

On /s/-voicing in Greek

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Abstract

Η μελέτη αυτή είναι πειραματική και διερευνά αν το /s/ αφομοιώνεται πάντα ως προς την ηχηρότητα όταν το ακολουθεί στην αρχή της επόμενης λέξης ηχηρός κλειστός ή αντηχητικός φθόγγος. Τα αποτελέσματα δείχνουν ότι η διαδικασία ηχηροποίησης του /s/ είναι βαθμιαία και όχι κατηγοριακή. Δηλαδή, κάποια δείγματα του /s/ ηχηροποιούνται, κάποια παραμένουν άηχα, ενώ κάποια τρίτα υπόκεινται σε μερική ηχηροποίηση. Τα δεδομένα έδειξαν συσχέτισμό μεταξύ των μερικώς ηχηροποιημένων φθόγγων και της κατηγορίας του συμφώνου που τα ακολουθεί: βρέθηκε μεγαλύτερο ποσοστό μερικώς ηχηροποιημένων φθόγγων για το /s/ πριν από αντηχητικό φθόγγο παρά πριν από ηχηρό κλειστό. Η εφαρμογή της ηχηροποίησης του /s/ δεν ήταν ομοιόμορφη παρά το γεγονός ότι όλα τα δείγματα βρίσκονταν στο ίδιο επιτονικό περιβάλλον. Τέτοιου είδους ευρήματα συνεπάγονται πρώτον, ότι, από τα φαινόμενα αφομοίωσης, τουλάχιστον η ηχηροποίηση του /s/ δεν είναι αξιόπιστο κριτήριο για την τεκμηρίωση ύπαρξης προσωδιακών ορίων και, δεύτερον, ότι χρειάζεται προσεκτική ποσοτική διερεύνηση των φαινομένων αφομοίωσης πριν θεωρηθούν αξιόπιστο κριτήριο για την τεκμηρίωση προσωδιακής δομής.

1. Introduction

Greek phonology is rich in assimilation phenomena, also known as sandhi, among which are vowel deletion, vowel degemination, /n/-deletion, /s/-voicing, stop voicing and consonant degemination. The process of /s/-voicing—/s/ turning to [z] when followed by a voiced consonant—is quite common in Greek both word internally and across words. In this paper I examine only cases of s-voicing across a word boundary, as is shown in example (1), where the two segments, the /s/ and the voiced consonant, belong to different words.

(1) *o ilios labi* → [oi ozlabi] ‘the sun is shining’

Cross linguistically, sandhi, in addition to the information it gives on the structure of the segmental phonological system, can also be useful for the detection of prosodic constituents and boundaries. There is the claim in the literature that some types of boundaries block coarticulation and therefore the existence of such boundaries can in

principle be detected by the influence it exerts on segments (Nespor and Vogel 1986; Selkirk 1978, 1981; Hayes and Lahiri 1991; Jun 1993).

On the other hand, a number of studies have shown that no sweeping generalizations can be made about the relation between prosodic structure and segmental effects. Instead this relation needs to be examined not only on a language specific basis, but also, within a single language, on a case by case basis. In particular, several studies have shown that, in English and other languages, some sandhi rules have categorical outputs, while others involve gradient, rather than categorical, changes (Holst and Nolan 1995; Jun 1995; Zsiga 1995, 1997; Smith 1997; Ellis and Hardcastle 1999).

For Greek, among the older phonological descriptions, sandhi phenomena have been characterized as categorical rules, in other words processes that always apply phrase internally (Kaisse 1985; Nespor and Vogel 1986; Condoravdi 1990; Malikouti-Drachman & Drachman 1992). In addition, these studies claim that strong prosodic boundaries block such assimilations. However, there is no agreement among these studies on how strong the intervening boundary has to be to block the rule application. There have been claims for a clitic group phrase (Nespor and Vogel 1986), a minimal phrase (Condoravdi 1990) and an Intonational phrase (Nespor and Vogel 1986). Furthermore, these studies rely exclusively on impressionistic descriptions of /s/-voicing and other sandhi rules to provide evidence for the existence of prosodic phrasing. In fact, the only evidence for some phrasal constituents in prosodic phonology literature comes from sandhi. Such arguments are circular, as has already been pointed out in Tserdanelis (2005), since the only explanation for the application of sandhi is the effect of boundaries on segments and, on the other hand, the only evidence for such boundaries comes from sandhi. To avoid circularity, it is necessary to give independent evidence for these phenomena. This independent evidence comes from recent acoustic analyses of various sandhi processes whose results disagree with the previous phonological descriptions. Let us now turn to these acoustic studies.

