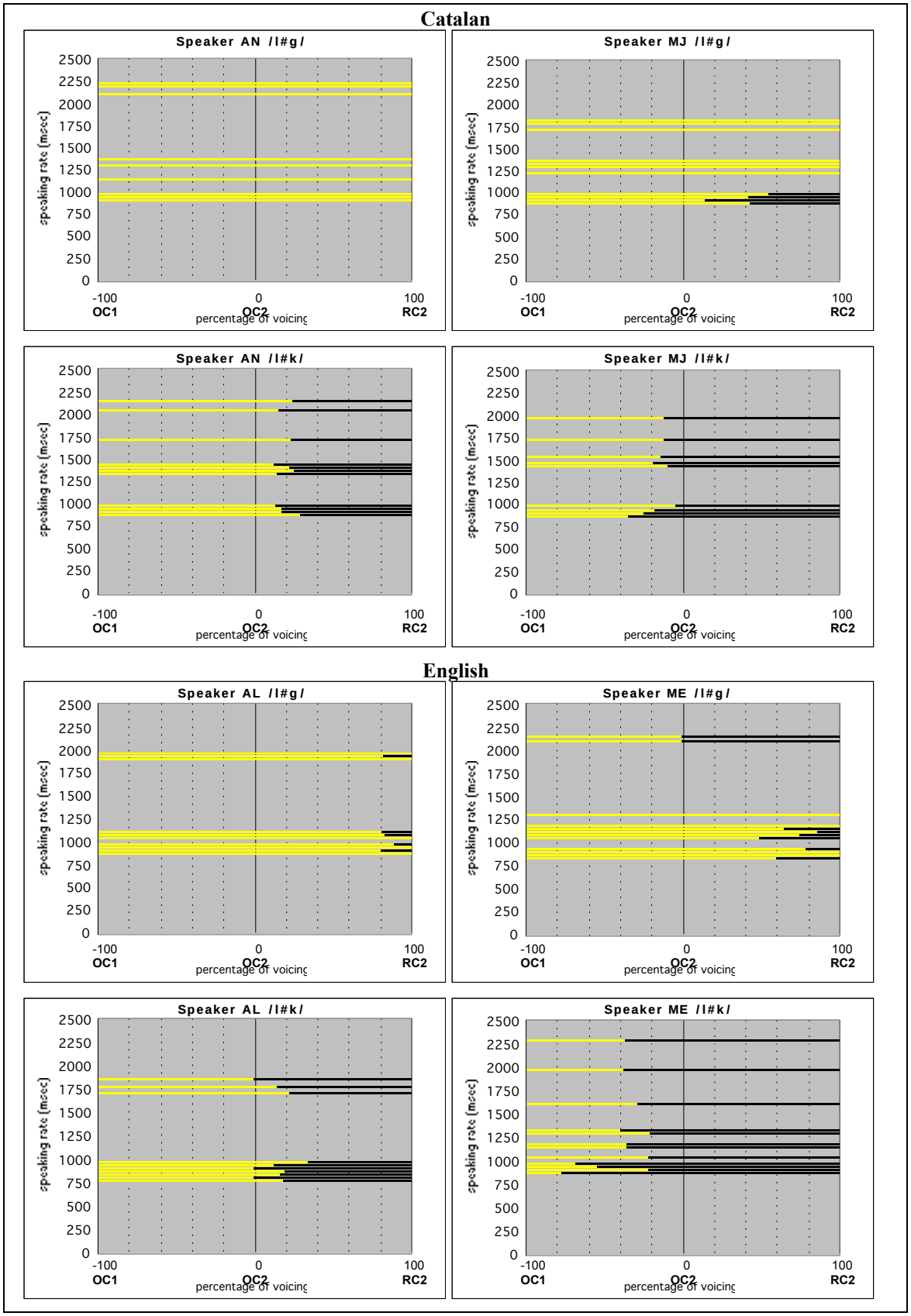

Figure 3.38. Vocal fold vibration in the consonant sequences in 'so**l g**al, fu**ll g**ap' (/l#g/) and 'so**l c**ar, fu**ll c**ap' (/l#k/) in Catalan and English. The yellow lines represent vocal fold vibration and the black lines represent absence of vocal fold vibration. Speaking rate appears on the ordinate and percentage of voicing in relation to supraglottal gestures appears on the abscissa. OC1 stands for onset of C1, OC2 stands for onset of C2 and RC2 stands for release of C2. Each line represents one observation.

