

An EPG and perceptual study of the postalveolar and palatal affricate contrast in Standard Croatian

Marko Liker & Fiona Gibbon

In Classical Standard Croatian affricates /tʃ/ and /dʒ/ are traditionally considered postalveolar, while /tʃ/ and /dʒ/ are described as palatal. However, researchers claim that a new sociophonetic norm has emerged in major Croatian cities during the last two decades, whereby postalveolar and palatal affricates are neutralised in the articulatory and acoustic space somewhere between postalveolar and palatal. These conflicting claims are based primarily on subjective listener judgements, however, and there are no recent instrumental studies to support either claim. This study used instrumental and perceptual analyses of nonsense sequences recorded from six speakers who were judged as representative of the new sociophonetic norm. In the instrumental study, electropalatographic (EPG) data were analysed to evaluate whether tongue palate contact data supported the traditional view or the more recent claims regarding Croatian affricates. The EPG results indicated that Croatian affricates were not separated in terms of postalveolar versus palatal place of articulation. Instead, speakers articulated both affricate targets in a similar – alveolar or postalveolar – region of the palate. However, the affricates were not neutralised either because all speakers had significantly higher amounts of contact particularly in the anterior four rows of electrodes for palatal affricate targets. The results of the EPG analysis were supported by the results of the perceptual study. This study involved 28 naïve listeners who were able to identify the overwhelming majority (86%) of affricates accurately. The perceptual and EPG results raised therefore the question of what phonetic features characterise modern Croatian affricates. In this paper, we argue that the EPG data is consistent with the view that speakers use different lingual articulators – apical versus laminal – to articulate these affricates. We speculate that the increased contact associated with laminal articulations enhances the perceptual cues of palatalization that are used by listeners to identify the palatal affricates and thus distinguish them from the postalveolar affricates.*

1. Introduction

Sociolinguistics is the empirical study of how language is used in society (Coulmas 2003: 563). Coulmas (2003) further explains that an important strand of sociolinguistic research focuses on language change and that it is widely considered that the proper task of a sociolinguistic theory should be to explain and predict language change. That languages change is not new to scholars and linguists (Lyons 1995) and researchers agree that any level of language can change (Joseph 2003). Changes in the phonetics and/or phonology of a language can be investigated within the relatively new discipline of sociophonetics. Sociophonetics brings principles, techniques and theoretical frameworks of phonetics to the field of sociolinguistics (Foulkes et al. 2010).

There is one type of phonetic/phonological change often referred to as merger or neutralisation, which is particularly interesting for at least two reasons: it represents the suspension of a phonetic contrast, often providing a chance to study sound change in progress, and it can be phonetically complete as well as incomplete (Almihmadi 2010, Foulkes et al. 2010). Incomplete neutralisation involves contrasts which are impressionistically described as neutralised, but phonology still refers to those contrasts under certain conditions (Almihmadi 2010: 102). Complete neutralisation is a much more thoroughly researched sound change than incomplete neutralisation or near merger. One example of complete neutralisation is the change from Ancient and Modern Greek, where several vowels merged eventually to [i] (Joseph 2003). To take a more recent example, Majors (2005, cited in Foulkes et al. 2010: 717-718) shows different tendencies in Missouri English, where a speaker from Springfield showed the merger between vowels /a/ and /ɔ/, while no merger was recorded in a speaker from St. Louis. Although there is no conclusive evidence that any of the sound changes are caused by social factors alone, research has shown that changes happen according to social patterns. The interplay between biomechanics of speech production and socially determined factors in a particular sound change is a rich area of research in sociophonetics.

Some researchers report that a similar process of neutralisation between the postalveolar and palatal affricates is taking place in Croatian. Croatian is a South Slavic language, and like many Slavic languages, has numerous affricate sounds (Hála 1957: 303). There are five affricate phonemes in Standard Croatian: /tʃ/, /dʒ/, /tɕ/, /dʑ/ and /ts/. The phonetic status of four of them (/tʃ/, /dʒ/, /tɕ/ and /dʑ/) has become

controversial from a phonetic as well as a sociophonetic point of view. In Classical Standard Croatian affricates /tʃ/ and /dʒ/ differ from affricates /t͡ɕ/ and /d͡ʒ/ according to the place of articulation (Škarić 1991, Bakran 1996, Landau et al. 1999, Škarić 2007a, Horga et al. 2010). However, researchers claim that a new sociophonetic norm has emerged in major Croatian cities during the last two decades, whereby these two groups of affricates are neutralised in the articulatory and acoustic space somewhere between postalveolar and palatal (Škarić 2000, 2001). This controversy motivates the present study, which uses articulatory and perceptual analyses of Croatian affricates to determine whether a merger is actually occurring.

Traditionally, affricates /tʃ/, /dʒ/, /t͡ɕ/ and /d͡ʒ/ are differentiated according to the primary place of articulation: /tʃ/ and /dʒ/ are described as postalveolar, /t͡ɕ/ and /d͡ʒ/ are referred to as palatal (Škarić 1991: 125, 144, 145, Bakran 1996: 109, 111, Landau et al. 1999: 66, Škarić 2007a: 53, Horga et al. 2010: 249). Škarić (1991: 144, translation by Marko Liker) summarises this in a single sentence: “In standard Croatian speech the affricate sounds are dental [ts], [dz], postalveolar [tʃ], [dʒ] and palatal palatalised [t͡ɕ], [d͡ʒ]”. Although rare, there are minimal pairs differentiated only by postalveolar and palatal affricates, such as *džak* (‘a sack’) / *đak* (‘a pupil’) and *spavačica* (‘a sleeping woman’) / *spavaćica* (‘a night gown’).

The traditional view of affricates was based primarily on impressionistic listener judgements, and there is no recent physiological articulatory evidence to support these claims. It is not clear why phoneticians and linguists used IPA symbols /t͡ɕ/ and /d͡ʒ/ to describe Croatian palatal affricates. According to the IPA notation, these symbols represent alveolo-palatal affricates, while true palatal affricates would be best represented by /cç/ and /jʝ/. Apparently this is another reflection of the uncertainty about the true articulatory nature of these affricates. When Croatian was presented in the *Handbook of the International Phonetic Association* (Landau et al. 1999), these affricates were labelled as palatal, nevertheless they were symbolised by /t͡ɕ/ and /d͡ʒ/. The uncertainty about the place of articulation of Croatian affricates was also reflected in some phonetic descriptions: some authors (e.g., Škarić 1991) described them as palatal and also palatalised, which in terms of a phonetic description, makes no obvious sense.