Several newer studies of Greek sandhi investigate the exact phonetic nature of these processes (Fallon 1994; Pelekanou and Arvaniti 2001; Arvaniti & Baltazani 2002; Tserdanelis 2005; Baltazani 2006). They look into (a) the various factors that influence the realization of these processes, (b) the exact phonetic outcome of sandhi and (c) whether it results in categorical sound alternations or in more continuous types of sound variation. These acoustic studies have revealed that many of these rules involve gradient changes.

The earliest such study, Fallon (1994), working with spontaneous speech, showed that vowel degemination is gradient and can apply across phrases regardless the boundary strength. Pelekanou and Arvaniti (2001), working mostly with spontaneous speech, found gradient phonetic output of several sandhi rules—particularly so of /s/-voicing and vowel-deletion—which applied across any level of prosodic constituents. Arvaniti & Baltazani (2002) report that, in their corpus, several types of sandhi apply across larger constituents than has previously been suggested, that sandhi does not appear to be obligatory at any level, and that at least some of the rules involve gradient, rather than categorical, changes. Tserdanelis (2005) found in a series of carefully controlled experiments that some of the sandhi processes he examined have gradient output, while

others do not. He examined vowel degemination, consonant degemination, and affricate formation and found that the output of consonant degemination and affricate formation was gradient. Baltazani (2006), examining laboratory speech, found gradient outputs of hiatus resolution across words. The outputs ranged over a continuum between complete deletion and total lack of assimilation. The majority of outputs were found to be somewhere between the two extremes, that is, merging of the two vowels in the center of the vowel space. Many of the above acoustic studies accounted for the gradient assimilation they found within the theory of Articulatory Phonology (Browman and Goldstein 1986, 1989, 1992). That is, they formulate the hypothesis that the varying degrees of assimilation found in their data are the result of varying degrees of overlap of the articulatory gestures for the two segments involved.

One important implication of these results is that sandhi is not a reliable criterion for detecting prosodic boundaries since its outcome is gradient. Such results also suggest the necessity for empirically re-examining the phonological descriptions of Greek sandhi in particular, and of the reliability of sandhi as a phrasing marker in general.

In this paper I re-examine /s/-voicing. Pelekanou & Arvaniti (2001) report that the output of this rule is gradient, while Tserdanelis (2005) reports it is categorical. The goal of the present study is to dispel this contradiction.

1.1 Previous acoustic studies of /s/-voicing in Greek

The reason for re-examining the process of /s/-voicing is that the results reported in the acoustic studies of /s/-voicing are contradictory. In particular, in their paper, Pelekanou & Arvaniti (2001) examined a variety of sandhi phenomena using both spontaneous speech material and read texts from 9 speakers. Their material contained only 9 /s/+sonorant tokens across both a prosodic word and an ip boundary (ip = intermediate phrase in the GRToBI model of Greek prosody). They report they found among them fully voiced ([z]), partially voiced, and voiceless ([s]) outputs. On the other hand, different results are reported in Tserdanelis (2005). In his experiment, which used controlled lab material, 2 speakers produced 24 /s/+voiced consonant tokens. Tserdanelis reports only fully voiced ([z]) outputs. There were differences in the materials between the two studies: Pelekanou & Arvaniti examined sandhi across both a prosodic word and an ip boundary while Tserdanelis examined sandhi only across a phrase boundary and this difference might partly explain the contradictory results.

In the present study I concentrate only on phrase internal occurrences of the segments and use only lab material. In the remainder of the paper I present the experiment in section 2, discuss the results in section 3 and conclude with section 4.

2. The experiment

2.1 Method

The present study extends the results of previous studies by examining the behaviour of /s/-voicing in more segmental environments, using a larger corpus. In particular, 5 speakers were recorded reading 3 repetitions of 15 sentences each. No special

instructions were given to the participants. They were all asked to read the sentences naturally. The resulting corpus contains 225 [s] tokens. The matrix sentence (1)

- (1) *o oros ___ silavizete efkola*
 the term be-syllabified-3s easily
 ‘The term ___ is easily syllabified’

generated all experimental sentences by filling the gap with words starting with the voiced obstruents, [b, d, g] or the sonorants [l, m] following the [s] at the end of the word ‘oros’. To my knowledge, the effect of voiced stops on /s/-voicing has not been examined before.

