PHONETIC MOTIVATION FOR CONSONANT GEMINATION: EVIDENCE FROM GREEK, ROMANCE, AND GERMANIC

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ABSTRACT

In the history of Greek, Romance and Germanic, certain consonant geminations were conditioned by immediate following glides and/or liquids. Despite phonological and prosodic differences across the three languages, this common conditioning of consonant gemination suggests that some property of these resonants causes strengthening of preceding consonants. This paper reports on an acoustic analysis of the English intervocalic and pre-resonant word-internal consonants of three speakers and reveals that resonants and high vowels have a lengthening effect on the VOT of stops and on constriction durations of nasals and liquids. These findings demonstrate that the geminations in Greek, Proto-Romance and Germanic may have been phonetically motivated fortitions.

1. INTRODUCTION

Geminate consonants may arise through a number of different common processes in the development of a given language, but three separate geminations in the early histories of Greek, Romance, and Germanic were all brought about in the environment of an immediately following glide or liquid. In Greek, the gemination involved sonorants and /s/ before /ʃ/ [1]; in both Proto-Romance and Germanic, consonants, except /l/, were lengthened by immediately following /ʃ/, /lw/, /wl/, and /l/ [2, 3, 4].

Murray and Vennemann [5] explained gemination in Germanic and Italian (and Maiden [2] follows them for Italian) by invoking the Syllable Contact Law (SCL) and the Stressed Syllable Law (SSL). The SCL states that syllable contacts are more preferred the greater the rise in strength from a syllable nucleus to a following onset, while the SSL stipulates that the preferred Germanic stressed syllable has two morae. Murra and Vennemann show that the (pre-gemination) Proto-Germanic (PGmc.) word *satjan ‘to set’ violates the SCL, but a simple resyllabification (*sa.tjan) would not have fulfilled the preference for bimoraic stressed syllables. The process of gemination, they argue, remedied this situation and resulted in an output which satisfied both conditions: West Germanic sat.jan, There are words in Germanic, Romance and Greek, however, in which either stress or syllable contacts clearly had little bearing on the gemination process, e.g., PGmc. *awjó- ‘meadow’ (where /w/ and /j/ are traditionally assigned the same degree of consonantal strength) > Old High German *au.wia; Proto-Romance *jan(uvarju) > *jan(uvarju) ‘January’; and Greek bórías > *bóryás > bóría ‘north wind’ (where gemination occurs in syllables without primary stress) [6, 2, 1].

These forms and the similar behavior of gemination in the three languages suggest that there is a feature common to liquids and glides which causes lengthening or fortition of preceding consonants.

1.1. Gemination as Fortition.

A number of acoustic studies suggest that VOT of stop consonants may be affected in pre-resonant positions. If the Greek, Romance and Germanic gemination processes had been motivated by purely phonetic factors and resulted in true geminates, we would expect that the gemination triggers would have increased the closure duration of preceding stops rather than just the VOT. In later stages of Italian and West Germanic, however, most of the double consonants which had resulted from these earlier gemination processes were simplified [7, 8]. In Germanic, those which were preserved into Modern Standard German were only voiceless stops and sonorants in certain morphological categories, although geminates from earlier processes were retained. This development suggests that the double consonants which arose from the geminations in question were not true geminates, but were, indeed, somehow different from their simple counterparts. The difference may have been one of strength or fortition rather than of length. Therefore, in attempting discover any phonetic motivation for these changes, it is prudent to examine the effects of following resonants on those aspects of the consonant which might lead to a perception of increased strength, such as consonant release and VOT, in addition to increased duration.

