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VOICE ONSET TIME PRODUCTION IN ALBANIAN AND GREEK INITIAL STOPS

1. Introduction

Voice Onset Time (VOT) has been defined as 'the time interval between the burst that marks release and the onset of periodicity that reflects laryngeal vibration' (Lisker and Abramson 1964, 422). The point zero is the moment of release, thus, VOT can have a positive or negative value depending on whether voicing starts after or before the release. VOT with a positive value is divided into two types of VOT 'short lag voicing' from 0 to +25 ms and 'long lag voicing' from +10 to +75ms, while VOT with a negative value is called 'lead voicing' (or prevoicing) and ranges from -125 to -75 ms (Lisker and Abramson 1964, 403).

The languages of the world choose among these VOT types to categorize their stops into voiced and voiceless (see, e.g. 11 languages examined in Lisker and Abramson 1964 and 18 languages in Cho and Ladefoged 1999).

Greek employs two of the VOT types; short lag voicing for voiceless stops and lead voicing VOT for voiced stops. Botinis, Fourakis and Prinou (2000), Fourakis (1986), Arvaniti (1987, 2001), Nicolaidis (2002) and Kollia (1993) report mean VOT values for voiceless stops which range from 9ms to 49ms. Voiced stops are produced with voicing lead, and their negative VOT ranges from -78ms to -106ms (Botinis, Fourakis and Prinou 2000; Kollia 1993) while Antoniou et al. (2010) report longer VOT values for voiced stops ranging from -124ms to -133ms for /b/ and /d/. Children studies on Greek VOT are limited. Okalidou et al. (2010) and Kong, Beckman and Edwards (2007) have studied the developmental patterns in the mastery of the VOT distinction in very young Greek children (2 to about 4 years old). VOT values range approximately between -140ms to -60ms for voiced stops and 10 to 50ms for voiceless stops in Okalidou et al. (2010). In Kong, Beckman and Edwards (2007) VOT values range between -200 to 30ms for voiced

stops[1]. Tsartsioni's (2011) study reports data from Greek children aged 10-16 years old. VOT durations range from 10ms to about 30ms for voiceless stops and from -90ms to -100ms for voiced stops.

Albanian also employs short lag voicing for voiceless stops and lead voicing VOT for voiced stops. (Tronnier and Zetterholm 2013; Belluscio 2005). Belluscio's (2005) two speakers from Tirana produced VOT mean values for voiceless stops ranging from 8ms to 60ms while their voiced stops were produced with voicing lead ranging from -7ms to -37ms. Unfortunately, literature on Albanian stops is mainly descriptive in nature (Weigand 1913, Cimochowski 1951, Haebler 1965, Beci 1977, Dodi 1983, Buchholz-Fiedler 1987 cited in Belluscio 2005) and lacks in children VOT data.

One of the main factors affecting VOT duration is place of articulation (Klatt 1975; Morris, McCrea and Herring 2008; Esposito 2002). In most languages, stops with positive VOT have longer VOT duration the further back the closure position (Cho and Ladefoged 1999; Port and Rotunno 1979). These findings agree with articulatory expectations as velars create a smaller cavity behind the closure which leads to greater pressure build-up. For this pressure to fall and allow for vocal fold vibration, a longer period of time is needed. In addition, the slow movement of the tongue body for the production of velars can also be related to the delay of pressure drop and, consequently, the longer VOT duration.

On the other hand, voiced stops produced with prevoicing demand different articulatory adjustments which lead to a reverse order in the VOT duration of stops. Since voicing co-exists with the closure period, the fronter the closure the longer the VOT duration as the retention of more supra-laryngeal air in the vocal cavity allows the vocal folds to vibrate for longer (Helgason and Ringen 2008). Lisker and Abramson's (1964) study provides VOT values from various languages whose mean VOT durations follow the b<d<g order, however, it is not stated if these durations are significantly different. Both in van Alphen and Smits' (2004) study on Dutch stops and in Botinis et al.'s (2000) study on Greek stops, the negative VOT of voiced stops was not significantly affected by place of articulation. As for Albanian voiced stops, Belluscio (2005) does not statistically analyze VOT durations, though, he reports

[1] It should be noted that these are approximate values based on the graphs provided in Okalidou et al. (2010) and Kong, Beckman and Edwards (2007). The papers do not provide the exact mean values in the text.

that there is variation in the order of VOT duration as a function of place of articulation for Albanian voiced stops.