The sibilants were marked by relying on both waveforms and spectrograms, in accordance with criteria specified in Tserdanelis (2005): The beginning of the sibilant was marked at the point where the higher formants of the preceding vowel ended and the sibilant noise of began. To decide on voicing I relied on the voice bar in the spectrogram and also periodicity in the waveform superimposed on the noise. The duration of all /s/ tokens was also measured in order to detect any differences between tokens with differences in voicing. For partially voiced tokens, the voiced and voiceless part was measured separately.

The intonational structure of the utterances produced was examined to ascertain that speakers did not produce a phrase boundary between the /s/ and the preceding consonant. The criteria used to analyze the intonational structure of the experimental sentences follow the guidelines set in the GRT_oBI model of Greek intonation (Arvaniti & Baltazani 2005). The resulting analysis showed that all the tokens were successfully produced in phrase internal positions. This means that if /s/-voicing is categorical we expect to find voiced outputs, since there are no boundaries to block the rule application. If, on the other hand, voiceless outputs or partially voiced ones are found, even though there are no boundaries present, this will suggest there are additional factors that regulate voicing—not only phrase boundaries. In that case, we are not justified in connecting absence of /s/-voicing necessarily with the presence of some prosodic boundary.

2.2 Results

The results showed variability in the production of /s/. More concretely, some of the produced tokens were voiced throughout their duration, some were completely voiceless, and there was a considerable number of tokens with partial voicing. Figures 1-3 illustrate the three different types of output—fully voiced, completely voiceless, and partially voiced, respectively.

Figure 1 shows a fully voiced [s], followed by the voiced obstruent [g] in (2):

- (2) *o oros grizos silavizete efkola*
 the term gray be-syllabified easily
 ‘The term ‘gray’ is easily syllabified’

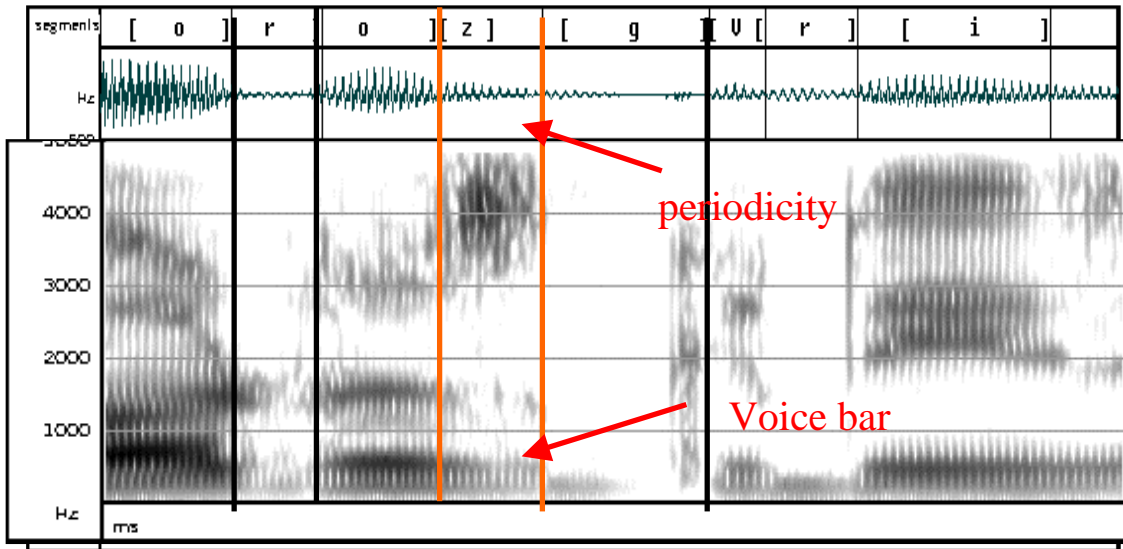


Figure 1. A fully voiced /s/.

The figure shows part of the utterance, containing the word *oros* and the first syllable of the word *grizos*. Notice the robust voice bar throughout the duration of the frication noise. Voicing is also evident in the periodicity superimposed on the noise in the waveform. The sibilant is transcribed [z] in the labeling tier above the waveform.