Although not recent, an early physiological investigation of Croatian was carried out by Miletić (1933). The results of his study did not support the differentiation according to place of articulation between these affricates. Miletić (1933) used indirect static palatogra-

phy to investigate sounds produced by 34 speakers of what was then known as Serbo-Croatian. His results showed that /tʃ/ and /dʒ/ were produced with contact at the alveolar ridge by some speakers, while other speakers produced them with contact in the postalveolar and prepalatal region. The presence of between-subject variability in place of articulation is not completely surprising. The reasons are two at least. First, the Miletić study used static palatography which provides a composite picture of “wipe-off” of tongue palate contact during articulation and therefore cannot give a precise record of place of articulation. Second, a more recent study of postalveolar affricates in English based on electropalatography revealed similar amounts of variability between speakers in place of articulation (Liker et al. 2007).

While the finding that postalveolar affricates were produced between the alveolar and prepalatal zone was unsurprising, Miletić’s findings concerning the place of articulation of the palatal affricates were more unexpected. The study found that /tʃ/ and /dʒ/ were produced with contact in the dento-alveolar region by the majority of the speakers (i.e., by 32 out of 34 speakers), while only two speakers articulated these two affricates at the alveolar ridge, without touching the teeth. The palatal affricates were in fact articulated with a place of articulation more anterior than that of the postalveolar affricates. This is a surprising finding in light of the traditional description of /tʃ/ and /dʒ/ as palatal affricates. With these data as the only physiological articulatory evidence, it is hard to justify the traditional classification of /tʃ/ and /dʒ/ as palatal as opposed to postalveolar /tʃ/ and /dʒ/. However, despite the existence of contrary evidence, the traditional description of Croatian affricates as postalveolar and palatal has persisted up to the present time.

The incongruity between the classical description of affricates and the physiological evidence of the Miletić’s study is increased by evidence during the last two decades reporting the emergence of a new spoken norm in Croatian, the so called Implicit Accepted Norm (Škarić 2000, 2001, 2007a, 2007b). It is claimed that young educated speakers from major urban areas in Croatia, especially from the capital Zagreb, are abandoning the classical norm in favour of the implicit norm. TV anchors and journalists on public television are also reported to be increasingly using the implicit norm. Six major characteristics of the Implicit Accepted Norm are typically listed. The neutralisation of the difference between postalveolar and palatal affricates is one of those characteristics (Škarić 2001). Although listed as one of the characteristics, there is currently no physiological evidence that the affricate contrast is neutralised as claimed in these studies.

The difference between the two types of affricates has been investigated to some extent perceptually and acoustically (Škarić 2000, 2007a, 2007b). In an extensive perceptual study, Škarić (2000) showed that affricates /tʃ/ and /tʃ̥/ were identified successfully only in 60% of the cases in the speech of public figures, while in the speech of two speakers of the Standard variety, listeners' identification accuracy was between 80 and 100%. Acoustic data supported the results of the perceptual study. This finding was somewhat weakened by the fact that it was made merely on the basis of visual inspection of the cumulative spectra, produced across all speakers and vowel contexts. Also, the sample of speech of public speakers was extracted from television and radio broadcasts, while the two speakers of the Standard were recorded in a recording studio while producing isolated words. In another investigation (Škarić 2007b) it was reported that only 6% out of the 226 speakers produced the two types of affricates differently. However, the analysis procedure was not reported in that paper.

It is clear from the discussion so far that there is a gap in knowledge about Croatian affricates. In the current study, we propose a more detailed articulatory investigation of these Croatian affricates than currently exists. We use perceptual tests and EPG data to further investigate the articulatory characteristics of Standard Croatian affricates. EPG will allow a direct analysis of tongue-to-palate contact dynamics. The perceptual tests will show whether there is a merger between the two types of affricates from the listeners' perspective.

2. Electropalatographic experiment

2.1. Method

2.1.1 Participants

Six native speakers of Croatian, aged between 26 and 35 years (mean of 30.8), participated in this study. There were three female (F1, F2, F3) and three male (M1, M2, M3) participants. Although being originally from six different Croatian cities, they all lived in Zagreb for a minimum of five years prior to recording, most of them having lived in Zagreb for more than 10 years. Participants had no history of speech, language or hearing impairments. Each speaker had an artificial palate individually constructed to fit against the hard palate (Wrench 2007). All speakers fitted the demographic description of the Implicit Accepted Norm speakers, and they demonstrated typical

stage the speakers needed at maximum one hour to adjust their articulation to the presence of the artificial palate. When their articulation was rated as acceptable by two trained phoneticians, the recording procedure began.

2.1.4 Analysis procedure

Annotation, segmentation and data preparation were performed with the Articulate Assistant software (Wrench et al. 2002). MS Excel was utilized for statistical analysis and data visualization. Segmentation and annotation of affricates were performed according to the EPG and acoustic criteria (Figure 2). The first EPG frame with full electrode activation across one or more rows was marked as the beginning of the occlusion. The end of the frication was determined acoustically, according to the presence of a clearly visible second formant and/or the absence of high frequency noise. The frame of maximum contact was determined automatically by the software. All maximum contact frames occurred during the occlusion phases of affricates. A minority (< 1%) had incomplete closure during affricate occlusion, and these cases were excluded from further analysis.