Another significant factor influencing VOT duration is the vowel context following the stop (Klaat 1975; Morris, McCrea and Herring 2008; Bijankhan and Nourbakhsh 2009; Esposito 2002). These studies report higher positive VOT values for voiceless stops followed by high vowels. For Greek voiceless stops, significant vowel context effects have been reported in Efstathopoulou (2007) and Fourakis's (1986) studies.

For voiced stops with negative VOT, Smith (1978) notes higher percentages and longer VOT durations for English prevoiced voiced stops before high vowels. However, Dutch prevoiced stops in van Alphen and Smits (2004) and French prevoiced stops in Nearey and Rochet (1994) present no vowel height effects.

The current study aims at i) comparing Albanian and Greek VOT values in children's speech and ii) investigating the influence that place of articulation and vowel context exert on VOT duration in both languages.

2. Methodology

Eight children were recorded for this study; four Albanian children from Tirana and four Greek children from Athens. Their ages ranged from 9 years and 5 months to 11 years and 11 months. For each child we tried to have an age-matching peer in the other language (Table 1).

Albanian children	Greek children
D.S. - aged 8;7	E. J- aged 8;7
A.F. - aged 9;5	M.M- aged 9;6
G. S.- aged 10;7	V. S. - aged 10;6
K. O. - aged 11;10	S. K. - aged 11;11

Table 1: Subjects' ages.

The speech material consisted of CVCV words with /p,t,k,b,d,g/ in word initial position followed by the vowels /i,e,a,o,u/. The stops under investigation were always in a stressed syllable. The words were placed in carrier phrases. The Greek carrier phrase was ['leɣe __ 'pali] which means 'say___ again' while the Albanian carrier phrase was [ai 'θiri ___ 'prapə] which means 'shout___again'. The phrases were presented on PowerPoint slides

for children to read, accompanied by a picture as a visual cue (Figure 1). The phrases were repeated five times by each subject. In total, 1200 phrases were recorded for both languages.

Albanian	Greek
	

Figure 1: Screenshots from the Albanian and Greek picture-naming task. Target words have word initial /p/ followed by the open vowel /a/.

Data were recorded on a portable Marantz Professional Recorder (PMD661 MKII) with a RØDE NTSS condenser microphone in a quiet room. PRAAT was used for the acoustic analysis. VOT duration was measured from the first burst to the onset of regular pulsing for the following vowel (Figure 2). VOT durations for voiced and voiceless stops were analyzed by factorial ANOVAs with consonant, vowel and language as factors. We used an alpha level of .05 for all statistical tests.

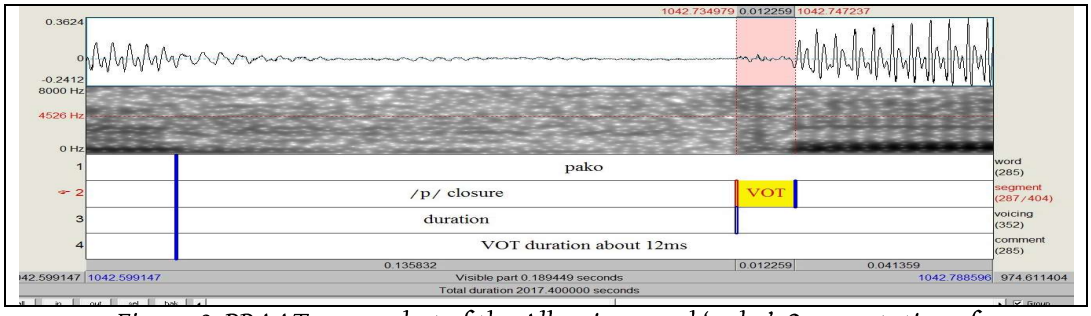

Figure 2: PRAAT screenshot of the Albanian word 'pako'. Segmentation of word initial /p/.

3. Results

Mean VOT values for Greek voiceless stops were 17ms for /p/, 16ms for /t/ and 37ms for /k/. Mean VOT values for Albanian stops were 15ms for /p/, 21ms for /t/ and 47ms for /k/ (Figure 3, see also Table A1 in the Appendix for standard deviation values). A two-way

ANOVA with language and place of articulation as factors revealed a significant main effect of language F(1, 587)=15,66, *p*<0,001, place of articulation F(2,587)=247,69, *p*<0,001 and their interaction F(2, 587)=10,84, *p*<0,001. Tukey post-hoc tests reveal that only /k/ is significantly longer in Albanian (*p*<0,001) while /p/ and /t/ have similar VOT values in the two languages.

