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Voice onset time of word initial /p, t, k/ in bilingual Hungarian-Croatian speakers and Hungarian monolingual speakers

A tanulmányban a magyar–horvát kétnyelvűek zöngétlen explozíváinak zöngekezdési idejét (VOT) mértem és vetettem össze magyar egynyelvű beszélők adataival. A kutatás fő kérdése az volt, hogy a kétnyelvűek vajon képesek-e az egynyelvűekhez hasonló VOT-értékeket produkálni. Mivel a korábbi kutatások szerint szignifikáns különbségek vannak a magyar–horvát kétnyelvűek és a horvát egynyelvűek zöngekezdési ideje és a követő magánhangzók időtartamai között, az első hipotézisem az volt, hogy a magyar egynyelvűek rövidebb VOT-értékeket, valamint magánhangzó-időtartamokat fognak produkálni, mint a kétnyelvűek. A kétnyelvűeket két csoportba osztottam: horvát dominánsok és magyar dominánsok. A második hipotézisem a dominancia szerinti összevetésre vonatkozott. Eszerint nincs különbség a horvát és a magyar dominánsok között. Az elemzett hanganyag harminc izolált magyar szóból állt, amelyekben a *[p, t, k]* zöngétlen mássalhangzók szókezdő pozícióban álltak, és *[i, ɛ, ɔ, o, u]* magánhangzó követte őket. Az eredmények csak néhány esetben mutattak szignifikáns különbséget a két beszélői csoport között.

1. Introduction

Nowadays the most accepted definition of bilingualism is the one by Grosjean (1982) who defines it as the regular use of two languages regardless of proficiency, sequence of language learning or age of acquisition. For many years the interaction between the two languages in an individual user has been an intriguing and widely debated topic (e.g. Appel–Muysken, 1987, Antoniou et al., 2011). However, the results have not yielded any unambiguous explanation on how this interlanguage interaction influences the phonetic details of a bilingual's speech in the L1 and L2 (e.g. Caramazza et al., 1973, Kang–Guion, 2006). Voice onset time (VOT) is defined as the time interval between release (burst) of a stop consonant and the onset of low-frequency periodicity in the subsequent vowel generated by quasy-periodic glottal pulsations (Lisker–Abramson 1964, Steinschneider et al., 1999, Fischer and Goberman, 2010). There are number of factors that influence VOT: place of articulation of the plosive, stress, quality of the following vowel, duration of the following vowel, type of speech and speech rate (Gósy, 2000, 2004, Fischer–Goberman, 2010, Bóna, 2011 Van de Weijer–Kupisch, 2015). Antoniou et al. (2011) state that there are four situations that cause interference between bilinguals' L1 and L2. The first one is when the

earlier-acquired knowledge of L1 influences the production of L2, hence the noticeable foreign accent is present in L2. Flege–Eefting (1987) found that Dutch (L1)–English (L2) bilinguals were constrained by the short-lag VOTs of Dutch voiceless stops, and produced English /t/ with shorter VOT (60 ms) than native speakers of English (90 ms). However, those bilinguals with the best English accent had more English-like VOTs (longer than bilinguals with poor English accents). They (the bilinguals with the best English accent) produced Dutch /t/ with significantly shorter VOTs than Dutch speakers with stronger accent in English. This suggests that learning English as an L2 influenced how the proficient Dutch speakers of English produced stops in their native language (Flege–Eefting 1987:197). This depicts the second situation which occurs when acquiring L2 affects the production of an earlier acquired L1. This kind of interaction between L1 and L2 can also depend on the level of competence in L1 prior to acquisition of L2. Flege (1987) found that Native French speakers who were profound in English produced longer French VOTs (more English-like) than French monolinguals, and native English speakers who were profound in French had shorter English VOTs (more French-like) than English monolinguals. A third situation of interlanguage interference is when a later acquired L2 becomes dominant, thus freeing itself of L1 influence and eventually influences the L1 (e.g. Flege, et al., 2002). The fourth possibility is that there is no interaction whatsoever between L1 and L2 and that they do not influence one another, which means that bilinguals are able to acquire monolingual-like production in both of their languages. Chionidou and Nicolaidis carried out research on VOT values of two groups of Greek-German bilingual pupils – six ones attending German school, and six ones attending Greek school in Germany. The speech material consisted of CVCV real words with word initial /p, t, k, b, d, g/ in the stressed syllable. When all pupils were pooled together, the results showed that they produced monolingual-like VOTs in both languages. However, when taking into consideration the school context, bilingual pupils attending the Greek school produced German stops with shorter VOT (more characteristic for Greek), while pupils attending the German school produced the Greek stops with longer VOT (more characteristic for German). These results illustrate the first situation in which speech production in non-dominant language is affected by dominant language.