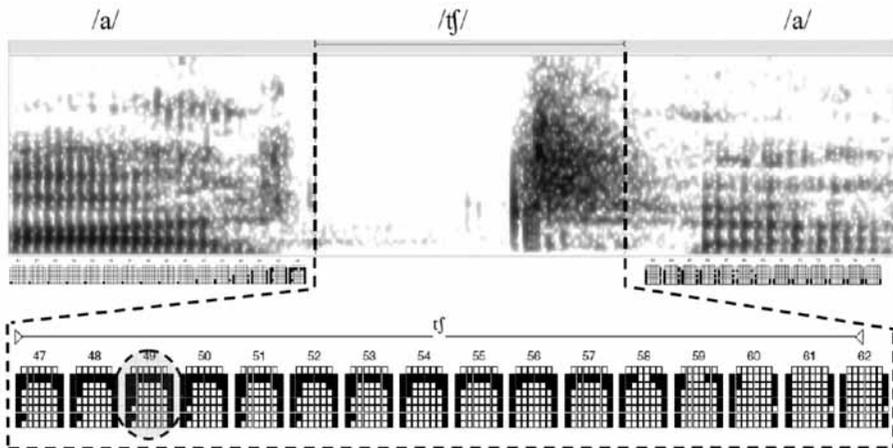


Figure 2. Segmentation and annotation criteria illustrated with the nonsense word /atʃa/ produced by the speaker F1. The frame of maximum EPG contact is encircled (ACoG is 6.5 and the amount of contact is 40%).

Two variables were analysed using the Articulate Assistant software (Wrench et al. 2002), place of articulation and amount of contact.

Place of articulation was analysed using the ACoG measure (Gibbon et al. 1993) at the point of maximum EPG contact:

$$ACoG = \frac{(4.5 \times R4) + (5.5 \times R3) + (6.5 \times R2) + (7.5 \times R1)}{R4 + R3 + R2 + R1}$$

where R1 – R4 represent the number of contacted electrodes in the four central electrodes over the four front rows of the palate (with R1 being the most anterior row and R4 the most posterior). ACoG utilises a modified CoG measure (Hardcastle et al. 1991) to calculate the area with the highest concentration of contacted electrodes in the four central electrodes over the four front rows of the palate. Although ACoG only uses data in the first four rows of electrodes, it is particularly suitable for this investigation for two reasons. First, a preliminary analysis showed that all speakers had the greatest amount of contacts in one of the first four rows of electrodes. This is also illustrated by average EPG frames across all repetitions and all vowel contexts at the point of maximum EPG contact (see Appendix 1). Second, ACoG is a measure that reduces the influence of side electrodes and back electrodes (Gibbon et al. 1993), hence it provides more precise measurements with anterior consonants. A higher ACoG value indicates a more anterior articulation, while a lower value indicates a more posterior articulation.

Amount of contact was calculated by means of the whole total measure at the point of maximum contact. It measures the total number of contacted electrodes and divides that number with the total number of electrodes on the palate (62). In this investigation the whole total measure is presented as a percentage.

Amount of contact was also calculated separately for the anterior four rows (anterior contact, AC) and for the posterior four rows of electrodes (posterior contact, PC).

Our aim was not to investigate coarticulation processes, so vowel context was not a controlled variable. Therefore, both EPG measures were calculated cumulatively across all repetitions and all vowel contexts for each speaker.

Statistical significance of differences was tested by means of heteroscedastic t-test.

2.2. Results

2.2.1 Place of articulation

The EPG data did not show consistent differences in place of articulation between the postalveolar and the palatal affricates, either voice-

less or voiced (Figures 3 and 4). Some speakers produced the postalveolar affricates with a more fronted place of articulation than the palatal affricates, whereas other speakers articulated the palatal affricates with a more anterior place of articulation than the postalveolar affricates.

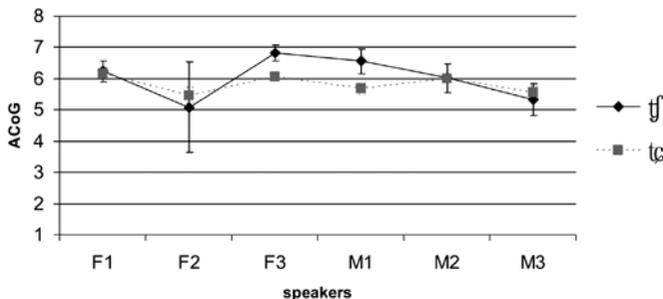


Figure 3. Place of articulation of voiceless affricates according to the ACoG measure. Standard deviation is visualised by vertical bars. Note that standard deviation in /tʃ/ is very low, making the vertical bars almost invisible.

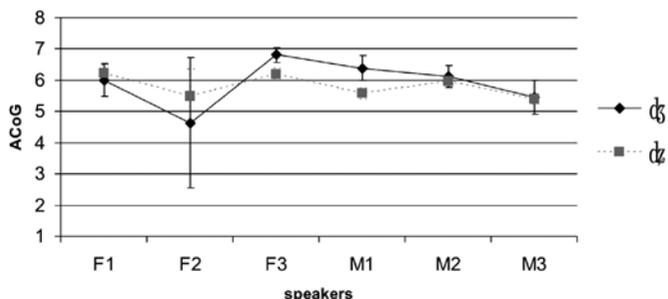


Figure 4. Place of articulation of voiceless affricates according to the ACoG measure. Standard deviation is visualised by vertical bars. Note that standard deviation in /tʃ/ is very low, making the vertical bars almost invisible.

Figure 3 shows the difference in the ACoG values for the voiceless pair. The difference was significant ($p < 0.01$) only for three speakers (F3, M1, M3). However, speaker M3 produced palatal affricates more fronted than postalveolar affricate, while the opposite was true for F3 and M1. The difference in the other three speakers (F1, F2, M2) is very small and statistically non significant. ACoG values in /tʃ/ ranged between 5.08 (sd 1.45) in F2 and 6.82 (sd 0.27) in F3, while for /tʃ/ they ranged between 5.45 (sd 0.25) in F2 and 6.15 (sd 0.19) in F1. Figure 5 shows ACoG value ranges and their overlap across affric-

ate categories. The ranges are based on average ACoG values for each speaker and do not include standard deviations.

Figure 4 shows the difference in the ACoG values for four speakers: F1, F3, M1 and M2 ($p < 0.01$). However, postalveolar /ɖʒ/ was more anterior in F3, M1 and M2, while F1 produced the palatal counterpart with a more fronted place of articulation. The difference in ACoG values was not significant in F2 and M3. The ACoG values for /ɖʒ/ ranged between 4.64 (sd 2.08) in F2 and 6.82 (sd 0.24) in F3, while for /dʒ/ the range was between 5.38 (sd 0.15) in M3 and 6.23 (sd 0.24) in F1. These ACoG ranges are visualised in Figure 5. Standard deviation for each speaker showed that intra-speaker variability was much lower for palatal affricates than for their postalveolar counterparts. Figure 5 also shows that interspeaker variability, as reflected in the ACoG range, was lower for palatal affricates than for postalveolars.