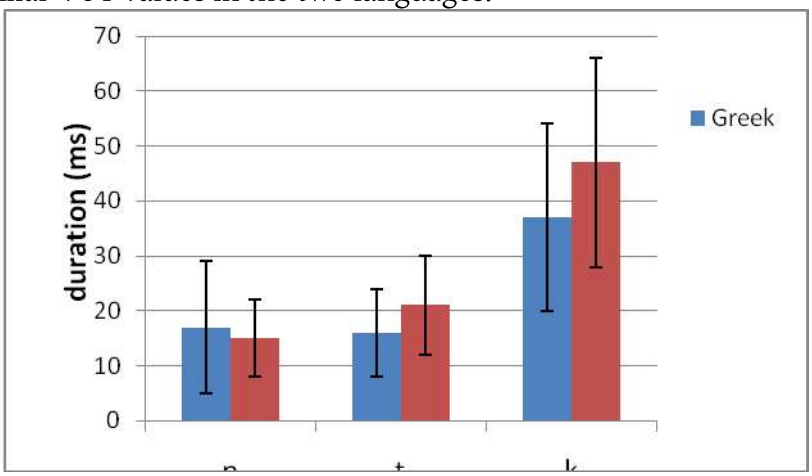

Figure 3: Mean VOT durations in ms and standard deviations for word initial /p,t,k/ in Greek and Albanian.

With reference to /b, d, g/, in average 96% of Greek voiced stops and 92% of Albanian voiced stops were prevoiced (Figure 4, see also Table A2 and A3 in the Appendix).

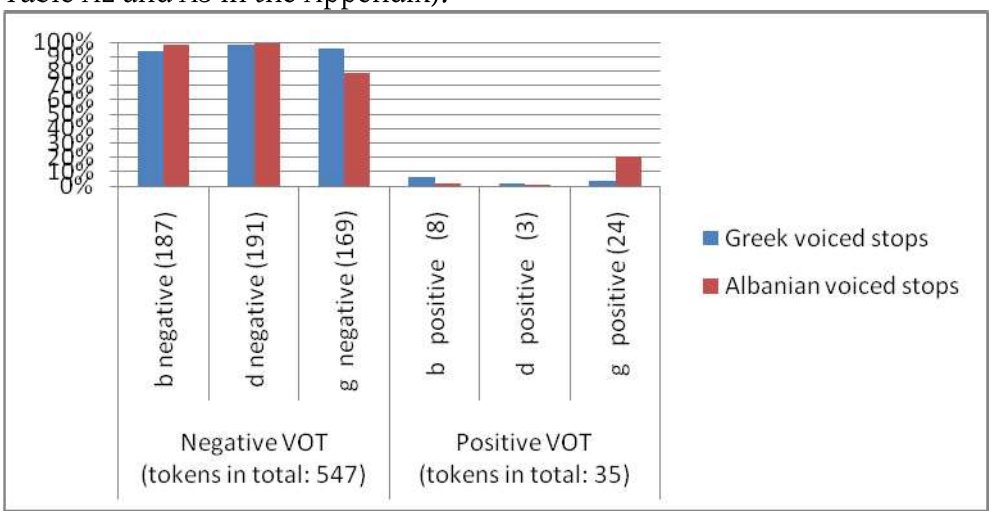

Figure 4: Percentages of Albanian and Greek voiced stops produced with voicing lead (i.e negative VOT) or short-lag voicing (i.e positive VOT). The number of voiced stop tokens produced with negative or positive VOT for each stop is presented in brackets below the bars; the total number of tokens is shown at the bottom of the graph.

Mean negative VOT values for Greek voiced stops were -105ms for /b/, -98ms for /d/ and -94 for /g/. Mean negative VOT values for Albanian voiced stops were -97ms for /b/, -80ms for /d/ and -77ms for /g/ (Figure 5, see also Table A3 for standard deviation values). Language and place of articulation were found to be significant factors (F (1,546)=101,89, *p*<0,001 and F(2, 546)=40,90, *p*<0,001 respectively). Tukey post-hoc tests showed that VOT values for all voiced stops were significantly different in the two languages (/b/ *p*=0,02, /d/ *p*<0,001, /g/ *p*<0,001) with the Albanian VOT duration being shorter than the Greek one.