Taking into consideration the influence of the quality of the following vowel on VOT, Flege (1991) found that English-Spanish early bilinguals produce both English and Spanish word-initial /t/ with a significantly longer VOT in the context of /i/ than /ɛ/ (60 vs 52 ms for English and 23 vs 18 ms for Spanish). Rochet–Fel (1991) studied the effects on vowel quality of VOT in ten native speakers of Mandarin Chinese. Speech material was derived from the subjects reading from a word-list. The words recorded consisted of an initial stop (/p, t, k, b, d, g/) and a following high (/i, u/) or a low vowel (/a/). The results showed that the quality of the following vowel had a significant effect on the VOT of the

/p/ and /t/ aspirated voiceless stop, while the place of articulation of the stop was insignificant. VOT values were significantly longer when the stop was followed by /i/ (106 ms) than by /a/ (96 ms). Gósy (2000) proved that VOT values did not only depend on the place of articulation of the target stop, but also on the (horizontal and vertical) movement of the tongue, and on the lip movements in the following vowel. VOTs before front vowels were shorter than before back vowels in the case of /p/, but longer for /t/ and /k/. Moreover, the higher the tongue position, the longer the VOT. As for lip movement, VOTs of /p, t/ were longer before rounded vowels, but shorter for /k/. Also, the longer the following vowel, the longer the VOT (which suggests an effect of speech rate). Whiteside et al. (2004) studied VOT in English-speaking children, and found longer VOT values for front and elevated /i/ vowels than in lowered /a/ vowels, although in this research the authors used syllables as stimuli rather than real words. Fischer–Goberman (2010) investigated VOT in Parkinson's disease and found that the height of the vowel had a significant effect on VOT. The VOT of voiceless stops was longer for high /i, u/ compared to low /a/. Van de Weijer–Kupisch (2015) proved in their research that a following high vowel yields a 14 ms longer VOT than the low vowels with French-German bilinguals. The above-mentioned research proved that the quality of the following vowel has a significant effect on VOT, i.e. high, close vowels give rise to a longer VOT. Ohala (1981, cited in Ohala, 2003: 2913) attributes this to aerodynamic factors: the onset of voicing is delayed if the oral pressure impulse from the stop decays more slowly due to the existing air encountering greater resistance to airflow.

Bakran (1996) investigated VOT in Croatian monolingual speakers and found that in spontaneous speech VOT values are 15 ms for /p/, 19 ms for /t/ and 25 ms for /k/, while in Hungarian spontaneous speech the VOT values for /p, t, k/ are 19, 27 and 35 ms, respectively (Gósy, 2000). In his study Bakran (1996) did not make a classification of VOT in the context of the following vowel. In the same study VOT was not investigated in isolated words. Gósy–Ringen (2009) measured VOT in isolated Hungarian words and found that the mean VOT for /p/ is 10 ms, for /t/ 16 ms and for /k/ 38 ms. All words were two-syllable. The authors state, that vowels were not systematically varied but most vowels were mid or low vowels. In her research on Hungarian VOT in 2, 3 and 4 year-old children Zajdó (2015) found that the VOT of /p/ was significantly shorter in the word initial (i.e. stressed) position than in word medial (i.e. unstressed) position. On the other hand, Bakran (1996) states that in Croatian the VOT is longer in stressed syllables than in unstressed ones. Jordanidisz et al. (2015) studied VOT of voiceless alveolar and velar stops in ten Hungarian-English bilingual children and in monolingual Hungarian controls, using the technique of single-word picture naming. Some of the (Hungarian) words used for this test were **teknős** (turtle), **telefon** (telephone), toll (feather), **kabát** (coat), **kalapács** (hammer), **kés** (knife). Their hypothesis was that bilinguals would produce longer VOTs than monolinguals. The results showed that the bilinguals aspirated /k/ (by about 10

