An electropalatographic and acoustic study of affricates and fricatives in two Catalan dialects

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The present study is an electropalatographic and acoustic investigation of the fricatives /s, ʃ/ and the affricates /ts, dz, tʃ, dʒ/ based on data from five speakers of Majorcan Catalan and five speakers of Valencian Catalan. Results show that the articulatory characteristics of fricatives and affricates agree in several respects: the sounds traditionally labeled /ʃ/ and /tʃ, dʒ/ are alveolopalatal, and are articulated at a less anterior location, are less constricted and show more dorsopalatal contact than the alveolars /s/ and /ts, dz/; the two place categories are closer to each other in Valencian than in Majorcan. Compared to voiceless affricates, voiced affricates are more anterior and more constricted, and show less dorsopalatal contact. Data also show that closure location for /tʃ, dʒ/ occurs at the alveolar zone, and that articulatory differences among affricates are better specified at frication than at closure. Strict homorganicity between the stop and frication components of affricates appears to hold provided that constriction location at frication is compared with place of articulation at closure offset. In comparison to voiceless affricates, voiced affricates were shorter, and exhibited a longer closure and a shorter frication period, in Majorcan; in Valencian, on the other hand, closures were shortest for /dʒ/, and frication was systematically longer for voiceless vs. voiced affricates. These duration data appear to conform to a universal trend in Valencian but not in Majorcan where voiced affricates are lengthened intentionally. In both Catalan dialects, vowel duration varies inversely with the duration of the affricate and of its closure and frication components. The implications of these articulatory and duration characteristics for the interpretation of sound changes affecting affricates, i.e. place merging, lenition and devoicing, are discussed.

1 Introduction

Little attention has been paid to the production characteristics of affricate consonants in the worlds' languages, though there has recently been an increasing interest in the study of these sounds in languages as diverse as Hindi (Dixit & Hoffman 2004), Korean (Kim 2001, 2004) and Italian (Faluschi & Di Benedetto 2001). The present paper is an electropalatographic (EPG) and acoustic investigation of affricate consonants in connection to their fricative

Journal of the International Phonetic Association (2007) 37/2
doi:10.1017/S0025100306002829

cognates in two Catalan[1] dialects, Majorcan and Valencian, where the two consonant classes involve relevant phonetic differences in place, voicing and/or duration.

Our study is an investigation of general issues about consonant production such as the articulatory differences between alveolar and palatal fricatives, how underlying place and voicing differences affect the articulatory and duration characteristics of affricates during the closure and frication phases, and whether the articulatory characteristics of affricates parallel those of fricatives. Catalan allows these issues to be explored because, in addition to the fricatives /s, z, ʃ, ʒ/, it has the complete series of affricates /ts, dz, tʃ, dʒ/ though subject to distributional restrictions (Recasens 1993: 158–161, Wheeler 2005: 11–23). The only exception is Valencian where /dʒ/ is always found in the place of /ʒ/. All four affricates occur intervocalically though not frequently in the case of /ts, dz/ (e.g. [puˈtse] *potser* 'perhaps', [ˈdodzə] *dotze* 'twelve', [ˈkotʃə] *cotxe* 'car', [ˈmedʒə] *metge* 'doctor' in Eastern Catalan). In word-final position, we only find the voiceless cognates due to final devoicing, the alveolar affricate appears almost exclusively in heteromorphemic plural endings ([tots] *tots* 'everybody'), and the palatal affricate may alternate with either affricate or fricative realizations intervocalically depending on dialect and lexical item (e.g. [bɔtʃ] *boig* 'masc. crazy' – [ˈbɔʒə] *boja* 'fem. crazy', [əsˈkitʃ] *esquitx* 'sprinkle' – [əskiˈtʃa] *esquitxar* 'to sprinkle' in Eastern Catalan). There is no contrast between fricatives and affricates word-initially and after a heterosyllabic consonant such that either one or the other occur depending on dialect and word (e.g. [ʃiˈnɛs] *xinès* 'Chinese', [ˈpunʃə] *punxa* 'sting' in Eastern Catalan, and [tʃiˈnes], [ˈpuntʃa] in Western Catalan).

Detailed phonetic studies on affricates may be relevant for the interpretation of changes affecting place, voicing and the stability of the closure and frication elements. Changes in place of articulation may cause alveolar affricates to undergo palatalization or palatal affricates to merge with alveolars, much in the same way as apical /s, z/ may palatalize before front vowels and glides and /ʃ, ʒ/ may become alveolar in Valencian and other Romance languages and dialects (see section 1.1). It may be that these changes are favored by the degree of proximity between alveolar and palatal fricatives and affricates which calls for an analysis of whether, in case that it occurs, articulatory proximity is achieved through the retraction of alveolars and/or the fronting of palatals.

Other changes such as the simplification and devoicing of affricates appear to be related to closure duration, i.e. long closures are prone to devoice and short closures may undergo lenition or elision. Majorcan and Valencian allow looking at this issue since affricates are supposed to be long in the former dialect and short in the latter (see section 1.2).

Closure reduction should be prone to affect (short) Valencian affricates. The fact that lenition may operate on voiced affricates in this dialect, e.g. word-initial and postconsonantal [dʒ] alternates with [(j)ʒ] intervocalically in Northern Valencian, implies that closure duration should be shorter in voiced affricates than in voiceless affricates. The presence of /dʒ/ for /ʒ/ in Valencian reflects the historical change /ʒ/ > /dʒ/ or the failure for /dʒ/ to become /ʒ/. In any case, the marked status of the voiced palatal fricative vis-à-vis other fricatives has also been pointed out for other consonant systems, i.e. its absence in Italian and Occitan and its marginal status in English (Wheeler 2005: 15).

[1] Catalan is a Romance language spoken in the Northeastern Spanish region of Catalonia, in the Valencian region to the south of Catalonia along the Mediterranean sea, in Majorca and the other Balearic islands, in the Southern French region of Roussillon and in the Sardinian town of l'Alguer. Of the four major dialects, Eastern and Western (in Catalonia), Majorcan and Valencian, the presence of specific phonetic and phonological features renders the status of the latter two quite unique within the Catalan linguistic domain. Thus, Majorcan exhibits stressed [ə] (presumably a linguistic relic from Old Catalan) and palatal stop allophones of /k, g/ occurring before front vowels and word finally (probably an autochthonous development). On the other hand, Valencian shows a trend for syllable final stops to undergo lenition whether autochthonous or due to Spanish influence (Veny 1983, Recasens 1996).

Affricate devoicing of voiced affricates if especially long may occur in favorable conditions, i.e. after stress (Eastern Catalan [ˈmeddʒə] *metge* 'doctor' may turn into [ˈmettʃə]). This calls for the investigation of whether lengthening affects all affricates or just voiced affricates. Descriptive data for Catalan suggest indeed that /dʒ/ is more prone to lengthen than /tʃ/ in specific dialectal areas ([ˈmeddʒə] *metge* 'doctor' cooccurs with [ˈkotʃə] *cotxe* 'car' in Eastern Catalan regions). The systematic replacement of /dʒ/ by /tʃ/ in areas of the Valencian region has been attributed to other factors such as the influence of Spanish where the only affricate available is /tʃ/.

This paper will analyze the production mechanisms of fricatives and affricates in order to uncover possible common characteristics between the two phonetic classes as well as dialect-dependent differences in terms of constriction fronting and articulatory distance for alveolars and palatals. It will also deal with the temporal structure of affricates and, more specifically, with the relative duration of the closure and frication components. The implications of the results for the interpretation of place merging, lenition and devoicing of affricates will be addressed.

1.1 Articulation of affricates and fricatives

1.1.1 Place of articulation

While language-dependent differences in constriction location for /s/ always occur within the alveolar zone, the place of articulation for /ʃ/ (and for its voiced cognate) is less clear. According to the International Phonetic Alphabet, the phonetic symbol [ʃ] corresponds to a postalveolar fricative, and the term 'palatoalveolar' which is also assigned to this fricative corresponds to a lamino-postalveolar articulation (see Ladefoged & Maddieson 1996: 14f.). Other close fricatives are the dorsopalatal [ç], which is an allophone of /x/ in German and Norwegian (Simonsen & Moen 2004), and the alveolopalatal [ɕ] in languages such as Chinese and Polish, where it is produced with a lowered tongue tip, a high tongue dorsum position and a long constriction extending from the alveolar zone to well inside the palatal zone (Ladefoged & Maddieson 1996: 150–164).

Electropalatographic data for five speakers of Eastern Catalan reported in Recasens & Pallarès (2001: 84f.) reveal that Catalan /ʃ/ is articulated essentially at the postalveolo-prepalatal zone for all speakers and involves much dorsal contact at both sides of the palate behind the constriction. Moreover, speakers seem to be having the tongue tip down during the production of this laminal or lamino-predorsal consonant, as suggested by the fact that the two frontmost rows of electrodes of the articial palate remain completely unactivated and that the frontmost lateral contact has a V-like shape. Based on these data, we believe that Catalan /ʃ/ ought to be labeled 'alveolopalatal' which is consistent with the presence of other alveolopalatal consonants such as /ɲ/ and /ʎ/ in the language. Accordingly, we will use this term to refer to /ʃ, ʒ/ and to /tʃ, dʒ/ in this paper.

It appears then that alveolopalatal articulations such as /ɲ/ in most Romance languages and /ʃ/ in Catalan cannot be possibly assigned a single articulatory zone: the IPA term 'postalveolar' would not be appropriate for Catalan /ʃ/ since the constriction for this consonant also occurs at the palatal zone, and the IPA term 'palatal' cannot be applied to /ɲ/ in languages or dialects where those consonants are alveolopalatal since closure location extends into the alveolar zone in this case. For all these articulations, closure or constriction location takes place not just at one articulatory zone but at two articulatory zones simultaneously. Based on these observations, it seems that the term 'alveolopalatal' would need to be included in the IPA chart, and that the phonetic symbols [ʃ] and [ɲ] could be assigned two possible places of articulation rather than just one, i.e. 'postalveolar' and 'alveolopalatal' for the former, and 'alveolopalatal' and 'palatal' for the latter.

A research issue addressed in the present paper is whether, analogously to the Eastern Catalan dialect, /ʃ/ is also alveolopalatal in Majorcan and Valencian.

1.1.2 Main articulator

Even though electropalatography (EPG) does not provide direct information about the lingual articulator involved in closure or constriction formation for consonants, it certainly allows speculating about what it might be. Another goal of this study is to determine whether Catalan dialects differ regarding the primary articulator for /s/ and /ʃ/, and whether this difference holds for affricates as well.

Previous studies on lingual fricatives have shown that both fricatives are subject to a great deal of speaker-dependent variability (Ladefoged & Maddieson 1996: 147f.). Thus, both tip and lamina may participate in the formation of the two fricatives such that, at least for English, apical realizations are dentoalveolar and more grooved while laminals are postalveolar and less grooved (Narayanan, Alwan & Haker 1995). The scenario appears to be different in the Romance languages where a three-fricative system composed of predorsodental /s/, apicoalveolar /s/ and palatal /ʃ/ was simplified into a two-fricative system with either predorsodental /s/ and /ʃ/ (French, Italian) or apicoalveolar /s/ and /ʃ/ (Catalan, Spanish). Since predorsal /s/ is more anterior, not more posterior than apical /s/ in Romance, the more anterior realization of /s/ in Valencian than in Majorcan is expected to be less apical as well. Moreover, less apical, more anterior realizations of /s/ ought to be less grooved (Navarro Tomás 1972: 106f.). Palatographic data for different /s/ types in Southern Spanish dialects presented by Navarro Tomás, Espinosa & Rodríguez-Castellano (1933) show indeed more dorsopalatal contact for laminal than for apical realizations of /s/ (which is in accordance with less grooving), but less contact at the sides of the palate for the most anterior, predorsal realizations of the alveolar fricative (which in principle does not seem to be consistent with the assumption that grooving should be minimal in this case). A possibility is that the production of predorsal /s/ involves a flat tongue dorsum position, marginal lateral contact and a large separation between the postdorsum and the pharyngeal wall.

1.1.3 Symmetrical relationship

Another research topic is whether the articulatory characteristics of the alveolar affricates /ts, dz/ and the alveolopalatal affricates /tʃ, dʒ/ parallel those for the corresponding alveolar and alveolopalatal fricatives.

There is a reason for studying the similarity between the phonetic realization of lingual fricatives and the fricative element of affricates, rather than the articulatory similarity between dental or alveolar stops and the affricate closing phase. Affricates have been viewed as stops with a slow release (Heffner 1950: 120, Ladefoged & Maddieson 1996: 90) or else as consonant sequences composed of a stop followed by a fricative (Abercrombie 1967: 147f., Smalley 1980: 136f.). The coarticulatory behaviour of lingual affricates in Catalan and other languages resembles that of stop + fricative clusters in that the stop is influenced by the fricative rather than the other way around. Thus, dental /t/ becomes alveolar before /s/ and alveolopalatal before /ʃ/. This assimilatory pattern follows from differences in coarticulatory aggressiveness and coarticulatory resistance between stops and fricatives (Recasens 1999).

Given that the articulatory characteristics of the fricative override those of the stop in affricates, they are expected to resemble fricatives of the same place of articulation both during the stop and the frication phases. Evidence in support of a symmetrical relationship in sibilant groove location and width between affricates and fricatives has been reported to occur in English (Fletcher 1988) and in Hindi (Dixit & Hoffman 2004). In Chinese, fricatives and affricates also appear to share a highly similar place of articulation and overall tongue shape: /s/ and /ts/ are apical and dentoalveolar or front alveolar, /s̺/ and /ts̺/ are laminal-like and centroalveolar or postalveolar, and /ɕ/ and /tɕ/ are palatalized alveolar or alveolopalatal (Ladefoged & Wu 1984).