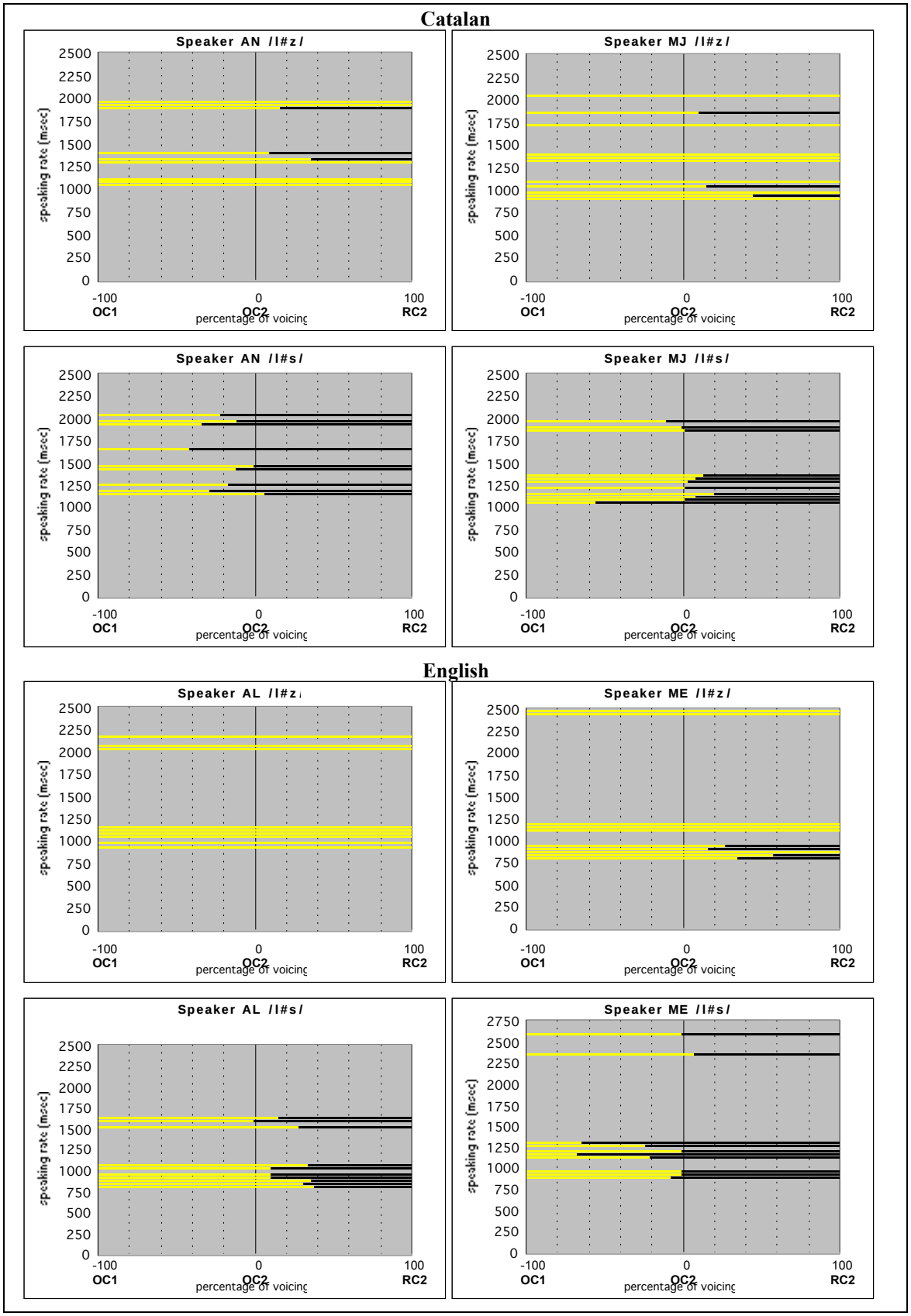

Figure 3.39. Vocal fold vibration in the consonant sequences in 'so**l z**íngar, fu**ll z**ip' (/l#z/) and 'so**l s**imple, fu**ll s**ip' (/l#s/) in Catalan and English. The yellow lines represent vocal fold vibration and the black lines represent absence of vocal fold vibration. Speaking rate appears on the ordinate and percentage of voicing in relation to supraglottal gestures appears on the abscissa. OC1 stands for onset of C1, OC2 stands for onset of C2 and RC2 stands for release of C2. Each line represents one observation.

3.5.3. Speaking rate effects

To analyze the effect of speaking rate on percentage of voicing in sequences where laterals combined with obstruents, the percentage of voicing for each individual sequence was plotted as a function of rate of speech. Figures 3.40 and 3.41 below display the results for the test sequences /k#l/ and /s#l/ for Catalan and English speakers, together with the control sequences /g#l/ and /z#l/. Figures 3.42 and 3.43 display the results for the reverse test sequences /l#k/ and /l#s/ together with the voiced control sequences /l#g/ and /l#z/.