ms) but not /t/ more than the monolinguals did. Trošelj (2016) investigated VOT in Hungarian-Croatian bilingual and 10 Croatian monolingual female speakers in the context of the following vowel. The speakers were asked to read a list of 30 isolated Croatian words with /p, t, k/ in the initial position. All words had short accents on the first syllable. Each stop was followed by one of the five Croatian vowels (/i, e, a, o, u/), and VOT and the duration of the following vowel were measured on that syllable. As a derived parameter, the VOT ratio was computed as VOT divided by the duration of the following vowel (and multiplied by 100, i.e. as a percentage). VOT, vowel duration and VOT ratio were analysed in the context of each following vowel. It was expected that differences in VOT between bilinguals and monolinguals would be caused by differences in the quality of the vowels between Croatian and Hungarian (more on differences in the quality of the vowels in Chapter 2 of the present study). It was found that Croatian monolinguals produced a significantly longer VOT for /p/ (20 vs 14 ms), for /t/ (21 vs 16 ms) and for /k/ (57 vs 44 ms). Croatian monolinguals produced significantly longer following vowels in the case of all three plosives: 127 vs 114 ms for /p/, 135 vs 124 ms for /t/ and 124 vs 113 ms for /k/. Moreover, monolinguals' VOT ratio was also significantly longer: 16 vs 12.8 % for /p/, 17 vs 14 % for /t/ and 48 vs 41 % for /k/.

When all three stops pooled together, the mean durations of Croatian monolinguals' /i, e, a, o, u/ were 108, 136, 147, 135 and 115 ms, respectively. These results follow a similar tendency as those of Bakran (1996) for two-syllable isolated words: open vowel /a/ was the longest (135 ms) followed by /e/ (127 ms), /o/ (126 ms), /i/ (111 ms) and /u/ (110 ms). No previous information was found on the duration of vowels in isolated words in Hungarian.

When the context of the following vowel was considered, Croatian monolinguals produced significantly longer VOTs in cases when /t/ was followed by /e/ (20 vs 17 ms), /o/ (17 vs 14 ms) and /u/ (26 vs 17 ms) and when /k/ was also followed by /e/ (44 vs 36 ms), /o/ (63 vs 44 ms) and /u/ (67 vs 49 ms). Vowels /e, a, o/ differ in their quality between Croatian and Hungarian (see Figure 1 of the present study). In all other cases of VOT the mean values of Croatian monolinguals were consistently longer than the bilinguals', although not significantly longer.

In regard to the duration of the following vowels, Croatian monolinguals produced significantly longer vowels when /p/ was followed by /i/ (125 vs 111 ms), /e/ (129 vs 113 ms) and /o/ (129 vs 115 ms), and when /t/ was followed by /e/ (150 vs 128 ms), /a/ (148 vs 128 ms) and /o/ (136 vs 116 ms). In the case when /k/ was followed by /e/ monolinguals also produced longer vowel (129 vs 113 ms). Only in the cases when /t/ was followed by /e, o/ and /k/ was followed by /e/ the differences between bilinguals and monolinguals were significant both for VOT and the following vowel duration.

Significant differences were also found for VOT ratio in the context of the following vowel. In the case of /p/ monolinguals produced significantly higher

VOT ratios for /a/ (10.2 vs 7.6 %) and /o/ (19.8 vs 13.4 %). Monolinguals' VOT ratio was significantly higher in the case of /t/ for vowels /i/ (24.3 vs 18.7 %) and /u/ (20.8 vs 13 %), as well as in the case of /k/ for /i/ (63.3 vs 54.2 %) and /o/ (46.1 vs 35.5 %).

In the same research bilinguals were divided into two groups: Croatian dominants and Hungarian dominants. The values of VOT, duration of the following vowels and VOT ratio were measured and compared between these two groups as well. No differences were found in VOT: 14 ms for both groups in the case of /p/, 16 ms for both groups in the case of /t/ and 45 ms for Hungarian compared to 43 ms for Croatian dominants in the case of /k/. No significant differences were found for vowel duration: 116 vs 113 ms in the case of /p/, 126 vs 116 ms in the case of /t/ and 118 vs 108 ms in the case of /k/, nor for VOT ratio: 13 vs 12.5 % for /p/, 15 vs 13 % for /t/ and 43.4 vs 38.5 % for /k/. Significant differences were found only for the vowel duration in the case when /t/ was followed by /e/ (121 ms for Hungarian compared to 134 for Croatian dominants), /a/ (120 ms for Hungarian compared to 136 ms for Croatian dominants) and /u/ (126 ms for Hungarian compared to 146 for Croatian dominants). In all, the values of Croatian dominants were more similar to the ones of Hungarian dominants than, as it would be expected, to the Croatian monolinguals'. This type of interference corresponds to the second possibility in Antoniou et al. (2011).