In order to be able to investigate articulatory symmetry between affricates and fricatives in Majorcan and Valencian, we will begin by identifying the production properties of /s/ and

/ʃ/ in the same dialects. Descriptive data in the literature suggest that either one or the two lingual fricatives are more anterior in Valencian than in Majorcan (Rafel 1981). Valencian fricatives could certainly be articulated at a further front location than Majorcan fricatives if the latter were as retracted as in Eastern Catalan, where /s/ is centroalveolar or postalveolar and /ʃ/ is alveolopalatal. Eastern Catalan /s/ exhibits a front-cavity dependent spectral peak at a lower frequency (about 3500–4500 Hz; Recasens 1986, Recasens & Pallarès 2001: 80f.) than /s/ in English (between 3500 Hz and 5000–7000 Hz; Heinz & Stevens 1961, Behrens & Blumstein 1988, Jongman, Wayland & Wong 2000) and in other languages (4500–6500 Hz or else 6500–9500 Hz; Nartey 1982: 80–85). The spectral peak for Eastern Catalan /ʃ/ (2000–3000 Hz) is perhaps lower or occurs within the same frequency range as that for English and other languages (2000–3500 Hz and 2000–4500 Hz, respectively, according to the same studies referred to above).

Other possible similarities between lingual fricatives and affricates will be examined. Thus, in comparison with /s/, /ʃ/ is expected to exhibit more tongue raising behind the constriction and more prominent F2 rising vowel transitions (Jongman et al. 2000), and a larger constriction width and sublingual cavity size (Fant 1960: 170, Fletcher 1988, Fletcher & Newman 1991).

1.1.4 Phonetic distance

Dialects such as Majorcan and Valencian may not only differ from one another regarding the articulatory characteristics of /s/ and /ʃ/ but also the phonetic distance between the two lingual fricatives. Thus, /s/ and /ʃ/ have been reported to be auditorily more similar to each other in Valencian than in Majorcan, such that place neutralization may occur in the former dialect (Rafel 1981). The issue here is what articulatory factors are responsible for the auditory proximity between /s/ and /ʃ/, and if place neutralization between the two fricatives actually occurs or not. Several descriptive studies suggest that place neutralization is mainly due to /ʃ/ depalatalization, mostly so in dialectal areas such as Northern Valencian where the alveolopalatal consonant may be produced as [js^j] or [js], e.g. [ˈkajsa] for General Catalan [ˈkaʃə] *caixa* ‘box’ (Colon 1970, Veny 1983: 170, Gimeno 1994: 35–41). This scenario is shared by other Romance languages. Thus, /ʃ, ʒ/ derived from several Latin consonant sequences appear to have merged with /s, z/ in French, N. Occitan areas and Venetian, perhaps in order to avoid a complex sibilant system composed of predorsodental, apicoalveolar and palatal fricatives (Tuttle 1985).

According to the symmetry hypothesis formulated above, Majorcan and Valencian ought to differ regarding the articulatory proximity between alveolar and alveolopalatal affricates. More specifically, smaller or no articulatory differences between both lingual fricatives in Valencian ought to be traced during affricate production as well. Descriptive data in the literature appear to be consistent with this possibility. Thus, General Catalan [mitʃ] *mig* ‘half’ and [ʎetʃ] *lleig* ‘ugly’ have been transcribed [mits] and [ʎets] in Central Valencian areas, and /tʃ/ has been reported to undergo depalatalization without merging with [ts] in words such as [baˈtʃaɾ] *baixar* ‘to go down’ and [petʃ] *peix* ‘fish’ in Southern Valencian areas (Saragossà 1987: 153, Beltran 1997: 23). The merging of alveolopalatal affricates with their alveolar cognates has taken place in dialects where alveolar and alveolopalatal fricatives also undergo neutralization, such as the N. Italian and N. Occitan zones referred to above (Rohlfs 1966: 316, 202, Alibèrt 1976: 28f., Lafont 1983: 47). The fronting of /tʃ/ may also have applied after velar softening in Western Romance, i.e. front /k/ > [c] > [tʃ] > [(t)s] (e.g. Catalan [sen] from Latin [ˈkento]), and appears to have occurred more recently in other linguistic domains such as Chilean Spanish and Basque from Bermeo (Lipski 1994: 223, Hualde 2000). In parallel to the scenario for lingual fricatives and based on the data just described, the present study will investigate whether the articulatory proximity between alveolar and alveolopalatal affricates in Valencian Catalan, if present, is achieved through /tʃ, dʒ/ depalatalization, and if depalatalization causes complete merging of /ts, dz/ and /tʃ, dʒ/.

1.1.5 Homorganicity

Another question addressed in this paper is the extent to which the closure and frication phases of affricates are homorganic. Strictly speaking, homorganicity would be more at work if closure release involves a slight widening of the articulatory constriction for the stop component than if the position of the active articulator is adjusted forwards or backwards during the transition from the stop phase to the frication period (Ladefoged & Maddieson 1996: 90). Gradual retraction in adjustment for frication starting already after closure contact maximum has been reported to occur for /tʃ/ (Mair, Scully & Shadle 1996). A gradual transition from closure to frication would render affricates more similar to biconsonantal sequences than to simple consonants with a long release (Catford 1977: 211f.).

A less strict requirement on homorganicity is for the fricative element to be homorganic with respect to closure location at offset vs. midpoint of the affricate stop phase. If so, place retraction during the second half of the closing period could be attributed to aerodynamic demands alone. In support of the effect of aerodynamic factors on affricate closure location, data from the literature indicate that both stop and fricative phases may not fully coincide in place of articulation all throughout the affricate consonant. Indeed, data on /tʃ, dʒ/ in different languages reveal that closure is often not alveolopalatal or postalveolar but may spread more towards the front and thus, be centroalveolar or even front alveolar (Josselyn 1907; Fernández 2000; Kim 2001, 2004; Recasens & Pallarès 2001; Dixit & Hoffman 2004). Speaker-dependent characteristics in palate shape could be responsible for at least part of the closure-to-frication adjustments under discussion.

1.1.6 Voicing

Differences in underlying voicing ought to be correlated with articulatory characteristics. This should be so for constriction location which is expected to be more anterior for voiced vs. voiceless affricates so as to facilitate vocal fold vibration by expanding the back cavity and keeping the intraoral air pressure level sufficiently low (Kohler 1984: 163). It remains unclear whether voiced affricates should be more or less constricted than their voiceless cognates and, indeed, constriction size has been reported to be narrower for /z/ than for /s/ according to some studies (Fletcher 1988, Farnetani 1989, Dagenais, Lorendo & McCutcheon 1994, Dixit & Hoffman 2004) but for /s/ vs. /z/ according to others (Perkell 1969, Pandeli 1993). A higher constriction degree for voiced vs. voiceless affricates would accord with a higher intraoral air pressure level and more airflow through an open glottis and the supraglottal constriction. The reverse relationship, i.e. a trend for voiced affricates to be less constricted than voiceless ones, would occur in order to keep the intraoral pressure low and thus facilitate voicing. It may also be that constriction size varies over time in order to facilitate glottal vibration as transglottal pressure decreases late in the fricative (Stevens 1998: 481). Finally, palatographic evidence for stop consonants suggests that tongue contact degree ought to be greater for voiceless vs. voiced and long vs. short affricates (Farnetani 1990).

1.2 Temporal structure of affricates

The present study also investigates the temporal structure of affricates and, more specifically, differences in duration and articulation between the closure and frication components.

Maximal affricate duration occurs for phonologically distinctive geminates, e.g. in Italian, where the realization /tːʃ/ in *faccia* 'face' contrasts with /tʃ/ in *amici* 'friends'. Non-geminate affricates may also be longer or shorter depending on the language, e.g. /tʃ/ duration has been found to vary in the progression English > Spanish > Italian (Maddieson 1980). Catalan is interesting in this respect since non-geminate affricates appear to be long or short in different dialects (Recasens 1996). Long affricates have been reported to occur in Eastern and Western Catalan, in Majorcan and in specific Northern and Southern Valencian areas, where the voiceless cognate may also shorten perhaps due to Spanish influence. Short affricates are widespread in Valencian. In this paper, we will study the extent to which affricates are long in Majorcan and short in Valencian.

Data from the literature indicate that, at least for geminates vs. non-geminates, affricate duration is correlated with closure duration rather than with frication duration (Tarnóczy 1988, Maddieson 1980). Moreover, (longer) voiceless affricates have been shown to exhibit longer closure and frication periods than their (shorter) voiced cognates in Italian, Hungarian and English (Vagges, Ferrero, Magno-Caldognetto & Lavagnoli 1975, Tárnoczy 1988, Lavoie 2001). This voicing-dependent difference in affricate closure duration may reflect a universal trend for closures to be longer if associated with underlying voiceless vs. voiced obstruents (J. Ohala 1983), and would account for why, analogously to other languages (Lipski 1994, Lavoie 2001: 126), realizations such as [(j)ʒ] or frictionless [ɟ] are found in the place of [dʒ] in intervocalic and preconsonantal position in Valencian, e.g. Northern Valencian [ˈme(j)ʒe] *metge* 'doctor' (Navarro Tomás & Sanchis Guarner 1934: 132, Guirau 1979). Articulatory reduction may not only affect voiced affricates but voiceless affricates as well, as shown for Tuscan Italian (Rohlfs 1966) and for Hindi (M. Ohala 2001).

This scenario is by no means unique since (longer) voiceless affricates may also involve a longer frication period but a shorter closure than (shorter) voiced affricates. This situation appears to hold in Eastern, Western and Majorcan Catalan, and in Italian according to Faluschi & Di Benedetto 2001 (see also Lepschy & Lepschy 1988 regarding the long realization of /dʒ/ in Central and Southern Italian). It may be claimed that, differently from the more general universal trend for the closing phase to be longer for voiceless affricates than for voiced affricates, the voiced cognate is lengthened intentionally in this case. Instead of simplification into less constricted consonant realizations, long voiced affricates may undergo devoicing if the intraoral pressure level becomes too high as subglottal air keeps flowing into the oral cavity during the closing phase (Westbury & Keating 1985). Indeed, devoicing of long or lengthened /dʒ/ has been reported to occur after stress in Catalan dialects (see section 1) and in Lenguadocian areas. While data on fricative and affricate devoicing in several positions and contexts have been reported for other languages (Haggard 1978, Smith 1997, Jesus & Shadle 2002), the issue as to whether devoicing applies to the frication and/or closure phase for affricates has received little attention in the literature. The present investigation will look into this double possibility.

Frication duration for affricates appears to be positively correlated with an increase in airflow and in intraoral pressure associated with voicelessness rather than with closure duration. Italian data reported by Faluschi & Di Benedetto (2001) indicate that, while closure may be longer for underlying voiced vs. voiceless affricates, the opposite holds invariably for frication duration. The duration of the vowel preceding the affricate ought to be strongly related to the duration of the entire affricate and of its closure period. Spanish, English and Italian data reveal indeed that vowel duration compensates for affricate and closure duration but less clearly so or not at all for frication duration, i.e. the vowel shortens as the affricate and its closure period lengthen and vice versa (Maddieson 1980, Kohler 1984: 155).

1.3 Summary of research issues

EPG (electropalatography) and acoustics will be used to analyze place of articulation, dorsopalatal contact, constriction degree and duration for Majorcan and Valencian fricatives and affricates. Research questions include whether affricates parallel fricatives at the articulatory level, if the articulatory distance between alveolar and alveolopalatal productions is less in Valencian than in Majorcan, and if /ʃ/ depalatalization in the former dialect causes complete merging of /s/ and /ʃ/, and of /ts, dz/ and /tʃ, dʒ/. Research on affricates will also deal with their temporal structure, the extent to which the closure and frication phases are homorganic, and possible articulatory differences as a function of underlying voicing. Regarding the latter issue, voiceless affricates are expected to exhibit more tongue contact and a more retracted constriction during frication than voiced affricates; it deserves to be seen

Table 1 Fricative and affricate sentence list with phonetic transcription, Catalan orthographic representation and English translation. In the phonetic transcription, accent marks are placed before the syllables receiving phrasal stress, and syllables with underlying word stress appear underlined.

FRICATIVES					
1.	/isi/	Majorcan	[əz um bɔm ˈmisil]		
		Valencian	[ez um bɔm ˈmisil]	*és un bon míssil*	'it is a good missile'
2.	/eʃi/	Majorcan	[o va təˈʃi]		
		Valencian	[o va tejˈʃiɾ]	*ho va teixir*	'he/she weaved it'
3.	/asa/	Majorcan	[də lajm pəˈsat]		
		Valencian	[de laɲ paˈsat]	*de l'any passat*	'from last year'
4.	/aʃa/	Majorcan	[mo va bəˈʃa]		
		Valencian	[mo va bajˈʃaɾ]	*m'ho va baixar*	'he/she brought it down for me'
5.	/usu/	Majorcan	[diw kə tu ˈsuəs]		
		Valencian	[diw ke tu ˈsues]	*diu que tu sues*	'he/she says that you are sweating'
6.	/uʃu/	Majorcan	[kəbəj ɣɾuˈʃut]		
		Valencian	[kabeʎ ɣɾujˈʃut]	*cabell gruixut*	'thick hair'
AFFRICATES					
7.	/ts/	Majorcan	[aɾə potsə ˈsoβɾə]		
		Valencian	[aɾa potseɾ ˈsoβɾa]	*ara potser sobra*	'it may be to spare now'
8.	/dz/	Majorcan	[əz əz dodzə ˈfij]		
		Valencian	[ez el dodze ˈfiʎ]	*és el dotzè fill*	'he is the twelfth son'
9.	/tʃ/	Majorcan	[te wnə ratʃə ˈbɔnə]		
		Valencian	[te wna ratʃa ˈbɔna]	*té una ratxa bona*	'he/she has a stroke of luck'
10.	/dʒ/	Majorcan	[unə pladʒə ˈʎarɣə]		
		Valencian	[una pladʒa ˈʎarɣa]	*una platja llarga*	'a long beach'

how voiced and voiceless affricates differ in constriction width, and if the underlying place and voicing contrasts are better implemented during the stop or the frication phase of the affricate. The analysis of the temporal structure of affricates will include three main areas: whether affricate duration correlates with closure duration, such that voiceless affricates have longer closures than voiced affricates (in Valencian) unless voiced affricates are intentionally lengthened (mostly in Majorcan); if frication is invariably longer for voiceless vs. voiced affricates independently of closure duration; the extent to which vowel duration is inversely related to affricate, closure and/or frication duration. In agreement with descriptive data from the literature, underlying voiced affricates could yield lenited realizations if extremely short and devoice if especially long.

