FINE-GRAINED PHONETICS AND ACQUISITION OF GREEK VOICED STOPS

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ABSTRACT

We explore the acoustics of Greek voiced stops produced by 2- and 3- year-old Greek-acquiring children and compare them with adult patterns, in order to understand developmental universals in the mastery of phonation-type contrast. A truly voiced stop (i.e., one realized with voicing onset before the burst), is a difficult sound because the buildup of supralaryngeal air pressure during stop closure conflicts with aerodynamic requirements of the glottal gesture. Prior studies show that young language learners of French, Thai or Spanish are hindered by this fact, not mastering the voiced stops of these languages until age 4 or 5 [1, 4, 8]. In order to assess the effects of such physical constraints on language acquisition, we examine the acoustics of Greek voiced stops and investigate how Greek learners deal with the articulatory difficulty of producing voiced stops. Word-initial Greek voiced stop productions were recorded in two sets of experiments and were analyzed in terms of amplitude change during the closure and around the burst. We discuss how the language-specific phonetic properties of Greek voiced stops affect the acquisition of them in Greek-speaking children. Our results suggest that the very detailed phonetic descriptions of phonetic categories must be counted to provide properly nuanced prediction about developmental universals.

Keywords: phonetics, Greek, voiced stops, developmental universals, acquisition.

1. INTRODUCTION

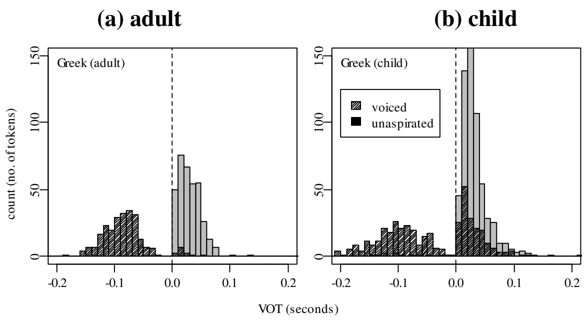
Jakobson's theory of implicational universals [5] includes a claim about acquisition of phonation types in languages where aspiration or voicing contrasts: voiceless unaspirated stops are produced first, and the mastery of voiced or aspirated stops implies the mastery of voiceless unaspirated ones. This claim is borne out in studies of many languages, which show that unaspirated stops are produced in babbling at 7-8 months, aspirated stops mastered at about 2 years across languages [4,6,8], and voiced stops not mastered until 4-5 years in French, Thai, Hindi, etc [1,4].

It has been suggested that this apparent universal order of mastery and the associated substitution patterns are due to the relative difficulty of producing different phonation types [6]. Although phonetically described in terms of glottal adduction simultaneous with oral release (i.e., short lag VOT [7]), a voiceless unaspirated stop differs from an aspirated stop in requiring neither a specific degree of glottal abduction nor any precise temporal coordination between the oral constriction and the sub-glottal abduction. It can even be produced with adducted glottis, if the transglottal pressure differential is not large enough to force the vocal folds apart. In contrast, a voiced stop requires not only an exact degree of glottal adduction, but also a sufficient difference between subglottal and supraglottal pressure for the characteristic voicing in the interval before the burst. That is, to produce a negative VOT, the speaker must either expand the supralaryngeal cavity or loosen the oral or nasopharyngeal seal to leak off some air pressure from the oral cavity in order to maintain vocal fold vibration as supraglottal pressure builds up.

This account has been supported by the findings that children adapt language-specific strategies to overcome the relative difficulty of producing voiced stops. For instance, Spanish-acquiring children often substitute fricatives for word-initial voiced stops, although the spirantized allophonic variant of a voiced stop is only acceptable word-medially in Spanish [8]. French-acquiring children tend to put voiced sonorants, most commonly nasals, before initial voiced stop in order to take advantage of voicing continuation [1]. This preceding nasal segment is then (mis-)interpreted by French-speaking adults as an inserted indefinite article in French [10].