The study by Trošelj (2016) showed that Croatian monolinguals produce longer VOTs and longer following vowels than Hungarian-Croatian bilinguals. The aim of the present article is to compare the mentioned parameters of the word initial /p, t, k/ between Hungarian-Croatian bilinguals and Hungarian monolinguals. The study will determine if bilinguals are able to produce monolingual-like VOTs and the durations of the following vowels in Hungarian. Based on a questionnaire of about 30 questions on their language background, habits of language use, and on their recordings of spontaneous speech (both in Hungarian and Croatian), bilinguals were divided into two groups – Hungarian dominant and Croatian dominant. The differences in VOT, following vowel duration and VOT ratio will also be examined as a function of language dominance.

2. Hungarian and Croatian stop and vowel systems

Before presenting the research and the results, stop and vowel systems of Croatian and Hungarian will be described and compared. Both languages contrast three voiced stops: bilabial /b/, dental /d/ and velar /g/ and three voiceless stops: bilabial /p/, dental /t/ and velar /k/. Neither Hungarian, nor Croatian stops are aspirated, and both languages are voiced languages (Gósy 2004, Škarić 1991). Pre-voicing, or negative VOT, is characteristic of voiced stops, and short lag, or positive VOT, of voiceless ones. When it comes to the vowels, differences between the two languages are substantial. Croatian has five

vowels: ‘a’ /a/, ‘e’ /e/, ‘i’ /i/, ‘o’ /o/ and ‘u’ /u/ whereas in Hungarian there are fourteen: ‘a’ /ɔ/, ‘á’ /a:/, ‘o’ /o/, ‘ó’ /o:/, ‘u’ /u/, ‘ú’ /u:/, ‘ö’ /ø/, ‘ő’ /ø:/, ‘ü’ /y/, ‘ű’ /y:/, ‘e’ /ɛ/, ‘é’ /e:/, ‘i’ /i/ and ‘í’ /i:/. Croatian language does not distinguish short and long vowels in writing like Hungarian does, but it does contrast four types of pitch accents on the stressed syllable: short-falling, short-rising, long-falling and long-rising. Previous research (Bakran, 1996) on vowel duration in spontaneous speech of Croatian monolinguals showed that the durations of vowels with short pitch accents were 57, 67, 77, 74 and 62 ms for /i, e, a, o, u/, respectively. For Hungarian monolinguals Gósy–Beke (2010) report that the duration of /i/ and /u/ in spontaneous speech is 62 ms and of /o/ 72 ms. In both researches the duration was measured on the stressed syllable. Bakran (1996) found that in Croatian spontaneous speech the duration of vowels with long pitch accents is 77, 86, 106, 89 and 76 ms for /i, e, a, o, u/, respectively while the duration of Hungarian long vowels /i:, o:, u:/ is 87, 108 and 98 ms, respectively (Gósy–Beke, 2010). Gósy–Beke (2010) do not provide values for /ɛ/, /e:/, /ɔ/, and /a:/. Falling/rising pitch was not controlled for in Bakran’s (1996) study. Gósy–Beke (2010) conclude in their study that horizontal movement of the tongue has significant effect in vowel duration, i.e. front vowels are shorter than the middle ones.

Regarding their duration, out of the 14 Hungarian vowels, 5 are most similar to the Croatian vowels with short pitch accents. These are ‘i’ /i/, ‘e’ /ɛ/, ‘a’ /ɔ/, ‘o’ /o/ and ‘u’ /u/. These five vowels will the focus of the present study. Figure 1 describes quality parameters of the five vowel pairs.

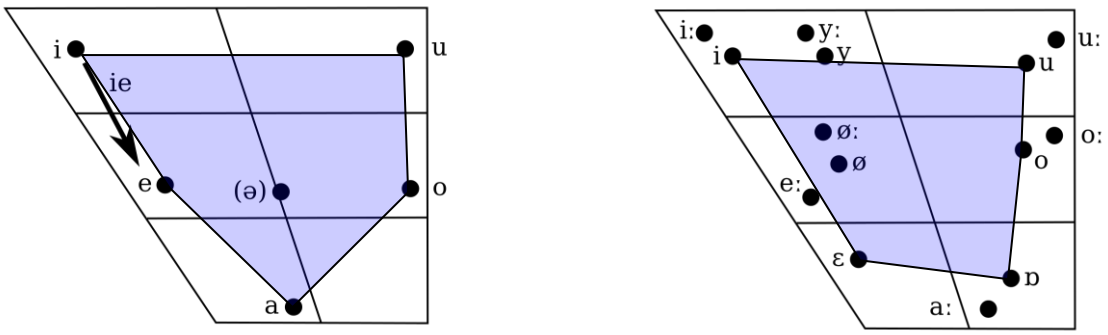

Figure 1: Left: Croatian vocal chart; right: Hungarian vocal chart

As shown in Figure 1 the articulatory properties of vowel /i/ and /u/ are the same in both languages. However, Croatian /e, a, o/ differ from their nearest Hungarian counterparts in vertical and horizontal movement of the tongue and lip rounding. Hungarian /ɛ/ is open-mid and front compared to close-mid and front Croatian /e/, while Hungarian /o/ is close-mid, but somewhat higher than Croatian close-mid /o/. Hungarian /ɔ/ is back, open-mid and rounded whereas