Figure 2 shows a voiceless /s/ followed by the sonorant [m] in (3):

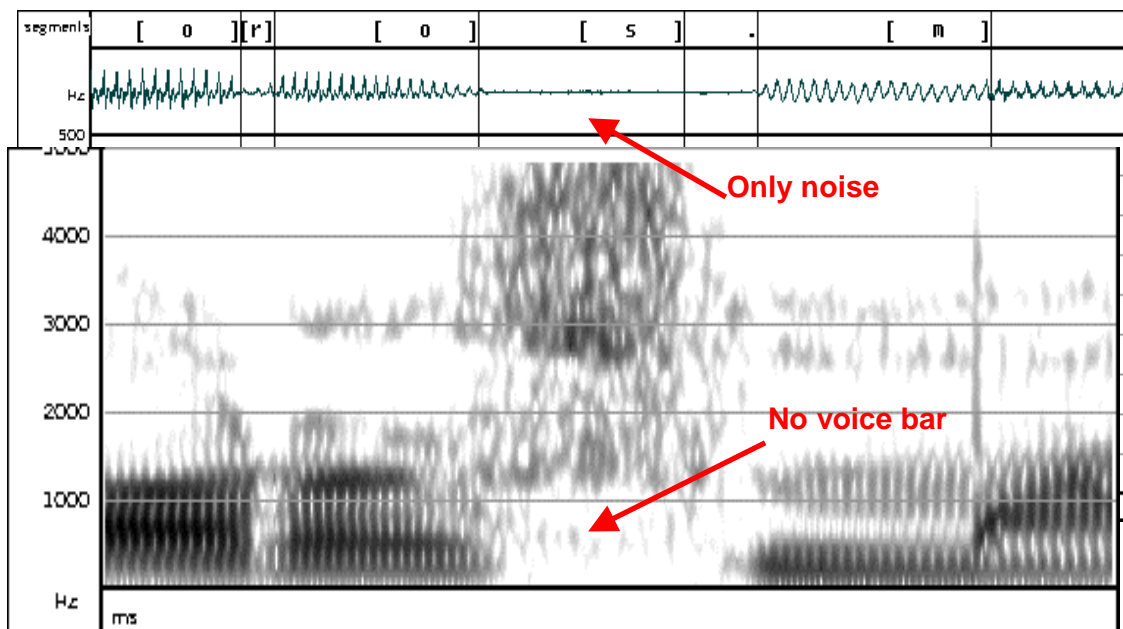


Figure 2. A completely voiceless /s/.

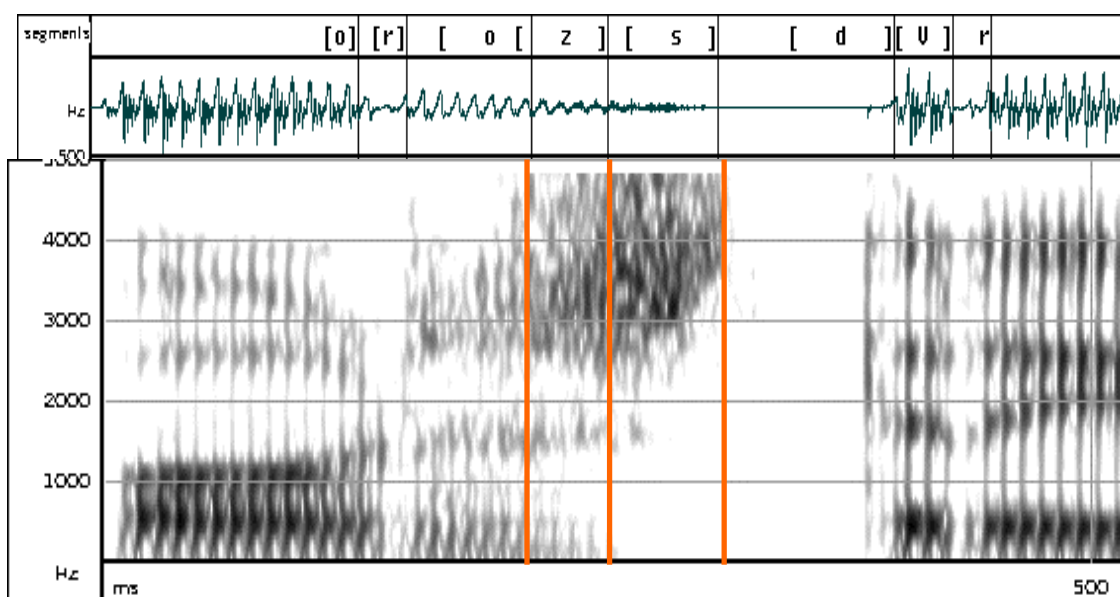


Figure 3. A partially voiced /s/.