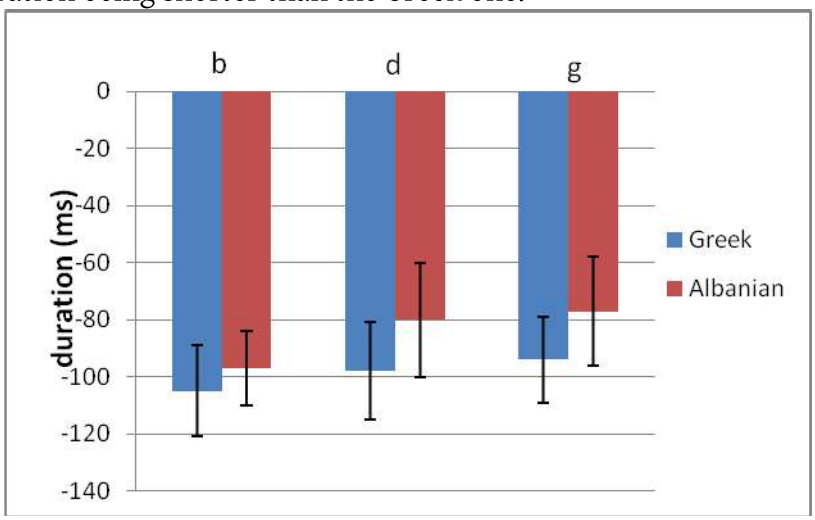

Figure 5: Mean VOT durations in ms and standard deviations for word initial /b,d,g/ in Greek and Albanian

A separate ANOVA on Greek voiceless stop VOT durations only showed a significant effect for place of articulation (F(2, 297)= 83,45, *p*<0,001). However, Tukey post-hoc tests showed that only the comparisons /p/ vs. /k/ and /t/ vs. /k/ were significantly different (*p*<0,001). An ANOVA on Albanian voiceless stop VOT durations also showed a significant effect for place of articulation (F(2, 289)=174,78, *p*<0,001); Tukey post hoc tests showed that all

comparisons were statistically different (/p/ vs./ /k/ and /t/ vs. /k/ (p<0,001), /p/ vs. /t/ (p<0,003)).
As for voiced stops, place of articulation was a significant factor in both languages (for Greek F(2, 282)=9,96, p<0,001 and for Albanian F(2, 263)=33,63, p<0,001). An examination of Tukey post-hoc tests reveals, however, that only the bilabials' negative VOT had significantly longer duration than /d/ and /g/ in both languages.
Vowel context was found to be a significant factor influencing the VOT duration of voiceless stops in both languages (for Greek: p=0,001, for Albanian: p=0,006). Voiceless consonants before high vowels (either /i/ or /u/) generally showed longer VOT durations; this was not always the case however and it did not occur for all consonants (see Table 2). On the other hand, voiced consonants were not significantly affected by vowel context.

	P	**t**	**k**
Greek	/a/ vs. /u/ (p<0,001) /e/ vs. /u/ (p<0,001) /o/ vs. /u/ (p=0,004)	No significant differences	/a/ vs. /i/ (p<0,001) /a/ vs. /u/ (p<0,001) /e/ vs. /i/ (p=0,008) /o/ vs. /i/ (p=0,005)
Albanian	No significant differences	/a/ vs. /i/ (p<0,003) /o/ vs. /i/(p<0,003)	/e/ vs. /i/ (p=0,003) /e/ vs. /u/ (p=0,002)

Table 2: Vowel contexts inducing significantly different VOT duration for Greek and Albanian /p, t, k/.

4. Discussion

As noted in the introduction, languages of the world use different VOT distinctions for voiceless and voiced stops. Both Greek and Albanian use short-lag VOT and voicing lead to distinguish between their voiceless and voiced stops.

This study has shown that Greek and Albanian voiceless stops are short-lag stops as mean VOT values are below 50ms; Cho and Ladefoged (1991, 223) indicate that 50ms is the boundary between aspirated and unaspirated stops. Greek children's VOT values are

within the mean VOT range of previous adult and children studies for Greek voiceless stops (Botinis, Fourakis and Prinou 2000; Kollia 1993 found in Okalidou et al. 2010; Antoniou et al. 2010; Fourakis 1986; Arvaniti 1987; Arvaniti 2001; Nicolaidis 2002; Tsartsioni 2011). Mean VOT values for Albanian stops are similar to the mean VOT values reported in Belluscio's (2005) study which analysed data from two adult speakers from Tirana.