Croatian /a/ is open and central (the degrees of vowel heights are taken from the IPA chart (www.internationalphoneticassociation.org/sites/default/files/IPA_Kiel_2015.pdf). The second large difference between Croatian and Hungarian language is in the place of stress in a word. In Hungarian a stress is, without exception, on the first syllable, while in Croatian a place of stress varies (although in standard Croatian it can never be on the last syllable).

The hypotheses of the present study are motivated by the findings in Trošelj (2016), which show that Croatian monolinguals produce significantly longer VOTs and following vowel durations than Hungarian-Croatian bilinguals. In the present research it is expected that the longer values in Croatian will influence speech production of Hungarian-Croatian bilinguals in Hungarian and (i) will make their VOTs and vowel durations longer. Since no consistent differences between Croatian dominants and Hungarian dominants were found in Trošelj (2016), it is expected that in the present study (ii) no significant differences will be found between these two groups.

3. Method

10 Hungarian-Croatian bilingual female and 10 Hungarian monolingual female speakers took part in this study. The mean age of the bilinguals is 33.2 and of the monolinguals 28.7 years. Bilinguals that participated in the present study are the same bilinguals that took part in study of Trošelj (2016). All bilinguals are early bilinguals who started acquiring their second language at preschool age. All of them are either students of Faculty of Humanities in Zagreb or Budapest (ELTE), or have already graduated from Faculty of Humanities in Zagreb or Budapest, and they live in one of those two cities. All of Hungarian monolingual speakers are students of the Faculty of Humanities (ELTE) in Budapest. Five bilingual speakers live and work and/or study in Budapest and use Hungarian more often than Croatian. They report that they feel they cannot express themselves in Croatian as well as in Hungarian and are aware of their foreign accent, i.e. Hungarian is their dominant language. The other five bilingual speakers live and work and/or study in Zagreb and speak Hungarian with noticeable Croatian accent. They claim it is easier to express themselves verbally in Croatian, and realize that their Croatian accent is heard while speaking Hungarian, i.e. their dominant language is Croatian. All participants reported normal hearing and no speech or language disorders. Participants were asked to read a list of 30 isolated Hungarian words, 10 of which starting with /p/, 10 starting with /t/ and 10 starting with /k/. Each stop is followed by one of the five Hungarian vowels described above (see Figure 1) and there were two words given for each vowel, hence ten words for each stop. Some of the given words were **pokróc** (blanket), **keres** (look for) **takaró** (cover) and **kacsa** (duck). Reading a word-list (speakers were asked to pause briefly between words)

individual factors that might occur in spontaneous speech, or might be more relevant in spontaneous speech (i.e. speech and articulation tempo), could not influence either VOT or the duration of the following vowel. The measured parameters of each word were compared only between the two groups of speakers, and not among speakers of the same group (i.e. words beginning with /pɔ/ pronounced by bilinguals were compared only with words beginning with /pɔ/ pronounced by monolinguals). Words with a different following vowel were not compared with each other (i.e. words beginning with /pɔ/ were not compared with words beginning with /po/). In this way identical phonetical context was provided for both groups of speakers which was then suitable for comparison. The material was recorded in a sound-attenuated booth and the analysis was carried out with Praat 5.4.04 software package (Boersma & Weenink, 2014). For the purposes of this study, VOT was defined as the time span between the beginning of the burst and the onset of voicing as observed in the oscillogram, and on the spectrogram in parallel (Beckman et al., 2011). The VOT and the duration of the following vowel were measured. As a derived parameter the VOT ratio was computed as VOT divided by the duration of the following vowel (and multiplied by 100, i.e. as a percentage). Such a display of results will give an insight in VOT with the effect of overall speaking rate removed (i.e. Fischer–Goberman, 2010). VOT ratio was calculated for each individual speaker in order to extract the mean of the whole group. The results will be presented for each following vowel. Statistical analysis was carried out in SPSS 20 software package with 95% confidence level. In the case of normal distribution ANOVA was applied whereas in the case of non-normal distribution Mann-Whitney-test was used.