2 Recording procedure

Ten meaningful Catalan sentences which contained bisyllabic words with /s, ʃ, ts, dz, tʃ, dʒ/ in intervocalic position were read by Majorcan and Valencian Catalan speakers (see table 1). The reason for not including /z, ʒ/ in the sentence list was that, as pointed out in the introduction (section 1), /dʒ/ instead /ʒ/ is found word medially in Valencian.

As shown in table 1, fricatives are flanked by /i, a, u/ in symmetrical VCV sequences, except for sentence 2 where the VCV sequence is /eʃi/ instead of the uncommon sequence /iʃi/. Three vowel contexts were taken into consideration for fricatives so as to find out whether differences in fronting between /s/ and /ʃ/ hold across contextual conditions (Shadle & Scully 1995). Affricates were embedded in more open vowel contexts, i.e. /oCe/ (/ts, dz/) and /aCa/

(/tʃ, dʒ/), because it is difficult to find meaningful words where affricates combine with high vowels in Catalan. Dialect-dependent differences in the realization of other phonetic segments in the sentences of table 1 should also be noted; thus, unstressed low and mid front vowels and sometimes stressed mid front vowels are produced as [ə] in Majorcan, and intervocalic /ʃ/ takes a transitional palatal on-glide in Valencian.

Phrasal stress and word stress fall on the syllable beginning with the target fricative (sentences 2–6), except for the word *míssil* in sentence 1 where stress falls on the first syllable. Alveolar and alveolopalatal affricates (sentences 7–10) in the same position with respect to sentence stress were used, i.e. for all four affricates, phrasal stress falls on the syllable immediately following the one beginning with the affricate. However, the two affricate groups were placed in different positions with respect to word stress so as to come up with the most frequent and widely used Catalan word structures: immediately after the stressed syllable of paroxytonic nouns for /tʃ/ and /dʒ/, and at the stressed syllable in oxytones for /ts/ and /dz/. This may have caused differences in affricate duration related to place of articulation (see Lavoie 2001 for this possibility in Spanish), but not to underlying voicing and dialect which were the phonetic aspects that we were especially interested in.

The ten speakers who participated in this study ranged from about 30 to 50 years of age, and used Majorcan or Valencian on a regular basis in their everyday life. The Majorcan speakers came from different population centers in the island of Majorca: AR from Manacor, BM from Algaida, MJ from Valldemossa, ND from Palma, and CA from Santanyí. The Valencian subjects speak Northern Valencian (speakers AV and MS are from Vinaròs and Castelló, respectively), Central Valencian (speaker JM is from Picassent), and Southern Valencian (speakers VB and VG are from Marina Baixa and Costera, respectively). Data for fricatives were collected and processed for all ten speakers. Affricates, on the other hand, were read by all speakers but processed for all Majorcans and for three of the five Valencians (VB, MS and VG) because the remaining two (JM and AV) did not produce the underlying affricate voicing or place contrast due to their dialectal origin.

Speakers were asked to read out all sentences given in table 1 seven times at a comfortable rate. Linguopalatal contact (EPG) configurations were gathered with the Reading EPG-3 system every 10 ms using ten artificial palates, one for each speaker, equipped with 62 electrodes (Hardcastle, Jones, Knight, Trudgeon & Calder 1989). Acoustic data were digitized at 10 kHz and processed with a Kay CSL analysis system. Electropalatography was chosen for analysis since it provides data on several articulatory parameters of interest, i.e. constriction fronting and width and dorsopalatal contact, and tongue contact events may be lined up quite easily with events in the acoustic signal for taking duration measurements (Gibbon & Nicolaidis 1999).

After recording the sentences of table 1, all speakers were asked to record a story with the artificial palate in place. These recordings provided an additional corpus of affricates in unscripted or spontaneous speech which could be used for checking possible instances of closure reduction.

3 Method of analysis

3.1 Segmentation

The stop element of affricates was considered to last from onset to offset of a complete closure at one or more rows of electrodes on the EPG record. Incomplete closure occurred often for voiced and voiceless affricates for speaker JM, and for /dʒ/ for speakers MS and VG. In this case, the temporal boundaries of the affricate closing phase were set at the onset and offset of a maximal constriction narrowing period which coincided, respectively, with the offset of the preceding vowel and the onset of frication. Fricatives and the frication period of affricates

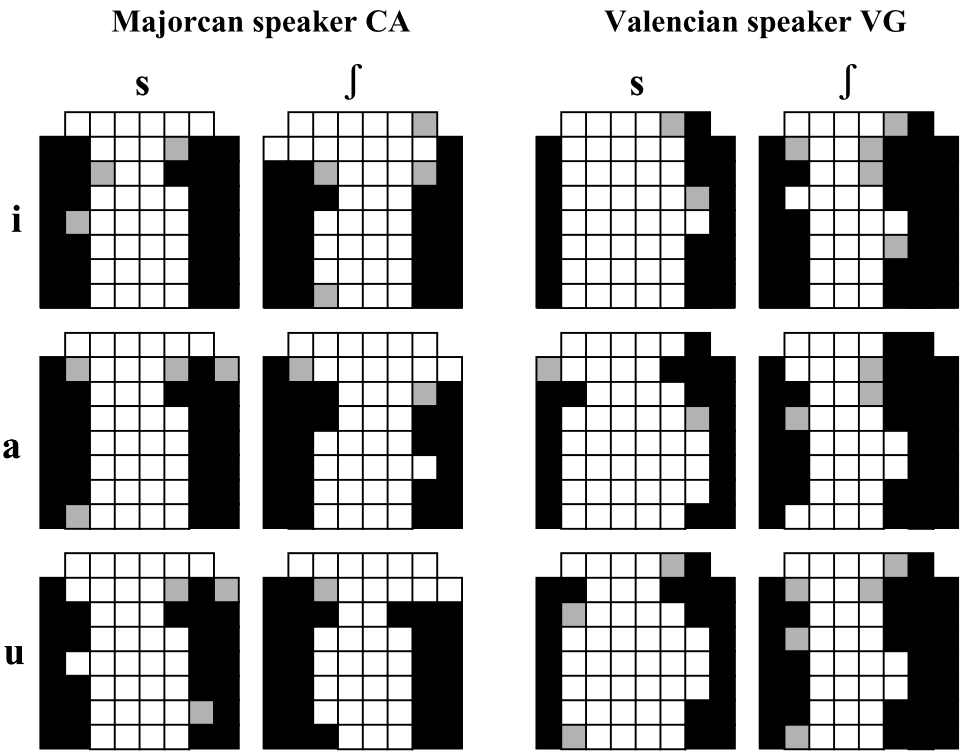

Figure 1 Linguopalatal contact configurations for /s/ and /ʃ/ for representative speakers of Majorcan (speaker CA; left) and Valencian (speaker VG; right). Data correspond to the midpoint of the frication phase.

were identified from onset to offset of the frication noise on spectrographic displays. Affricate closures for speaker VB were presumably dental, and thus released earlier at the alveolar zone than at the teeth; in this particular case, closure offset was identified at the frame preceding the frication noise on spectrographic displays, despite the fact that the EPG closure ended a few frames before frication. We also measured the vowel preceding the affricate from onset to offset of vowel-related formant structure. The presence of vocal fold vibration during affricate production was inferred from inspection of the voicing bar on spectrographic displays.

3.2 Linguopalatal contact

Tongue contact data were processed on linguopalatal contact configurations such as those presented in figure 1. EPG contact patterns were gathered at the midpoint of the frication period for fricatives, and at the midpoint of the closure and frication periods for affricates. In these patterns, electrodes are arranged in eight rows and in four columns on each half of the artificial palate. The frontmost row 1 (just behind the upper teeth) appears at the top of the graphs and the backmost row 8 (just in front of the soft palate) at the bottom; on the other hand, column 1 is the outermost column and colum 4 the innermost one. Electrodes appear in black, grey or white depending on frequency of activation across repetitions, i.e. 80–100% (black), 40–80% (grey) and less than 40% (white). The surface of the palate was subdivided into two articulatory zones for data analysis, i.e. an alveolar zone including the five frontmost rows and a palatal zone including the three backmost rows. Smaller areas may be identified within those zones, namely front alveolar (rows 1 and 2), postalveolar (rows 3, 4 and 5), prepalatal (row 6), mediopalatal (row 7) and postpalatal (row 8).

Contact changes at and posterior to the place of articulation were computed using the contact indices CAa (alveolar contact anteriority index), Qp (quotient of overall electrode activation at the palatal zone) and CCa (alveolar contact centrality). The latter contact index was evaluated at the frication phase of fricatives and affricates only.

The alveolar contact anteriority index (CAa) was calculated for the five front rows using the following formula (Fontdevila, Pallarès & Recasens 1994):

(1) $$CAa = [\log[[1(R_5/8) + 9(R_4/8) + 81(R_3/8) + 729(R_2/8) + 4921(R_1/6) + 1]]/[\log(5741 + 1)]$$

In the ratios within parentheses, the number of contacted electrodes on a given row (R_5, R_4, R_3, R_2 and R_1) is divided by the total number of electrodes on that row (8 or 6). Each ratio is multiplied by a coefficient number. Coefficients are chosen so that the activation of all electrodes at a specific row yields a lower value than the activation of one electrode at more anterior rows.

CAa increases with alveolar contact fronting. CAa values are strongly correlated with place of articulation provided that frontmost contact occurs at the center of the alveolar zone which was always the case for the stop component of affricates. Regarding fricatives, CAa may be a reliable indicator of place of articulation if the lingual constriction is quite central and anterior, and less so if contact occurs at the sides of the alveolar zone only. For that reason, CAa data for fricatives will be complemented with data on constriction location obtained from inspection of EPG contact configurations.

The quotient of overall electrode activation at the palatal zone (Qp) was obtained averaging all on-electrodes at the palatal zone by the total amount of 24 electrodes, and the resulting value was rescaled so that the final values proceeded from 0 to 1. Qp is positively related to dorsopalatal contact size and, therefore, to tongue dorsum raising towards the hard palate.

The alveolar contact centrality index (CCa) was calculated for the four symmetrical columns of electrodes at the left and right sides of the alveolar zone using the following formula (Fontdevila et al. 1994):

(2) $$CCa = [\log[[1(C_1/8) + 11(C_2/10) + 121(C_3/10) + 1331(C_4/10)] + 1]]/[\log(1464 + 1)]$$

In this formula, C_1, C_2, C_3 and C_4 are the total number of electrodes on two given symmetrical columns, which are divided by the total number of electrodes placed on those columns (8 or 10). CCa increases as alveolar contact becomes more central.

Data for the corpus of unscripted speech were also analyzed. Percentages of occurrence of complete and incomplete closure were calculated for each affricate over all available tokens in the corpus.

3.3 Duration

Affricate durations were normalized against the duration of the whole sentence so as to account for speaker-dependent differences in speech rate. For that purpose, three duration ratios were calculated for each affricate and speaker: affricate/sentence, closure/sentence and frication/sentence. The vowel/affricate, vowel/closure and vowel/frication duration ratios were also computed to determine whether vowel duration varied inversely with the duration of the affricate and its two components.

3.4 Statistics

CAa, Qp and CCa values for fricatives and affricates, and duration values for affricates, were tested statistically by means of ANOVAs with repeated measures. ANOVAs for fricatives were run on data for /isi, asa, usu, eʃi, aʃa, uʃu/ with ‘consonant’ (/s/ and /ʃ/), ‘vowel’ (/i/, /a/ and /u/) and ‘dialect’ (Valencian and Majorcan) as variables. ANOVAs for affricates were performed on contact index and duration data for both dialects with ‘consonant period’ (with the conditions ‘occlusion’ and ‘frication’) as the within-subject factor, and ‘place’ (‘palatal’ and ‘alveolar’), ‘voicing’ (‘voiced’ and ‘voiceless’) and ‘dialect’ (‘Majorcan’ and ‘Valencian’)

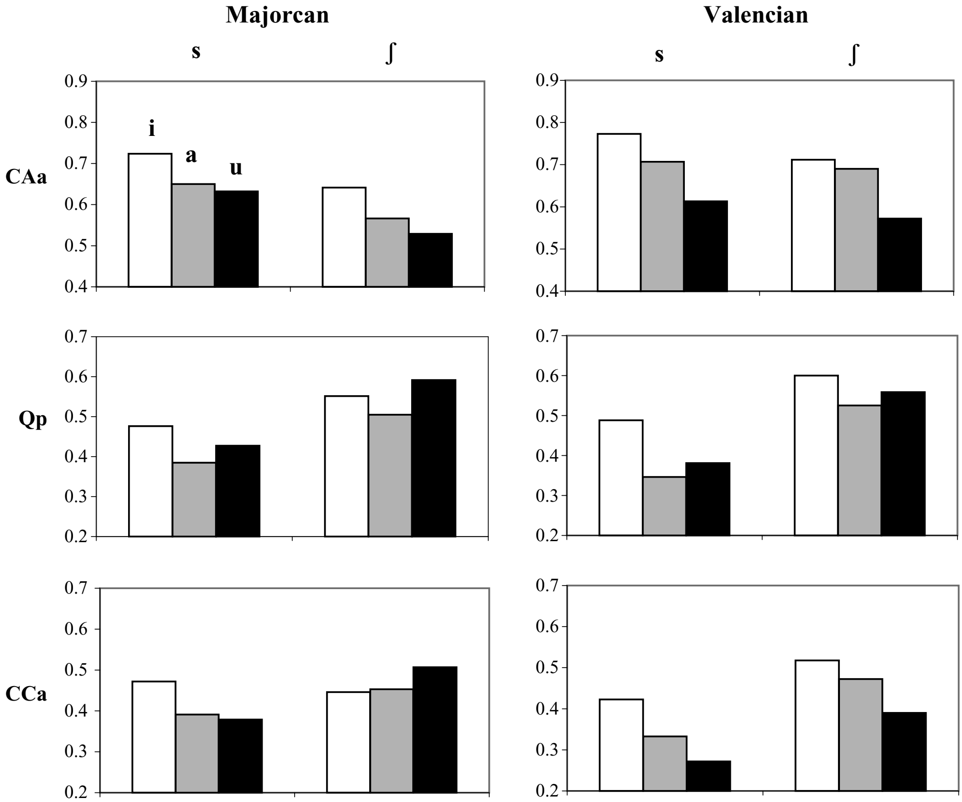

Figure 2 Mean CAa, Qp and CCa index values for /s/ and /ʃ/ in the vowel contexts /i/ (unfilled bars), /a/ (dotted bars) and /u/ (filled bars) across data for all Majorcan (left) and Valencian (right) speakers.

as the between-subject factors. They were also carried out separately for the Majorcan data and for the Valencian data using the same independent variables except for 'dialect'. The level of significance for all statistical tests was $p < 0.05$, and Bonferroni multiple comparisons tests were applied to significant main effects and interactions.