1.2. Previous Studies.

In a study of word-initial stop consonants and clusters, Klatt [9] found that VOT’s of pre-vocalic voiceless stops were 15% longer before a high syllable nucleus (/i, u/) than before /ay, el/. Klatt’s findings, however, are in contrast with earlier work by Lisker and Abramson [10], which showed that the quality of the syllable nucleus has no effect on VOT of the preceding consonant. In an attempt to discover the factors at work in these, and other, seemingly conflicting data sets, Weismer [11] studied the VOT sensitivity of initial voiceless stops in CVC sequences to the tense/lax distinction of following vowels. His analysis showed VOT’s of word-initial /p, t, k/ to be longer when immediately followed by tense vowels than by lax, and that, with the exception of /k/, it is tenseness rather than tongue height which systematically influences VOT. The voiceless velar articulation, however, seems to be sensitive to both tongue height and tenseness. An aspect of Klatt’s study that Weismer did not address in his investigation into the role of tenseness in VOT, was the effect of following sonorant consonants on stop

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VOT’s. Klatt examined English word-initial stop-sonorant clusters (labials and velars before /l/ and /l/, and coronals before /l/ and /w/) and found that VOT’s of /p, t, k/ were 10-40 ms. greater before sonorant consonants than before vowels.

Ohala [12] reported on a study of “abnormally prolonged” voiced stops in VCV sequences spoken in isolation by a single male speaker. He states that “the stops coarticulated with the high vowels [i, u] permitted voicing to continue longer than those coarticulated with low vowels.” Thus, the high vowel environment seems to have an effect on voicing, which raises the question whether glides articulated in the same vicinity as the high vowels would exert similar influences.

1.3. Purpose of the Experiment.
The segments most commonly affected by gemination in Greek, Romance, and Germanic were the stops and the sonorants. Therefore, one of the first priorities in exploring the role of phonetic factors in these geminations is to investigate the effect of glides and liquids, the gemination triggers, on word-internal stops and sonorants. A second task is to examine any variations in closure or constriction durations, in addition to VOT, for effects of the following segment. Working with the hypothesis that liquids and glides will demonstrate lengthening effects similar to those found by Klatt, Weismer, and Ohala, a new experiment was undertaken to test English word-internal consonants before glides and liquids in the speech of three subjects. It was anticipated that if the consonant geminations at issue had been phonetically motivated, some of the effects which ultimately led to consonant strengthening in these languages might be visible in this data set.

A further motivation for this study was the hope of discovering some insight into the details of the Germanic geminations. In West Germanic, only voiceless stops were regularly geminated by all four resonants /y, w, r, l/, although only /k/ was affected by /w/. In North Germanic, /g/ was also strengthened by /w/, suggesting an affinity of /w/ for velar consonants. Thus, we might expect to see a difference in how the resonants affect voiceless versus voiced stops or velars versus non-velars. Finally, the West Germanic voiced stops were only lengthened by /y/, with the exception of /d/, which occasionally appears doubled before /l/. So, again, we might hope to see some signs of lengthened durations of /d/ before /l/.

2. METHODS

2.1. Materials.
The tokens used for acoustic analysis were nonsense words of the shape /a(C)(R)V/. The consonants were the American English voiceless stops, voiced stops, nasals and liquids. The stops /p, t, k/ and /b, d, g/ occurred one time in each of seven environments /a--/l/, /a--l/, /a--/l/, /a--yl/, /a--wa/, /a--la/, and /a--ra/. The sonorants /m, n, l, r/ were followed by /a-/l/, /a-l/, or /ayl/. Each nonsense word was presented three times in the carrier sentence “I said ______ too” and various distractor sentences were added to the list, resulting in 280 total sentences, 162 of which contained the tokens of interest. The sentences were blocked by category and voicing of the nonsense word consonants, i.e., by voiceless stops, voiced stops, and sonorants. Within each block, the sentences were randomized with the final two sentences of each block being distractor sentences to avoid list intonation on nonsense words in these pre-pausal positions.

Three subjects, one female and two males, were recorded at the University of Chicago Language Laboratories and Archives. All three subjects were native speakers of a variety of American English most easily characterized as Midwestern. The subjects were instructed that all nonsense words had word initial stress and that the syllable boundary was marked between the first vowel and the following consonants as in ‘a-tra, ‘a-gya, ‘a-nya, and so on. Each subject was recorded in a single session in a sound-proof room using a DAT recorder. The tokens were digitized at a sampling rate of 20,000 Hz using Ka Elemetrics Computerized Speech Lab (CSL).