4. Results

4.1. Bilinguals compared with monolinguals

Table 1 Mean VOT (ms), duration of following vowel (ms) and VOT ratio (%) for Hungarian-Croatian bilinguals and Hungarian monolinguals

Stop	Raw parameter values				VOT ratio	
	Hun.-Cro. bilinguals		Hun. monolinguals		Hun.-Cro. bilinguals (SD)	Hun. monolinguals (SD)
	VOT (SD)	Vowel (SD)	VOT (SD)	Vowel (SD)		
/p/	16 (6)	107 (30)	16 (8)	110 (37)	16.2 (8)	16.6 (11.4)
/t/	17 (5)	103 (31)	19 (6)	113 (40)	18.2 (7.8)	18.6 (9.4)
/k/	38 (10)	95 (23)	40 (13)	97 (23)	43.7 (19.3)	44.7 (22.6)

The results in Table 1 show that the hypotheses did not come true. Observing the VOT and VOT ratio, we notice that there are no differences between the two groups of speakers. In the case of the duration of the following vowel, Hungarian monolinguals produce significantly longer vowels for /t/ ($Z = -2{,}171$; $p = 0{,}030$). For all three stops the VOT values are longer than the ones in Gósy–Ringen (2009). Comparing the values of Hungarian monolinguals and Croatian monolinguals (Trošelj, 2016), it can be noticed that the Croatian monolinguals' VOTs (20 ms for /p/, 21 ms for /t/ and 57 ms for /k/) and vowel durations (127 ms for /p/, 135 ms for /t/ and 124 ms for /k/) are longer. Pooling all three stops together, the mean vowel durations of Hungarian monolinguals for /i, ɛ, ɔ, o, u/ are 93, 128, 99, 121 and 93 ms, respectively. These values are shorter than the ones of Croatian monolinguals (108, 136, 147, 135 and 115 ms for /i, e, a, o, u/, respectively) (Trošelj, 2016).

Table 2 (see Appendix) shows that there are no differences in VOT and VOT ratio between bilinguals and monolinguals for /p/. Significant differences between the two groups of speakers are found only for the duration of vowel /u/ ($F(1, 39) = 5{,}134$; $p = 0{,}029$; $\eta^2 = 0{,}119$). Hungarian monolinguals produce it longer**.** The duration of /u/ following /p/ in Croatian monolinguals was 93 ms (Trošelj, 2016).

Observing the values for /t/ in Table 2, we can see no differences between bilinguals and monolinguals either in VOT, or in the vowel duration, or in the VOT ratio.

Table 2 shows that as in previous research (Gósy, 2000, Gósy–Ringen, 2009) mean VOT values for the velar /k/ are longer than for the bilabial and dental stops. Significant differences in VOT are found in the cases of /i/ ($Z = -2{,}371$; $p = 0{,}018$) and /ɔ/ ($Z = -2{,}099$; $p = 0{,}036$). Hungarian monolinguals produce longer VOT for /i/, while for /ɔ/ VOT is longer in bilinguals. This could be explained by the bilinguals' /ɔ/ becoming more front i.e. more Croatian-like, which is in accordance with Gósy's (2000) claim that in the case of velar stop VOTs preceding front vowels are longer. No differences were found in other measured parameters.

4.2. Croatian dominant bilinguals compared with Hungarian dominants

Table 3 Mean VOT (ms), duration of following vowel (ms) and VOT ratio (%) for Croatian dominants and Hungarian dominants

Stop	Raw parameter values				VOT ratio	
	Cro. dominants		Hun. dominants		Cro. dominants (SD)	Hun. dominants (SD
	VOT (SD)	Vowel (SD)	VOT (SD)	Vowel (SD)		
/p/	18 (7)	107 (26)	14 (5)	106 (37)	17.6 (9)	14.8 (6.5)
/t/	17 (4)	105 (35)	17 (5)	102 (26)	18.3 (8.4)	18 (7.3)
/k/	38 (11)	93 (23)	38 (9)	97 (23)	44.3 (20.4)	43 (18.3)

In all, Table 3 shows no significant differences between Croatian dominants and Hungarian dominants.

Table 4 (see Appendix) shows that for /p/ Croatian dominants produce significantly longer VOT in the case of /u/ ($Z = -2{,}475$; $p = 0{,}013$). This VOT value of Croatian dominants is exactly the same as the VOT of Hungarian monolinguals in the case when /p/ is followed by /u/ (Table 2). No consistency is found in the differences for vowel duration between Croatian and Hungarian dominants. Hungarian dominants produce a significantly longer /ɛ/ vowel ($F(1, 19) = 75{,}198$; $p < 0{,}001$; $\eta^2 = 0{,}807$), while Croatian dominants produce a significantly longer /ɔ/ vowel ($Z = -2{,}495$; $p = 0{,}013$), but these longer vowels do not yield longer VOTs. No differences are found for VOT ratio. Negative correlations between VOT and the duration of the following vowel are apparent in the cases of /ɛ, o/. Such a result contrasts with Gósy's (2000) claim that the longer the following vowel, the longer the VOT.