In the great majority of cases, vocal fold abduction/adduction takes place at the onset of the constriction for C2 (*i.e.*, around 0) regardless of speaking rate. Pearson's correlation did not show any significant relationship between speaking rate and percentage of voicing in any of the test sequences, as shown in Table XVI, except for the English speaker ME in the sequence /k#l/, who showed more devoicing of C2 the faster the speaking rate. In addition, Figure 3.40 shows that complete regressive assimilation of voicing in the Catalan sequence /k#l/ uttered by subject AN only took place at fastest rates of speech.

Table XVI. Results of Pearson's correlation exploring the effect of speaking rate on percentage of voicing in sequences where laterals combined with obstruents in Catalan and English. * = $p<.05$, ** = $p<.01$

Sequence	Speaker	r^2	*p.*	Sequence	Speaker	r^2	*p.*
Catalan				English			
/k#l/	AN	0.355	0.052	/k#l/	AL	0.013	0.763
	MJ	0.293	0.085		ME	0.653	0.0008**
/s#l/	AN	0.031	0.602	/s#l/	AL	0.210	0.214
	MJ	0.327	0.051		ME	0.237	0.077
/l#k/	AN	0.005	0.836	/l#k/	AL	0.014	0.742
	MJ	0.213	0.210		ME	0.064	0.424
/l#s/	AN	0.134	0.331	/l#s/	AL	0.177	0.225
	MJ	0.0014	0.912		ME	0.276	0.118

3.5.4. Effect of degree of overlap

Concerning the effect of articulatory overlap on percentage of voicing, Figures 3.44 and 3.45 present the results for the Catalan and English sequences /k#l/ and /g#l/, and /l#k/ and /l#g/, respectively. No effect of articulatory overlap is observed except for the sequence /k#l/ in speaker MJ, with more devoicing of C2 the greater the degree of overlap (both for OIOC and OIACO indexes). The results of Pearson's correlation tests are reported in Tables XVII (OIACO) and XVIII (OIOC). For the other sequences and speakers, the correlation between the two variables did not reach significance.

Table XVII. Results of Pearson's correlation exploring the effect of overlap index OIACO on percentage of voicing in sequences where laterals combined with obstruents in Catalan and English. * = $p<.05$, ** = $p<.01$.

Sequence	Speaker	r^2	p.	Sequence	Speaker	r^2	p.
Catalan				English			
/k#l/	AN	0.0059	0.821	/k#l/	AL	0.286	0.137
	MJ	0.651	0.0026**		ME	0.157	0.180
/l#k/	AN	0.380	0.430	/l#k/	AL	0.027	0.648
	MJ	0.100	0.407		ME	0.361	0.083

Table XVIII. Results of Pearson's correlation exploring the effect of overlap index OIOC on percentage of voicing in sequences where laterals combined with obstruents in Catalan and English. * = $p<.05$, ** = $p<.01$.

Sequence	Speaker	r^2	p.	Sequence	Speaker	r^2	p.
Catalan				English			
/k#l/	AN	0.041	0.548	/k#l/	AL	0.001	0.931
	MJ	0.505	0.014*		ME	-	-
/l#k/	AN	0.229	0.135	/l#k/	AL	0.069	0.463
	MJ	-	-		ME	-	-

To summarize, in sequences of consonants where voiceless obstruents combined with laterals, the voicing gesture was switched at the onset of the oral constriction for C2. The actual implementation of the glottal abductory/adductory gesture showed some variability, so that the glottal gesture could be partially advanced to C1, or it could partially spread onto C2. Furthermore, the data showed that there may be complete regressive assimilation of voicing into C1 in the Catalan sequence /k#l/.