4 Results

4.1 Fricative articulation

4.1.1 Alveolar contact anteriority index (CAa) and constriction characteristics

ANOVAs with repeated measures run on the overall CAa data set yielded a significant effect of 'vowel' ($F(2,136) = 50.17$, $p < 0.001$), 'consonant' ($F(1,68) = 43.65$, $p < 0.001$) and 'dialect' ($F(4,737) = 1.68$, $p < 0.05$), and significant 'vowel × dialect' and 'consonant × dialect' interactions ($F(2,136) = 4.92$, $p < 0.01$; $F(1,68) = 6.59$, $p < 0.05$). As shown in figure 2 and table 2, main effects are associated with variations in contact anteriority for /i/ > /a/ > /u/, for /s/ > /ʃ/ and for Valencian > Majorcan. Dialect-dependent differences are larger for /ʃ/ than for /s/ since the CAa value for the former fricative appears to be exceptionally high in Valencian. In spite of the similarity in the degree of alveolar contact anteriority between

Table 2 CAa, Qp and CCa values and standard deviations for /isi, asa, usu, eʃi, aʃa, uʃu/ according to individual speakers and across speakers of Majorcan (left) and Valencian (right).

		Majorcan							Valencian					
		isi	asa	usu	eʃi	aʃa	uʃu		isi	asa	usu	eʃi	aʃa	uʃu
CAa	AR	0.826	0.633	0.594	0.766	0.660	0.476	VB	0.727	0.634	0.611	0.697	0.652	0.466
		0.064	*0.039*	*0.045*	*0.072*	*0.086*	*0.068*		*0.047*	*0.023*	*0.055*	*0.028*	*0.022*	*0.000*
	BM	0.747	0.678	0.598	0.534	0.404	0.518	JM	0.819	0.796	0.643	0.707	0.773	0.623
		0.083	*0.045*	*0.042*	*0.090*	*0.018*	*0.105*		*0.064*	*0.048*	*0.021*	*0.087*	*0.087*	*0.054*
	MJ	0.662	0.523	0.633	0.685	0.573	0.669	MS	0.603	0.445	0.297	0.600	0.442	0.298
		0.034	*0.111*	*0.015*	*0.089*	*0.083*	*0.032*		*0.101*	*0.065*	*0.183*	*0.037*	*0.117*	*0.086*
	ND	0.670	0.755	0.658	0.596	0.596	0.492	VG	0.858	0.806	0.861	0.862	0.879	0.860
		0.066	*0.083*	*0.142*	*0.079*	*0.034*	*0.084*		*0.029*	*0.067*	*0.031*	*0.033*	*0.025*	*0.038*
	CA	0.714	0.662	0.678	0.626	0.598	0.490	AV	0.858	0.854	0.653	0.692	0.705	0.614
		0.022	*0.102*	*0.053*	*0.165*	*0.033*	*0.043*		*0.063*	*0.092*	*0.096*	*0.014*	*0.031*	*0.030*
	$\bar{X}$	**0.724**	**0.650**	**0.632**	**0.641**	**0.566**	**0.529**	$\bar{X}$	**0.773**	**0.707**	**0.613**	**0.712**	**0.690**	**0.572**
	sd	*0.067*	*0.084*	*0.037*	*0.088*	*0.096*	*0.080*	*sd*	*0.109*	*0.168*	*0.202*	*0.094*	*0.162*	*0.208*
Qp	AR	0.470	0.399	0.435	0.488	0.458	0.560	VB	0.524	0.345	0.363	0.631	0.589	0.619
		0.052	*0.033*	*0.033*	*0.052*	*0.000*	*0.041*		*0.022*	*0.031*	*0.031*	*0.016*	*0.029*	*0.016*
	BM	0.500	0.369	0.375	0.565	0.542	0.595	JM	0.506	0.321	0.363	0.583	0.488	0.399
		0.042	*0.016*	*0.000*	*0.022*	*0.000*	*0.020*		*0.037*	*0.020*	*0.040*	*0.090*	*0.062*	*0.033*
	MJ	0.429	0.238	0.357	0.601	0.542	0.702	MS	0.512	0.375	0.435	0.560	0.476	0.565
		0.075	*0.020*	*0.072*	*0.022*	*0.042*	*0.016*		*0.058*	*0.024*	*0.033*	*0.053*	*0.083*	*0.047*
	ND	0.494	0.464	0.488	0.560	0.506	0.565	VG	0.411	0.292	0.363	0.607	0.560	0.571
		0.051	*0.045*	*0.020*	*0.063*	*0.098*	*0.063*		*0.078*	*0.000*	*0.020*	*0.022*	*0.022*	*0.020*
	CA	0.488	0.452	0.482	0.542	0.476	0.536	AV	0.488	0.399	0.381	0.619	0.512	0.637
		0.031	*0.074*	*0.033*	*0.064*	*0.047*	*0.029*		*0.020*	*0.053*	*0.051*	*0.051*	*0.020*	*0.046*
	$\bar{X}$	**0.476**	**0.385**	**0.427**	**0.551**	**0.505**	**0.592**	$\bar{X}$	**0.488**	**0.346**	**0.381**	**0.600**	**0.525**	**0.558**
	sd	*0.029*	*0.091*	*0.060*	*0.041*	*0.038*	*0.065*	*sd*	*0.045*	*0.042*	*0.031*	*0.029*	*0.048*	*0.094*
CCa	AR	0.488	0.282	0.296	0.511	0.497	0.512	VB	0.396	0.157	0.234	0.517	0.376	0.414
		0.091	*0.025*	*0.057*	*0.030*	*0.109*	*0.017*		*0.053*	*0.016*	*0.108*	*0.093*	*0.086*	*0.000*
	BM	0.479	0.322	0.315	0.398	0.262	0.427	JM	0.295	0.217	0.170	0.321	0.321	0.163
		0.158	*0.198*	*0.061*	*0.091*	*0.012*	*0.114*		*0.033*	*0.036*	*0.023*	*0.092*	*0.099*	*0.057*
	MJ	0.274	0.281	0.273	0.422	0.472	0.536	MS	0.493	0.337	0.202	0.489	0.373	0.311
		0.017	*0.053*	*0.019*	*0.088*	*0.094*	*0.040*		*0.023*	*0.112*	*0.135*	*0.023*	*0.127*	*0.108*
	ND	0.575	0.588	0.551	0.459	0.562	0.572	VG	0.373	0.390	0.442	0.694	0.722	0.609
		0.075	*0.068*	*0.022*	*0.121*	*0.077*	*0.103*		*0.078*	*0.067*	*0.037*	*0.125*	*0.124*	*0.108*
	CA	0.542	0.481	0.462	0.437	0.475	0.487	AV	0.557	0.562	0.311	0.567	0.568	0.452
		0.118	*0.157*	*0.035*	*0.081*	*0.035*	*0.039*		*0.042*	*0.079*	*0.076*	*0.045*	*0.027*	*0.076*
	$\bar{X}$	**0.472**	**0.391**	**0.379**	**0.446**	**0.453**	**0.507**	$\bar{X}$	**0.423**	**0.333**	**0.272**	**0.518**	**0.472**	**0.390**
	sd	*0.117*	*0.138*	*0.121*	*0.043*	*0.113*	*0.055*	*sd*	*0.103*	*0.158*	*0.109*	*0.135*	*0.169*	*0.166*

the two fricatives, the corresponding CAa distance turned out to be significant in Valencian, which suggests that neutralization of the place of articulation distinction does not take place in this dialect ($F(1, 34) = 10.99$, $p < 0.01$). As expected, the degree of significance for the CAa distance between /s/ and /ʃ/ was higher in Majorcan ($F(1,34) = 33.45$, $p < 0.001$). Regarding vowel coarticulation, CAa values for /aCa/ and /uCu/ were significantly different in Valencian but not in Majorcan.

In order to gain more detailed information about differences in alveolar contact fronting between /s/ and /ʃ/, speaker-dependent differences in CAa for the two fricatives are presented in figure 3 (top graphs). Bars are positive whenever contact anteriority for /s/ exceeds that for /ʃ/ and negative when the opposite relationship holds. The Majorcan data reveal that the alveolar fricative is clearly more anterior than the alveolopalatal fricative in practically all vowel conditions and for four of the five speakers (AR, BM, ND, CA). Regarding the Valencian data, /s/–/ʃ/ differences are generally positive but often small for speakers VB and JM, and none or negative for speakers MS and VG.

These dialect-dependent characteristics are also exemplified by the linguopalatal configurations for the Majorcan speaker CA and the Valencian speaker VG shown in figure 1. Constriction location is centroalveolar or postalveolar for /s/ and postalveolar or alveolopalatal for /ʃ/ in the case of speaker CA, and front alveolar for /s/ and centroalveolar or postalveolar for /ʃ/ in the case of speaker VG. Inspection of all EPG contact patterns reveal that Majorcan subjects exhibit an analogous constriction location to that for speaker CA. As for Valencian, constriction fronting varies with speaker in the following progression: VB, JM (front alveolar for /s/, centroalveolar or postalveolar for /ʃ/) > AV (centroalveolar for /s/, postalveolar for /ʃ/) > MS (postalveolar for /s/, alveolopalatal for /ʃ/). Consonant-dependent differences in place of articulation may also be related to the extent of the lingual constriction towards the postalveolar area for /ʃ/ > /s/ in both Catalan dialects (see EPG data for speaker VG in figure 1).

Inspection of linguopalatal contact configuration for all speakers suggests that Valencian and Majorcan /s/ may be apical in both dialects or else that the alveolar fricative is more laminal in the former dialect than in the latter. According to the EPG patterns, the former possibility is consistent with the fact that maximal constriction for /s/ involves basically one electrode only in Valencian and Majorcan (see also figure 1). Regarding the fricative /ʃ/, on the other hand, it appears that the tongue tip is lowered in Majorcan and may be more or less raised in Valencian. On the one hand, EPG patterns for /ʃ/ for all Majorcan speakers show complete absence of contact at the frontmost row 1 and, to a large extent, at row 2 of electrodes, and a V-like shape at frontmost tongue contact location (see also figure 1). On the other hand, there may be lateral contact at those rows for /ʃ/ in Valencian while a V-like shape is only available for speaker MS in this dialect. This fricative is presumably laminal in Valencian, and laminal or lamino-predorsal in Majorcan, and exhibits a constriction longer than /s/ in most cases.

In summary, we may be confident that lingual fricatives are more anterior and more sensitive to vowel coarticulation in Valencian than in Majorcan, and that differences between /s/ and /ʃ/ are smaller in the former dialect than in the latter, mostly due to differences in contact anteriority for /ʃ/. Even though both fricatives exhibit practically identical CAa values for some Valencian speakers, /s/ appears to be consistently more anterior than /ʃ/ at constriction location in this dialect as a general rule. The lack of correspondence between the CAa data and data on constriction location and extent for some Valencian speakers suggests that the two measures capture related but non-identical articulatory events.

4.1.2 Quotient of contact at the palatal zone (Qp)

ANOVAs on the Qp data for both dialects yielded a significant effect of 'vowel' ($F(2,136) = 96.48$, $p < 0.001$) and 'consonant' ($F(1,68) = 201.53$, $p < 0.001$) but no effect of 'dialect', and the significant interactions 'vowel × dialect' ($F(2,136) = 15.13$, $p < 0.001$) and 'vowel × consonant' ($F(2,136) = 24.29$, $p < 0.001$). The 'consonant × dialect' interaction was nearly significant ($F(1,68) = 3.45$, $p = 0.067$).

According to figure 2 and table 2 above, main effects are related to Qp differences for /i/ > /u/ > /a/ and for /ʃ/ > /s/. Qp differences between the two fricatives are larger in Valencian than in Majorcan since /s/ was produced with less dorsopalatal contact in the former dialect than in the latter (see also EPG configurations in figure 1). Statistical results for each dialect are consistent with this observation, i.e. $F(1,34) = 190.36$, $p < 0.001$ (Valencian), $F(1,34) = 57.52$, $p < 0.001$ (Majorcan). Moreover, Qp values for the high vowels /i/ and /u/ were found not to differ significantly in Majorcan.