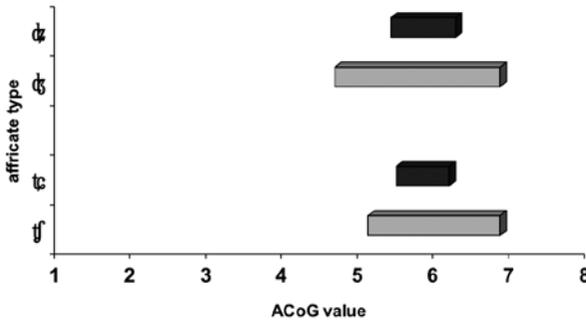


Figure 5. The range of ACoG values in the group of speakers (calculated on the basis of the average minimum and maximum ACoG value) for the four affricates under investigation.

Average EPG contact frames across all repetitions and all vowel contexts for the different affricates are shown in Appendix 1. These show that for most speakers, the location of the main constriction for the affricates is in row 2 for both postalveolar and palatal affricates. This indicates that for most speakers, all affricates have an alveolar place of articulation. Some speakers, however, have a broader contact in the anterior region that includes the postalveolar as well as the alveolar region (e.g., M1, M3).

2.2.2. Amount of contact

The data showed that all speakers produced palatal affricates /dʒ/ and /ɖʒ/ with more tongue-to-palate contact than postalveolar

affricates /tʃ/ and /dʒ/ (Figures 6 and 7). This is also illustrated in Appendix 1, where average EPG frames at the point of maximum contact of palatal and postalveolar affricates are shown for each speaker. These differences were consistent and statistically significant ($p < 0.001$) for all speakers. The difference in the amount of contact between the two affricates ranged between 16% in M1 and 22% in F1 and F2 for the voiceless pair. For the voiced pair, the difference in the amount of contact ranged between 16% in M3 and 20% in M2. The amount of contact for /tʃ/ ranged between 42% (sd 15) in F2 and 64% (sd 12) in M1, while for /tʃ/ the range was between 64% (sd 10) in F2 and 82% (sd 4) in F3. For the voiced pair, the amount of contact for /dʒ/ ranged between 39% (sd 16) in F2 and 59% (sd 13) in M1, while for /dʒ/ it was between 54% (sd 13) in F2 and 76% (sd 8) in M1.

Intra-speaker variability indicated by vertical lines in Figures 6 and 7 was lower for the palatal affricates in the speech of all speakers.

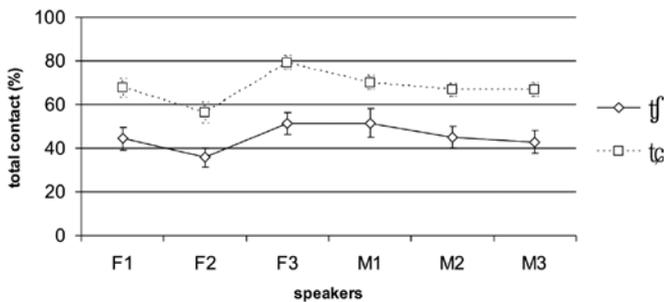


Figure 6. Amount of contact in voiceless affricates /tʃ/ and /tʃ/. Standard deviation is visualised by vertical bars.

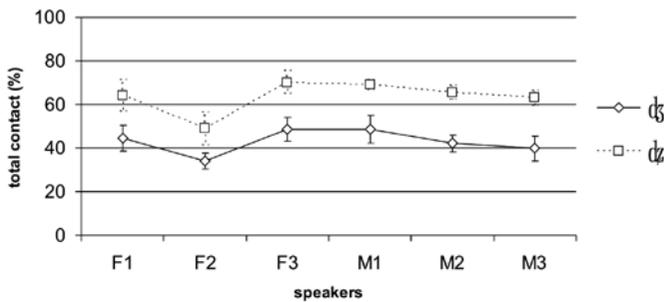


Figure 7. Amount of contact in voiced affricates /dʒ/ and /dʒ/. Standard deviation is visualised by vertical bars.

The separate analysis of anterior contact (AC) and posterior contact (PC) showed that the increase in the amount of contact for palatal affricates /tʃ/ and /dʒ/ was primarily the result of the increased contact in the first four rows (Tables 1 and 2). The contact difference between the postalveolar and the palatal affricates was much greater in AC (25% in the voiceless pair and 21% in the voiced pair) than in the PC (15% in the voiceless pair and 12% in the voiced pair). This point is also illustrated in the Appendix 2 (available on line at: <http://linguistica.sns.it/RdL/2012.htm>), where changes in the amount of contact are visualised in each row of electrodes during affricate production by speaker F1.

Table 1. Anterior contact (AC) for the four affricates expressed as a percentage.

AC (%)	tʃ	tʃ̥	dʒ	dʒ̥
F1	57	87	56	81
F2	41	74	37	64
F3	67	92	63	86
M1	72	87	65	82
M2	61	83	60	81
M3	58	81	56	72
Average	59	84	56	77
S.D.	11	6	10	8

Table 2. Posterior contact (PC) for the four affricates expressed as a percentage.

PC (%)	tʃ	tʃ̥	dʒ	dʒ̥
F1	48	63	48	59
F2	43	54	42	44
F3	55	72	51	62
M1	57	73	53	70
M2	42	57	38	57
M3	52	71	49	65
Average	50	65	47	59
S.D.	6	8	6	9

3. Perceptual experiment

3.1. Method

3.1.1 Participants

Twenty-eight naïve listeners participated in the experiment. The participants were native speakers of Croatian, aged between 19 and 23, with no self-reported speech or hearing difficulties. They had no formal phonetic training and were undergraduate students at the University of Zagreb.