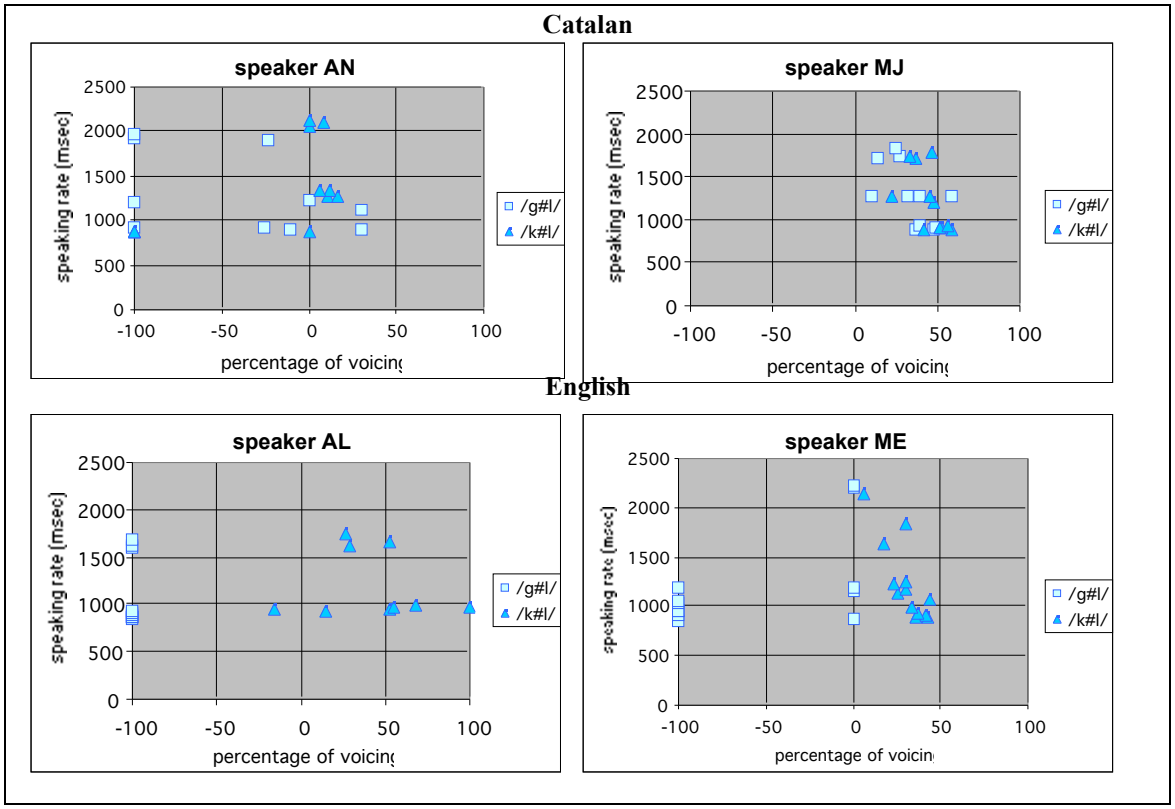

Figure 3.40 Scattergrams of percentage of voicing (horizontal axis) plotted as a function of speaking rate (vertical axis) in the Catalan and English sequences 'mag lent, big lap' (/g#l/) and 'Mac lent, thick lap' (/k#l/), with higher values indicating slower speaking rates. Each dot corresponds to one observation.