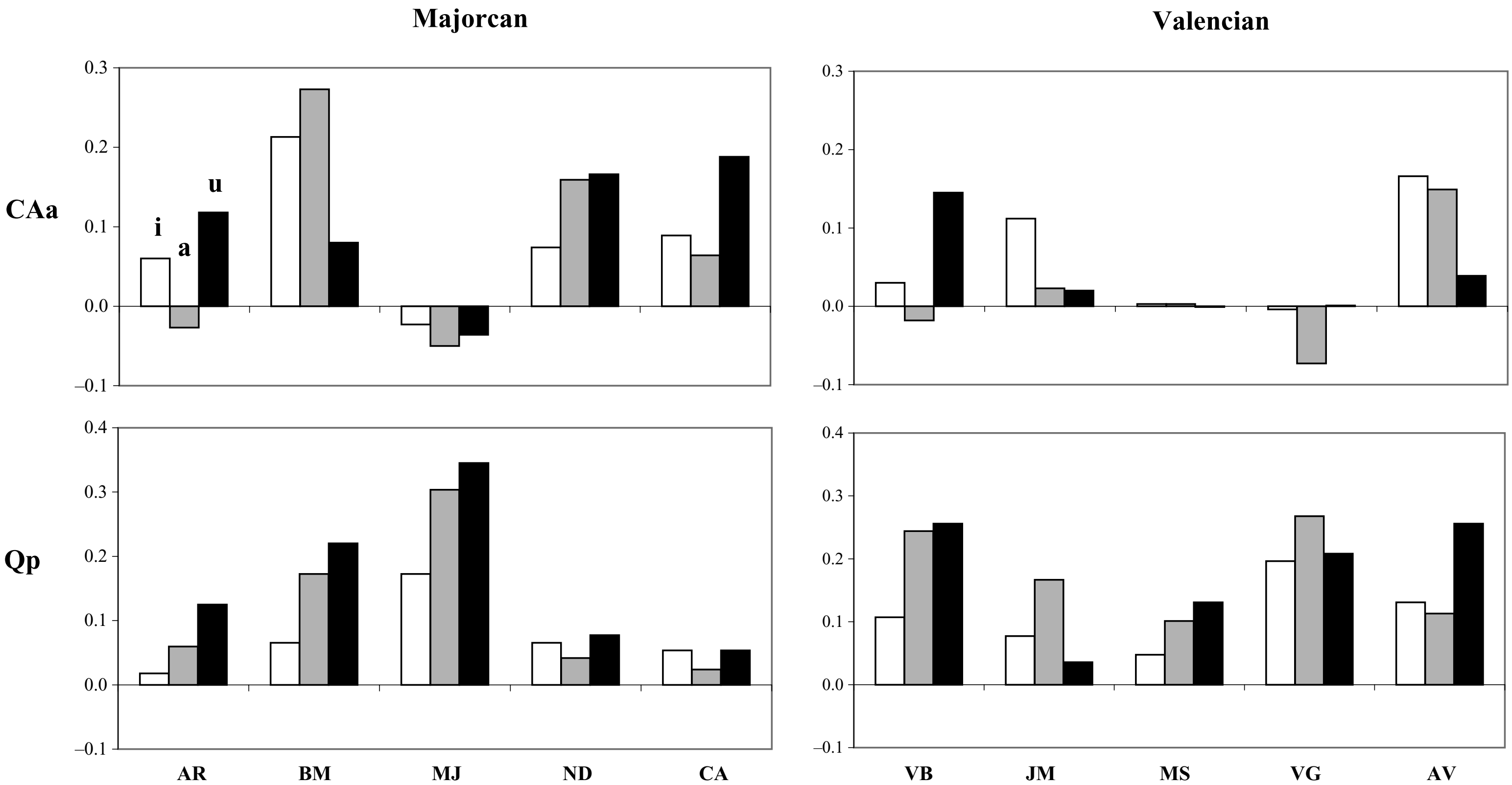

Figure 3 CAa and Qp differences between /s/ and /ʃ/ in the vowel contexts /i/ (unfilled bars), /a/ (dotted bars) and /u/ (filled bars) for the individual speakers of Majorcan (left) and Valencian (right). Positive bars indicate higher CAa values for /s/ vs. /ʃ/ (top) and higher Qp values for /ʃ/ vs. /s/ (bottom).

Speaker-dependent Qp differences between the two fricatives are presented in figure 3 above. Positive bars indicate that /ʃ/ is produced with more dorsopalatal contact than /s/. Bars for all ten speakers are positive independently of vowel context, meaning that the two fricatives differ in tongue contact degree at the palatal zone in Majorcan and Valencian.

It may be concluded that /s/ is somewhat less palatalized in Valencian than in Majorcan, and that Valencian does not neutralize the contrast between /s/ and /ʃ/ at the palatal zone. Results indicate that there is an inverse relationship between anteriority and palatality both for different varieties of /s/ and for /s/ vs. /ʃ/.

4.1.3 Alveolar contact centrality (CCa)

ANOVAs run on the CCa data yielded a main effect of 'vowel' ($F(1,68) = 19.17$, $p < 0.001$) and 'consonant' ($F(1,68) = 37.82$, $p < 0.001$) but no main effect of 'dialect', and the significant interactions 'vowel × dialect' ($F(1,68) = 12.77$, $p < 0.001$), 'vowel × consonant' ($F(2,136) = 10.95$, $p < 0.001$), 'consonant × dialect' ($F(1,68) = 5.03$, $p < 0.05$) and 'vowel × consonant × dialect' ($F(2,136) = 5.67$, $p < 0.01$).

As shown in figure 2 and table 2 above, differences in constriction narrowing were significant for /i/ > /a, u/ and for /ʃ/ > /s/. Significant interactions are indicative of a larger CCa difference between the two fricatives in Valencian than in Majorcan since /s/ is produced with a wider central channel in the former dialect vs. the latter (see also figure 1 above). The 'consonant' factor achieved significance in both dialects though the degree of significance was higher in Valencian ($F(1,34) = 38.17$, $p < 0.001$) than in Majorcan ($F(1,34) = 7.09$, $p < 0.05$). There is considerably more vowel coarticulation in Valencian than in Majorcan, where CCa differences turned out to be non-significant for the pairs /asa/–/usu/ and /iʃi/–/aʃa/, and the CCa values for /uʃu/ exceeded those for /iʃi, aʃa/.

In summary, /s/ is less constricted in Valencian than in Majorcan, and constriction width for both lingual fricatives is more coarticulation sensitive in the former dialect vs. the latter.

4.2 Affricate articulation

4.2.1 Alveolar contact anteriority index (CAa), closure and constriction characteristics

CAa yielded a significant effect of 'consonant period' ($F(1,211) = 381.65$, $p < 0.001$), 'dialect' ($F(1,211) = 15.04$, $p < 0.001$), 'place' ($F(1,211) = 24.16$, $p < 0.001$) and 'voicing' ($F(1,211) = 29.43$, $p < 0.001$). There were several significant interactions involving the 'consonant period' factor: 'consonant period × dialect' ($F(1,211) = 3.65$, $p = 0.057$), 'consonant period × voicing' ($F(1,211) = 27.66$, $p < 0.001$), 'consonant period × dialect × place' ($F(1,211) = 4.25$, $p < 0.05$) and 'consonant period × dialect × voicing' ($F(1,211) = 12.48$, $p < 0.001$).

As shown in figure 4 and table 3, main effects are associated with more alveolar contact fronting during the closure period than during the frication period, for Valencian vs. Majorcan affricates, and for the alveolar vs. alveolopalatal and the voiced vs. voiceless cognates. Significant interactions were observed during the frication phase: dialect-dependent CAa differences are mostly associated with /dʒ/, and there is a greater distance between alveolar and alveolopalatal affricates in Majorcan vs. Valencian and between voiceless and voiced affricates in Valencian vs. Majorcan. According to results from statistical tests run on data for each dialect, differences in contact anteriority between alveolar and alveolopalatal affricates are significant in Majorcan, more so during frication ($F(1,136) = 39.85$, $p < 0.001$) than during closure ($F(1,136) = 8.29$, $p < 0.01$), but not in Valencian. On the other hand, the degree of significance for the underlying voicing contrast is more obvious in Valencian ($F(1,75) = 22.19$, $p < 0.001$) than in Majorcan ($F(1,136) = 5.82$, $p < 0.05$), and the magnitude of the CAa difference between voiced and voiceless affricates is larger during frication than during closure in the former dialect ($F(1,75) = 19.93$, $p < 0.001$).

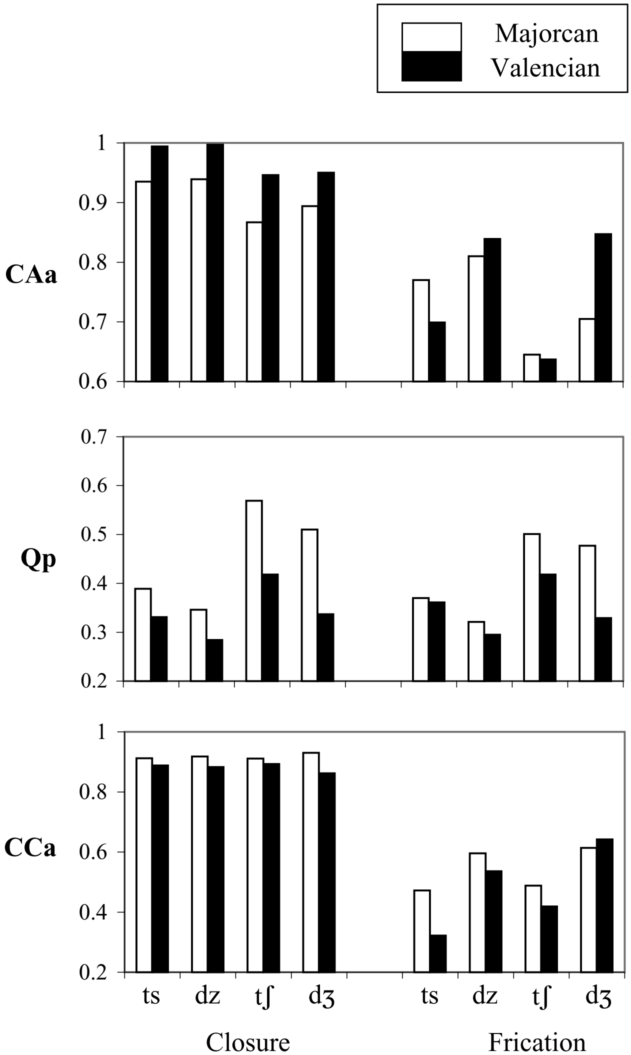

Figure 4 Mean CAa, Qp and CCa index values across Majorcan speakers (unfilled bars) and Valencian speakers (filled bars). Data correspond to the midpoint of the closure (left) and frication (right) periods of the affricate.

Speaker-dependent characteristics in alveolar contact at closure and at frication for all four affricates are shown in figures 5 and 6, and linguopalatal configurations for subjects CA and VG are illustrated in figure 7.

Figure 5 shows differences in closure location and extent as a function of place, voicing and speaker during the stop component of the affricate. Vertical lines are plotted at rows exhibiting more than 80% of activation of all electrodes except for the two central ones which were allowed to exhibit variable degrees of activation. Lines reveal that differences in closure fronting are mostly associated with place of articulation, namely, affricate closure is alveolar for all consonants but usually more anterior for /ts/ vs. /tʃ/ and for /dz/ vs. /dʒ/. This scenario holds for four out of five Majorcan speakers (AR, BM, MJ and CA but not ND), and for two out of three Valencian subjects (MS and VG but not VB, who shows an especially anterior closure location for all affricates).

Table 3 CAa, Qp and CCa values and standard deviations for /ts, dz, tʃ, dʒ/ according to individual speakers and across speakers of Majorcan (left) and Valencian (right). Data are presented separately for the closure and frication periods.