- (3) *o oros marka silavizete efkola*
 the term brand be-syllabified easily
 ‘The term ‘brand’ is easily syllabified’

The figure shows part of the first vowel and the last syllable of the word *oros* followed by the first syllable of the word *marka*. In this token there is no voice bar at all during the frication noise and no periodicity on the noise in the waveform. The sibilant is transcribed [s] in the labeling tier above the waveform.

Figure 3 shows a partially voiced /s/ followed by the sonorant [m] in (4)

- (4) *o oros drili silavizete efkola*
 the term cloth be-syllabified easily
 ‘The term ‘cloth’ is easily syllabified’

The figure shows the word *oros* and the first syllable of the word *drili*. Notice that in this token the sibilant starts with a period of voicing which lasts 20 ms. This is followed by a period of voicelessness which lasts 28 ms. Almost all tokens of partial voicing show the same structure: the first part is voiced and also shorter in duration than the second, voiceless part. The sibilant is transcribed [z] in the first part and [s] in the second.

2.2.1 Distribution of tokens

The results show that across all segmental environments and across all five speakers, 49% of the output tokens were fully voiced, 16% completely voiceless, and 35% partially voiced.

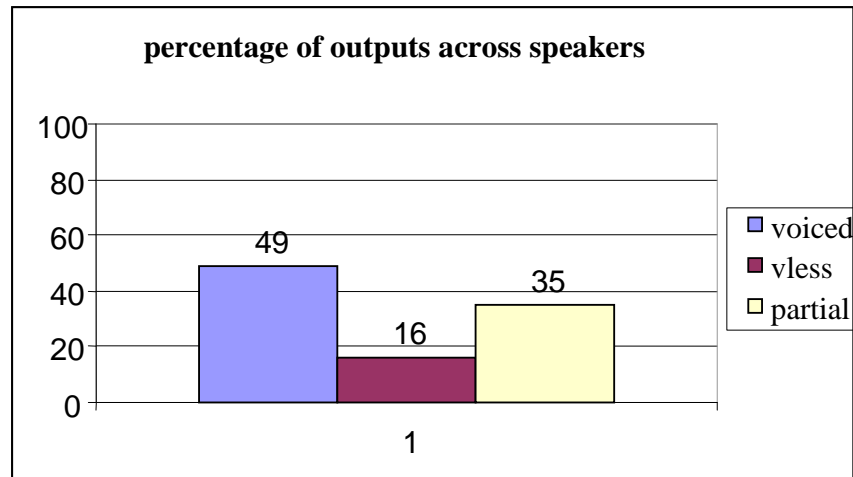


Figure 4: Distributions of voiced, voiceless and partially voiced tokens of /s/ across speakers.

More detailed examination of the data revealed a trend not observed before for Greek to my knowledge. The phonetic quality of the segment following /s/ is important for the output of /s/-voicing. Specifically, for /s/+voiced stop sequences, 70% of the tokens were fully voiced, 8% completely voiceless, and 23% partially voiced. For /s/+sonorant sequences, only 19% were fully voiced, 29% were completely voiceless, and 53% partially voiced.

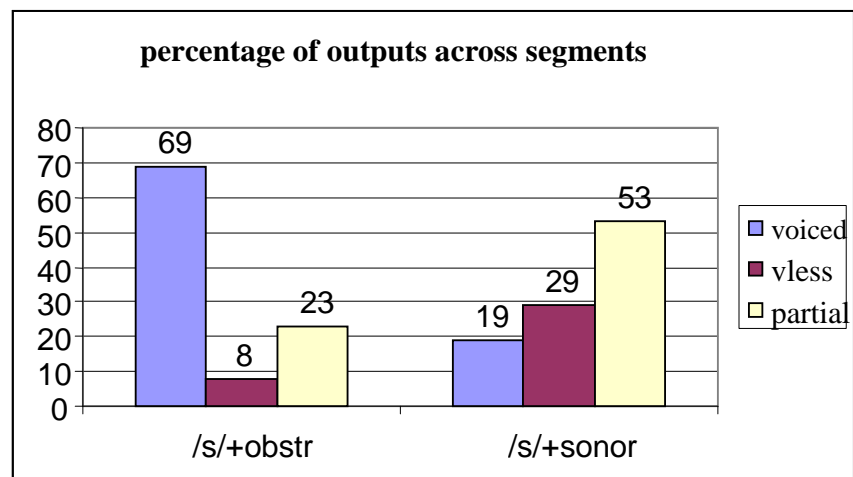


Figure 5: Output distribution before obstruents and before sonorants.

