

# Phrase-initial geminate stops: articulatory evidence for phonological representation

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## ABSTRACT

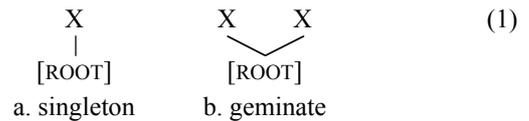
Swiss German dialects have contrastive singleton and geminate voiceless stop consonants in all word positions. This contrast is acoustically manifested in short and long closure duration, which constitutes the primary cue. Within words as well as within phrases, intersonorant contexts facilitate the perception of the contrast while obstruent contexts neutralize the contrast. Crucially, in phrase-initial position listeners cannot recover the contrast either. In this study we present articulatory evidence that phrase-initial geminates are nonetheless produced with significantly longer closure duration than singletons. Thus, the phrase-initial imperceptibility is not due to the primary cue, i.e. closure duration, not being produced. It results from the primary cue not being implementable because the starting point of the closure is not discernable.

## 1. INTRODUCTION

Initial geminates are cross-linguistically rare and theoretically problematic. With only a few studies in the literature [1-5,8,10-15], their phonetic nature is still unclear, and their phonological representation continues to be a moot point. Building on our earlier investigations, we report on an ongoing production study on Swiss German, which provides articulatory evidence for the phonological representation of voiceless initial stop geminates in terms of timing positions.

## 2. THEORETICAL AND EMPIRICAL BACKGROUND

Early representations of geminates in a non-linear fashion were a single melodic unit linked to two timing positions. In contrast, the subsequent moraic representation of geminates [10,6], with a single melodic segment linked to a coda mora and a syllable onset, crucially relied on the assumption that geminates are heterosyllabic and, moreover, that weight always goes in tandem with quantity. Syllable-final and syllable-initial geminates were ignored or considered phonologically unrepresentable. We disagree, and represent initial geminates in terms of length or quantity without weight, i.e. with a single melody associated to two X-slots.



This representation corresponds to the one proposed for Leti by Hume *et.al.* [11]. Like Leti initial geminates, Swiss German initial geminates do not contribute to weight, nor do medial or final ones [13]. The structures in (1) predict that contrast neutralization, brought about by degemination, should be totally independent of weight.

Within the stops, Swiss German has a perceivable singleton–geminate contrast in intersonorant context position which phonetically correlates with short–long closure duration (2). Neutralization occurs after an obstruent-final word through geminate shortening (3).

$$\begin{array}{ll} /t/ & /tt/ \\ [\text{en } \text{taŋkx}] \text{ 'a thank'} & [\text{en } \text{ttaŋkx}] \text{ 'a tank'} \\ [\text{s } \text{taŋkxə}] \text{ 'the thanking'} & [\text{s } \text{taŋkxə}] \text{ 'the filling-up'} \end{array} \quad (2)$$

We claim that this phonetic shortening reflects the elimination of the first X-slot, which cannot be licensed or prosodically incorporated [12,13].

Phrase-initially, the situation is different. It has been shown by Abramson [1,2,3,4] that Pattani Malay listeners are able to perceive the quantity contrast of phrase-initial voiceless stops in the absence of the primary cue, closure duration, by using secondary cues such as relative amplitude of the syllable containing the sound and fundamental frequency of the sound itself. In contrast, a perception experiment conducted by the first author [13] revealed that Swiss German listeners cannot recover the length contrast. We argue, however, that the non-recoverability of the quantity contrast is not due to phonological cum phonetic neutralization as it occurs phrase-medially (cf. (3)), but rather due to the primary cue not being implementable at the phrase edge since there is no discernable starting point of the closure duration. If there are any secondary cues – as have been found by Fulop [8] – they do not seem to be strong enough for contrast recoverability.

The goal of our kinematic electropalatographic study was to show that this perceptual neutralization does not go hand-in-hand with an articulatory neutralization. In other words, we wanted to test our hypothesis that absolute

phrase-initial voiceless geminates are produced with a longer closure duration, i.e. a longer tongue-to-palate contact by the articulators, than corresponding singletons.