If we compare the VOTs and VOT ratios of /t/ in Table 4, we notice that no differences exist between the two groups of speakers. Interestingly, when it comes to the duration of the following vowel, Croatian dominants produce significantly longer vowels /ɛ/ ($F(1, 19) = 36{,}129$; $p < 0{,}001$; $\eta^2 = 0{,}667$), /o/ ($F(1, 19) = 26{,}105$; $p < 0{,}001$; $\eta^2 = 0{,}592$) and /u/ ($F(1, 19) = 7{,}567$; $p = 0{,}013$; $\eta^2 = 0{,}296$). There is a negative correlation for /o/, where a longer vowel duration of Croatian dominants does not yield a longer VOT.

In the case of /k/ (Table 4) Hungarian dominants produce a significantly longer /ɔ/ vowel ($F(1, 19) = 8{,}802$; $p = 0{,}008$; $\eta^2 = 0{,}333$/), and a significantly longer VOT in the case of /ɛ/ ($F(1, 19) = 4{,}752$; $p = 0{,}043$; $\eta^2 = 0{,}209$). Since the Croatian /e/ is higher than the Hungarian /ɛ/ it would be expected that Croatian dominants would produce longer VOT in the case of this following vowel.

For other VOTs and for the durations of vowels no differences were found. There are negative correlations between VOT and the duration of the following vowel in the cases of /i, ɔ, o, u/. This may be caused by the slower movement of

the back of the tongue which then yields longer noise burst that eats into the vowel duration.

5. Conclusion

The aim of this research was to compare VOT and the duration of the following vowel between Croatian–Hungarian bilinguals and Hungarian monolinguals. The stated hypothesis that bilinguals will produce longer VOTs and following vowels was not realized. Except in some cases, almost no differences were found between Croatian-Hungarian bilinguals and Hungarian monolinguals (i.e. fourth situation in Antoniou et al., 2011). In comparing Croatian dominants and Hungarian dominants, some consistency in the differences in vowel duration can be noticed for /t/, where /ɛ, o, u/ are produced longer by the Croatian dominants. In other cases no consistent differences were found between Croatian dominants and Hungarian dominants.

Taking into account that in Trošelj (2016) significant differences were found between Hungarian-Croatian bilinguals and Croatian monolinguals (i.e. Croatian monolinguals produced longer VOTs and longer vowel durations), the questions that emerge are: Why are Hungarian-Croatian bilinguals able to match Hungarian monolingual production (in Hungarian) whereas they produce shorter VOTs and vowel durations than the Croatian monolinguals (in Croatian)? Is the shorter VOT of bilinguals (compared to Croatian monolinguals) a result of differences in a vowel quality between Croatian and Hungarian or is it a result of a shorter vowel duration?

Since the present study has been a first effort to examine the speech production of Hungarian-Croatian bilinguals and in order to provide a thorough answers to the above questions, further research is warranted on this topic. To better understand how acoustical properties of the vowel affect VOT, and why bilingualism exercises influence on the VOT and vowel duration in the case of Croatian pronunciation, and not in the case of Hungarian, more attention should be devoted to vowel production. The quality of the bilinguals' vowels, i.e. formants, and not only temporal parameters of the vowels should be taken into consideration and analyzed. To conduct a thorough investigation on the quality of the vowels in Hungarian-Croatian bilinguals, other Hungarian vowels, much more different in their quality and duration (i.e. phonemically long vowels) from Croatian ones, should also be analyzed, not only in the reading of isolated words but in spontaneous speech as well. Unlike spontaneous speech, prepared reading does not require utilization of higher levels of speech planning and therefore more attention can be devoted to articulation (Levelt, 1989), which means that it is much more difficult to control speech production during spontaneous speech, and more interference between the bilinguals' two languages can be expected. Only then we will be able to fully understand how vowel production is realized in Hungarian-Croatian bilinguals, i.e. bilinguals in languages that greatly differ,

not only in vowel phonology, but in their grammar, syntax and morphology (Hungarian is agglutinative language, Croatian is not) as well.