53% were partially voiced. So there is a much bigger tendency to produce a voiceless sibilant or a partially voiced one before a sonorant than before a voiced stop. Also the percentage of voiced /s/ tokens is drastically reduced before a sonorant.

2.2.2 Cross-speaker variability

There is variability in the amount of voicing across speakers, as well. Some speakers, like speaker 2 and speaker 3 tend to produce very few tokens of voiceless sibilants. This might explain the results reported in the Tserdanelis (2005) study. The speakers in his study might belong in the same category like speakers 2 and 3 in the present experiment, producing few voiceless outputs. Speaker 5 produced a lot of partially voiced segments and the same amount of completely voiced or completely voiceless ones. For speakers 1 and 4 about half the segments were voiced but also there was a substantial amount of voiceless and partially voiced segments. It seems that different speakers have different assimilation habits. This shows another aspect of variability in the application of the /s/-voicing process.

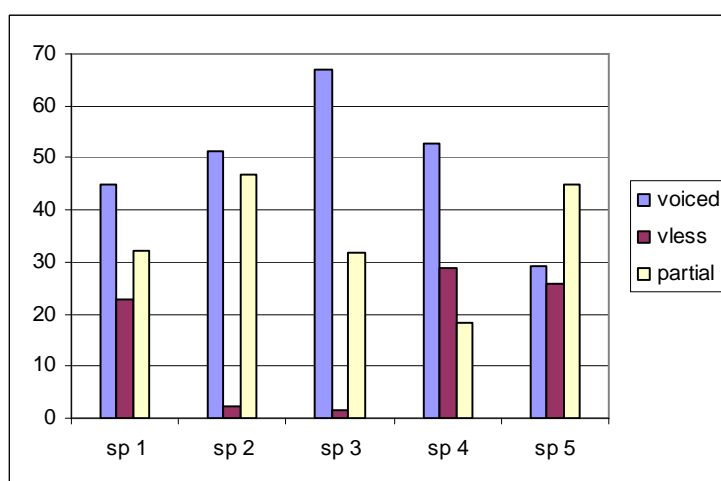


Figure 6: Output distributions by speaker

2.2.3 Duration

The duration of the output of all tokens of /s/-voicing was measured so that any differences of duration between the different states of voicing would be detected. In general, the results show that there is an asymmetry in duration, depending on voicing: voiceless outputs have longer duration than voiced ones, across speakers and segmental environment.

Figure 7 shows the duration of all three voicing states, voiced, voiceless, and partially voiced outputs of the sandhi process. The values shown in the columns represent averages across speakers. Each triad of columns shows durations of /s/ outputs before a

different segment. Across all segments that followed /s/ in this experiment, the voiceless tokens had consistently the longest duration. Notice in particular that the duration difference between the voiceless outputs, on one hand, and the voiced and partially voiced outputs, on the other, is the greatest when /s/ is followed by a homorganic segment to /s/, that is, /d/ or /l/.