		Closure				Frication					Closure				Frication			
		ts	dz	ts	dʒ	ts	dz	tʃ	dʒ		ts	dz	tʃ	dʒ	ts	dz	tʃ	dʒ
CAa	AR	0.937	0.983	0.756	0.761	0.758	0.888	0.658	0.679	VB	0.997	0.993	0.996	0.997	0.745	0.868	0.724	0.919
		0.026	*0.021*	*0.040*	*0.092*	*0.080*	*0.026*	*0.027*	*0.048*		*0.002*	*0.001*	*0.008*	*0.001*	*0.079*	*0.045*	*0.051*	*0.034*
	BM	0.997	1.000	0.989	0.962	0.931	0.917	0.625	0.736	MS	1.000	1.000	0.929	0.898	0.475	0.745	0.303	0.721
		0.007	*0.000*	*0.015*	*0.024*	*0.010*	*0.017*	*0.105*	*0.087*		*0.000*	*0.000*	*0.055*	*0.058*	*0.102*	*0.065*	*0.000*	*0.018*
	MJ	0.772	0.733	0.743	0.762	0.686	0.680	0.698	0.726	VG	0.985	0.997	0.913	0.955	0.877	0.904	0.883	0.901
		0.034	*0.032*	*0.014*	*0.015*	*0.060*	*0.032*	*0.063*	*0.028*		*0.026*	*0.007*	*0.068*	*0.011*	*0.029*	*0.030*	*0.023*	*0.017*
	ND	0.971	0.979	0.927	0.997	0.788	0.701	0.632	0.665									
		0.025	*0.055*	*0.060*	*0.007*	*0.100*	*0.135*	*0.016*	*0.075*									
	CA	1.000	1.000	0.919	0.989	0.687	0.865	0.613	0.719									
		0.000	*0.000*	*0.057*	*0.019*	*0.029*	*0.058*	*0.092*	*0.021*									
	$\bar{X}$	**0.935**	**0.939**	**0.867**	**0.894**	**0.770**	**0.810**	**0.645**	**0.705**	$\bar{X}$	**0.994**	**0.997**	**0.946**	**0.950**	**0.699**	**0.839**	**0.637**	**0.847**
	sd	*0.095*	*0.115*	*0.111*	*0.122*	*0.101*	*0.111*	*0.034*	*0.031*	*sd*	*0.008*	*0.004*	*0.044*	*0.050*	*0.205*	*0.083*	*0.300*	*0.109*
Qp	AR	0.292	0.238	0.536	0.464	0.321	0.244	0.494	0.452	VB	0.339	0.250	0.438	0.405	0.429	0.260	0.427	0.393
		0.042	*0.031*	*0.045*	*0.029*	*0.046*	*0.037*	*0.037*	*0.016*		*0.037*	*0.000*	*0.000*	*0.052*	*0.046*	*0.029*	*0.020*	*0.033*
	BM	0.387	0.369	0.542	0.482	0.423	0.363	0.530	0.500	MS	0.351	0.286	0.423	0.281	0.321	0.292	0.375	0.260
		0.052	*0.016*	*0.000*	*0.058*	*0.016*	*0.031*	*0.031*	*0.048*		*0.041*	*0.029*	*0.037*	*0.021*	*0.031*	*0.034*	*0.000*	*0.021*
	MJ	0.369	0.339	0.530	0.530	0.292	0.250	0.500	0.476	VG	0.304	0.315	0.393	0.325	0.333	0.333	0.452	0.333
		0.029	*0.066*	*0.062*	*0.052*	*0.034*	*0.000*	*0.000*	*0.033*		*0.020*	*0.022*	*0.033*	*0.019*	*0.000*	*0.000*	*0.016*	*0.029*
	ND	0.435	0.435	0.542	0.500	0.363	0.387	0.440	0.446									
		0.072	*0.063*	*0.068*	*0.068*	*0.075*	*0.095*	*0.033*	*0.052*									
	CA	0.464	0.351	0.696	0.571	0.452	0.363	0.542	0.512									
		0.045	*0.041*	*0.046*	*0.052*	*0.091*	*0.031*	*0.064*	*0.020*									
	$\bar{X}$	**0.389**	**0.346**	**0.569**	**0.510**	**0.370**	**0.321**	**0.501**	**0.477**	$\bar{X}$	**0.331**	**0.284**	**0.418**	**0.337**	**0.361**	**0.295**	**0.418**	**0.329**
	sd	*0.066*	*0.071*	*0.071*	*0.042*	*0.067*	*0.069*	*0.039*	*0.029*	*sd*	*0.025*	*0.033*	*0.023*	*0.063*	*0.059*	*0.037*	*0.039*	*0.066*
CCa	AR	0.915	0.912	0.892	0.899	0.385	0.577	0.564	0.685	VB	0.828	0.786	0.868	0.833	0.425	0.523	0.422	0.603
		0.027	*0.018*	*0.021*	*0.021*	*0.076*	*0.065*	*0.070*	*0.085*		*0.044*	*0.002*	*0.033*	*0.030*	*0.026*	*0.116*	*0.054*	*0.111*
	BM	0.933	0.934	0.945	0.929	0.799	0.820	0.485	0.662	MS	0.944	0.935	0.930	0.855	0.183	0.609	0.138	0.576
		0.002	*0.000*	*0.019*	*0.025*	*0.019*	*0.043*	*0.110*	*0.127*		*0.011*	*0.007*	*0.016*	*0.018*	*0.049*	*0.124*	*0.000*	*0.099*
	MJ	0.829	0.838	0.866	0.876	0.298	0.374	0.506	0.577	VG	0.892	0.929	0.881	0.897	0.358	0.475	0.698	0.745
		0.046	*0.035*	*0.038*	*0.014*	*0.050*	*0.087*	*0.086*	*0.023*		*0.044*	*0.008*	*0.026*	*0.015*	*0.089*	*0.113*	*0.095*	*0.058*
	ND	0.944	0.969	0.950	0.980	0.477	0.593	0.422	0.562									
		0.030	*0.016*	*0.036*	*0.013*	*0.133*	*0.117*	*0.113*	*0.075*									
	CA	0.940	0.935	0.901	0.966	0.401	0.618	0.465	0.585									
		0.009	*0.008*	*0.054*	*0.020*	*0.070*	*0.103*	*0.092*	*0.063*									
	$\bar{X}$	**0.912**	**0.918**	**0.911**	**0.930**	**0.472**	**0.596**	**0.488**	**0.614**	$\bar{X}$	**0.888**	**0.883**	**0.893**	**0.862**	**0.322**	**0.536**	**0.419**	**0.642**
	sd	*0.048*	*0.049*	*0.036*	*0.044*	*0.194*	*0.158*	*0.052*	*0.055*	*sd*	*0.058*	*0.084*	*0.033*	*0.032*	*0.125*	*0.068*	*0.280*	*0.091*

Figure 6 reports CAa differences for the pairs /ts/–/tʃ/ and /dz/–/dʒ/ during the frication period. Positive bars in the figure indicate the existence of more contact anteriority for alveolar affricates than for their alveolopalatal cognates. A comparison between figures 3 and 6 reveals that Majorcan exhibits more alveolar contact fronting for alveolar vs. alveolopalatal affricates for the same speakers showing more alveolar contact fronting for /s/ than for /ʃ/, i.e. AR, BM, ND and CA. On the other hand, CAa differences between affricates of the two places of articulation are small or absent for the Valencian speakers VB, MS and VG.

Moreover, in contrast with the scenario for fricative consonants, inspection of linguopalatal contact patterns for the affricate frication phase in figure 7 reveals the existence

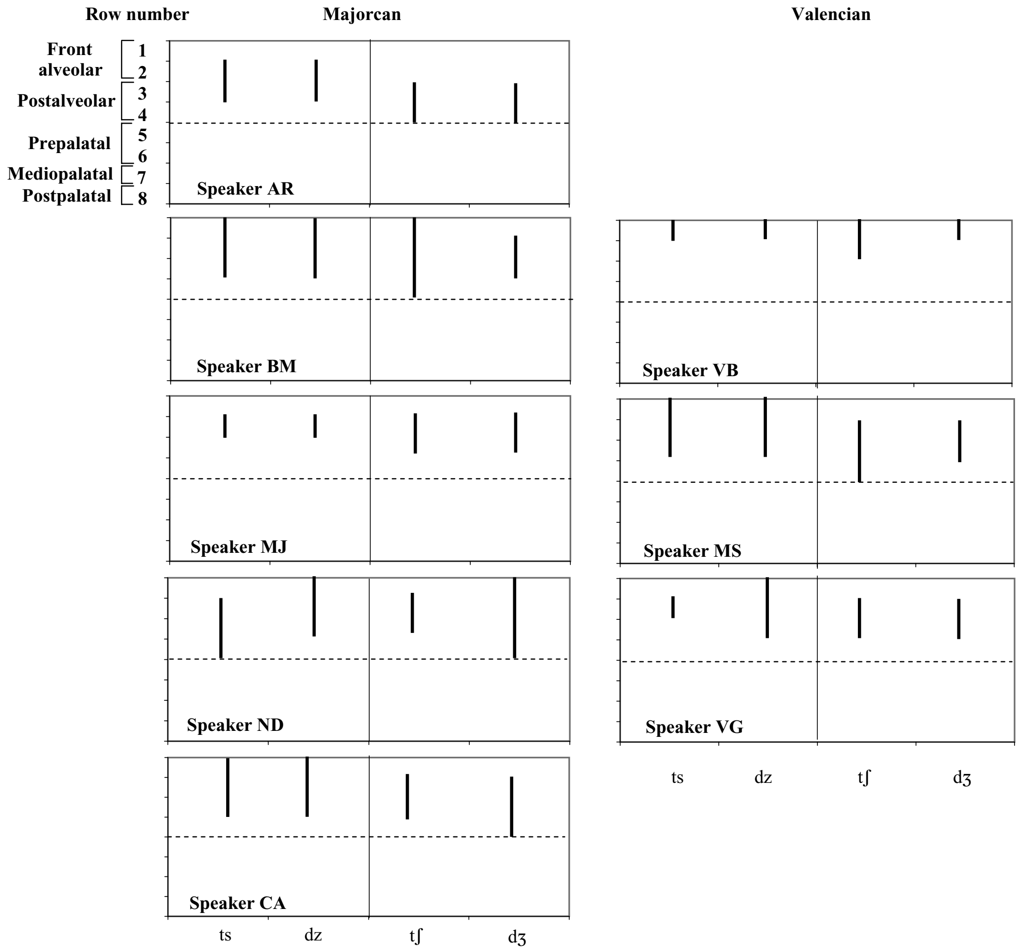

Figure 5 Closure location and extent for /ts, dz, tʃ, dʒ/. Data are plotted for all individual Majorcan speakers (left) and Valencian speakers (right). Row numbers and articulatory zones over the artificial palate have been identified along the vertical axis.

of small or no differences in constriction extent towards the back alveolar zone between /ts, dz/ and /tʃ, dʒ/.

To summarize, CAa differences as a function of place of articulation between alveolars and alveolopalatal affricates occur in Majorcan but not clearly in Valencian, where they could be traced during closure but not during frication. Therefore, the place distinction, if present, is less obvious for affricates than for fricatives. On the other hand, Valencian speakers were more successful than Majorcans in implementing differences in alveolar contact anteriority associated with underlying voicing, and these differences were more apparent during the frication phase than during the stop phase.

4.2.2 Quotient of contact at the palatal zone (Qp)

ANOVAs for the Qp data yielded a main effect of 'consonant period' ($F(1,211) = 9.79$, $p < 0.01$), 'dialect' ($F(1,211) = 95.35$, $p < 0.001$), 'place' ($F(1,211) = 197.98$, $p < 0.001$) and 'voicing' ($F(1,211) = 50.92$, $p < 0.001$). There were also the significant interactions 'consonant period × dialect' ($F(1,211) = 36.5$, $p < 0.001$), 'consonant period × place' ($F(1,211) = 13.95$, $p < 0.001$) and 'dialect × place' ($F(1,211) = 28.49$, $p < 0.001$).

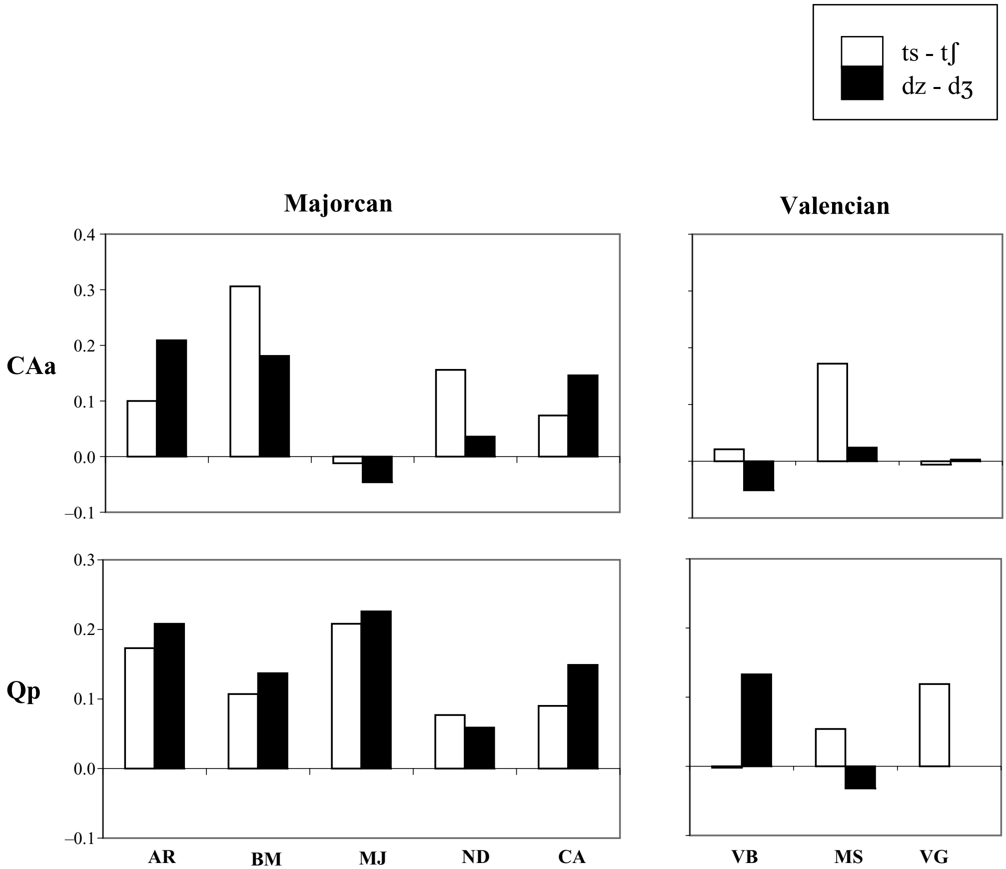

Figure 6 CAa and Qp differences between /ts/ and /tʃ/ (unfilled bars) and between /dz/ and /dʒ/ (filled bars) for the individual speakers of Majorcan (left panel) and Valencian (right panel). Positive bars indicate higher CAa values for /ts, dz/ vs. /tʃ, dʒ/ (top) and higher Qp values for /tʃ, dʒ/ vs. /ts, dz/ (bottom).

As revealed by figure 4, main effects are related to higher Qp values for affricates during closure vs. frication, for Majorcan vs. Valencian affricates, and for the alveolopalatal vs. alveolar and voiceless vs. voiced cognates. Significant interactions were associated with larger dialect-dependent differences in dorsopalatal contact for alveolopalatals than for alveolars, and with higher Qp values in Majorcan vs. Valencian and for alveolopalatals vs. alveolars during closure than during frication. In fact, Valencian affricates exhibit more dorsopalatal contact during the frication period than at closure ($F(1,75) = 4.90$, $p < 0.05$). According to statistical results for data for each dialect, Qp differences between alveolar and alveolopalatal affricates turned to be greater in Majorcan ($F(1,136) = 214.01$, $p < 0.001$) than in Valencian ($F(1,75) = 51.01$, $p < 0.001$), and during closure ($F(1,136) = 7.51$, $p < 0.01$) than during frication ($F(1,75) = 8.82$, $p < 0.01$) in both dialects.