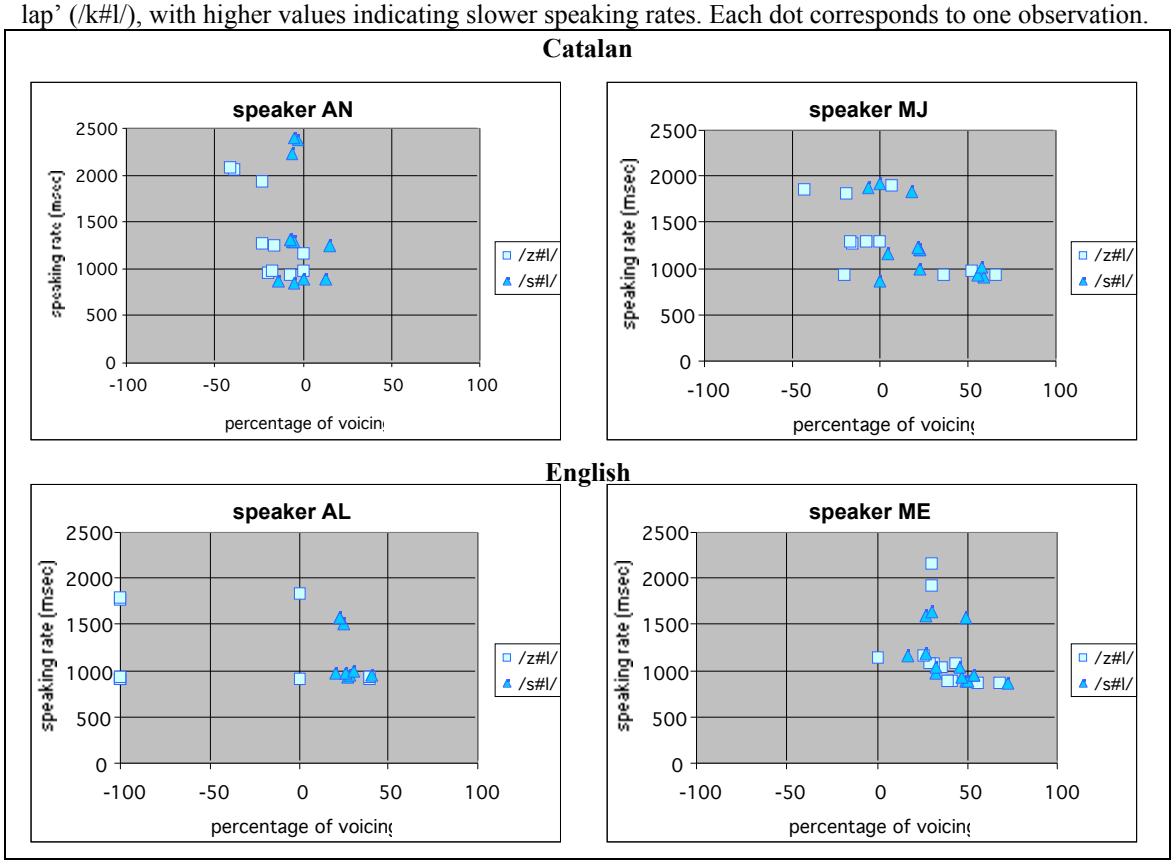

Figure 3.41. Scattergrams of percentage of voicing (horizontal axis) plotted as a function of speaking rate (vertical axis) in the Catalan and English sequences 'gas lent, his lap' (/z#l/) and 'pas lent, this lap' (/s#l/), with higher values indicating slower speaking rates. Each dot represents one observation.

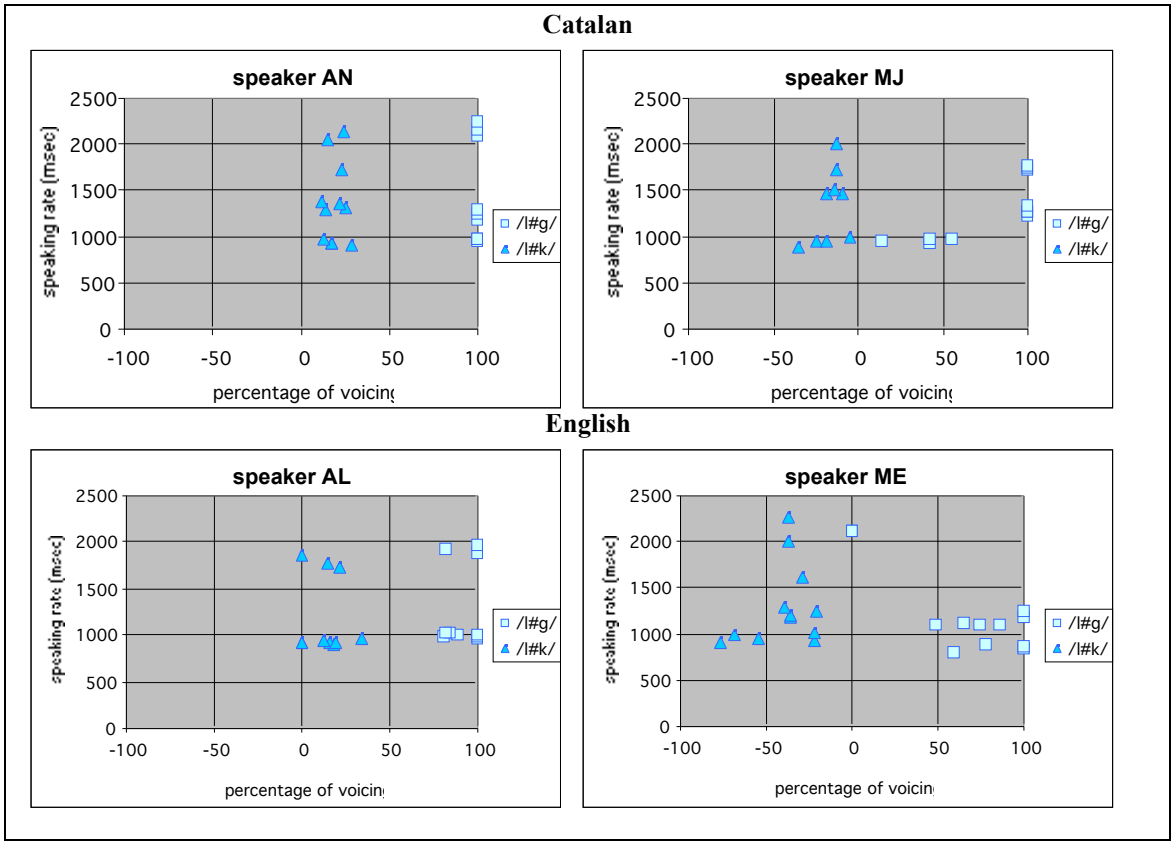

Figure 3.42. Scattergrams of percentage of voicing (horizontal axis) plotted as a function of speaking rate (vertical axis) in the Catalan and English sequences 'sol gal, full gap' (/l#g/) and 'sol car, full cap' (/l#k/), with higher values indicating slower speaking rates. Each dot represents one observation.