3.1.2 Procedure

Perceptual and EPG analysis were performed on the same speech corpus, the simultaneous EPG and acoustic corpus CROELCO of Croatian speech (Liker 2009). The recordings used for the perceptual task were selected from the speech corpus analysed in the EPG experiment. However, in the previously described EPG experiment both symmetrical and asymmetrical vowel contexts were used (1296 items), while for the purposes of the perceptual study only sequences with symmetrical vowel contexts were utilised (432 items out of the total 1296). Therefore, 6 repetitions of 12 VCV sequences (four affricates in three symmetrical vowel contexts: e.g., /aʦa/, /iʦi/, /uʦu/, etc.) produced by 6 speakers resulted in 432 items. The listeners were presented with a list of 432 nonsense VCV sequences in a random order over a high quality speaker system in a silent room. Each VCV sequence was played twice and after a three-second-pause the next one was played. The listeners were instructed to indicate which of the four affricates they heard in each sequence. If they were not able to decide on one, they were allowed to indicate their dilemma by encircling the two most likely responses.

3.1.3 Data analysis

Listeners' answers were categorised in five types: 1. A correct identification of affricate type; 2. Dilemma: palatal/postalveolar (encircled both postalveolar and palatal affricate); 3. Dilemma: voicing (encircled both voiced and voiceless affricates, but identified the correct place of articulation); 4. Error: palatal/postalveolar (palatal instead of postalveolar and vice versa); 5. Error: voicing (voiced instead of voiceless and vice versa, but identified the correct place of articulation).

For the purpose of this research answers from the category 3 and 5 were classified as correct, because a correct identification of the affricate type (postalveolar / palatal) was achieved. The error in perception of voicing was not relevant here, as long as the listener identified affricate type according to place of articulation (postalveolar / palatal).

3.2. Results

The results showed that listeners identified palatal and postalveolar affricates well above the chance level, with correct responses in 86% of the cases. Listeners' success ranged between 98% (L9) and 70% (L5) (Figure 8).

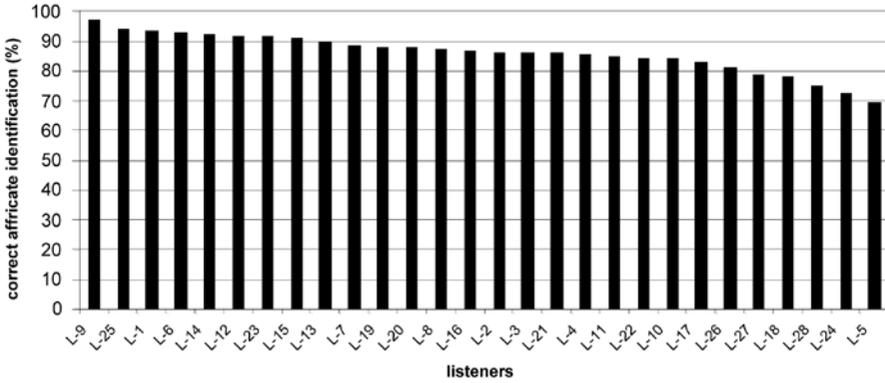


Figure 8. Percent of correctly identified affricates by listeners (L1-28).

When results were considered according to the speaker, it could be seen that listeners were more successful in identifying affricates produced by F1 (90%), M2 (90%) and M3 (91%), while they were less successful in identifying affricates from F2 (81%), F3 (85%) and M1 (81%). The high level of correct responses in the perceptual test provides evidence that Croatian listeners are able to hear a difference between the affricates; in other words, the results do not support the hypothesis of affricate neutralisation.

4. Discussion

We used EPG to investigate the place of articulation, measured by means of the ACoG index, and the amount of contact, measured by means of whole total measure, of four Croatian affricates. The results showed that postalveolar and palatal affricates did not consistently differ in place of articulation. Although some differences were statistically significant, some speakers produced postalveolar affricates with a more anterior place of articulation than their palatal counterparts, while in other speakers this relationship was reversed.

The analysis showed that ACoG ranges (articulatory zones) determined by the average minimum and maximum ACoG values for the two affricate types completely overlapped, with the articulatory zone for the palatal affricates being narrower than the articulatory zone for the postalveolar affricates. These results did not support the traditional description of affricates /tʃ/ and /dʒ/ as palatal, as opposed to postalveolar /tʃ/ and /dʒ/. The data suggest that the place of articulation of these two pairs of affricates is best described as alveolar - postalveo-

lar, with some variation according to different speakers. The results of this study were comparable to those reported by Miletić (1933), but were not in complete agreement. While Miletić's results agreed in suggesting that the two groups of affricates partially overlapped for place of articulation, they also showed that /tʃ/ and /dʒ/ (dentoalveolar and alveolar affricates) were slightly more anterior than /tʃ/ and /dʒ/ (alveolar and postalveolar/prepalatal affricates). In the present investigation, a similar tendency cannot be observed consistently in voiced and voiceless affricates for any of the speakers. Miletić also described affricates /tʃ/ and /dʒ/ as having more inter-speaker variability than /tʃ/ and /dʒ/. The data in the present investigation did not support these findings, because /tʃ/ and /dʒ/ showed lower inter-speaker variability as shown by narrower ACoG ranges than /tʃ/ and /dʒ/. Additionally, our results showed that intra-speaker variability was also lower in /tʃ/ and /dʒ/.

Although there was no measurable difference in place of articulation (ACoG values), the analysis of the amount of contact showed consistent and highly significant differences between /tʃ/ - /dʒ/ and /tʃ/ - /dʒ/, with /tʃ/ and /dʒ/ having a higher amount of contact in all speakers.