The very early acquisition of voiced stops in Greek appears to contradict this universal tendency toward late mastery of voiced stops cross-linguistically. As shown in Fig.1a, the two-way phonation-type contrast in Greek word-initial stops patterns in adult productions as a difference between short lag VOT values versus lead VOT values. Moreover, as Fig.1b shows, the VOT values of word-initial stops produced by Greek children aged 2 and 3 pattern similarly, displaying even more robustly negative VOT values for many voiced stops. Noting that these Greek children are all much younger than the ages reported for mastery of voiced stops in French, Thai, Hindi, and Spanish, we were prompted to ask how the Greek children are capable of producing the very long voicing lead values characteristic of the Greek voiced stops.

Figure 1: VOT values for word-initial lingual stops produced by Greek adult (left panels) and Greek child (right panels) speakers.



We suspected that the Greek voiced stops pattern this way because they can be partially nasalized. Greek voiced stops developed relatively recently from clusters of nasal followed by voiceless stop, and many speakers still produce them as clusters or as pre-nasalized stops in at least some prosodic environments [2]. Greek children may be taking advantage of this nasalized variant of voiced stops in order to side-step the articulatory difficulty of controlling oral cavity pressure for vocal fold vibration during closure.

If the voiced stops are partially nasalized, VOT, a temporal measure, will not capture this nasal characteristic. The possibility of nasal venting calls for another type of acoustic analysis that describes the spectral quality of the stop closure. In this study, we introduce two kinds of acoustic measures that we used to assess the nasal quality of Greek voiced stops in order to test our hypothesis about the relationship between the early mastery of Greek voiced stops and the language-specific phonetic details of the category.

2. PRODUCTION EXPERIMENT 1

First, we conducted a production experiment to collect Greek word-initial voiced stop productions.

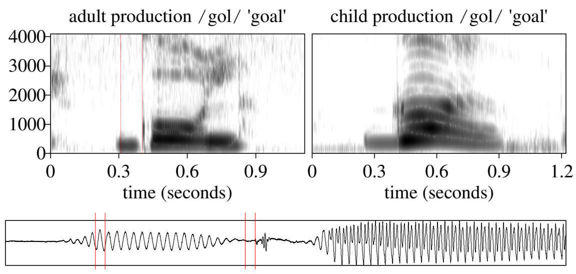
2.1. Data

Twenty Greek-acquiring children, aged 31 to 46 months, participated in a word-repetition task and were recorded saying words elicited using audio and picture prompts. Three Greek female adults were recorded using the same method. Twenty seven of the elicited words begin with the target consonants /d, g, g^j/ in a variety of following vowel contexts — e.g., *dúku* 'bang', *dulápi* 'closet', and *dúz* 'shower' for /d/ before /u/ and *gofréta* 'candy bar', *golf* 'golf', and *gol* 'goal' for /g/ before /o/.

2.2. Acoustic measures

We measured VOT, with results shown in Fig. 1 and also measured the peak amplitude of the voice bar during the closure (i.e., amplitude of the first spectral peak in a spectrum calculated over a 6 ms window centered at the highest intensity glottal pulse during closure) relative to the amplitude of the voice bar in the region just before the burst, as illustrated in Fig.2.

Figure 2: Spectrograms of adult (left) and child (right) productions of the Greek word /gol/ and zoomed-in waveform showing the windows over which the spectra were calculated for the peak closure amplitude measure in the adult production.