2.2. Measurement.

2.2.1. Stop Consonants. Measurements were taken from each digitized sound file using wave form and spectrographic displays in addition to the sound of the token. For each token containing a stop consonant, measurements were taken at five locations: the beginning of the first /a/ vowel, the beginning of the stop closure, the beginning of the burst, the beginning of voicing, and the end of the second vowel. The beginning of the first /a/ was measured from the abrupt appearance of energy in the displays following the burst of the final /d/ of “said” in the carrier phrase. In cases in which the first /a/ of the di-syllable began without voicing or visible formants, the cursor was placed immediately following the /d/ burst (or after the closure when no burst was apparent). The beginning of consonant closure was measured from the first significant drop in amplitude of the preceding /a/’s second formant. The cursor was aligned with the left edge of the burst, where a burst was present, and with the beginning of frication or aspiration in those cases where no burst was discernible. Voicing was measured from the first voicing striations visible in F2 and the first periodicity of the wave form. The end of the /di-syllable was measured at the significant drop in amplitude of F2 of the final vowel.

From these landmarks were calculated duration of the first /a/ vowel, duration of the closure, VOT, and the total duration of the token. VOT here, for both voiceless and voiced stops will be defined as the period from the beginning of the consonant burst or release to the onset of voicing. The consonant release was included in this measure due to the difficulty of locating the end of the burst in the wave form and spectrographic displays. The high level of frication at the release of many of the stops made this task impossible. Any voiceless period prior to the stop release was also not included in this measurement.

2.2.2. Sonorants. Tokens containing the sonorants /l, r, m, n/ were recorded and digitized as for the stop consonants. Four measurements were taken for each of the tokens containing an intervocalic /l, m, n/: the beginning of the first /a/, the beginning of consonantal constriction, the end of consonantal constriction, and the end of the second vowel. The liquid and nasal constrictions were measured from the beginning of the transitions and concomitant drop in amplitude. Additional landmarks were also noted, such as abrupt or fricative releases of sonorant consonants or their following glides.
3. RESULTS

3.1. Voiceless stops.
Because true geminate or long stops are generally distinguished by their increased closure duration when compared to simple consonants, the first measure that was examined was the closure durations of voiceless and voiced stops. Each of the three speakers demonstrated a different relationship between duration and phonological environment such that no cross-speaker correlation between these two variables was apparent nor were any other significant trends.

This was not the case for VOT. There was a difference in VOT of 10-19 ms. or 18-30% between /p, t, k/ before /a/ and the same stops before the other environments. This is shown in Figure 1. Of the three places of articulation of voiceless stops, the labials have the shortest VOT, and of them, the pre-/a/ environment has the shortest duration at 42 ms. The coronal stops showed the longest VOT’s, counter to what was expected from previous studies and general belief—that velars have the longest VOT’s, but this may have been an effect of the following resonants and vowels.

In accordance with Klatt’s and Weismer’s studies, the voiceless stops generally showed longer VOT’s before /i/ and /u/ than before /a/. In comparing the effects of high vowels versus high glides, seen in Figure 2, the lengthening effect was more pronounced before /y/ than before /i/, while the pre-/a/ environment generally effected longer VOT’s than the environment before /w/. Klatt [9] found a difference of 10-40 ms. between stops in the pre-vocalic and pre-sonorant position. A similar comparison in this study revealed differences of 5-30 ms. between pre-/a/ and pre-sonorant voiceless stops. The smaller differences in this experiment may be explained by the fact that all consonants measured were in medial position in di-syllabic words with word-initial stress, whereas Klatt studied word-initial consonants in mostly mono-syllabic words.

3.2. Voiced Stops.
As with the voiceless stops, no systematic trends were observed for closure durations across the three speakers. Figure 3 shows VOT’s of voiced stops /b, d, g/ where we see the general tendency for VOT’s to be greatest in the pre-sonorant positions. Although there were also positive differences between stops in the pre-/a/ and pre-high vowel environments for some speakers and at some places of articulation, this was not a general trend. Thus, /y/ had a greater influence on VOT than /i/, and /w/ had more lengthening power than /a/. /y/, /w/ and /l/ effected the largest differences—/y/ and /w/ on preceding /g/, and /l/ and /y/ when they followed /d/.