### 3. METHODS

#### 3.1 Technical set-up

A production study was conducted in which we used an electropalatograph (WinEPG system; Articulate Instruments Ltd, Edinburgh, UK) to record information about speakers' tongue-to-palate contact over time. An artificial palate of thin acrylic with 62 embedded electrodes was custom-fitted from a dental stone cast made from the impression of the speaker's hard palate.

The EPG system scans the palate at a sampling rate of 100Hz. The acoustic signal is recorded simultaneously with the linguapalatal information at a sampling rate of 22,050Hz. Data analysis is comparatively straightforward with the specialized software (Articulate Assistant, Version 1.3) provided in the package. We concentrated on analyses yielding temporal information about the articulatory closure of word-initial singleton and geminate consonants.

EPG studies have a number of real and disputed limitations that require careful consideration. First, the manufacturing of such specialized pseudopalates is rather expensive and time consuming. Therefore our study as of now contains data of a single subject only. Second, it has been claimed that pseudopalates may interfere with sensory feedback, thus potentially inducing untypical or even unnatural articulation. This claim, however, has been contested by Fletcher [7], who contends that lingual response is sufficient to compensate for the loss of tactile feedback from a pseudopalate. Other research by Hamlet and Stone [9] has shown no significant difference in patterns of tongue-to-palate contact between direct palatography and EPG. To minimize any potential interference of this type our subject received the pseudopalate to wear and get used to two weeks prior to the scheduled recordings. In addition, immediately before the recordings we engaged her in "warm-up" talking of about half an hour until she felt comfortable. Third, the electrode coverage is limited mostly to the hard palate area, which makes the analysis of velar closures difficult or even impossible. This was a serious problem in our case for two reasons. On the one hand, the palate of our subject was extremely steep and narrow such that velar closure only involved the backmost electrodes on each side. Even velars before the high front vowel [i], i.e. potentially palatalized velars, showed this pattern. On the other hand, Swiss German velars are claimed to have a rather uvular articulation [5] and thus would involve the soft palate rather than the hard palate in any event. Therefore our analyses concentrated on the alveolar stops [t] and [tt].

#### 3.2 Stimuli and task

A list of nine word pairs was compiled in which the initial alveolar stops contrasted in quantity. Four of these were minimal pairs, five near-minimal pairs; two were disyllabic, seven monosyllabic (e.g. /taŋkx̄/-/ttaŋkx̄/ 'thank - tank', /taix̄/-/ttaix̄/ 'dike - pond', /teppo/-/tteppix̄/ 'deposit - carpet'). Main stress always was on the initial syllable, that is, on the syllable that contained the sound under investigation.

These target words were randomized together with filler items. The combined stimuli were put in three different contexts: (a) a carrier sentence in which the word preceding the target word ended in an obstruent ([i ha elf \_\_\_ ksaitt] 'I said eleven \_\_\_'), (b) a carrier sentence in which the word preceding the target word ended in a vowel ([i ha tsvai \_\_\_ ksaitt] 'I said two \_\_\_'), and (c) in absolute phrase-initial position as word spoken in isolation. Under the obvious assumption that the duration of linguapalatal contact correlates directly with the duration of phonetic closure, our predictions for the three contexts were the following. In the obstruent context (a), singletons and geminates should exhibit the same amount of contact. In other words, they should be indistinguishable on the basis of this measure since phonological neutralization will occur. The vocalic context (b), in contrast, should reveal an unambiguous differentiation between singletons and geminates because all phonological positions can be licensed. The phrase-initial context (c), finally, is the decisive test for our hypothesis. If we are correct, we predict the same maintenance of contrast; that is, geminates should exhibit longer contact of the articulators than singletons.

In a final step, the whole sentences and the words in isolation were typed individually on flash cards. They were presented to the subject by one of the authors to be read aloud. The subject repeated the three different conditions twice. In the phrase-initial context she was asked to produce the isolated words starting with the mouth slightly ajar such that there was no linguapalatal contact prior to the onset of the word.