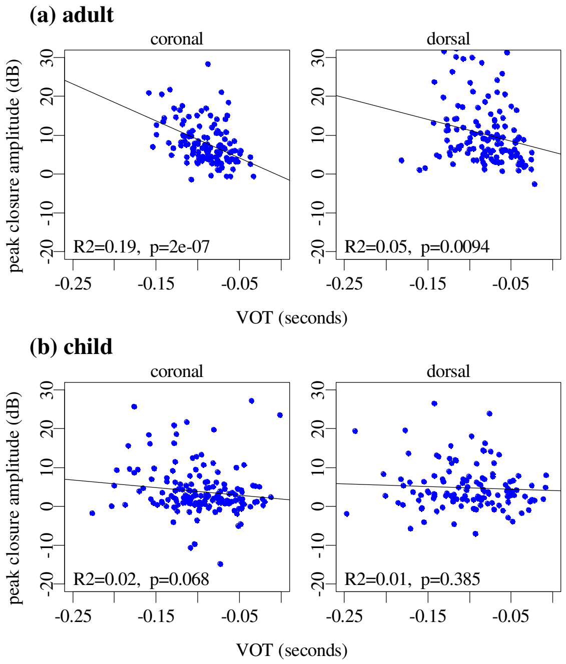


This measure was inspired by Burton, Blumstein, & Stevens's [3] analysis of the contrast among oral voiced stops, pre-nasalized stops, and nasals in Moru, with results showing that the two types of stop are distinguished from nasals by a falling off of intensity just before the burst, and the pre-nasalized stops are distinguished from the oral stops by the intensity of the nasal murmur during closure. We predicted that we would see an energy drop between our two measurement points in any Greek voiced stops that are pre-nasalized. We also expected to see a negative correlation between the extent of this drop and VOT, if speakers take advantage of the acceptability of nasal venting of oral air pressure during the stop closure to allow an earlier initiation of sustained voicing before the stop release.

2.3. Results

The amplitude difference between the peak during the closure and the peak just before the release is plotted in Fig.3 as a function of VOT value. The adult's voiced stops with longer lead VOT tend to show bigger relative peak closure amplitude (Fig. 3a), suggesting that the stops with longer lead values are pre-nasalized to some extent. The correlation between relative peak voice bar amplitude and VOT is less evident in the children's voiced stops (Fig. 3b), possibly because many of the children's stops are more like nasals than they are like pre-nasalized stops. This possibility was tested in the second experiment by direct comparison of acoustic qualities between nasals and voiced stops in Greek.

Figure 3: Relative peak voice bar amplitude as a function of VOT.



3. PRODUCTION EXPERIMENT 2

The second production experiment was done to elicit word-initial voiced stops and nasals in Greek in order to examine their acoustic similarity in adults and children's production.

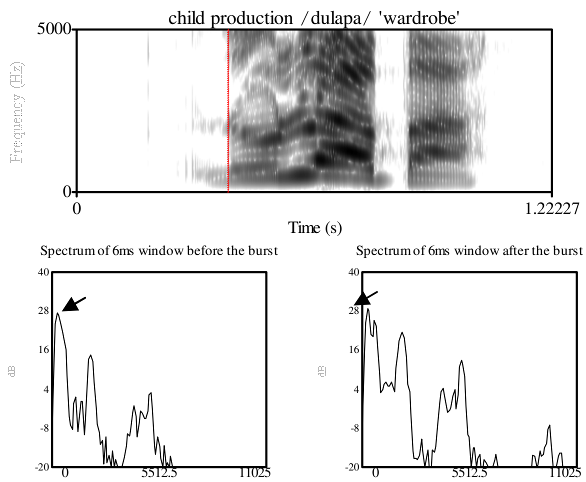
3.1. Data

More child production data were collected from 46 Greek-acquiring children of the same age as those who participated in Experiment. 1, using a picture naming task designed as a clinical test for speech delay. Targets were initial and medial nasals /m, n/ and stops /d, g/. Also, a new set of target words were elicited from one Greek female adult (not included in Experiment 1) using a reading task. Targets were initial nasals /m, n/ and stops /d, g/. Due to a limited number of medial nasals and stops in these productions, we supplemented the adult dataset with medial targets collected from the adults who participated in Experimnet.1.