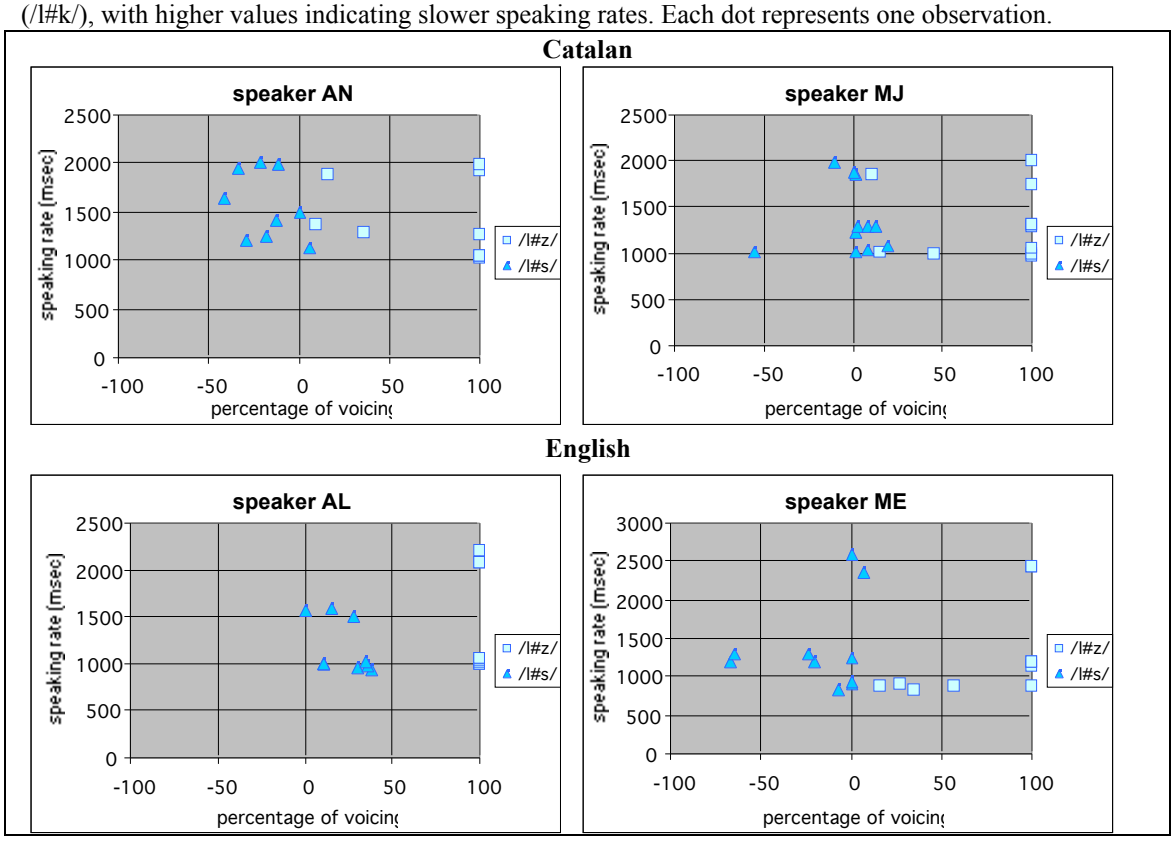

Figure 3.43. Scattergrams of percentage of voicing (horizontal axis) plotted as a function of speaking rate (vertical axis) in the Catalan and English sequences 'sol zíngar, full zip' (/l#z/) and 'sol simple, full sip' (/l#s/), with higher values indicating slower speaking rates. Each dot represents one observation.