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Appendix

Table 2 Mean VOT (ms), duration of following vowel (ms) and VOT ratio (%) for /p/, /t/ and /k/ in the context of the following vowel for Hungarian-Croatian bilinguals and Hungarian monolinguals

	Raw parameter values				VOT ratio	
Stop and the following vowel	Hun.-Cro. bilinguals		Hun. monolinguals		Hun.-Cro. bilinguals (SD)	Hun. monolinguals (SD)
	VOT (SD)	Vowel (SD)	VOT (SD)	Vowel (SD)		
/p/						
/i/	13 (4)	89 (11)	15 (5)	94 (20)	15.3 (4.5)	16 (7)
/ɛ/	12 (3)	147 (38)	12 (4)	150 (56)	9 (3.3)	9 (4)
/ɔ/	14 (5)	96 (22)	14 (7)	92 (22)	15.2 (5.7)	16.2 (9.6)
/o/	21 (7)	107 (19)	16 (6)	107 (18)	20.3 (9.3)	15.6 (7.4)
/u/	20 (7)	95 (10)	23 (11)	105 (16)	21.2 (9.2)	26.3 (18)
/t/						
/i/	18 (4)	89 (18)	20 (5)	100 (18)	21 (7.2)	20.5 (6.4)
/ɛ/	15 (4)	106 (31)	17 (6)	113 (30)	15.3 (6.3)	16.7 (8)
/ɔ/	16 (4)	100 (16)	15 (5)	101 (17)	16 (4.3)	15.8 (6.5)
/o/	16 (4)	138 (36)	17 (4)	165 (51)	12.5 (3.9)	11.2 (4.8)
/u/	22 (5)	84 (14)	24 (7)	88 (18)	26.1 (8.5)	30 (10.3)
/k/						
/i/	41 (9)	78 (21.)	49 (12)	85 (18)	57.2 (24)	61.8 (26.7)
/ɛ/	32 (9)	117 (22)	32 (9)	120 (16)	28.4 (10)	27 (7)
/ɔ/	36 (8)	104 (17)	32 (8)	103 (19)	35.7 (10)	31.8 (8)
/o/	47 (9)	91 (19)	47 (12)	92 (23)	55.3 (18)	54 (18.2)
/u/	35 (9)	85 (14)	39 (12)	86 (18)	42 (12.8)	49 (24.3)

Table 4 Mean VOT (ms), duration of following vowel (ms) and VOT ratio (%) for /p/, /t/ and /k/ in the context of the following vowel for Croatian dominants and Hungarian dominants

	Raw parameter values				VOT ratio	
Stop and the following vowel	Cro. dominants		Hun. dominants		Cro. dominants (SD)	Hun. dominants (SD)
	VOT (SD)	Vowel (SD)	VOT (SD)	Vowel (SD)		
/p/						
/i/	15 (4)	93 (7)	12 (3)	85 (12)	16.5 (4.7)	14.2 (4.1)
/ɛ/	13 (4)	140 (34)	12 (2)	154 (42)	9.7 (3.8)	8.4 (2.7)
/ɔ/	14 (5)	101 (23)	14 (3)	90 (21)	14.7 (6.5)	15.7 (5)
/o/	22 (8)	104 (18)	19 (8)	109 (21)	22.3 (9.3)	18.3 (9.3)
/u/	23 (7)	98 (11)	16 (3)	93 (8)	24.7 (11)	17.6 (5.1)
/t/						
/i/	17 (5)	80 (12)	18 (2)	98 (18)	22.4 (8.6)	19.5 (5.6)
/ɛ/	15 (2)	112 (37)	15 (5)	101 (25)	14.8 (6.3)	16 (6.5)
/ɔ/	16 (3)	101 (14)	15 (4)	98 (18)	16.4 (4.9)	15.5 (3.8)
/o/	16 (3)	145 (45)	17 (4)	132 (24)	12.3 (4)	12.6 (4)
/u/	22 (5)	89 (15)	22 (4)	79 (11)	25.7 (9.4)	26.5 (7.4)
/k/						
/i/	41 (10)	74 (23)	40 (8)	83 (19)	62 (26.4)	52.4 (21.5)
/ɛ/	28 (8)	115 (25)	36 (9)	120 (20)	25 (8.4)	31.7 (11)
/ɔ/	38 (8)	101 (16)	34 (6)	107 (17)	38.1 (10)	33.4 (10.6)
/o/	47 (11)	94 (15)	48 (7)	87 (23)	52 (19.7)	58.7 (18)
/u/	36 (9)	83 (16)	33 (8)	87 (13)	44.5 (12.3)	39.3 (13.5)