As for voiced stops, the percentages of prevoiced stops in our study agree with previous Greek and Albanian studies which report voiced stops produced with voicing lead for both languages (Antoniou et al. 2010; Botinis, Fourakis and Prinou 2000; Belluscio 2005). Although not all voiced stops in our data are produced with voicing lead (i.e. negative VOT), percentages of prevoiced voiced stops in the two languages are high enough to safely claim that these languages produce voiced stops with lead-voicing. Our percentages are similar or higher to those found in other studies of languages using the voicing lead vs. short-lag VOT opposition (van Alphen and Simts's (2004) study of Dutch with 75% of voiced stops prevoiced, Ringen and Suomi's (2012) study of Fenno-Swedish with 87% of voiced stops prevoiced, Ringen and Kulikov's (2012) study of Russian with 97% of voiced stops prevoiced).

The two languages, however, do not have identical VOT values for all their stops. Greek and Albanian voiced stops are significantly different with Albanian /b, d, g/ being shorter than Greek. VOT duration was similar for /p/ and /t/ in the two languages but significantly different for Albanian /k/ which is longer than the Greek velar. Its long VOT duration (about 50ms) places it in the 'slightly aspirated' stops category, according to Cho and Ladefoged's categorization (1999, 223). This might explain why in previous literature Albanian voiceless stops are characterized as slightly aspirated (Dodi 1983 and Owman 1932 found in Belluscio 2005) although Albanian does not use the short-lag vs. long-lag VOT distinction.

Place of articulation was found to significantly influence the VOT duration of the voiceless stops. The Albanian VOT duration followed the expected order (p<t<k), i.e. VOT duration increases as place of articulation moves further back in the oral cavity (Cho and Ladefoged 1999; Port and Rotunno 1979; for Albanian Belluscio 2005). While previous studies on Greek report significant place of articulation effects (Fourakis 1986; Efstathopoulou 2007), this study has shown that bilabials and dentals have similar VOT durations. A similar finding has been reported in Cho and Ladefoged (1999) for

13 languages and in Nearey and Rochet (1994) for French. This study has shown however that the velar /k/ is significantly longer than /p/ and /t/.

Similarly, for voiced stops, place of articulation was found to be a significant factor contrary to studies by van Alphen and Smits (2004) for Dutch, Botinis, Fourakis and Prinou (2000) for Greek and Belluscio (2005) for Albanian. However post-hoc analysis showed that only the VOT duration of the bilabial /b/ was significantly longer than /d/ and /g/ in both languages. This finding may be explained on an articulatory basis. Bilabials, in contrast to stops produced at other places of articulation, can exploit not only the pharyngeal walls and the soft palate to enlarge the oral cavity but also the cheeks. This may allow them to retain prevoicing for a longer period of time.

In conclusion, this study has provided data on the VOT duration of /p, t, k/ and /b, d, g/ produced by 8-12 year old Albanian and Greek children. To date, there has been very limited research on VOT duration produced by children in the two languages. Further research currently underway examines VOT duration for a larger number of children as well as phonetic/phonological variation in bilingual Greek-Albanian children.

5. Acknowledgments

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Appendix

	/p/	/t/	/k/
Greek	17 (12)	16 (8)	37 (17)
Albanian	15 (7)	21 (9)	47 (19)

Table A1: VOT duration in ms and Standard Deviation in parentheses for /p/,/ t/, /k/ in Greek and Albanian.

	Positive VOT					
	/b/		/d/		/g/	
	Number of tokens	VOT duration	Number of tokens	VOT duration	Number of tokens	VOT duration
Greek	6	21 (4)	2	27 (1)	4	67 (6)
Albanian	2	20 (14)	1	17 (0)	20	38 (4)

Table A2: The number of voiced stop tokens produced with positive VOT in Greek and Albanian, their VOT duration and standard deviation in parentheses.

	Negative VOT					
	/b/		/d/		/g/	
	Number of tokens	VOT duration	Number of tokens	VOT duration	Number of tokens	VOT duration
Greek	93	-105 (16)	95	-98 (17)	95	-94 (15)
Albanian	94	-97 (13)	96	-80 (20)	74	-77 (19)

Table A3: The number of voiced stop tokens produced with negative VOT in Greek and Albanian, their VOT duration and standard deviation in parentheses.