3.3. Sonorants.
The /r/ phoneme carries a number of difficulties for this type of study. First, rhotic articulations can vary in so many ways from one language to another, that studying only American English /r/ durations in order to shed light on ancient sound changes is of questionable utility, especially given that these changes occurred in three different language families which may have had three completely different rhotic articulations. Secondly, in an examination of spectrograms of nonsense words containing /l/, it was discovered that when the /l/ was in the coda of the first
syllable, its properties were spread across that entire syllable. Similarly, when it was in the syllable onset, it rhotacized the following nucleus. Although this is an extremely interesting finding, it makes the /r/ constriction much more difficult to separate from the surrounding vowels as was done for the other sonorants. Therefore, the effect of following /y/ and syllable boundaries on American English /r/ will be dealt with elsewhere.

The durations for the remaining sonorants /l, m, n/ are shown in Figure 4. All three sonorants have similar values for the environments before /a/ and before /i/. Thus, unlike the stops, the high vowel environment seems not to influence sonorant duration—at least as far as constriction durations are concerned. Following /y/, however, does have an effect and produces constriction durations that are 10-15% longer than those before the vowels. A particularly interesting point observed from the spectrograms is that a number of the /l/ tokens contained edges or releases at the end of their constriction periods. All of these tokens were cases of /l/ before /l/ or /y/ with five of the nine /-ly-/ tokens exhibiting a clear /l/ edge and three of the nine /-li-/ tokens doing the same. Considering that this experiment has shown the high vowels and resonants to have an effect on the VOT of preceding stops, it is conceivable that following resonants and high vowels could also influence the oral release of /l/.

The strengthening effect of West Germanic resonants on the voiceless series of stops is mirrored here by the data shown in Figure 2, which shows all four pre-resonant positions to condition longer VOT’s in /p/, /t/, and /k/. In Figure 3 we also see the influence of /y, w, r, l/ on the voiced stops, but the greatest differences in VOT here are in those specific environments which conditioned gemination of voiced stops in Germanic: /b/ by following /y/, /d/ by /y/ and /l/, and /g/ by /y/ and /w/. The resulting high VOT’s of coronals and velars in these particular environments brings them into the upper range of VOT’s for voiced stops. Indeed /g/ in the environment before /l/ has a VOT of 44 ms. This is longer than some voiceless stops and it is not difficult to imagine how such consonants could have eventually been perceived as different from, perhaps more fortis than, the voiced stops at other places of articulation or those in non-resonant environments.

The sonorant consonants in this experiment all exhibited increased constriction durations in the environment before /y/. These are instances of true lengthening, as opposed to the strengthening of consonant releases. It may be due to such a lengthening effect that geminate sonorant consonants were often longer lived than geminate stops. It is particularly interesting that the release of /l/ also appears to be strengthened by a following glide and, to a lesser degree, by a high front/tense vowel. The possible influences of resonant environment on lateral releases and how these effects might be perceived are intriguing topics for further research.

This investigation has demonstrated that the initial variations in consonantal strength and duration which ultimately led to geminations in Greek, Romance, and Germanic, may have had their base in the same coarticulatory effects we have seen in Modern American English consonants.

![Figure 4. Sonorant Constriction Duration as Percentage of Preceding /a/](image)

4. CONCLUSIONS.

The present study confirms findings from previous investigations that syllable initial stop consonant VOT’s are sensitive to following vowels and sonorants. The results presented here do not resolve the question of whether VOT is sensitive to vowel height, as Klatt suggested, or to the tense/lax distinction as Weismer argued. However, this investigation has demonstrated that certain resonants have the capability to strengthen preceding consonants. Specifically, when phonological environments are recreated in American English resembling those in which gemination occurred in three different languages over 1500 years ago, we see durational variations in portions of the same consonants and in the same environments in which gemination occurred.

REFERENCES