#### 3.3 Measurement criteria

For the analysis of the data we annotated the obtained acoustic and articulatory EPG files in order to extract the two duration measurements.

For the articulatory annotations the frame at which there was complete contact of row one and/or two of the pseudopalate was chosen as the onset, and the last frame before the partial or total contact release was chosen as the offset. We call this measure the *duration of maximum contact*.

The criteria for the annotation of closure duration were the offset of the regular waveform pattern of the preceding sound and the point of closure release. Such acoustic

annotation was only possible for the phrase-medial contexts since for the phrase-initial context there were no preceding sounds.

#### 4. RESULTS

Analyses of variance were performed with the dependent variable being *duration of maximum contact* and independent variables being *context* and the *geminate–singleton contrast within context*. Significance was computed at the 0.05 level (5%).

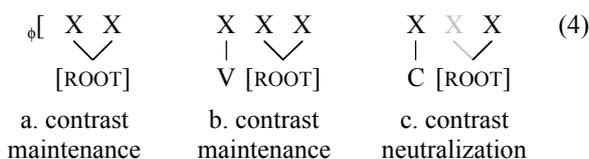
Overall, there was a highly significant difference between the duration of maximal contact of singletons (82ms) and geminates (133ms). Post-hoc tests, as listed in Table 1, revealed that this difference remained significant for the contexts after a vowel-final word (V) and phrase-initially (#) but is not significant for the context after an obstruent-final word (C).

Context	Mean	Stand. dev.	Prob> t
C geminate	72.2	7.8	0.2478
C singleton	59.4	7.8	
V geminate	78.8	8.0	0.0017*
V singleton	42.4	8.0	
# geminate	227.6	7.2	<.0001*
# singleton	148.8	8.2	

**Table 1:** Mean durations of maximum contact, standard deviations, and probability values for geminates and singletons in obstruent (C), vowel (V), and phrase boundary (#) context. Asterisks indicate significance.

These results of the kinematic measurements not only mirror the results of the acoustic measurements – overall closure durations being 54.0ms for singletons and 81.4ms for geminates – but also meet our predictions and fully support our hypothesis that phrase-initial geminates are articulated with a longer contact phase than singletons.

Thus, the articulatory data show that indeed a longer closure duration is produced for geminates. In terms of phonology, this strongly indicates that initial geminates pattern the same at a phrase boundary and after a vowel-final word within a phrase, i.e. in both cases a single root node is linked to two timing slots (4a,b). These phonological positions get phonetically interpreted as long closure duration, kinematically as long duration of maximum contact. The first phonological position in obstruent context, however, is deleted (4c), which results in phonetic and articulatory neutralization.



The fact, then, that in perception the phrase-initial quantity contrast cannot be recovered is not a consequence of any phonological neutralization since no X-slot is removed.

Rather, the nature of the primary acoustic cue is responsible. Since we are dealing with voiceless stops, the closure duration is a period of silence. For the perception of the cue both starting and end point of this period need to be discernable. Phrase-initially the starting point is missing, and therefore geminates and singletons are indistinguishable.

#### 5. CONCLUSIONS

Our study clearly established that phrase-initially in Swiss German a phonological quantity distinction is being made which is articulatorily realized as long and short linguapalatal contact for geminates and singletons, respectively. The phrase-initial context, then, is substantially different from the obstruent context, in which no articulatory differentiation is made due to contrast neutralization – phonological and phonetic. The fact that listeners cannot hear the articulated difference phrase-initially is not due to such neutralization. Finally, the proposed phonological representation of geminates in terms of two timing positions fully takes into account that weight is not at issue at all. A geminate remains articulatorily long phrase-medially where it can be partly syllabified in a preceding coda (as in the vocalic context) as well as phrase-initially, where no syllabification across the word boundary is possible.

#### ACKNOWLEDGMENTS

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