A higher amount of tongue-to-palate contact is interpreted as a direct consequence of a larger surface of the tongue touching the hard palate. Even though EPG does not allow a direct analysis of the active lingual articulator in the production of these affricates, it gives a fair amount of information, which can be used to speculate on the nature of the lingual articulator (Recasens & Espinosa 2007). The data on the amount of contact seems to suggest that these two pairs of affricates differ according to the active articulator, with /tʃ/ and /dʒ/ being laminal, /tʃ/ and /dʒ/ being apical. This is supported by the contact analysis, which showed that the increase in contact was much greater in the anterior palate than in the posterior palate. The breadth of contact in the front of the mouth has importance because it influences the shape of the tongue further back, and therefore the shape of the resonant cavity (Recasens et al. 1983, Recasens & Espinosa 2007). Therefore, it can be argued that this difference in the amount of contact enhances the perceptual cues for the secondary place of articulation of laminal affricates, thus making palatalisation a strong perceptual cue for the differentiation between the two groups of affricates. This increase in contact for /tʃ/ and /dʒ/ is also illustrated in Appendix 2, where the amount of contact in the four affricates produced by F1 is shown. The figures show how the amount of contact in each row of electrodes (vertical axis) changes throughout affricate duration. The figures clearly show that /tʃ/ and /dʒ/ are produced with a more tongue-to-

palate contact throughout their duration when compared with /tʃ/ and /dʒ/. This is an indication of raised tongue blade and dorsum (Dixit & Hoffman 2004, Recasens & Espinosa 2007, Recasens 2011). Increased tongue-to-palate contact around the alveolar ridge without a change in place of articulation is often an indication of laminal as opposed to apical articulation. Similar conclusions from EPG data were drawn by Recasens & Espinosa (2007) for two Catalan dialects and by Dixit & Hoffman (2004) for Hindi.

Miletić (1933) also noticed an increased amount of contact in /tʃ/ and /dʒ/ as opposed to /tʃ/ and /dʒ/ and noted that increased tongue-to-palate contact in these consonants was often connected with laminal articulation as opposed to apical. Similar processes in affricate sounds were reported in Serbian (Miller-Ockhuizen & Zec 2003), where the differentiation between the two groups of affricates was reported to be based on the apical versus laminal distinction rather than on the postalveolar vs. palatal distinction. Morén (2003) accepted the laminal versus apical distinction for Serbian affricates in his analysis of the segment inventory of Serbian. However, there is a lack of detailed instrumental data to fully support the claims about the place of articulation. Rochon and Pompino-Marschall (1999) analysed palatalised consonants in Polish. They concluded that palatalised /t/ in Polish was characterised by tongue dorsum raising and not by a change in the place of articulation with respect to the non-palatalised /t/. Mair et al. (1996: 1597) quoted research by Keating, which showed that palatoalveolar and alveolar sounds did not differ in the place of articulation as much as in the overall position and shape of the tongue. In that investigation Keating used radiography to show that palatoalveolars were produced with the whole body of the tongue raised and fronted. On that basis, Standard Croatian affricates /tʃ/ and /dʒ/ may be described as postalveolar and palatalised. However, since the laminal articulation results in tongue dorsum raising, also necessary for palatalisation, they are better described as laminal. Future research should investigate whether similar articulatory processes occur in laminal sounds which are not palatalised.

Laminal articulation and raised tongue dorsum in /tʃ/ and /dʒ/ can be the cause of the reduced articulatory variability evident in those affricates when compared to /tʃ/ and /dʒ/. This data fits nicely with the degree of articulatory constraint (DAC) model proposed by Recasens (Recasens et al. 1997, Recasens 1999). According to this model, speech sounds are more resistant to coarticulation and consequently less variable when there is a high degree of tongue-dorsum constraint during production. Data in the present research indicated that the affricates

/tʃ/ and /dʒ/ were produced with increased tongue dorsum requirements, thus allowing less variability in their articulation.

The results of the perceptual experiment showed that listeners' differentiation between the postalveolar and the palatal affricates was successful at 86%. This result is in contrast with the results of Škarić's studies (2000, 2001, 2007a, 2007b). These showed that one of the characteristics of the new norm in Croatian was the neutralisation of the postalveolar versus palatal affricates contrast. In his most extensive research on this subject, Škarić (2000) showed that the postalveolar and palatal affricates produced by public speakers, who represented the new norm, were identified correctly by listeners only in 60% of the cases. In contrast, productions of the affricates from two model speakers of the Classical Standard were identified correctly by listeners at a much higher rate (80-100%). Škarić interpreted these results as evidence of a change in progress in Croatian concerning affricate production.

However, there are alternative explanations for Škarić's results, and some questions may be raised about the conclusion of the presence of an affricate merger in the new Croatian norm. For example, the speech of public speakers used in the Škarić (2000) study was a sample of recordings from the electronic media, while the speech of the two model speakers was recorded in a recording studio while reading isolated words. Therefore, relatively low identification accuracy in the public speakers' sample might have been influenced by poorer recording quality, which could have obscured to some extent the phonetic cues relevant to detect the affricate contrast. Furthermore, the model speakers could have been using a careful, formal style of speech in their reading aloud of single words, in comparison to the spontaneous speech produced by the public speakers. According to Lindblom's theory of Adaptive Variability and Hyper-Hypo-Speech, speech production mechanism adapts to a particular communicative situation (Farnetani 1999: 381) and the acoustic characteristics of speech can vary accordingly. Since speakers typically tune their performance according to the situational demands (Lindblom 1990), it is reasonable to suppose that listeners had a harder task of identifying affricates in the speech of public speakers than affricates in the speech of the two model speakers. The current study used speakers who were considered representative of the new norm, and they produced affricates in nonsense sequences. These sequences were identified correctly with a high rate of accuracy by listeners. There is an obvious need for further research to investigate whether a merger of affricates is evident in various speech styles of the new Croatian norm. Due to sound changes being more likely to emerge first in the speech of younger

speakers of a particular speech community (e.g., Labov 2001), this issue should be further investigated with speakers from different age groups. Also, further research is needed using real words and sentences because sound changes in progress may be more likely to occur in real speech material than in nonsense sequences.

The results of the perceptual study provided evidence against an affricate merger; listeners were able to identify the affricates used as speech stimuli in the current study with a high degree of accuracy. Having in mind previously discussed EPG results, this finding is an indication that this differentiation was not due to affricates having different places of articulation, but to differences in the amount of contact in the anterior region of the palate. A visual inspection and a direct comparison between the perceptual and articulatory data reveal an interesting relationship. The two speakers whose affricates were less successfully identified by the listeners (i.e., F3, M1) were among the speakers who articulated postalveolar and palatal affricates with a significantly different place of articulation (i.e., F3, M1, M2, M3). This suggests that place of articulation is not a particularly strong cue for perceptual differentiation between these affricates.