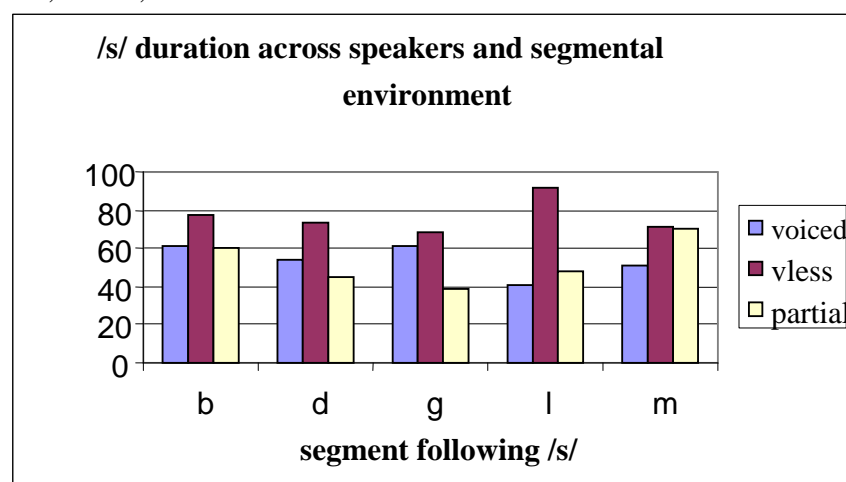


Figure 7: Duration of outputs of /s/-voicing

3. Discussion

The existence of partially voiced outputs suggests that /s/-voicing involves gradient, not categorical changes and the existence of completely voiceless outputs suggests that /s/-voicing is optional, confirming Pelekanou and Arvaniti (2001).

Various sandhi processes whose output is gradient have been accounted for using the theory of Articulatory Phonology (Browman and Goldstein 1986, 1989, 1992). The hypothesis is that there is variability in overlap of articulatory gestures for neighboring segments, so that less or more gestural overlap correlates with more or less acoustic assimilation. It has been claimed that more time allows articulators to reach their target positions, but when time is compressed articulators do not have time to reach the target and only reach intermediate positions approximating the target. As a result, gestures are compressed by overlapping with each other more, that is, articulators do not reach their target, and each gesture lasts a shorter time. Pelakanou and Arvaniti's (2001) account of the /s/ voicing sandhi in Greek also explains this process as the result of gestural overlap. Gradient assimilation in voicing is described as variable reduction in the amplitude of the opening gesture of the glottis, which is responsible for the voicelessness, in Jun 1995, who examined the lenis stop in Korean. Absence of assimilation, in other words, is related to an opening gesture of the glottis which has big amplitude. Furthermore, voicing is correlated in Jun (1995) with duration: voiced outputs correlate with shorter duration of the segment. This is what the duration results presented in section 2.2.3 showed for the Greek data: voiceless outputs were longer than voiced ones, across all speakers and all

segments. Although the results of this study could certainly accommodate such an explanation, it should be borne in mind that this was an acoustic study, not an articulatory one, and no hard evidence can be provided for or against an explanation within Articulatory Phonology.

Several other factors have been shown to influence the amount of /s/-voicing. The differences in /s/ duration found in section 2.2.3 varied depending on the segment following /s/: when homorganic segments follow /s/ there is more assimilation and /s/ before homorganic segments is shorter in duration than when it is found before heterorganic ones. We can hypothesize that more gestural overlap is allowed for homorganic segments than for heterorganic ones. Although we cannot argue for a causal link between the assimilation results and the duration results, there is strong positive correlation between segmental duration and the degree of assimilation. Furthermore, the results presented in section 2.2.2 revealed a trend not observed before, to my knowledge, that there is a much bigger tendency to produce a voiceless sibilant or a partially voiced one before a sonorant than before a voiced stop.

The implication of such findings for the relation between segmental and prosodic phenomena is that at least /s/-voicing is a not reliable criterion for establishing the existence of prosodic boundaries. If /s/ voicing does not always apply we cannot use it as evidence for phrasing.

What is still lacking in the research literature is information about the acoustic and articulatory characteristics of segments participating in sandhi processes. There is a need for careful investigation of the various sandhi rules, most of which have not yet been examined in the laboratory. In this way we will arrive at a better understanding of how such rules function within the phonological system of Greek. Moreover, in this way we can determine how reliable sandhi rules are as criteria for prosodic phrasing.

4. Conclusion

In summary, this paper has shown that the process of /s/-voicing in Greek is gradient, not categorical. Moreover, the degree of assimilation between /s/ and a following voiced obstruent or sonorant has a negative correlation since more assimilated segments are shorter. Finally, the degree of assimilation is affected by the nature of the segment following /s/: there is more assimilation before homorganic segments and also there is more assimilation before voiced obstruents than before sonorants.

These results unequivocally demonstrate the need for careful acoustic investigation of the various sandhi rules. First of all, such investigation will help us understand better how such rules function within the phonological system of Greek, which of them are categorical and which of them are gradient and why. Secondly, discovering whether such rules are gradient or categorical will also determine how reliable they are as criteria for prosodic phrasing. Finding reliable segmental cues for the presence of prosodic boundaries is a valuable resource for intonational phonology.

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