Speaker-dependent Qp differences for the pairs /ts/–/tʃ/ and /dz/–/dʒ/ during the frication period are shown in figure 6. Positive bars in the figure indicate the existence of more dorsopalatal contact for alveolopalatal than for alveolar affricates. Qp differences are clearly greater for the Majorcan subjects than for the Valencian ones. Linguopalatal contact configurations in figure 7 also exhibit larger dorsopalatal contact differences between voiced

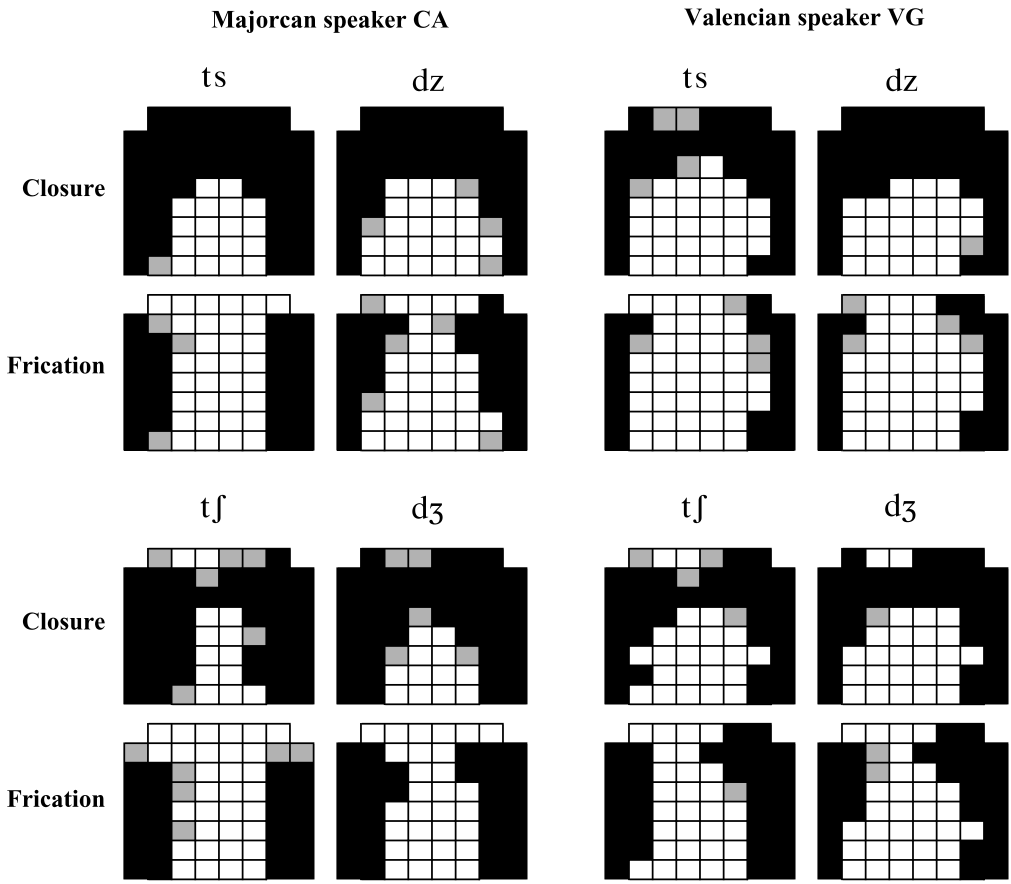

Figure 7 Linguopalatal contact configurations for /ts, dz, tʃ, dʒ/ for representative speakers of Majorcan (speaker CA; left) and Valencian (speaker VG; right). Data correspond to the midpoint of the closure and frication phases.

alveolar and alveolopalatal affricates for the Majorcan speaker CA than for the Valencian speaker VG.

It appears then that differences in dorsopalatal contact between alveolar and alveolopalatal affricates occur in both dialects and are more prominent in Majorcan than in Valencian. In conjunction with CAa data for affricates (alveolars and alveolopalatals were barely distinguished in Valencian; see section 4.2.1) and Qp data for fricatives (place-dependent differences were larger in Valencian than in Majorcan; see section 4.1.2 above), this finding confirms the hypothesis that articulatory differences are less likely to be found in affricates than in fricatives. Dorsopalatal contact variations as a function of voicing occurred systematically in the two dialects.

4.2.3 Alveolar contact centrality index (CCa)

ANOVAs for the CCa data yielded a main effect of 'consonant period' ($F(1,211) = 1243.32$, $p < 0.001$), 'dialect' ($F(1,211) = 19.47$, $p < 0.001$), 'place' ($F(1,211) = 6.24$, $p < 0.05$) and 'voicing' ($F(1,211) = 54.46$, $p < 0.001$). There were the significant interactions 'consonant period × place' ($F(1,211) = 7.79$, $p < 0.01$), 'consonant period × voicing' ($F(1,211) = 63.16$, $p < 0.001$), 'consonant period × dialect × place' ($F(1,211) = 5.13$, $p < 0.05$) and 'consonant period × dialect × voicing' ($F(1,211) = 7.96$, $p < 0.01$).

As revealed by the bars in the bottom graph of figure 4, main effects are associated with higher CCa values and thus, a narrower central channel, for Majorcan than for Valencian affricates, and for the alveolopalatal vs. alveolar and voiced vs. voiceless cognates. Place and voicing differences hold during frication but not during the closure phase, and are usually larger in Valencian than in Majorcan. Separate ANOVAs for each dialect reveal significant CCa differences for 'place' in Valencian ($F(1,75) = 6.50$, $p < 0.05$) and for 'voicing' in Majorcan and Valencian ($F(1,136) = 25.04$, $p < 0.001$; $F(1,75) = 30.72$, $p < 0.001$). As shown in figures 4 and 7, dialect-dependent differences in CCa between alveolar and alveolopalatal affricates are related to a particularly wide constriction for /ts/ in Valencian.

This CCa scenario resembles the one for fricatives in that differences in constriction width between /s/ and /ʃ/ were also greater in Valencian than in Majorcan due to the presence of a wider central passage for /s/ in the former dialect than in the latter. Underlying voicing differences in constriction width for affricates were oberved in the two dialects.

4.2.4 Other characteristics

EPG contact configurations at frication onset may be strictly homorganic with those at closure offset but not necessarily with those at closure midpoint. This is so because several speakers (BM, ND, CA and MS) exhibit alveolar contact loss proceeding backwards from closure midpoint to closure offset. Linguopalatal patterns for speaker CA in figure 7 show indeed a more anterior place of articulation at closure midpoint (usually front alveolar) than during frication (generally centroalveolar or postalveolar). There were no changes in place of articulation throughout the affricate for other speakers (AR, MJ, VB, VG). Thus, as shown in the same figure, speaker VG performs closure release approximately at the same place of articulation as closure midpoint.

Inspection of linguopalatal contact configurations indicate that /dʒ/ may fail to achieve a complete closure for some Valencian speakers (MS and VG) but that this is never the case for Majorcans. The corpus of unscripted speech also showed instances of incomplete closure for the Valencian speakers JM, MS and VG, but not for VB, AV and the five Majorcans. Affricates subject to closure reduction may be voiced ([dz] in *tots arriben* 'they all arrive' for those three speakers, [dʒ] in *metge* 'doctor' and *mitja* 'half' for VG) but also voiceless ([tʃ] in *la meua xiqueta* 'my little daugther' for VG, *hostatjar* 'to lodge' for JM).

The voicing bar in spectrographic displays indicates that affricate devoicing is triggered by closure lengthening, i.e. long affricate closures in Majorcan may undergo devoicing presumably in line with the aerodynamic requirements involved (Smith 1997, Jesus & Shadle 2002). Indeed, while vocal fold vibration is maintained during the entire closure period for /dz, dʒ/ in the case of speakers BM, ND and CA, speaker AR and occasionally MJ devoice the closing and frication phases or just the frication phase for /dʒ/. Valencian voiced affricates exhibit voicing all through for all speakers under analysis. These data are consistent with instances of affricate devoicing in the story corpus. Also here, affricate devoicing could occur during the fricative phase and perhaps the second half of the closing phase (/dʒ/ in *patge* 'page' for speaker BM, /dz/ in *setze* 'sixteen' for speaker VB).

4.3 Affricate duration

ANOVAs run on the affricate duration data across dialects yielded a main effect of 'dialect' ($F(1,211) = 113.4$, $p < 0.001$), 'place' ($F(1,211) = 169.84$, $p < 0.001$) and 'voicing' ($F(1,211) = 51.55$, $p < 0.001$), and the significant interactions 'place × voicing' ($F(1,211) = 8.66$, $p < 0.04$) and 'dialect × place × voicing' ($F(1,211) = 6.07$, $p < 0.01$). As shown in figure 8 and table 4, affricates were longer in Majorcan than in Valencian, voiceless affricates were longer than voiced affricates, and the alveolar affricates were longer than the alveolopalatal affricates. While overall affricate duration decreased in the progression /ts/ > /dz/ > /tʃ/ > /dʒ/ in both dialects, /dʒ/ appears to be especially short in Valencian. Also, statistical tests for each dialect yielded a main effect of 'place' and 'voicing' in Majorcan and Valencian,

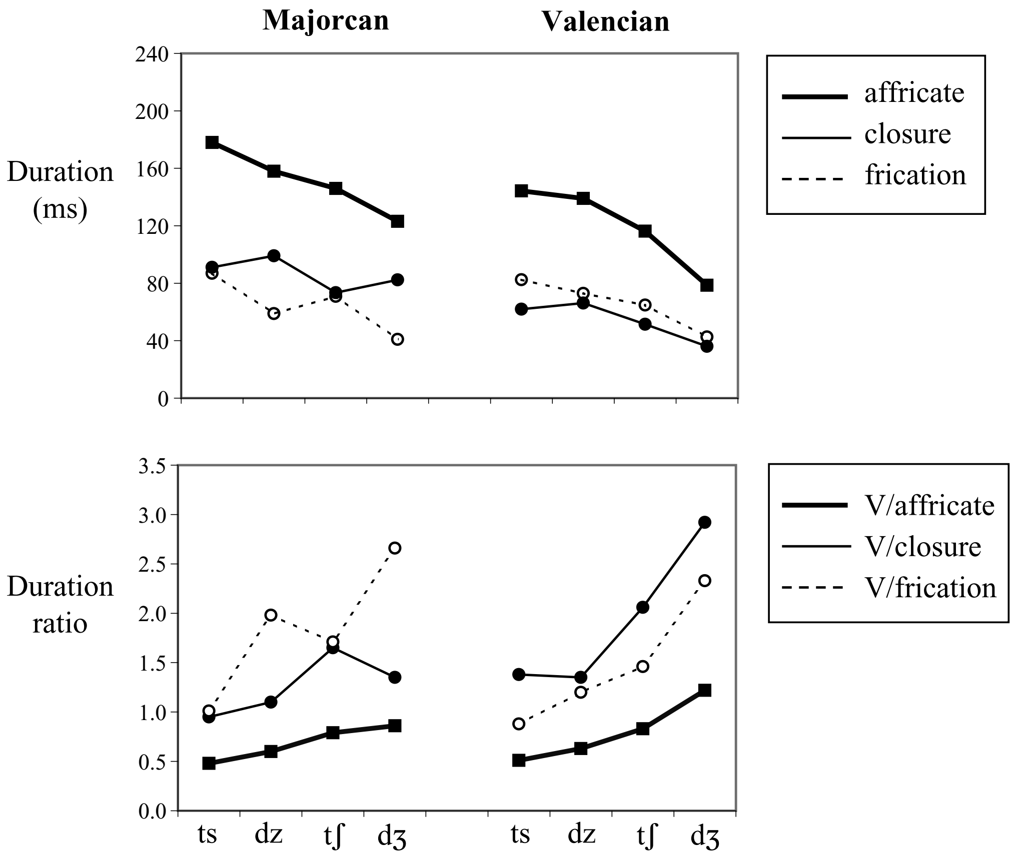

Figure 8 Duration data for /ts, dz, tʃ, dʒ/. Top: durations for the entire affricate (thick lines), the affricate closure phase (thin lines) and the affricate frication phase (dotted lines). Bottom: vowel/affricate ratios (thick lines), vowel/closure ratios (thin lines) and vowel/frication ratios (dotted lines).

and a significant 'place × voicing' interaction in Valencian but not in Majorcan due to the extremely short /dʒ/ duration ($F(1,75) = 9.92$, $p < 0.01$).

ANOVAs for the entire data set also yielded a main effect of 'consonant period' ($F(1,211) = 9.13$, $p < 0.01$), and the significant interactions 'consonant period × dialect' ($F(1,211) = 74.23$, $p < 0.001$), 'consonant period × voicing' ($F(1,211) = 35.97$, $p < 0.001$) and 'consonant period × dialect × voicing' ($F(1,211) = 9.23$, $p < 0.01$). These statistical results reflect the presence of a longer closing vs. frication phase for Majorcan voiced affricates but not for Valencian affricates or for Majorcan voiceless affricates, as shown in figure 8.

Separate ANOVAs for each dialect yielded a significant effect of 'consonant period' in Majorcan ($F(1,136) = 71.42$, $p < 0.001$) and Valencian ($F(1,75) = 29.76$, $p < 0.001$), and a higher degree of significance for the 'consonant period × voicing' interaction in the former dialect ($F(1,136) = 43.05$, $p < 0.001$) than in the latter ($F(1,75) = 8.32$, $p < 0.01$). These results suggest that there is an inverse relationship between the duration of the closure and frication periods for the two affricate voicing types in Majorcan; thus, within each place of articulation, closures are longer for voiced affricates than for voiceless affricates, and the duration of the frication period shows the opposite relationship. In Valencian, the frication period is also slightly longer for voiceless vs. voiced affricates while closure duration does not exhibit a clear voicing-dependent pattern.

Table 4 Mean duration values and standard deviations for /ts, dz, tʃ, dʒ/ according to individual speakers, and across speakers of Majorcan (left) and Valencian (right). Durations are given for the vowel preceding the affricate, for the affricate consonant, and for the closure and frication periods of the affricate.