Based on the present research, it is our opinion that, while a new implicit norm might be emerging, a complete neutralisation between the two types of affricates is certainly not part of that norm yet. Nevertheless, it can be predicted that these affricates will probably be completely neutralised in the future. This prediction is explained by answering to two questions: 1. Do Croatian speakers need this distinction?, and 2. Do Croatian speakers perceive this distinction?. It seems that Croatian speakers do not need this distinction, but according to our data most of them still perceive it. Why do we think that speakers of Croatian do not need this difference? There are at least two reasons for this: one is language internal (in the system itself, in the area of linguistics) and another is language-external (in society, in the area of sociolinguistics) (Labov 1994, 2001). Linguistically, there are very few minimal pairs differentiated only by these two groups of affricates (Škarić 2000), so it is not physiologically economical to make such a precise differentiation of such complex sounds for such a small number of minimal pairs. Sociolinguistically, after Croatian independence in 1991, the old Serbo-Croatian Standard was no longer the best representative of the speakers living in Croatia, so a new implicit norm started to emerge. This new norm was characterised by more influences from the dialects and the speech of major cities, in which the differentiation between the two pairs of affricates is not produced by the majority of speakers (Škarić 2000, 2007b).

EPG data only allow us to speculate about the identity of the active articulator. In order to fully investigate the role of tongue tip, lamina and dorsum in the production of Croatian affricates, other instrumental techniques would be needed, possibly coupled with EPG via multichannel systems. Imaging techniques, such as Ultrasound Tongue Imaging, and point tracking techniques, such as Electromagnetic Midsagittal Articulometer (EMA), could provide valuable information on tongue dynamics during the production of these affricates. The combination of ultrasound and EPG could prove ideal for the continuation of this research; EPG is very useful for looking into the details and variability of anterior constrictions, while ultrasound is well suited for secondary articulations (Foulkes et al. 2010). On the other hand, EPG and EMA have often been used in laboratory phonetic research, because they provide complementary information on tongue motion and tongue-to-palate contact (Stone 2010). The benefit of EMA is that it can provide precise simultaneous data on the movement of different articulatory systems of the tongue.

5. Conclusions and future work

The results presented in this study showed that Croatian affricates did not differ according to place of articulation, as traditionally believed. However, the results also showed that these affricates were not neutralised either. The EPG results showed clear separation according to the amount of contact, with /t͡ɕ/ and /d͡ʒ/ having significantly more contact than /t͡ɕ/ and /d͡ʒ/ in all speakers. Based on the conclusions from other research, we speculated that increased amount of contact, especially increased anterior contact, in /t͡ɕ/ and /d͡ʒ/ is indicative of laminal articulation, while lower amount of contact, especially decreased anterior contact, in /t͡ɕ/ and /d͡ʒ/ indicated apical articulation. Perceptual results provided further evidence against affricate neutralisation in Croatian.

Having in mind the limitations of this study, the issue of neutralisation should be further investigated with speakers from different age groups and with a speech corpus comprised of real words and sentences. Finally, coupling EPG with other instrumental techniques, such as EMA and ultrasound, would enable us to fully investigate articulatory gestures of tongue tip, lamina and dorsum during the production of affricates.

Addresses of the Authors

Marko Liker, Department of Phonetics, Faculty of Humanities and Social Sciences, University of Zagreb, Ivana Lucica 3, 10000 Zagreb, Croatia <mliker@ffzg.hr>

Fiona Gibbon, Department of Speech and Hearing Sciences, Brookfield Health Sciences Complex, University College Cork, Cork, Ireland <f.gibbon@ucc.ie>

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Bibliographical References

- ALMIHMADI Mariam 2010. Exploring the phonetics of neutralisation with phonology in mind. *UCL Working papers in linguistics* 22. 101-117.
- BAKRAN Juraj 1996. *Zvučna slika hrvatskoga govora*. Zagreb: Ibis grafika.
- COULMAS Florian 2003. Sociolinguistics. In ARONOFF Mark & Janie REES-MILLER (eds.). *The handbook of linguistics*. Oxford: Blackwell. 563-581.
- DIXIT Rahul P. & Paul R. HOFFMAN 2004. Articulatory characteristics of cricatives and affricates in Hindi: an electropalatographic study. *Journal of the International Phonetic Association* 34. 141-160.
- FARNETANI Edda 1999. Coarticulation and connected speech processes. In HARDCASTLE William J. & John LAVER (eds.). *The Handbook of Phonetic Sciences*. Oxford: Blackwell. 371-404.
- FOULKES Paul, James M. SCOBIE & Dominic WATT 2010. Sociophonetics. In HARDCASTLE William, John LAVER & Fiona E. GIBBON (eds.). *The Handbook of Phonetic Sciences*. Malden-Oxford-Chichester: Wiley-Blackwell. 703-754.
- GIBBON Fiona, William HARDCASTLE & Katerina NICOLAIDIS 1993. Temporal and spatial aspects of lingual coarticulation in /k/ sequences: a cross-linguistic investigation. *Language and Speech* 36. 261-277.
- HÁLA Bohuslav 1957. The Slavonic Languages. In KAISER Louise (ed.). *Manual of Phonetics*. Amsterdam: North-Holland Publishing Company. 302-311.
- HARDCASTLE William J., Fiona GIBBON & Katerina NICOLAIDIS 1991. EPG data reduction methods and their implications for studies of lingual coarticulation. *Journal of Phonetics* 19. 251-266.
- HORGA Damir, Vesna POŽGAJ HADŽI & Marko LIKER 2010. Fonetski opis segmentalne razine hrvatskog jezika i sposobnost hrvatskih govornika u slušnom razlikovanju bošnjačkog, hrvatskog i srpskog govora. In TOŠOVIĆ Branko & Arno WONISCH (eds.). *Hrvatski pogledi na odnose između*