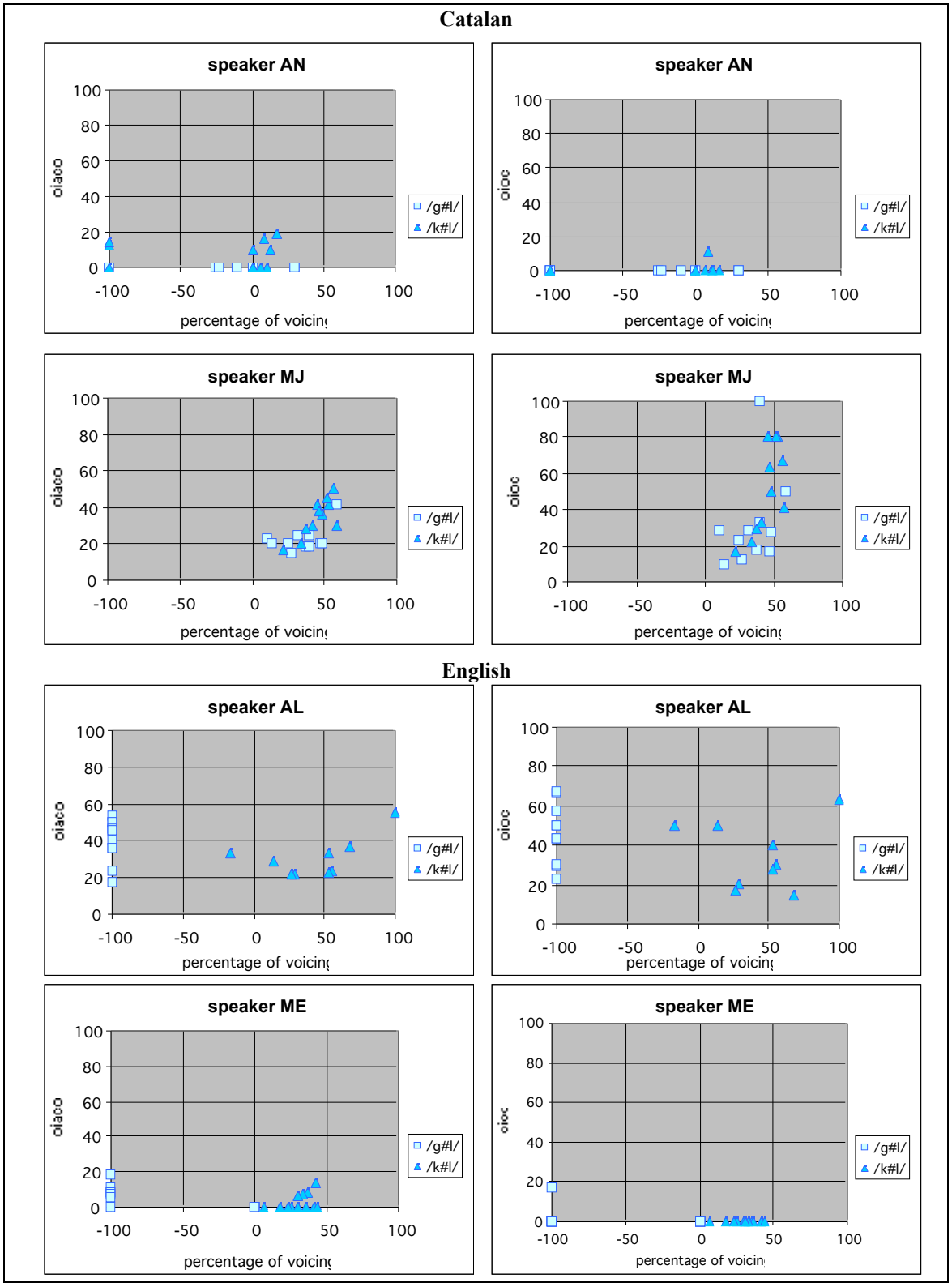

Figure 3.44. Scattergrams of percentage of voicing (horizontal axis) in the individual tokens plotted as a function of overlap indexes OIACO and OIOC (vertical axis) in the Catalan and English sequences 'mag lent, big lap' (/g#l/) and 'Mac lent, thick lap' (/k#l/). Each dot represents one observation.