		Majorcan					Valencian			
		Vowel	Affricate	Closure	Frication		Vowel	Affricate	Closure	Frication
ts	AR	81.4	158.6	81.4	77.1	VB	77.1	174.3	88.6	85.7
		3.8	*12.2*	*10.7*	*13.8*		*4.9*	*9.8*	*3.8*	*7.9*
	BM	91.4	168.6	91.4	77.1	MS	70.0	137.1	58.6	78.6
		10.7	*10.7*	*10.7*	*17.0*		*8.2*	*16.0*	*12.1*	*10.7*
	MJ	75.7	194.3	95.7	98.6	VG	68.6	121.4	38.6	82.9
		7.9	*9.8*	*5.3*	*13.5*		*6.9*	*12.2*	*12.1*	*7.6*
	ND	85.7	178.6	100.0	78.6					
		7.9	*14.6*	*26.5*	*16.8*					
	CA	85.7	190.0	87.1	102.9					
		5.3	*21.6*	*11.1*	*15.0*					
	$\bar{X}$	**84.0**	**178.0**	**91.1**	**86.9**	$\bar{X}$	**71.9**	**144.3**	**61.9**	**82.4**
	sd	*5.8*	*14.8*	*7.2*	*12.8*	*sd*	*4.6*	*27.1*	*25.2*	*3.6*
dz	AR	105.7	141.4	91.4	50.0	VB	85.7	162.9	81.4	81.4
		5.3	*10.7*	*10.7*	*8.2*		*9.8*	*12.5*	*3.8*	*12.1*
	BM	92.9	155.7	97.1	58.6	MS	97.1	135.7	62.9	72.9
		4.9	*14.0*	*9.5*	*12.1*		*9.5*	*19.0*	*12.5*	*11.1*
	MJ	112.9	174.3	81.4	92.9	VG	72.9	118.6	54.3	64.3
		13.8	*9.8*	*13.5*	*9.5*		*7.6*	*12.2*	*7.9*	*5.3*
	ND	102.9	168.6	130.0	38.6					
		7.6	*6.9*	*10.0*	*9.0*					
	CA	104.3	150.0	95.7	54.3					
		12.7	*11.6*	*14.0*	*15.1*					
	$\bar{X}$	**103.7**	**158.0**	**99.1**	**58.9**	$\bar{X}$	**85.2**	**139.0**	**66.2**	**72.9**
	sd	*7.2*	*13.4*	*18.3*	*20.4*	*sd*	*12.1*	*22.3*	*13.9*	*8.6*
tʃ	AR	117.1	115.7	50.0	65.7	VB	88.6	128.6	62.9	65.7
		7.6	*7.9*	*11.5*	*5.3*		*6.9*	*6.9*	*7.6*	*7.9*
	BM	100.0	134.3	75.7	58.6	MS	92.9	137.1	60.0	77.1
		8.2	*7.9*	*9.8*	*6.9*		*4.9*	*4.9*	*8.2*	*7.6*
	MJ	131.4	163.0	80.1	82.9	VG	91.4	82.9	31.4	51.4
		20.4	*18.9*	*29.3*	*23.6*		*6.9*	*7.6*	*9.0*	*6.9*
	ND	111.4	162.9	108.6	54.3					
		10.7	*12.5*	*13.5*	*11.3*					
	CA	102.9	154.3	65.7	88.6					
		26.9	*9.8*	*15.1*	*9.0*					
	$\bar{X}$	**112.6**	**146.0**	**73.4**	**70.9**	$\bar{X}$	**91.0**	**116.2**	**51.4**	**64.8**
	sd	*12.6*	*20.6*	*21.7*	*16.1*	*sd*	*2.2*	*29.2*	*17.4*	*12.9*
dʒ	AR	110.0	97.1	61.4	35.7	VB	95.7	81.4	45.7	35.7
		11.5	*13.8*	*12.1*	*5.3*		*5.3*	*3.8*	*5.3*	*7.9*
	BM	85.7	108.6	65.7	42.9	MS	85.0	82.5	32.5	50.0
		5.3	*15.8*	*12.7*	*7.6*		*12.9*	*9.6*	*9.6*	*8.2*
	MJ	118.6	128.6	78.6	50.0	VG	102.0	72.0	30.0	42.0
		16.8	*13.5*	*10.7*	*15.3*		*4.5*	*11.0*	*10.0*	*8.4*
	ND	110.0	145.7	108.6	37.1					
		5.8	*22.3*	*21.2*	*9.5*					
	CA	90.0	135.7	97.1	38.6					
		5.8	*9.8*	*11.1*	*6.9*					
	$\bar{X}$	**102.9**	**123.1**	**82.3**	**40.9**	$\bar{X}$	**94.2**	**78.6**	**36.1**	**42.6**
	sd	*14.2*	*19.9*	*20.2*	*5.8*	*sd*	*8.6*	*5.8*	*8.4*	*7.2*

Duration data in table 4 show that, while the production of voiced /dz, dʒ/ involves longer closure than frication periods for all Majorcan subjects (with the exception of /dz/ in the case of speaker MJ), this difference holds for /ts, tʃ/ in two of the five Majorcan speakers only (BM, ND). On the other hand, none of the three Valencian speakers MS, VG and AV exhibit clearly longer closure vs. frication periods for /ts, dz, tʃ, dʒ/.

In summary, closure/frication ratios are higher in Majorcan than in Valencian, mostly so for the voiced affricates /dz, dʒ/ than for the voiceless cognates /ts, tʃ/. These dialect-dependent differences appear to be highly robust judging from the fact that the relationship between the normalized durations for the entire affricate and for its closure and frication periods (i.e. the duration of these three events normalized against the duration of the whole sentence) did not differ substantially from the corresponding unnormalized durations.

Data shown in figure 8 also revealed a trend for vowel duration to compensate for affricate duration. All vowel duration ratios, i.e. vowel/affricate, vowel/closure and vowel/frication, varied in the progression /dʒ/ > /tʃ/ > /dz/ > /ts/ and thus, inversely to absolute affricate duration. Moreover, vowel/closure ratios (thin lines) were higher in Valencian than in Majorcan which is in accordance with differences in closure duration between the two Catalan dialects.

5 Discussion

5.1 Place of articulation and main articulator for fricatives

Linguopalatal contact data reported in this study indicate that Valencian /s/ is apical or laminal and articulated at the frontmost or central alveolar zone, while Majorcan /s/ is apical and formed at the centroalveolar or postalveolar zone (as in Eastern Catalan). Less dorsopalatal contact for Valencian /s/ implies presumably the existence of a flatter tongue dorsum rather than more grooving. In line with data on /s/ for other languages presented in the Introduction, this may mean that the primary articulator rather than the degree of constriction fronting determines grooving degree and that dorsopalatal contact size is not necessarily correlated with grooving.

The fricative /ʃ/, on the other hand, is laminal and centroalveolar or postalveolar in Valencian, and laminal or lamino-predorsal and postalveolar or alveolopalatal in Majorcan (and thus close to Eastern Catalan /ʃ/ in the latter dialect). It appears that the tongue tip is lowered in Majorcan and may be more or less raised in Valencian.

5.2 Relationship between affricates and fricatives

The existence of a symmetrical relationship between fricatives and affricates at the production level has been confirmed. As a general rule, both sound classes agree in showing less anteriority, more dorsopalatal contact and a narrower constriction for the alveolopalatal than for the alveolar cognates. Moreover, these place-dependent differences were found to occur throughout the entire affricate. Results regarding constriction width are not in accordance with data from previous studies (Fletcher 1988, Fletcher & Newman 1991) showing that /s/ is more constricted than /ʃ/. The close articulatory relationship between fricatives and affricates also applies to other related sound classes such as oral and nasal (alveolo)palatal stops in Majorcan (Recasens & Espinosa 2006). These may be the sort of phonetic regularities that could be looked for in the vowel and consonant inventories of the worlds' languages.

Dialect-dependent differences in affricate production also parallel differences in fricative production, mostly during the frication phase. Thus, fricatives and affricates turned out to be more anterior, to involve less dorsopalatal contact and to be more vowel coarticulation sensitive in Valencian than in Majorcan as a general rule. The dialect-dependent difference in alveolar contact anteriority applies mostly to alveolopalatal fricatives and affricates, which is in agreement with descriptive and sound-change data in the literature. On the other hand, dialect-dependent differences in dorsopalatal contact apply basically to the fricative /s/ and to the affricates /tʃ, dʒ/. Regarding constriction width, /s/ and /ts/ exhibit a wider constriction in Valencian than in Majorcan.

5.3 Phonetic distance between alveolars and alveolopalatals

Lingual fricatives and affricates are closer to each other in Valencian than in Majorcan, mostly due to the anterior realization of the alveolopalatal cognates. While close to each other, Valencian alveolar and alveolopalatal affricates and fricatives were found not to undergo neutralization but to differ from each other in production. For both fricatives and affricates, the place distinction applies mostly to constriction location and length, dorsopalatal contact and constriction width, but not so clearly to alveolar contact fronting. In light of these results, CAa may be taken as an indicator of place of articulation for fricatives and affricates only if complemented with lingual constriction data.

Findings regarding the phonetic distance issue are relevant to sound change. They suggest that two phonemes may remain phonologically distinctive for a long time even if they only differ slightly at the articulatory and auditory levels. Moreover, data presented in this paper reveal that certain changes in place of articulation for affricates (i.e. alveolopalatal fronting, place neutralization) may be associated with the articulatory proximity between /ʃ/ and /s/ in the same language or dialect.

5.4 Other articulatory characteristics of affricates

In agreement with recent studies dealing with affricates in other languages (Kim 2001, 2004; Dixit & Hoffman 2004), all affricates under analysis were articulated at the alveolar region during the closure phase, which raises the question of whether /tʃ, dʒ/ must be invariably labeled palatoalveolar or alveolopalatal. Either label, i.e. palatoalveolar or alveolopalatal, appears to be adequate provided that we are referring to the frication phase rather than to the occlusion phase.

Catalan affricates were found to be homorganic in terms of the linguopalatal contact configurations at frication onset and at closure offset. Full homorganicity may not necessarily hold if the comparison is carried out between frication onset and closure midpoint since place of articulation may change during closure in adjustment for frication. The change in question does not wait for the seal of contact during affricate release to be broken but takes place already during the stop phase (Dixit & Hoffman 2004).

Voiced affricates turned out to be more anterior and more constricted during the frication phase, and exhibited less dorsopalatal contact, than voiceless affricates. Differences in constriction width as a function of underlying voicing are in support of the notion that this articulatory attribute varies directly with airflow volume for voiceless vs. voiced fricatives.

Place of articulation and voicing differences among affricates at closure/constriction location become more obvious during the frication phase than during the closure phase. It may be suggested that those underlying phonemic differences are present during the stop phase but remain partly hidden, as it were, in line with the requirements on central contact. For an analogous reason, articulatory differences between alveolars and alveolopalatals were found to be smaller in affricates than in fricatives, mostly so in Valencian where /ts, dz/ and /tʃ, dʒ/ were produced through similar linguopalatal contact configurations.

5.5 Duration

Majorcan affricates were longer than Valencian. This situation conforms to previous descriptive data in the literature, and parallels the scenario for simple affricates in other languages. Dialect-dependent differences in the duration of underlying voiced vs. voiceless affricates and of their components were also found to hold. In Majorcan, voiced affricates are shorter, and exhibit a longer closure and a shorter frication period, than voiceless affricates. In Valencian, on the other hand, affricate and closure duration are less for /dʒ/ than for /ts, dz, tʃ/, and the frication period is longer for voiceless affricates than for their voiced cognates. These voicing-dependent differences in duration may not always be perceived by listeners but are highly robust in production.

Affricate duration was correlated with closure duration in Valencian but not in Majorcan. The fact that affricates and their closures are shorter if underlyingly voiced than voiceless in Valencian may be said to conform to a universal trend. It accords with more articulatory reduction for the former voicing class, as shown by instances of incomplete closure in our study and closure lenition and deletion for /dʒ/ in several languages. Majorcan speakers appear to lengthen voiced affricate closures intentionally. Dialect-dependent differences in closure duration for voiced affricates are related to their lenition and elision in Valencian and to their devoicing in Majorcan. One may speculate that closure lengthening for underlying voiced affricates in Catalan dialects (and in Central and Southern Italian) may be used by speakers to prevent otherwise short voiced affricate realizations from undergoing extreme articulatory reduction. Instances of /dʒ/ devoicing in Majorcan (as well as in Lenguadocian Occitan) could be associated with closure lengthening. Moreover, devoicing appears to affect the frication phase before it occurs during the closing phase which is consistent with glottal vibration ceasing at some time during the second half of intervocalic voiced fricatives (Stevens 1998: 479f.).

The prominence of the frication period was found not to depend on closure duration but on the underlying voicing status of the affricate. A longer frication for voiceless vs. voiced affricates in both Catalan dialects appears to conform to a universal trend for voiceless affricates to involve a high flow rate through the constriction and a high intraoral pressure level. Results also show a trend for vowel duration to compensate not only for affricate and closure duration (as reported in previous studies) but for the duration of the frication phase as well.

6 Conclusions

Data on constriction fronting and other articulatory characteristics for Majorcan and Valencian fricatives and affricates are in support of the notion that related sound classes in a given language or dialect may share highly specific phonetic properties. Moreover, place of articulation differences for affricates are specified at frication rather than at closure while underlying voicing differences are mainly opposed through dialect-specific closure duration differences (also through articulation). It has been argued that closure lengthening in voiced affricates should be viewed as intentional as opposed to a universal pattern for closure for those affricates to stay short. Affricates are articulated at the alveolar zone during the occlusion phase, and speakers appear to use different release strategies and thus different degrees of homorganicity. Phonetic data presented in this paper also show that lenition applies to extremely short closures; moreover, devoicing is prone to occur when the affricate closing phase is especially long, and involves the second half of the closing phase and, more often, the frication phase of the affricate. Future research will explore in more detail the active articulator and the overall tongue configuration for fricatives and affricates in both dialects, and the perception of the alveolar/alveolopalatal contrast for both consonant classes in Valencian.

Acknowledgements

This research was supported by the Spanish Ministry of Education and Science (BFF2003-09453-C02-01) and FEDER, and by the Catalan Government (2005SGR00864). We would like to thank Maria Josep Solé and three anonymous reviewers for helpful comments on a previous manuscript version.

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