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- hrvatskoga, srpskoga i bosanskoga/bošnjačkoga jezika (Svezak 1). Graz, Zagreb: KFU, Izvori. 241-254.
- JOSEPH Brian D. 2003. Historical linguistics. In ARONOFF Mark & Janie REES-MILLER (eds.). *The Handbook of Linguistics*. Oxford: Blackwell. 105-129.
- LABOV William 1994. *Principles of Linguistic Change: Internal Factors*. Oxford: Blackwell.
- LABOV William 2001. *Principles of Linguistic Change: Social Factors*. Oxford: Blackwell.
- LANDAU Ernestina, Mijo LONČARIĆ, Damir HORGA & Ivo ŠKARIĆ 1999. Croatian. In IPA (ed.). *Handbook of the International Phonetic Association*. Cambridge: Cambridge University Press. 66-69.
- LIKER Marko 2009. *Electropalatographic analysis of Croatian sounds*. Zagreb: University of Zagreb. Unpublished PhD thesis.
- LIKER Marko, Fiona E. GIBBON, Alan A. WRENCH & Damir HORGA 2007. Articulatory characteristics of the occlusion phase of /tʃ/ compared to /t/ in adult speech. *Advances in Speech-Language Pathology* 9. 101-108.
- LINDBLOM Björn 1990. Explaining phonetic variation: A sketch of the H&H theory. In HARDCASTLE William J. & Alain MARCHAL (eds.). *Speech Production and Speech Modelling: Proceedings of the NATO advanced study institute*. Dordrecht: Kluwer. 403-440.
- LYONS John 1995. *Language and Linguistics: An Introduction*. Cambridge: Cambridge University Press.
- MAIR Sheila J., Celia SCULLY & Christine H. SHADLE 1996. Distinctions between [t] and [tʃ] using electropalatography data. In BUNELL Timothy H. & William IDSARDI (eds.). *Proceedings of ICSLP 96. IVth International Congress in Spoken Language Processing* (October 3-6, 1996). Philadelphia, Pennsylvania. Vol. 3. 1597-1600.
- MCAULIFFE Megan J., Michael P. ROBB & Bruce E. MURDOCH 2007. Acoustic and perceptual analysis of speech adaptation to an artificial palate. *Clinical Linguistics & Phonetics* 21. 885-894.
- MCLEOD Sharynne & Jeff SEARL 2006. Adaptation to an electropalatographic palate: acoustic, impressionistic, and perceptual data. *American Journal of Speech-Language Pathology* 15. 192-206.
- MILETIĆ Branko 1933. *Izgovor srpskohrvatskih glasova: eksperimentalno-fonetska studija*. Beograd: Srpska kraljevska akademija.
- MILLER-OCKHUIZEN Amanda & Draga ZEC 2003. Phonetics and phonology of contrastive palatal affricates. *Working Papers of the Cornell Phonetics Laboratory* 15. 130-193.
- MORÉN Bruce 2003. Affricates, palatals and iotization in Serbian: Representational solutions to longstanding puzzles. In EGEBERG Eric & Lenart LÖNNGREN (eds.). *Poljarnyj Vestnik* 6. Tromsø University: Tromsø. 46-70.
- RECASENS Daniel 1999. Lingual coarticulation. In HARDCASTLE William J. & Nigel HEWLETT (eds.). *Coarticulation: Theory, Data and Techniques*. Cambridge: Cambridge University Press. 80-104.
- RECASENS Daniel 2011. Linguistic phonetics: A look into the future. In LEE Wai-Sum & Eric ZEE (eds.). *Proceedings of the XVIIth International Congress of Phonetic Sciences* (August 17-21, 2011). Hong Kong, China. 44-50.

- RECASENS Daniel & Aina ESPINOSA 2007. An electropalatographic and acoustic study of affricates and fricatives in two Catalan dialects. *Journal of the International Phonetic Association* 37. 143-172.
- RECASENS Daniel, Edda FARNETANI, Jordi FONTDEVILA & Maria D. PALLARÉS 1983. An electropalatographic study of alveolar and palatal consonants in Catalan and Italian. *Language and Speech* 36. 213-234.
- RECASENS Daniel, Maria D. PALLARÉS & Jordi FONTDEVILA 1997. A model of lingual coarticulation based on articulatory constraints. *Journal of the Acoustical Society of America* 102. 544-561.
- ROCHON Marzena & Bernd POMPINO-MARSCHALL 1999. The articulation of secondarily palatalized coronals in Polish. In OHALA John J., Yoko HASWAGAWA, Manjari OHALA, Daniel GRANVILLE & Ashlee C. BAILEY (eds.). *Proceedings of the XIVth International Congress of Phonetic Sciences* (August 1-7, 1999). San Francisco. California. 1897-1900.
- ŠKARIĆ Ivo 1991. Fonetika hrvatskoga književnog jezika. In KATIČIĆ Radoslav (ed.). *Povijesni pregled, glasovi i oblici hrvatskoga književnog jezika*. Zagreb: Nakladni zavod Globus. 61-372.
- ŠKARIĆ Ivo 2000. Č i Ć. *Govor/Speech* 17. 77-104.
- ŠKARIĆ Ivo 2001. Kakav pravopis (između fonetike i fonologije). *Govor/Speech* 18. 1-32.
- ŠKARIĆ Ivo 2007a. Fonetika hrvatskoga književnoga jezika. In KOVAČEC August (ed.). *Glasovi i oblici hrvatskoga književnog jezika*. Zagreb: Nakladni zavod Globus. 17-157.
- ŠKARIĆ Ivo 2007b. Hrvatski izgovorni identitet. *Govor/Speech* 24. 79-90.
- STONE Maureen 2010. Laboratory techniques for investigating speech articulation. In HARDCASTLE William J. & John LAVER (eds.). *The Handbook of Phonetic Sciences*. Malden-Oxford-Chichester: Wiley-Blackwell. 9-38.
- WRENCH Alan A. 2007. Advances in EPG palate design. *Advances in Speech-Language Pathology* 9. 3-12.
- WRENCH Alan A., Fiona E. GIBBON, Alison M. MCNEILL & Sara E. WOOD 2002. An EPG therapy protocol for remediation and assessment of articulation disorders. In HANSEN John H.L. & Brian L. PELLOM (eds.). *Proceedings of ICSLP02. VIIth International Congress of Spoken Language Processing* (September 16-20, 2002). Denver. Colorado. 965-968.