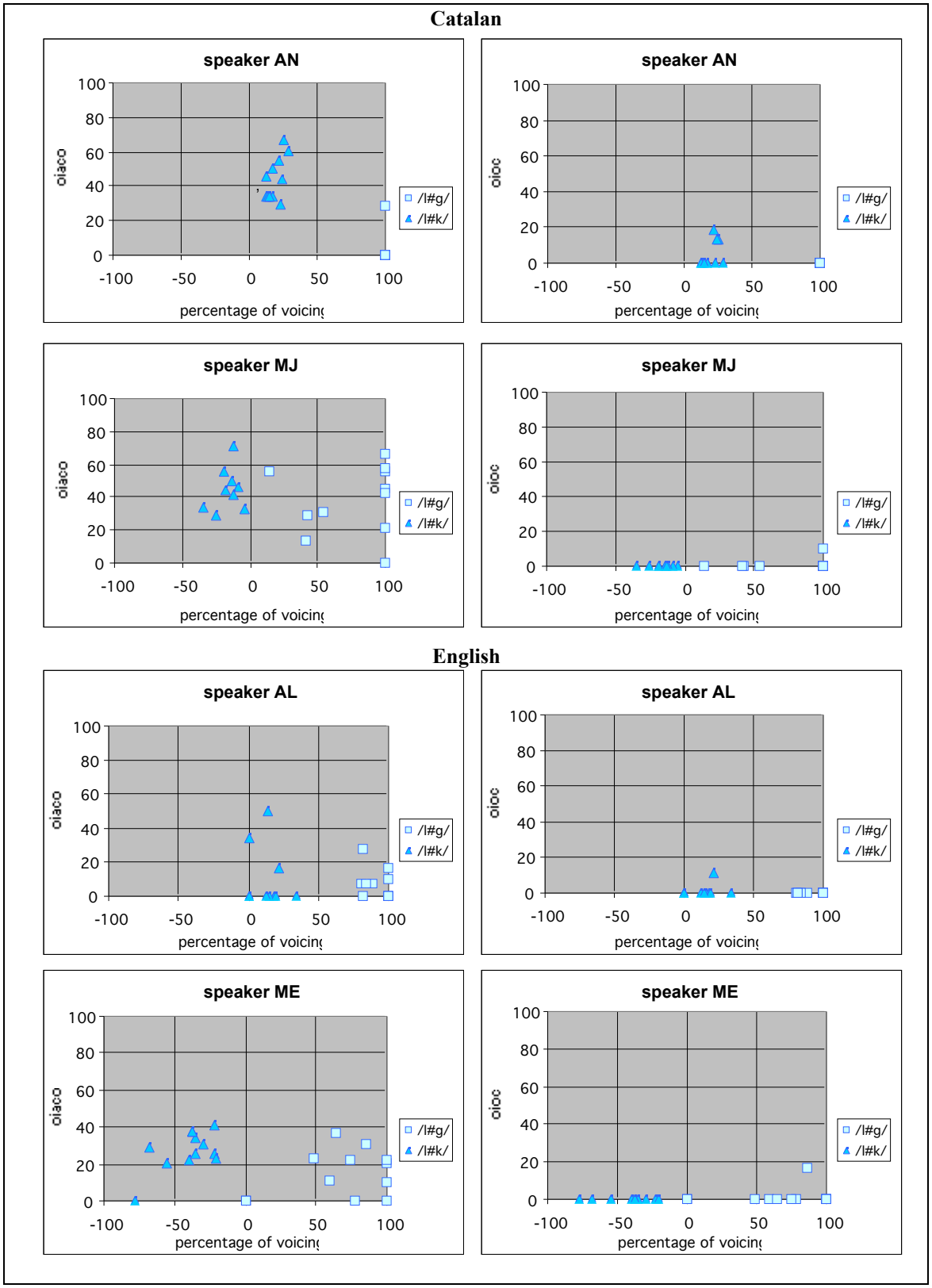

Figure 3.45. Scattergrams of percentage of voicing (horizontal axis) in the individual tokens plotted as a function of overlap indexes OIACO and OIOC (vertical axis) in the Catalan and English sequences 'sol gal, full gap' (/l#g/) and 'sol car, full cap' (/l#k/). Each dot represents one observation.

SUMMARY

To summarize, the results of the present experiment show that there is complete regressive assimilation of voicing in Catalan obstruent sequences so that the glottal gesture for C2 is advanced to the onset of the oral constriction for C1. However, this process does not apply in all cases, as has been stated by traditional descriptions: in the sequence /d#k/, one of the Catalan speakers showed partial regressive assimilation of voicelessness.

In English, some variability was found in obstruent sequences, although the general tendency seems to be devoicing obstruents adjacent to voiceless obstruents. However, speakers may maintain voicing in C1 in the sequence /d#k/ and they may display regressive assimilation in sequences like /t#g/.

In sequences where obstruents combined with sonorants, Catalan and English displayed similar behaviours: the switch of glottal gestures seemed to be coordinated with the onset of oral constriction for C2 and mechanical anticipatory or progressive movements were possible. In Catalan, however, complete regressive voice assimilation was found.

In addition, in nasal – obstruent sequences voicing penetrated into C2 when C2 was a stop in both languages and also in English when C2 was a fricative but less than in nasal – stop sequences. This may be attributed to the fact that fricatives are less prone to maintain voicing than stops due to aerodynamic factors. Conversely, no spreading of voicing was observed into the following obstruent in any of the two languages when C1 was a lateral. Table XIX below summarizes the coordination of oral and glottal gesture in sequences where sonorants combined with obstruents in Catalan and English.

Table XIX. Summary of the results obtained in sequences where obstruents combined with sonorants.

<table>
<tr><th></th><th>English</th><th>Catalan</th></tr>
<tr><td>Nasal – stop</td><td colspan="2">Voicing into 1/3 to 2/3 of C2</td></tr>
<tr><td>Nasal – fricative</td><td>Voicing into 1/10 of C2</td><td>Voicing gesture switched at the onset of C2</td></tr>
<tr><td>Stop – nasal</td><td colspan="2">Voicing gesture switched at the onset of C2</td></tr>
<tr><td>Fricative – nasal</td><td colspan="2">Partial devoicing of C2 or voicing gesture switched at the onset of C2</td></tr>
<tr><td>Lateral – stop</td><td colspan="2" rowspan="2">Voicing gesture switched at the onset of C2</td></tr>
<tr><td>Lateral – fricative</td></tr>
<tr><td>Stop – lateral</td><td colspan="2" rowspan="2">Partial devoicing of C2 or voicing gesture switched at the onset of C2</td></tr>
<tr><td>Fricative – lateral</td></tr>
</table>