3.2. Acoustic measure

In order to compare Greek voiced stops with nasals, we calculated the intensity before the burst with the intensity after the burst. According to Burton et al. [3], the voice bar in a voiced stop has less amplitude than does nasal murmur. Also, there is a sudden energy increase after the burst release whereas the first peak amplitude in nasal murmur does not change after the release [9].

Figure 4: Spectrogram of a child's production of the Greek word /dulˈapa/ 'closet' and two spectra calculated over 6ms windows taken before the burst (left) and after the burst (right) with arrows pointing to the first peak amplitudes to be compared.

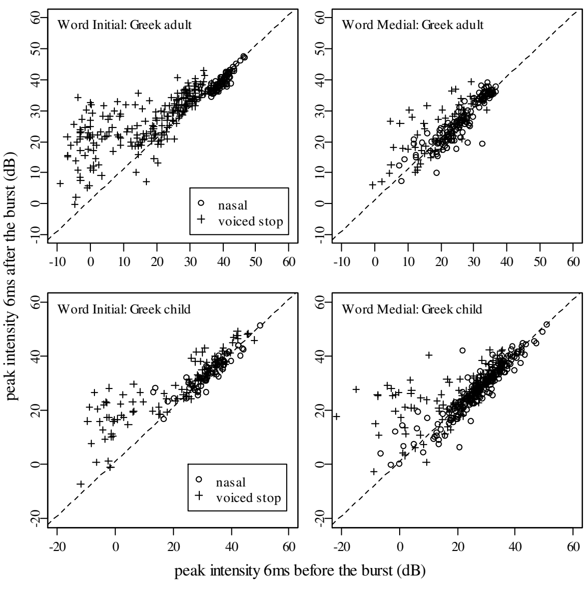


Spectra were calculated over 6ms Hamming windows before the burst and after the burst, as illustrated in Fig.4. The first peak amplitude in each of the two spectra was measured and compared to quantify the energy change around the burst. (The boundary between the nasal murmur and vowel for a nasal is treated as the analogous location to the burst for a voiced stop to get comparable analysis windows.)

3.3. Results

Fig.5 plots the intensity after the burst as a function of intensity before the burst in the adult's and children's productions. The top panels in the figure show that, word-initially, the adult's voiced stops were effectively distinguished from her nasals by these acoustic measures, showing overall lower amplitude than nasals, and a higher amplitude after the burst than before the burst, whereas word-medial voiced stops completely overlap with word-medial nasals. Children's voiced stops behave like adult word-medial voiced stops by overlapping with nasals both in word-initial position and in word-medial position. As a result, Greek voiced stops are acoustically similar to nasals in children's productions, indicating that nasality during the closure is the strategy that children use to ensure voicing during closure.

Figure 5: Relationship between amplitude peaks after and before release in target /m,n,d, g/ Exp.2.



4. DISCUSSION & CONCLUSION

In order to account for Greek children's relatively early mastery of voiced stops, we investigated the acoustic properties of Greek voiced stops, comparing them to Greek nasal consonants as well as evaluating the degree of nasality during closure using a measure proposed for the contrastively prenasalized stops of another language. If the Greek voicing contrast is described only in terms of VOT, then Greek has a simple two-way phonation-type contrast between short lag (for voiceless stops) and voicing lead (for voiced stops). However, a closer examination of the acoustics of the voiced stops in Greek suggests that more is involved than control of VOT in defining Greek voiced stops. The voice bar during the stop closure acoustically resembles a nasal murmur. This pattern is seen in adult productions of word-medial stops and in children's productions of both word-medial and word-initial stops. The Greek children seem to use nasalization to vent air pressure during closure, making for earlier mastery of voicing lead than in other languages such as French and Thai.

In conclusion, these minor variations on the general tendency for voiced stops to be mastered late lend a more nuanced interpretation to Jakobson's developmental universal; they should be understood in terms of the universal constraints imposed by specific articulatory and aerodynamic requirements. That is, voiced stops are late only if the phonetics of the language precludes a strategy such as nasalization during closure to overcome their more difficult aerodynamic requirements.

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